

REFERENCE MANUALS ON CONSTRUCTION AND OPERATIONAL PRACTICES OF EHV SUBSTATIONS& LINES AND COMMERCIAL AND LOAD DESPATCH OPEATIONS



TRANSMISSION CORPORATION OF ANDHRA PRADESH LIMITED

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VOLUME - I

MANUAL ON TRANSMISSION PLANNING

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1.1 Objective

1.1.1 Expansion of Transmission and Distribution network commensurate with the addition of generation capacity and growth in demand is required, in order to extend a reliable, stable and secure power supply. This needs an optimal and economical planning of the transmission system.

1.1.2 Analysis of a Transmission system is technically complex, though in terms of economics and finance, it is not as great as Generation or Distribution. Typically for a given period, the investments in Transmission system are much less as compared to either Generation or Distribution. The objective of system planning is to evolve a power system with a level of performance characterized by an acceptable degree of adequacy and security based on a trade-off between costs and risks involved.

1.1.3 Transmission planning is carried out to determine new Transmission facilities required over a planning horizon, timing of each addition / modification of the system and to select most suitable type for each new development stage. Capital cost requirements and investment plans associated with such plans should be developed.

1.1.4 APTRANSCO has the key responsibility of network planning and development in coordination with all concerned in respect of intra -state transmission system. Network expansion should be planned and implemented keeping in view the anticipated transmission needs that would be incident on the system in the open access regime.

1.2 Impacts of Restructuring

1.2.1 With a view to improve performance of the power sector and provide customers with a choice of supplier for their electrical energy needs, reforms were brought in power sector. This resulted in unbundling of monolithic organization (erstwhile Electricity Board) into separate entities for Generation, Transmission and Distribution, each responsible solely for its own area. While it is possible to generate competition in Generation and Distribution, it is unlikely that such a competition could develop in Transmission for a number of reasons.

1.2.2 Transmission systems do not have the facility for directing power from a specific producer to a specific consumer.

1.2.3 Providing competing transmission facilities by separate companies or business units over the same geographical area may not be practically feasible. Apart from the cost involved in duplicating the transmission facilities, the presence of multiple transmission systems in the same area would be environmentally undesirable.

1.2.4 While individual generating companies or distribution companies can position themselves in response to the market or can even influence the market through various strategies, the transmission system is uniquely positioned in that it can actually destroy the market. If the transmission system is unable to deliver power from the suppliers to the consumers, the market consequences can be disastrous.

1.2.5 Because of the above reasons, transmission systems appear to be developing on the lines of a single entity which will deliver power from individual generating companies to the individual distribution companies. The role of a transmission system, whether as a public

company or as a private company is therefore the same: to deliver power from generating stations to the distribution networks in a safe, reliable and efficient manner. With the introduction of open access, transmission system is often expected to wheel power; i.e. transfer power between two utilities.

1.2.6 In the past when generation was planned in a coordinated manner over the whole system, the transmission system could be planned on the basis of planned generation expansion. In the restructured environment particularly with the open access generators and consumers coming up, this approach needs a review. Transmission system may need to accommodate a wide range of generating station types and sizes in various geographical locations. This is likely to result in a more extensive transmission system with higher degree of flexibility than previous systems.

1.3 Planning Philosophy:

1.3.1 Over the years, transmission system planning exercises were taking place on the basis of regional self sufficiency. Development of transmission system based on this philosophy resulted in emergence of strong regional grid systems. During the period from mid 70s and up to beginning of 90s, while the regional grids were in initial phases of development and required support from the interconnected state grid systems, the growth plan of regional systems and the state grid networks were critically matched. The process of techno economic appraisal and clearance by the Central Electricity Authority played a key role in achieving this objective in transmission system development. Subsequently the emergence of strong regional grid systems and the role of state grid systems getting more focused towards meeting needs within the intra-state system, allowed the planning and development process for two segments to run somewhat independently.

1.3.2 Today, regional grid systems are strong enough to meet inter-state transmission needs without significant support from the connecting state grid network. With this, the need of coordination for planning state's transmission system requires focus mainly at the interface of regional grid power supply or power lifting points.

1.3.3 With the generation planning moving towards all India basis so as to develop generation resources optimally, the focus in transmission planning for regional grids has shifted from regional concept to National concept. This has emerged in view of cost economics favoring transmission of electricity over the transportation of coal, saving in investment in generation (when planned on all India basis) and savings on account of diversity in regional demand, sharing of reserves, better utilization of hydro resources and reduced operational costs.

1.4 Transmission Planning Requirements

1.4.1 Basic requirements for carrying a transmission planning study are

- Information on the existing transmission facilities
- Load forecast
- Generation plan

1.4.2 Information on the existing transmission facilities: Collection of all the available information on the existing system forms the first stage in the planning process. Data required is as given below. Data is usually available in the records maintained at the substations. Basic parameters required are,

1.4.2.1 Transmission Line Data: line voltage, number of conductors per phase, size and type of conductor and shield wire

Line resistance, reactance and susceptance (positive and zero sequence)

Thermal capacity

Size and location of line connected shunt reactors

Size and location of series capacitive compensation

1.4.2.2 Substation Data: Data required for transmission planning purposes, at the substation level and for each year consists of

Real and reactive demand (MW and MVAR)

Peak and minimum demands

Seasonal variation of demand

Single line diagram and layout plan

Transformer rating, impedance, tap- changer ranges and type

Transformer winding arrangement

Transformer grounding arrangement

Circuit breaker continuous and interrupting current ratings

Shunt reactor / capacitor ratings

1.4.2.3 Generator Data: Generator data is required for both steady state and dynamic studies. For steady state studies the required parameters are: generator rating (MW, MVAR limits), generator voltage and generator transformer rating / impedance / taps. In addition, data on inertia constant, machine impedances and time constants (d and q axes, synchronous, transient and sub-transient) are required for dynamic studies.

1.4.2.4 Operational Data: Operational data is concerned with the manner in which the installed equipment is utilized. It covers such areas:

- a. Generation dispatch schedules (which may vary seasonally: maximum hydro / minimum hydro) for both peak and light load conditions
- b. Interchange agreements with other systems

- c. Fault clearing times
- d. Levels of spinning reserve maintained on the system at various times of the year and at various load levels
- e. Under-frequency and load shedding strategies

1.4.2.5 Cost Data: Cost data is required to estimate capital cost, operating cost and loss cost for future system and as such forms the basis for the economic analyses that may be carried out later. For long range planning studies, it is normal to consider economic price levels for all equipment and requirements. The use of economic prices attempts to eliminate the effect of subsidies, taxes and duties, and artificial price levels of certain commodities and equipment. Normally cost data for transmission equipment is prepared in the form of unit costs. These may be in the form of costs / km for different types of transmission lines, costs per entry and costs per MVA of transformer capacity for substations, costs per kW and kWh for losses, etc.

1.4.3 Load Forecast:

1.4.3.1 Load forecast is the process, which involves estimation of future loads and ways in which these loads can be met. The existence of a load forecast that covers the planning period is essential to the overall planning task and is the foundation for all the planning studies. Load forecasts carried out on a state-wide, regional or national basis provide satisfactory input to the generation expansion planning. In case of transmission planning, knowledge of the distribution of the total load over the geographical area of the system is required. Normally the total load is distributed over all the existing bulk substations within the system. Historical records can provide this distribution for past loads, but unless the load forecast is available at the substation level, some estimate is required about the distribution of future loads. In the absence of any information, it is common to use the existing distribution of load in percentage terms and apply those percentages to the total future load in any year. If the load forecast is available district wise or operating area wise, then the future load can be distributed amongst the substations within each district as a percentage of the total future district load.

1.4.3.2 Load forecast defines the amount of growth expected from the power system and the generation expansion plan defines the generating resources that will be used to supply the forecast demand and energy. The function of transmission system is to connect the two and deliver the generated power and energy to the major load centres within the system in a safe, reliable and efficient manner. Load forecasting provides means of avoiding over or under utilization of generation capacity, and helps to make use of best possible generation capacity. Too high forecast leads to more system which means unnecessary capital expenditure. Too low forecast prevents optimum economic growth and leads to system getting over burdened.

1.4.3.3 Demand for electricity depends on a number of socioeconomic factors such as Economic growth, Industrial production, New technological developments that influence life styles, Government policies etc. Forecast needs to be revised at regular intervals to take care of new policies and changes in socioeconomic trends. Forecasting should consider lead time for project execution, taking into consideration previous history. By incorporating the role of uncertainty into the analysis techniques, the emphasis of planning moves from mere

making of an accurate forecast to constructing a system that can adapt readily to changes. Ability to forecast the long term demand for electricity is a fundamental prerequisite for development of a secure and economic power system.

1.4.3.4 Based on the time period, load forecast can be divided into three categories:

(a) Short term forecast - usually from one hour to one week. Provides basis for planning startup and shutdown schedules of generator units, reserve planning and study of transmission constraints.

(b) Medium term forecast - usually from a week to one year. Used mainly for scheduling fuel supplies, maintenance programme, financial planning and tariff formulation.

(c) Long term forecast - usually for longer than one year. Facilitates in economic planning of new generating capacity and transmission networks.

3.3.5. The forecasts for different time horizons are important for different operations within a utility. Forecasting should be done for both electrical energy and demand levels.

1.4.4 Load Forecasting Methods:

1.4.4.1 Over the last few decades a number of forecasting methods have been developed. Few of the methods, viz., **Trend**, **End-use**, and **Econometric approach** are broadly used for short, medium and long- term forecasting.

(A) Trend Method

This method is a non-casual method of demand forecasting which assumes that the underlying factors which drive the demand for electricity are expected to follow the same trend as in the past and hence the forecast is also based on the assumption that the past trend in consumption of electricity will continue in future. The strength of this method, when used with balanced judgment lies in its ability to reflect recent changes and therefore is probably best suited for a short term projection as used for ARR /Tariff filing. However the trend based approach has to be adjusted for judgment on the characteristics of the specific consumer groups/ categories. For example, while this method may provide a better estimate of consumption by the domestic and commercial categories of consumers, it may not be suitable for the industrial category because of high dependence of demand on the end- use and also on the macroeconomic variables. In any case, the forecasts arrived at by using the trend method need to be modified for impact of any other considerations like increasing commercialization / development in certain districts / regions to incorporate the impact of econometric variables. The Discoms generally project category-wise sales based on the adjusted trend approach with requisite inputs from other approaches as well as from past experience and judgment.

(B) End-use Method

The End-use approach directly estimates energy consumption by using extensive information on end use and end users, such as appliances, the customer use, their age, sizes of houses and so on. Statistical information about customers along with dynamics of change is the basis for the forecast. These models are based on the principle that electricity demand is derived from

customers demand. Thus end-use models explain energy demand as a function of number of appliances in the market. Ideally this approach is very accurate. However, it is sensitive to the amount and quality of end-use data. End-use forecast requires less historical data, but more information about customers and their equipment.

Features of End-use Method:

1. Focus on uses of electricity
2. used primarily in residential, commercial and industrial sectors
3. Takes account of:

- Specific consumption of major appliances
- Degree of saturation of each appliance per customer
- Number of customers
- Growth of each of the above

This method is used to forecast the load of Low tension agriculture category.

(C) Econometric Approach

In this method, demand for electricity is expressed as a function of various economic and demographic factors. These variables could be population, GDP, per capita income or value added output (in industry or commercial sectors), price of power, price(s) of alternative fuels (that could be used as substitutes), proxies for penetration of appliances / equipment etc. The relationships are estimated by the least squares method or time series method or regression method. The relationship between the consumption of electricity and the economic factors varies for different categories of consumers and hence several functional forms need to be explored depending on the consumer category till a statistically significant relationship is established between electricity consumption and various factors.

Segmentation of consumers is the starting point for this approach. For different consumer categories the segmentation is based on different variables, for e.g., for domestic consumers, it can be done for different income level, level of consumption and / or the geographical location.

Features of Econometric Method:

1. Focuses on identification of correlation between demand for electricity and explanatory variables.
2. Provide insights into causes of past growth and variation in growth
3. To produce a forecast, projections of independent variables are needed
4. Combines economic theory and statistical techniques
5. Allows explicit evaluation of impacts of change factors
6. Useful in objectively evaluating likely consequences of various policy options
7. Relates energy sales to demographic and socio- economic explanatory variables
$$\text{Sales GWh (t)} = a + b_1 (\text{demographic indicators, t}) + b_2 (\text{economic indicators, t})$$
8. Assumes relationships between demand and explanatory variables such as GDP, population and number of households

9. Requires stable historical data
10. Test relationship for logical rationale and goodness of fit
11. Select the relationship that is most appropriate

This method is used to forecast the loads of all categories except low tension agriculture category.

1.5 Planning Norms and Guidelines:

1.5.1 Load is a constantly changing variable and since the load and generation must be matched at all times to maintain a reasonably constant frequency, the duties imposed on a transmission system are infinitely variable within the extremes of minimum load and maximum load. To this must be added the uncertainties associated with both the load forecast and the generation plan. This will enable the power system to operate without any constraints in the event of any changes occurring in the load forecast or the generation plan.

1.5.2 The objective of the plan shall be to install sufficient capacity to evacuate power from generating stations to grid substations (having regard to the load forecast) to evolve a power system with a level of performance characterized by an acceptable degree of adequacy and security i.e. maintaining voltage levels under different system operating conditions within normal limits prescribed in Grid code and containing transmission losses at levels consistent with its load forecast and providing for the economic exchange of power with contiguous states. Since the cost of transmission system is only a fraction of total investment requirement for power, high levels of reliability can be achieved at moderate cost due to economic and safe designs. Savings in transmission costs at the expense of reliability may render the system unable to service the load, resulting in lost revenues and dissatisfied customers. The transmission planning must focus on identifying optimum technical alternatives to meet the future load. Ultimately, however, the selection of final plan will be made on economic and / or environmental conditions.

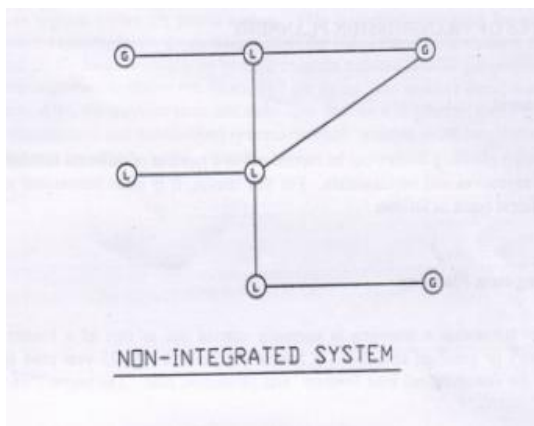
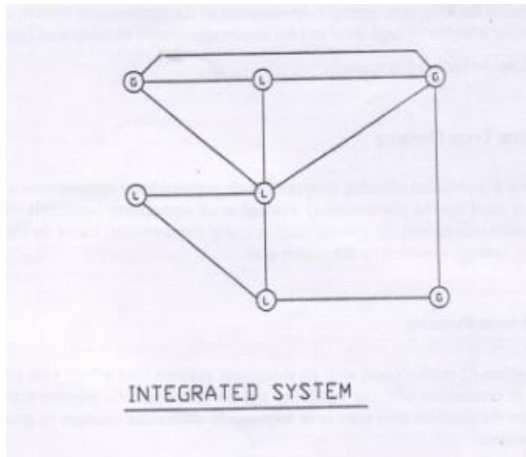
1.5.3 Power transmission system connecting generation to the load can be broadly classified into following types.

(a) Bulk Power Transmission: Bulk transmission system connects major power plants to the regional load centres. This system delivers large blocks of power to the areas that contain large concentration of load. It normally operates at highest network voltage. This system also interconnects generating stations, and load centres. Bulk transmission system is operated as a meshed system and normally covers a wide geographical area.

(b) Area Transmission: Area transmission system connects regional load centres (bulk supply points) to area load centres such as cities, large towns and large industrial consumers. Area transmission system is at a lower voltage than the bulk transmission system.

(c) Sub-Transmission: The sub-transmission system serves to connect area supply points to the distribution centres. This system is predominantly operated as a radial system from each area or bulk supply point. Sub-transmission systems are at a lower voltage level than the bulk system. In any system as the load levels increase, it becomes more economic to introduce higher voltage levels into the network to maintain or improve the efficiency of the transmission system. In these circumstances, the erstwhile bulk system takes the role of an area transmission system and ultimately a sub-transmission system.

1.5.4 At the bulk transmission level, there are two basic system types, known as integrated and non-integrated. Major generating plants are connected to major load centres in a non-integrated system, whereas an integrated system also connects major generating plants to each other and connects major load centres to each other.



1.5.4.1 Integrated system offers a high degree of flexibility, but requires a significantly larger transmission system. It provides flexibility in the location of generating stations, and allows the system to be operated with a reduced generation reserve. It improves the ability to withstand sudden changes or disturbances caused by faults or load changes.

1.5.4.2 Considering the Regulatory Commission's directive emphasizing extension of reliable and secure power supply to consumers and the advantages of an integrated system, due weightage for an integrated system in the transmission planning be given. As load develops, transmission system which originally started as non-integrated system may be evolved into integrated system.

1.5.5 Definitions of certain terms used in planning

1. **System Elements:** All switchable components of a transmission system such as Transmission lines, Transformers, Reactors etc.
2. **Contingency:** Temporary removal of one or more system elements from service. The cause or reason for such removal may be a fault, planned maintenance / repair

a) Single Contingency: The contingency arising out of removal of one system element from service.

b) Double Contingency: The contingency arising out of removal of two system elements from service. It includes a double Circuit line (D/C line), two Single Circuit lines (S/C lines) in same corridor or different corridors, a S/C line and a Transformer etc.

c) Rare Contingency: Temporary removal of complete generating station or complete substation (including all the incoming and outgoing feeders and transformers) from service, HVDC bi pole and stuck breaker condition.

3. Annual Peak Load: It is the simultaneous maximum demand of the system being studied. It is based on latest Electric Power Survey (EPS) or total peaking power availability, whichever is less.

4. Minimum Load: It is the expected minimum system demand and is determined from average ratio of annual peak load and minimum load observed in the system for the last 5 years.

5. Maximum Hydro Generation: It is the condition when hydro power availability is maximum during the year. It is also known as High Hydro condition.

6. Maximum Thermal Generation: It is the condition when hydro generation is low (not necessarily minimum) and thermal generation kept maximum to meet seasonal peak loads (not necessarily annual peak load). In other words it is the condition when the gap between monthly peak demand and hydro power availability is maximum.

7. Special Area Dispatch: It is the condition when power output from all the generating stations located in an area (in close proximity) is kept at the maximum feasible level.

Maximum feasible level of a generating station is the maximum power output when all the units in a power station are in service assuming no planned or forced outages. However, in case of power station/complex where six or more units exist, for every six units one unit (second largest) is assumed to be under annual planned maintenance.

8. System Stability : A stable power system is one in which generators, when disturbed, will either return to their original state if there is no change in exchange of power or will acquire new state asymptotically without losing synchronism. Usually the disturbance causes a transient that is oscillatory in nature. In a stable power system the oscillations will be damped.

9. Damping: A system is said to be adequately damped when halving time of the least damped electro-mechanical mode of oscillation is not more than 5 seconds.

10. Oscillatory Stability: When voltage or rotor angle oscillations are positively damped following a grid disturbance, the system is said to have oscillatory stability.

11. Voltage Stability: It is the ability of a system to maintain voltage so that when load admittance is increased, load power will also increase so that both power and voltage are controllable.

12. Transient Stability: This refers to the stability following a major disturbance (faults, opening of a major line, tripping of a generator) and relates to the first few swings following disturbance.

13. Temporary Over voltages: These are power frequency over voltages produced in a power system due to sudden load rejection, single-phase-to-ground faults, etc.

14. Switching Over voltages: These are over voltages generated during switching off of lines, transformers and reactors etc. having wave fronts 250/2500 micro seconds.

15. Surge Impedance Loading: It is the unit power factor load over a Resistance line such that series reactive loss (I^2X) along the line is equal to shunt capacitive gain (V^2Y). Under these conditions the sending end and receiving end voltages are equal in magnitude but different in phase position.

16. Thermal Capacity of Line: It is the amount of current that can be carried by a line conductor without exceeding its designed operating temperature.

1.5.6 Transmission planning can be categorized into three types:

1.5.6.1 Long- term Planning

Long-term planning is normally carried out as part of a master plan with a horizon of 15-25 years and is based on the state load forecast and generation plan. Long-term plan serves to verify the technical feasibility of the selected generation plan to determine the long term strategic development of the transmission system; in particular the need for a higher voltage level and the implementation of an integrated system

1.5.6.2 Medium-term Planning

Medium-term transmission planning is carried out over a 10-15 year period. It is used for the pre-feasibility evaluation of alternatives associated with generation additions or specific system reinforcement requirements, based on the long-term development strategy provided by the master plan.

1.5.6.3 Short-term Planning

Short-term planning is carried out over a 5-10 year period. It is carried out in connection with the feasibility and design of specific projects that have been selected from the medium-term plan or in response to unforeseen changes in generation and load requirements.

1.5.7 Nature of load forecast used for planning study varies with each type of transmission planning. In a long-term study, forecasts are carried out on a total system basis and sometimes can be subdivided into operating areas or districts within the total system. This is sufficient as long-term planning is mainly concerned with the development of the bulk system. For medium-term and short-term studies, the focus is mainly on specific projects within a smaller geographical area and it becomes important to define the location of the future load in more detail than in the long-term plan. Also, medium-term and short-term studies will examine the lower voltage (sub transmission and distribution) systems in detail.

Transmission system shall be evolved based on detailed power system studies which shall include

- Power Flow Studies
- Short Circuit Studies
- Stability Studies (including transient stability, voltage stability and steady state oscillatory stability studies)
- EMTP Studies to determine switching / temporary over voltages

Note: Voltage stability, oscillatory stability and EMTP studies may not form part of long-term planning studies. These studies are required to be done before any scheme report is finalized.

1.5.8 Load- Generation Scenarios

1.5.8.1 The load - generation scenarios shall be worked out so as to reflect in a pragmatic manner the daily and seasonal variations in load demand and generation availability.

1.5.8.2 Load Demands: The profile of annual and daily demands will be determined from the past data. These data will usually give the demand at grid supply points and for the whole system identifying the annual and daily peak demand. The load demands at other periods (seasonal variations and minimum loads) shall be derived based on the annual peak demand and past pattern of load variations. From practical considerations the load variations over the year shall be considered as under.

- Annual peak load
- Seasonal variation in peak loads (corresponding to high thermal and high hydro generation)
- Minimum load
- Off-peak load relevant where pumped storage plants are involved or inter-regional exchanges are envisaged.

1.5.8.3 Reactive Power (MVAR)

Reactive power plays an important role in EHV transmission system planning and hence forecast of reactive power demand on an area-wise or substation-wise basis is as important as active power forecast. This forecast would require adequate data on the reactive power demands at different substations as well as the projected plans for reactive power compensation.

For developing an optimal power system, data on the substation-wise maximum and minimum demand in MWs and MVARs on seasonal basis, needs to be prepared. This will require compilation of past data in order to arrive at reasonably accurate load forecast. While every effort shall be made to assess the data on reactive power demand, in the absence of

such data load power factor at 220/132 kV voltage levels shall be taken as 0.85 lag during peak load condition and 0.9 lag during light load condition excepting areas feeding predominantly agricultural loads where power factor can be taken as 0.75 lag and 0.85 lag for peak and light load conditions respectively. In areas where power factor is less than the limit specified above, utility shall endeavor to bring the load power factor to these limits by providing shunt capacitors at appropriate places in the system.

1.5.8.4 Generation Dispatches

Generation dispatch of Hydro and Thermal units would be determined judiciously on the basis of hydrology as well as scheduled maintenance programme of the generating stations. The norms for working out the peaking availability of different types of generating units are given below. In case of nuclear units minimum level of output shall be taken as not less than 70% of the rated capacity.

1.5.9 Norms for Peaking Capability of Generating Stations

1.5.9.1 The peaking availability of generating units would be taken on the basis of the latest norms laid down by CEA. The spinning reserve of 5% for Thermal, Nuclear, Hydro generation and Backing down allowance of 5% for Gas based generation as laid in the present norms of Generation Planning Criteria of CEA may not be taken into consideration for Transmission Planning due to continuing peaking shortage of power in all the regions during eighth plan period - and beyond.

1.5.9.2 Thermal Stations:

The peaking capability of generating units would be computed as given below

Unit Capacity (MW)	Outage rates			Aux. Consumption (AC)	Capacity availability factor (CAF)	Peaking capability factor (PCF)
	Planned (PMR)	Forced (FOR)	Partial (POR)			
200 MW & above	10.0	14.0	9.0	10.0	67.0	60.3
Below 200 MW	10.0	16.0	14.0	10.5	60.0	53.7

Note: i) $CAF = 100 - (PMR + FOR + POR)$
 $PCF = CAF - CAF \times AC$

ii) In case of Eastern and North-Eastern Regions forced outage rate will be increased by 5%.

1.5.9.3 Hydro stations:

Capital Maintenance (CM) = 3%
 Forced Outage rate (FOR) = 4.5%
 Auxiliary Consumption (AC) = 1.0%
 Capacity availability factor (CAF) = $100 - (CM + FOR) = 92.5\%$
 Peaking Capability Factor (PCF) = $CAF - CAF \times AC = 91.5\%$

1.5.9.4 Gas based Stations:

The gas based power stations are grouped into two categories namely base load stations and peak load stations. The base load stations are normally combined cycle power plants which have Gas Turbine units and Steam Turbine units. The peak load stations are open cycle Gas Turbines which are generally used for meeting peak load for about 8 Hours in a day at 80 % of their rated capacity.

For combined cycle gas based power station, the peaking capability would be as given below:

Unit Capacity (MW)	Outage rates			Aux. Consumption (AC)	Capacity availability factor (CAF)	Peaking capability factor (PCF)
	Planned (PMR)	Forced (FOR)	Partial (POR)			
Gas Turbine units	15.0	10.0	10.0	1.0	65.0	64.4
Steam Turbine units	15.0	10.0	10.0	4.0	65.0	62.4

Note: $CAF = 100 - (PMR + FOR + POR)$

$PCF = CAF - CAF \times AC$

1.5.9.5 Generation dispatches corresponding to the following operating conditions shall be considered depending on the nature and characteristics of the system.

- Annual peak load
- Maximum thermal generation
- Maximum hydro generation
- Annual minimum load
- Special area dispatches
- Special dispatches corresponding to high agricultural load with low power factor, wherever applicable
- Off peak conditions with maximum pumping load where pumped storage stations exist and also with the inter-regional exchanges, if envisaged
- Complete closure of a generating station close to a major load centre.

1.5.9.6 The generation dispatch for the purpose of carrying out sensitive studies corresponding to complete closure of a generating station close to a major load centre shall be worked out by increasing generation at other stations to the extent possible keeping in view the maximum likely availability at these stations, ownership pattern, shares etc.

1.5.9.7 The adequacy of the transmission system should be tested for different feasible load generation scenarios

1.5.9.8 The following options may be considered for strengthening of the transmission network.

- Addition of new transmission lines to avoid overloading of existing system. (Whenever three or more circuits of the same voltage class are envisaged between two substations, the next transmission voltage should also be considered.)
- Application of Series Capacitors in existing transmission line to increase power transfer capability.
- Up gradation of existing AC transmission lines.
- Re-conductoring of the existing AC transmission line with higher size conductors or with AAAC, Al. alloy conductors, INVAR Conductors etc.
- Adoption of multi-voltage level and multi-circuit transmission lines.

1.5.9.9 The choice shall be based on cost, reliability, right-of-way requirements, energy losses, downtime (incase of up gradation and re conductoring options) etc. The adoption of FACTS (Flexible AC Transmission System) in transmission up gradation may also be kept in view.

1.5.9.10 Incase of generating station close to a major load centre, sensitivity of its complete closure with loads to be met (to the extent possible) from other generating stations shall also be studied.

1.5.9.11 Incase of transmission system associated with Nuclear Power Stations there shall be two independent sources of power supply for the purpose of providing start-up power facilities. Further the angle between start-up power source and the NPP switchyard should be, as far as possible, maintained within 10 degrees.

1.5.9.12 The evacuation system for sensitive power stations shall generally be planned so as to terminate it at large load centres to facilitate islanding of the power station incase of contingency.

1.5.9.13 Where only two circuits are planned for evacuation of power from a generating station, these should be (as far as possible) two single circuit lines instead of a double circuit line.

1.5.9.14 Reactive power flow through ICTs shall be minimal. Normally it shall not exceed 10% of the rating of the ICTs. Wherever voltage on HV side of ICT is less than 97.5% of rated voltage no reactive power shall flow through ICT.

1.5.9.15 Thermal / Nuclear Generating units shall normally not run at leading power factor. However, for the purpose of charging, generating unit may be allowed to operate at leading power factor as per the respective capability curve.

1.5.10 Permissible Line Loading Limits

1.5.10.1 At some point in the planning process, it will be necessary to evaluate the performance of individual transmission lines against a pre assigned capacity limit. Permissible line loading limit depends on factors, such as voltage regulation, stability and current carrying capacity (thermal capacity). Line loading can be limited by voltage and stability factors, these are system-dependent line loading limits, which will vary from year to year and system to system. A useful capacity limit that is independent of system configuration is that of thermal capacity and represents maximum loading level of a circuit that must be observed to avoid permanent damage to the equipment.

1.5.10.2 Thermal capacity of a transmission line is decided by design practice based on the conductor size and type and environmental factors viz., ambient temperature, wind speed, solar radiation and on maximum permissible conductor temperature. Ambient temperatures in various parts of the country are different and vary considerably during various seasons of the year. Design of transmission line with ACSR conductors in EHV system will normally be based on a conductor temperature limit of 75°C. In the case of AAAC conductors, maximum conductor temperature limit will be taken as 85°C. The maximum permissible line loadings in respect of different types of conductors for different ambient and maximum temperatures as given in the chart below may be followed if permitted by stability and voltage regulation considered.

1.5.10.3 THERMAL LOADING LIMITS

Conductor type and dimension	Ambient Temp. (°C)	AMPACITY FOR Maximum Conductor Temperature		
		65	75	85
ACSR PANTHER 210 Sq mm	40	312	413	
	45	244	366	
	48	199	334	
	50		311	
ACSR ZEBRA 420 Sq. mm	40	454	622	
	45	339	546	
	48	240	493	
	50		454	
ACSR MOOSE 520 Sq. mm	40	487	684	
	45	345	595	
	48	214	532	
	50		487	
ACSR BERSIMIS 680 Sq. mm	40	565	804	
	45	388	697	
	48	220	621	
	50		565	
AAAC 420 Sq. mm	40			762
	45			701
	48			661
	50			632
AAAC	40			843

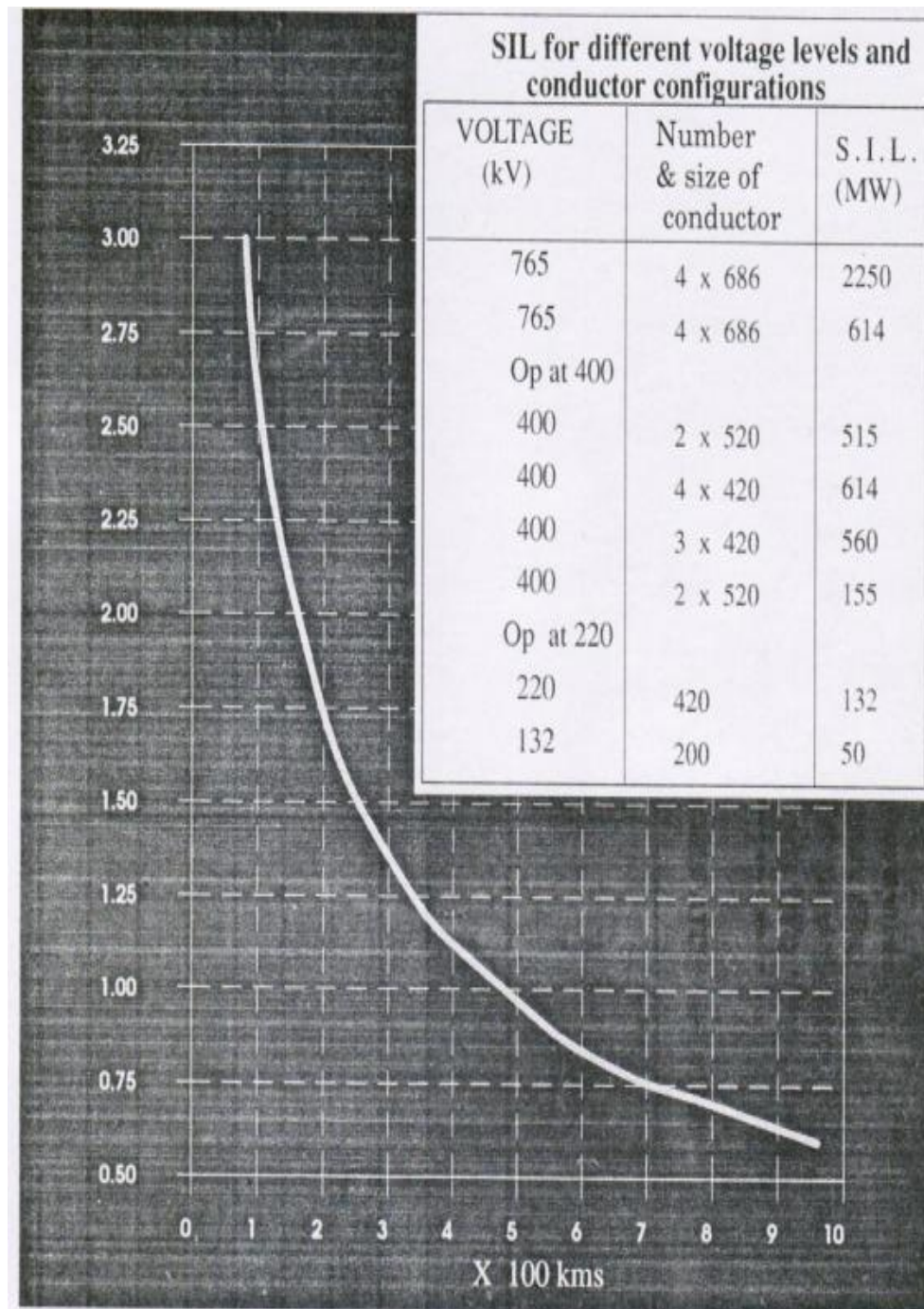
520 Sq. mm	45			773
	48			726
	50			694
AAAC 560 Sq. mm	40			882
	45			808
	48			759
	50			725

Assumptions: solar radiations = 1045W/sq.mt., Wind velocity = 2km/hour

Absorption coeff. = 0.8, Emissivity coeff = 0.45 Age > 1 year

1.5.10.4 While Surge Impedance Loading (SIL) gives a general idea of the loading capability of the line, it is usual to load short lines above SIL and long lines lower than SIL (because of stability limitations). SIL at different voltage levels is given below.

1.5.11 LINE LOADING AS FUNCTION OF LENGTH



1.5.11.1 The above chart shows the line loading (in terms of surge impedance loading of uncompensated line) as a function of line length assuming a voltage regulation of 5% and phase angular difference of 30 deg. between the two ends of the line. In case of shunt compensated lines, the SIL will get reduced by a factor k, where

$$k = \sqrt{1 - \text{degree of compensation}}$$

1.5.11.2 For lines whose permissible line loading as determined from the curve is higher than the thermal loading limit, permissible loading limit shall be restricted to thermal loading limit.

1.5.12 Steady State Analysis

For the initial and final years in any study period and for selected intermediate years, it is necessary to determine the steady state performance of the system. This allows the planner to review the system performance and determine the requirements for any reinforcement. The steady state analysis is carried out using a conventional load flow programme which calculates the voltages and circuit loadings for a given set of load and generation levels. This type of analysis will also investigate alternative reinforcement schemes in order to allow the planner to select those alternatives worthy of further investigation. It is normal to investigate the system under both normal conditions and contingency conditions (where one or more circuits are out of service)

1.5.13 Dynamic Analysis

Dynamic analysis is carried out using a conventional stability program to verify the dynamic performance of the system and to determine the need for reinforcement in addition to that required for satisfactory steady state performance. While steady state analysis gives the ability of the system to perform under both normal and contingency conditions, the dynamic analysis demonstrates the ability of the system to survive the transition from normal to contingency conditions. Short circuit studies are required to be carried out as a part of dynamic analysis to determine the future values of short circuit current at various points in the system. These are used to select the fault current interrupting ratings for future circuit breakers.

The planning process must bear in mind the Operation and Maintenance aspects. Various reinforcements considered in planning may be reviewed from an O&M aspect to avoid building potential bottlenecks into the system

1.5.14 Economic and Environmental Impacts

Major work in transmission planning is technical in nature and identifies optimum technical alternatives to meet the future load. Ultimately, however, the selection of final plan will be made on economic and/or environmental considerations. As part of the overall planning process it is, therefore necessary to examine the economic and environmental impact of the alternative development plans being considered. The evaluation of economic impacts involves an estimation of capital costs, operating costs and the cost of losses associated with each alternative and comparing these costs. The environmental impacts are usually relatively small for transmission lines and substations and difficult to translate into equivalent costs. This factor can therefore be ignored.

1.6 Planning Criteria

1.6.1 Planning criteria are the set of rules used to determine whether the system performance considered is satisfactory or not. They allow alternative development scenarios to be compared on a common technical basis. They constitute one of the most important parts of any planning study. Criteria can be broadly divided into three main categories; Steady state performance, dynamic performance, and economic.

1.6.1.1 Planning criteria need not be rigidly applied in long-term planning study. Although the criteria are meant to be applied on a system-wide basis, there may arise situations when

engineering judgment is required. Remote parts of the system may suffer from low voltage problems at peak load or due to export to other Regions. If the low voltage is just outside the specified limits, it may be prudent sometimes to accept a minor deviation from the criteria, particularly if the remedial cost is high (such as providing an additional circuit). In the planning context, such relaxations can be accepted provided:

- The identified problem is common to all the alternative development plans,
- It does not cause potential damage to equipment.
- It does not represent a safety hazard.

1.6.1.2 Thus while for specific cases it would be acceptable to relax the voltage criterion or even the single contingency criterion, it would not be acceptable to allow any equipment overloads.

1.6.2 Steady State Performance Criteria

1.6.2.1 The steady state criteria normally cover the following:

- Voltage limits
- Equipment loading limits
- Type of contingencies

1.6.2.2 Voltage Limits: Voltage limits are based on the normal working range of major items of equipment, which is normally +10% of the nominal value. The steady state voltage shall be maintained within the limits given below.

VOLTAGE (kV rms)

Nominal	Maximum	Minimum
765	800	728
400	420	380
220	245	198
132	145	122

1.6.2.3 It is normal to select a smaller range (+ 5%) for operation under normal conditions to allow a margin of safety, in the event that the system operator is unable to apply sufficient corrective action to the system following the contingency. The application of a +5% limit, even for outage conditions would result in additional transmission or reactive compensation on the EHV system, while a +10% limit for outage conditions might result in a need for additional reactive compensation at the lower voltage levels.

1.6.2.4 Temporary Over Voltages: due to sudden load rejection.

420kV system 1.5 p.u. peak phase to neutral (343kV = 1p.u.)

800kV system 1.4 p.u. peak phase to neutral (653kV = 1p.u.)

1.6.2.5 Switching Over Voltages: 420kV system 2.5 p.u. peak phase to neutral (343kV = 1p.u.)

800kV system 1.9 p.u. peak phase to neutral (653kV = 1p.u.)

1.6.2.6 Equipment Loading Limits:

Equipment loading limits may be based on voltage or stability limits, but should never exceed the thermal capacity of the equipment. Operating the transmission line above the design temperature for longer periods will result in an increase in the sag of the conductor, reducing ground clearance of the line, which may cross the statutory regulation limits. Transmission line shall not be loaded beyond thermal capacity limit. In case of lines with bunched conductors i.e., each phase has multiple conductors, these limit conductor surface gradients, corona and radio noise and in these cases, the thermal limit is rarely approached.

1.6.2.7 Type of Contingency

Historically, transmission planning has been carried out on the basis of a deterministic, single contingency criterion. This involves testing the system for the outage of a single element (transmission circuit, transformer or generator) and applying the voltage and loading criteria mentioned above. Loss of both circuits of a double circuit line (e.g. as a result of tower failure) can be considered as a single contingency, where the probability of such tower failure is considerable (from historical data).

1.6.2.8 Operational Standards

The operational standards normally define the expected level of power system performance under different operating conditions of the system. The following operational standards provide guiding objectives for planning and design of transmission system.

1. System parameters (voltage and frequency) shall be as close to the nominal values as possible and there shall be no overloading of any system element under normal conditions and different feasible load-generation conditions.
2. System parameters and loading of system elements shall remain within prescribed limits and not necessitate load shedding or generator re-scheduling in the event of outage of any single system element over and above a pre-contingency system depletion of another element in another corridor. In case of 220kV and 132kV systems this shall hold good for outage of Double Circuit lines. In case of power evacuation from major generating station (when the terrain indicates possibilities of tower failure) the system shall withstand the outage of two 400kV circuits if these are on the same tower. Also in the case of large load complexes with demands exceeding 1000MW the impact of outage of two incoming 400kV circuits (if these are on the same towers) shall be minimum.
3. The system shall remain in synchronism without necessitating load shedding or islanding in the event of single-phase-to-ground fault (three-phase fault in the case of

220kV and 132kV systems) assuming successful clearing of fault by isolating/opening of the faulty system element.

4. The system shall have adequate margins in terms of voltage and steady state oscillatory stability.
5. No more than four 220kV feeders/two 400kV feeders/one 765kV feeder shall be disrupted in the event of a stuck breaker situation.

1.6.2.9 As a general rule, the EHV system shall be capable of withstanding without necessitating load shedding or re-scheduling of generation, the following contingencies:

- Outage of a 132kV D/C line or,
- Outage of a 220kV D/C line or,
- Outage of a 400kV single circuit line or,
- Outage of a 765kV single circuit line or,
- Outage of one pole of HVDC Bipolar line or
- Outage of an interconnecting Transformer

1.6.2.10 The above contingencies shall be considered assuming pre contingency system depletion (planned outage) of another 220kV D/C line or 400kV single circuit line in another corridor and not emanating from the same substation. All the generating stations shall operate within their reactive capability curves and the network voltage profile shall also be maintained within voltage limits specified above.

1.6.2.11 The power evacuation system from major generating station/complex shall be adequate to withstand outage of a 400kV Double Circuit line if the terrain indicates such a possibility.

1.6.2.12 In case of large load complexes with demands exceeding 1000MW the need for load shedding in the event of outage of a 400kV Double Circuit line shall be assessed and kept minimum. System strengthening required if any, on account of this shall be planned on an individual case-to-case basis.

1.6.2.13 The maximum angular separation between any two adjacent buses shall not normally exceed 30 degrees.

1.6.3 Stability Considerations

A. Transient Stability

1. The system shall remain stable under the contingency of outage of single largest unit.
2. The system shall remain stable under the contingency of a temporary single-phase-to-ground fault on a 765kV single circuit line close to the bus assuming single pole opening

of the faulted phase from both end substations in 100msecs (5 cycles) and successful reclosure (dead time 1 sec.).

3. The system shall be able to survive a single-phase-to-ground fault on a 400kV line close to the bus as per the following criteria:

A. 400kV S/C line: System shall be capable of withstanding a permanent fault. Accordingly, single pole opening (100msec) of the faulted phase and unsuccessful reclosure (dead time 1 sec.) followed by 3-pole opening (100msec) of the faulted line shall be considered.

B. 400kV D/C line: System shall be capable of withstanding a permanent fault on one of the circuits when both circuits are in service and a transient fault when the system is already depleted with one circuit under maintenance/outage. Accordingly, 3-pole opening (100msec) of the faulted circuit shall be considered when both circuits are assumed in operation (single pole opening and unsuccessful auto-reclosure is not considered generally in long 400kV D/C lines since the reclosure facility is bypassed when both circuits are in operation, due to difficulties in sizing of neutral grounding reactors) and single pole opening (100msec) of the faulted phase with successful reclosure (dead time 1sec) when only one circuit is in service.

4. In case of 220 /132 kV networks, the system shall be able to survive a three-phase fault with a fault clearing time of 160msec (8 cycles) assuming 3-pole opening.

5. The system shall be able to survive a fault in HVDC Converter station resulting in permanent outage of one of the poles of HVDC Bipoles.

Besides the above the system may also be subjected to rare contingencies like outage of HVDC Bipole, delayed fault clearance due to stuck breaker conditions etc. The impact of these on system stability may also be studied while working out defence mechanisms required in system operation such as load shedding, generation rescheduling, islanding etc.

B. Voltage Stability

Each bus shall operate above knee point of Q-V curve under normal as well as the contingency conditions as mentioned above.

1.6.4 Reactive Power Compensation

1.6.4.1 Shunt Capacitors: As far as possible shunt reactive compensation should be provided in the low voltage system, close to the load points, to meet the reactive power requirements of load, thereby avoiding need for VAR transfer from high voltage system to the low voltage system. Where 132/220kV voltage level is not represented in the system planning studies, shunt capacitors required for meeting the reactive power requirements of loads shall be provided at 132/220kV buses.

1.6.4.2 Shunt Reactors: Switchable reactors shall be provided at EHV substations for controlling voltages within the specified limits without resorting to switching off of lines. Under steady state condition, switching on and off of the reactors shall not cause a voltage

change beyond 5%. Suitable size of Reactor shall be selected. Some standard sizes of reactors (MVAR) are

400kV (3-ph units)	50, 63 & 80 at 420kV
765kV (1-ph units)	50, 63 & 110 at 800kV

Fixed line reactors may be provided to control temporary power frequency overvoltage (after all voltage regulation action has taken place) within the limits specified above, under all probable operating conditions.

Line reactors (switchable/controlled/fixed) may be provided if it is not possible to charge EHV line without exceeding the specified voltage limits. The possibility of reducing pre-charging voltage of the charging end shall also be considered, while examining the need for reactors.

1.6.4.3 Static VAR Compensation (SVC)

Static VAR Compensation shall be provided where needed to damp the power swings and provide the system stability under all operating conditions defined above. The dynamic range of static compensators shall not be utilized under steady state operating condition as far as possible.

1.7 Sub-Station Planning Criteria

1.7.1 Planner shall take into consideration, the total load to be catered by an EHV substation of a particular voltage level, its MVA capacity, number of feeders permissible etc. to know about the time for going in for adoption of next higher voltage level substation and also the number of substations required for meeting a particular quantum of load. The following criteria shall be considered while planning a substation.

1.7.2 The maximum fault level on any new substation bus should not exceed 80% of the rated rupturing capacity of the circuit breaker. 20% margin is intended to take care of the increase in short-circuit levels as the system grows. The rated rupturing current capacity of switchgear at different voltage levels presently in use are:

132kV	-	25 /31.5 kA
220kV	-	31.5 /40 kA
400kV	-	40kA

1.7.3 The maximum short-circuit levels at all EHV substations shall be computed taking into consideration generation expansion plan and corresponding expansion in transmission network, to assess the adequacy of the switchgear capacity. Where the above margins are exceeded, action to replace the switchgear with higher capacity ones shall be taken. The next higher capacity shall be so chosen to be adequate for the useful life period of the switchgear. It may be borne in mind that higher breaking current capability requires major design change in the equipment.

The capacity of any single substation shall not normally exceed:

765kV - 2500 MVA

400kV - 1000 MVA

220kV - 320 MVA

132kV - 150 MVA

1.7.4 Size and number of interconnecting transformers (ICTs) shall be planned in such a way that the outage of any single unit would not overload the remaining ICT(s) or the underlying system.

1.7.5 A stuck breaker condition shall not cause disruption of more than four feeders for 220kV system and two feeders for 400kV system and one feeder for 765kV system.

1.7.6 Dynamic Performance Criteria

1.7.6.1 The dynamic criteria set out the type of fault and fault duration for which the system shall be tested. For the type of fault: a three-phase dead fault (zero fault impedance) may be considered. Although this is a very rare fault, it is relatively easy to study. A three-phase fault, cleared by primary protection, gives a similar result as the more common single-phase to ground fault, cleared by back-up protection. Fault durations are generally a function of the voltage level but are more accurately determined by reference to the protection scheme available on each circuit with its corresponding settings and the operating time of the circuit breakers.

1.7.6.2 Where high speed auto-reclosing schemes are in service, the same may be used for single-phase to ground faults. For three-phase faults, delayed auto-reclosing is used to avoid damage to rotating machinery which can occur following a high speed auto-reclose.

1.7.7 Economic Criteria

In carrying out economic analysis, the following criteria shall be considered:

(a) Discount rate to be used in any discounted cash flow calculations.

$$\text{Discounted cost} = \frac{\text{Actual cost}}{(1 + r)^n}$$

r = Discount rate (%) / 100

n = number of years from the reference year

The discount rate is similar to an interest rate in reverse, but its value is not necessarily related to current interest rate.

(b) The cost of power and energy losses

Transmission losses are an important factor to consider when comparing the benefits of transmission at different voltage levels, using different conductor sizes or no. of conductors per phase, etc.

(c) Equipment economic life.

The life time cost of the system consists of capital cost (cost of land, building, equipment, installation) and the working capital plus operating cost (mostly cost of losses and maintenance) plus interest and insurance. An optimal project requires minimum total life time cost. In transmission planning studies it is not usual to consider replacement of a transmission line or a transformer because of age since, with proper maintenance and repair, its useful life will be in excess of 50 years. For economic analysis it is normal to amortize the cost of transmission line over a 30 year period since the use of a longer amortization period would have little effect on the results.

1.8 Planning Methodology

1.8.1 Performance of the existing system is evaluated with the system data collected. Next the horizon year of the study time frame should be examined. With the horizon year fixed and initial and final systems defined, the intermediate years can be examined to determine the timing of new facilities.

1.8.2 As a part of the horizon year studies, it is convenient to first examine the new, remote generating plants or sub-systems that must be integrated into the main system. The nature of transmission for such systems is usually straightforward in terms of no. of alternatives available and they can usually be examined without reference to the overall development of the main system. The main objective of these studies is to determine the optimum voltage and number of circuits required to integrate these systems into the main system. Focus should be on long range development of 220kV, 400 kV systems plus higher voltage levels and other transmission types such as HVDC.

1.8.3 Development of Alternative Schemes:

1.8.3.1 An important part of the planning process is to develop alternative horizon year systems that perform satisfactorily according to the selected criteria, for the overall development of the main system. It requires a subjective examination of the system and the development of imaginative, alternative solutions to overcome the identified shortcomings.

1.8.3.2 The following factors need to be considered in developing alternative transmission schemes.

- Region shall be divided into zones on a geographical and/or topographical basis. By identifying generation and load centres within each zone it is possible to develop the year-by-year generation /load balances for each zone.
- Generation / load balances together with the knowledge of existing system will allow the planner to identify alternatives for connecting zones together (i.e. zones with surplus generation need to be connected to zones with a deficit, either directly or via other zones).
- In developing these alternatives, different transmission routes, different voltage levels and alternative transmission types shall be examined.

- Technical analysis of the alternatives shall be done by conducting load flow studies, short circuit analysis, and stability and reliability studies.
- Preliminary design for each alternative shall be made and preliminary cost analysis to be done.

1.8.3.3 Preliminary design for each type of transmission system to determine the probable voltage level and conductor size is carried out and cost estimates for each design prepared. Most attractive alternatives are retained for further technical analysis.

1.8.4 Technical Analysis of Alternatives

Technical analysis determines the reinforcement required to the transmission system and the timing of these reinforcements. Each alternative must be developed on a consistent basis and must be technically equivalent as far as possible.

1.9 Load flow Studies

Load flow studies are conducted to determine the steady state performance of the system, which may, in fact, exist only a few minutes each year. Since it is impractical to analyze the system for each possible load level, extremes of the operating states may be considered for analysis, the rationale being that if system operates satisfactorily for the extreme states, then it will be satisfactory for all intermediate states. To achieve this, it is usual to define a number of operating scenarios for which the system will be analyzed. Some possible scenarios are peak load and minimum load. These load levels may correspond to annual peak and minimum or may consist of seasonal peaks and minimums. These scenarios are normally sufficient to examine the transmission stresses from the load point of view, but it is also necessary to consider the transmission stresses from the generation point of view. Additional scenarios may be required to examine such as maximum hydro generation levels, maximum thermal generation levels and maximum import/export levels from other systems.

1.9.1 Short Circuit Studies

Short circuit studies are carried out to determine the required interrupting capability for circuit breakers and short circuit withstand capacity for Power transformers and associated switch gear. These studies give the range of fault currents that can be expected at each substation corresponding to minimum and peak load scenarios. This information is useful for substation and protection system design. Maximum and minimum short circuit levels can also provide some guidance in the allocation of reactive power support.

The present short circuit capabilities in APTRANSCO are

- 400kV and 220kV: 40kA
- 132kV: 31.5kA
- 33kV: 25kA

1.9.2 Stability Studies

Stability studies are done under the same scenarios as in the load flow studies. Results of load flow studies can be used to select the stability cases to be examined since the load flow results show the loading on each circuit. Stability studies for transmission line outages would simulate a three phase zero impedance fault at one end of the line applied for a specified duration, after which the line is removed from service. The fault duration should be representative of the fault clearing times achievable with existing protection schemes and circuit breakers. Specified fault durations in CEA Manual are

- 400kV faults: 5 cycles
- 220kV faults: 8 cycles

1.9.3 Preliminary Design and Costing

1.9.3.1 Voltage Selection: The studies described above allow the system planner to determine the need for additional transmission facilities. First choice to be made for any new line is the voltage level of the circuit(s). In making this choice, account should be taken of the following factors:

- The existing voltage levels within the system
- The power transfer levels across the circuit(s)
- The transmission distance involved

1.9.3.2 New voltage levels should never be introduced arbitrarily into an existing system. Such a step must be supported by long-term development studies which demonstrate a clear economic benefit for the new voltage level over the existing voltage levels.

1.9.3.3 The power transfer level and the transmission distance are linked together: - the shorter the length, more power can be transferred. In bulk power transmission systems where the voltage levels are normally above 220kV, the electrical design requirements usually result in large conductors or multiple conductors being used to limit electrical interference. In addition to thermal capacity of the conductor, power transfer capability of a circuit may be limited by stability considerations. Surge Impedance Loading (SIL) of a circuit provides useful guide between power transfer capability and transmission distance. The SIL of a circuit is the loading level at which reactive power absorbed by the circuit (Inductive) is balanced by the reactive power (capacitive) generated by the circuit due to line charging. This parameter is independent of line length and is relatively insensitive to the number and size of the conductors.

Surge Impedance, $Z_s = \sqrt{X \div B}$

Where X is the reactance and B the susceptance of the circuit. Z_s is in units consistent with X and B (either in ohms or in per unit).

$SIL = 100/Z_s$ where SIL is in MW and Z_s is in per unit on 100 MVA.

1.9.3.4 From stability point of view, it is recommended to operate the system in a manner so that the phase angle difference between voltages across any transmission circuit is less than 30° . The expected power transfer level for a particular line can be divided by SIL at each of

the voltage levels being considered. Number of circuits required to produce a satisfactory loading level can then be determined. This approach can be used to identify the voltage levels that could reasonably be used for the particular transmission line being investigated.

1.9.3.5 While giving consideration to the voltage level of any new transmission circuit, investigation should be made of different types of transmission line. i.e. alternative transmission techniques like HVDC and the use of Series Compensation. Series Compensation effectively shortens the electrical length of the line, allowing more power to be transferred. HVDC effectively isolates two AC systems from each other and thus stability of the link is not a determining factor in its design.

1.9.4 Conductor Selection: For each voltage level being considered, it is necessary to select the number and size of conductors. Conductor sizes have been standardized in APTRANSCO over years. Standard size of conductors used and their thermal ampacities for different operating temperatures are furnished below.

Conductor	40° C ambient	45° C ambient	40° C ambient
	75° Cond. Temp	75° Cond. Temp	100° Cond. Temp
	Amp/MVA at100%kV	Amp/MVAat100%kV	Amp/MVAat100%kV
400kV			
Twin Moose ACSR	1368 / 948	1190 / 825	1800 /1247
220kV			
Zebra ACSR	622 / 237	546 / 208	795 / 303
Moose ACSR	684 / 261	595 / 227	900 / 343
132kV			
Panther ACSR	413 / 95	366 / 84	520 / 119

1.9.4.1 In general conductor selection is made in two stages:

- determine the minimum conductor size that gives acceptable performance
- determine the optimum conductor size that results in the lower cost

1.9.4.2 The minimum conductor size is determined by the thermal capacity required and the conductor surface gradient. High conductor surface gradients (above 17kV/cm) will result in high levels of radio and television interference, high levels of audible noise and increased corona losses.

1.9.4.3 Optimum conductor size is determined by estimating the capital cost of the line for a range of conductor sizes and calculating the line losses expected with the planned power transfer levels over the life of the line. These line losses can be converted into an equivalent capital cost which is added to the capital cost of the line. As the conductor size increases, the capital cost increases and the cost of losses decreases. At some conductor size an optimum

can be found where the sum of the capital and loss cost is minimum. If the optimum size is below the minimum size then minimum must be selected.

1.10 Substation Design

1.10.1 For planning purposes, it is necessary to consider general type of arrangement envisaged for any new substations and the ratings of major equipment (transformers, switchgear, and reactive power compensation equipment).

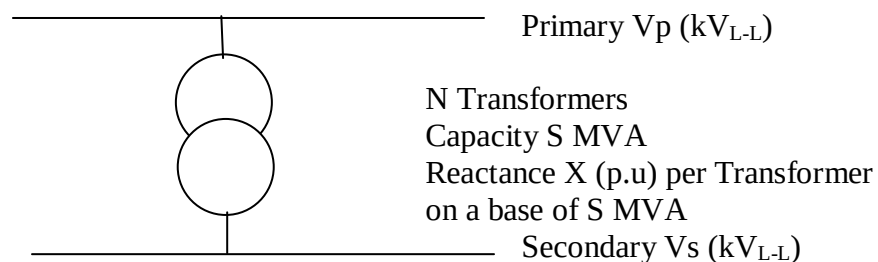
1.10.2 Selection of a particular type of arrangement should be based on existing substations and the importance of the new substation within the system. For major stations (400kV, 220kV), the most common arrangements are main and transfer bus, double-bus, double bus with transfer bus, ring bus, and breaker- and- a- half. Ratings of major equipment are obtained from the technical analysis of the system.

1.10.3 Standard ratings for transformers adopted in APTRANSCO are furnished below.

Voltage	ONAN Rating (MVA)	ONAF Rating (MVA)
400/220 kV	190	315
220/132 kV	100	160
	60	100
220/33 kV	30	50
	20	31.5
132/33 kV	50	80
	30	50
	20	31.5

1.10.4 Maximum of three transformers are considered per substation.

Substation Maximum Capacity:



Assuming an infinite bus on the primary side, and no contribution from the secondary side:

$$\text{Total reactance to the secondary bus} = \frac{X * 100}{N * S} \quad \text{p.u. on 100 MVA}$$

$$\text{Secondary Short Circuit Level (MVA)} = \frac{N * S}{X} \text{ MVA}$$

$$\text{Secondary Short Circuit Current} = \frac{\text{MVA} * 1000}{\sqrt{3} * V_S} \text{ A}$$

For Maximum secondary short circuit current I_{max} ,

$$\text{Maximum number of transformers} = \frac{I_{\text{max}} * X * \sqrt{3} * V_S}{1000 * S}$$

1.10.5 In addition to the studies described above, it is sometimes necessary to examine other properties of transmission system. Some of the more commonly encountered types of analysis are given below.

1.10.5.1 Reliability: Since the transmission system must be able to deliver power from specific generating stations to specific load centres, reliability analysis should consider generation and transmission systems together. This type of analysis requires the basic reliability data for each transmission circuit and generator (failure rate and repair time) and examines all possible combinations of outages (single and multiple) that can occur. For each outage examined, the power flows and voltages are calculated and compared with pre-set limits. Exceeding the limit constitutes a system failure event for which the probability and duration are computed. The failure statistics of all such events are then combined to provide a system reliability index.

It has been found in practice that usefulness of such studies is limited. A well planned and designed transmission system is inherently reliable and practical values of availability obtained for such a system are always in the range of 98-99%.

1.10.6 Voltage and Steady State Stability: As transmission system becomes more and more heavily loaded, it is normal that shunt compensation levels are increased to maintain satisfactory voltages. In severe cases, since the compensation itself is voltage dependent, small changes in load can result in large changes in voltage, and in the extreme case can cause voltage collapse or instability. Such phenomena can be examined with conventional load flow and stability analysis. Customized programmes are available to examine these phenomena in a shorter time.

1.10.7 Evaluation of Alternative Plans:

1.10.7.1 Alternative plans developed through technical analysis need to be evaluated for economic comparison. Different alternatives will have different costs associated with their reinforcements and these will probably occur at different times during the study period. Money has a time value; affixed amount spent now represents a greater economic burden

than the same amount spent at a later date. In order to represent this time value of money, costs associated with each alternative are discounted back to a reference year (usually the starting year of the study period). This discounting process decreases the economic value of money spent in the future.

1.10.7.2 The discount rate is similar to an interest rate in reverse, but its value is not necessarily related to the current interest rate. Economic analysis may be carried out for other discount rates above and below the base rate to test the sensitivity of comparison to the assumed rate. It is also necessary to review the value to be used for the discount rate on a regular basis to take account of changes in economic conditions. Effect of inflation can be ignored in an economic analysis, since in the long term all the costs and revenues involved in the analysis will inflate at similar rates.

1.10.7.3 Once all the costs associated with each alternative have been discounted back to the reference year, they can be directly compared with each other. Costs associated with environmental impacts and the annual costs towards operation and maintenance and losses may also be included in the cost comparison between alternatives.

1.10.7.4 Selection of an optimum development plan should take into account the technical performance, economic comparison and other factors viz. environmental impacts, flexibility, reliability, ease of operation and maintenance, etc.

1.10.7.6 Various planning processes adopted should be documented in preparing a planning report. These documents are:

- Objectives of the study
- Basic data used for the study
- Planning criteria and assumptions made
- Alternatives developed and screening of alternatives
- Technical analysis of each alternative
- Cost basis used for developing cost estimates
- Economic analysis of each alternative
- Selection of optimum development plan

Justification for the planning decisions made should be furnished with the report.

1.11 Power System Studies for Identification of Projects and Prioritization

1.11.1 Power system studies include modeling of transmission schemes for generation evacuation, system strengthening through improvement schemes including reactive power compensation and system studies on the proposals received from projects units and stakeholders. Load flow diagrams will be developed and schemes prepared through the above studies. Power systems study group shall interact with CEA, Standing Committee and AP Electricity Regulatory Commission on technical clearance of the schemes proposed through studies.

1.11.2 System studies involve revalidation of network configuration, generation and load particulars at each node (substation). The following data forms the basis for the various studies conducted by power system group:

- Details of modified network since previous study such as addition, deletion, enhancement of transformer capacities with details of capacity, % impedances, voltage ratios etc., change in the configuration of the network, modification of existing lines resulting in change of length and corresponding alteration of line parameters.
- Details of upcoming generators if any
- Details of active power, reactive power, bus voltages, reactive elements at substations.

1.11.3 The data collected is entered in to the computer. Cyme international software is used power system studies. Load flow diagrams are developed separately using Auto Cad for interfacing the load flow results. Each case is studied for various alternatives. Results of each alternative are then analyzed for line overload, voltage violation and system losses and better option is selected. Final report along with load flow diagrams are prepared and submitted for approval.

1.11.4 Generation evacuation schemes involve schemes requiring development of AP transmission system only and schemes requiring connectivity to CTU network necessitating joint studies by APTRANSCO and CEA.

1.11.5 System Improvement Schemes: Monthly maximum demand load flow studies are conducted. Reactive Power studies are done every quarter and short term system studies for 3 to 5 years plan are conducted with intermittent intervention.

1.11.6 Studies for schemes for extension of supply to bulk loads such as major lift irrigation projects, SEZs etc. at EHV are also conducted based on the proposals from the projects units.

1.11.7 DISCOMS will send proposals for setting up 132kV substations in a particular area based on the load growth in that area. Power system group would obtain data pertaining to sub-transmission in that area (data of 33kV feeders and substations existing and new 33kV feeders and substations in that area) and conduct load flow studies based on this data along with the data in respect of transmission network. Load flow studies will be conducted using DISBUT software. Technical feasibility will be ascertained based on the regulation of 33kV feeders (to be within 9%). If voltages are beyond permissible limits, optimization techniques like reinforcement of 33 or 11kV feeders, re-configuration of sub-transmission system etc. are to be examined. Use of tap changers of power transformers and addition of capacitors cannot be relied upon as complementing techniques for improving the regulation due to limitation on capacity of transformers, maintaining uniform power factor and reduction of losses. Use of capacitors in steps switching in/out commensurate with the load, together with tap changers on transformers may be considered as a short term option for maintaining voltage regulation in limits. In spite of examining all these techniques if still the 33kV voltages are not improving in the scheme area then a 132kV substation can be proposed. With the proposed station, system studies will be conducted and the proposal for technical feasibility will be cleared.

1.11.8 Each district can be regarded as a particular area. DISCOMS shall furnish data on load growth in the district on a yearly basis together with the proposals for 132kV substations and locations where they are required. Power systems can obtain the data as required above and conduct studies to determine the number and location for the substations.

Long term perspective transmission planning will be done by power systems wing with the following inputs:

- Present network will be adopted and proposed lines and substations and generation are considered for perspective planning
- Long term load forecast will be adopted as furnished by DISCOMS and consolidated load forecast for state will be arrived.
- District wise demand forecast will be arrived from state forecast
- New generating stations expected to be commissioned during the above period will be considered in the network planning.

Due to generation uncertainties, transmission schemes are subject to modifications.

1.12 APERC Directives:

1.12.1 Load Forecast: Pursuant to clause 17.12 of Transmission and Bulk Supply License or clause 19.2 Of Distribution and Retail Supply License, load forecasts to be submitted to

1.12.1.1 Electricity Regulatory Commission shall contain a forecast of future energy(in megawatt-hour or MWh) and demand (in megawatts or MW) in the respective years of supply of each licensee for two control periods (Control Period means a multiyear period fixed by the commission, presently 5 years) for which the principles for determination of revenue requirement will be fixed.

1.12.1.2 Detailed forecast shall be for each year of a control period under consideration for tariff review purpose and a simple forecast for the subsequent control period.

a) Detailed forecast for the control period shall include

- i. Forecast of energy, demand and number of consumers for each class of consumers (other than scheduled consumers) category-wise, voltage-wise and slab-wise, supplied by distribution licensee
- ii. Forecast of energy, demand and number of consumers (category-wise, voltage-wise) supplied by the distribution licensee to the scheduled consumers or licensees or traders within the State of AP and outside the State through open access
- iii. Forecast of energy, demand and number of consumers for each class of consumers (category-wise, voltage-wise) supplied by a person other than the distribution licensee of his area of supply through open access
- iv. Forecast of energy and demand for each class of consumers (category-wise, voltage-wise) utilized from captive generating plants of an aggregate capacity of 1 MW and above
- v. Forecast of standby or backup support in terms of energy and demand
- vi. Load profiles for consumer categories for representative days including load factors, non-coincident and coincident peak demand for each category of consumers and the entire AP system
- vii. Technical and commercial losses for each voltage and category of consumers in the distribution system and Transmission losses
- viii. Developing scenarios to show the impact of Government policies
- ix. Considering alternative approaches (viz. simple trend approach, behavioral approach linking with key drivers etc.) for the forecast during the control period

- x. Inputs from consultation with major consumers (large HT Industrial consumers, other licensees, RESCOs, Railway Traction etc.) that could affect load forecast

b) Simple forecast for the subsequent control period shall include

- i. Forecast of energy and demand for each class of consumers (category-wise) supplied by the distribution licensee
- ii. Forecast of energy and demand for each class of consumers (category-wise) supplied by a person other than the distribution licensee of his area of supply through open access
- iii. Forecast of energy and demand for each class of consumers (category-wise, voltage-wise) utilized from captive generating plants of aggregate capacity of 1 MW and above
- iv. Forecast of standby or backup support in terms of energy and demand
- v. Total distribution losses in the distribution system and transmission losses in the intra-state transmission system

Reasonable assumptions made in the forecasts shall be described and criticality of such assumptions demonstrated through a sensitivity analysis.

c) The following information relevant to the forecast shall be submitted:

- i. Historical consumer category-wise, slab-wise, voltage-wise data of energy in MWh demand in MW, number of consumers for the last five years
- ii. Existing and proposed Demand Side Management (DSM) programmes and their impact on energy and demand, together with cost-benefit analysis in brief
- iii. Historic data on standby or backup support availed of by the consumers in terms of energy and demand.
- iv. Historic data on technical and commercial losses in the distribution system and transmission losses in the intra-state transmission system and
- v. Energy utilization, peak load, power factor data and annual load factors for the previous 5 years.

1.12.2 The methodology approved by the Commission shall be followed in estimating consumption for LT agriculture category, appropriately incorporating policy directions of State Government, if any.

1.12.3 APTRANSCO shall collect and consolidate the distribution licensee load forecasts and submit load forecast for the AP power system after making suitable adjustments if any, duly recording the

1.12.4 For the purpose of load forecast, the year shall begin on 1st April and end on the following 31st March. Load forecast shall be submitted by the licensee to the commission on 1st April of the year proceeding the first year of the control period and/ or at such other time as required by the Commission.

1.12.5 Transmission Planning:

1.12.5.1 APTRANSCO shall plan transmission system in coordination with other transmission licensees, if any for two control periods in accordance with the provisions of Section 39 of electricity Act 2003 and clause 17 of Transmission licensee.

1.12.5.2 APTRANSCO shall submit a detailed transmission plan for the control period listing out proposed new lines, substations, reactive compensation and other investment proposals, together with planned years of execution, cost estimate and location. An indicative overall investment plan for the subsequent control period shall also be submitted. The transmission plan shall clearly be categorized into the following schemes:

- **System expansion plan:** This shall include list of schemes which cater to network reinforcement or expansion commensurate with the load growth
- **System improvement plan:** This shall contain schemes whose primary objective is loss reduction or in improvement in quality of supply or automation of operations
- **Generation evacuation plan:** This shall list out schemes intended to evacuate generated power to major load centres.

The plan shall include interconnections at which power is exported/imported, from/to other entities, including other states. It shall take account of any demand on APTRANSCOs existing or planned transmission capacity arising from projected transmission transactions as submitted in the load forecast, including the transport of power through APTRANSCOs transmission system for delivery to customers outside the State.

1.12.6 State Electricity Plan:

1.12.6.1 APTRANSCO shall formulate a State Electricity Plan in coordination with others for the promotion of generation, transmission, distribution and supply of electricity and notify the same once in the control period under consideration for tariff review.

1.12.6.2 The State Electricity Plan would be for a short term framework of a period equal to control period, while giving a perspective for two control periods (control period under consideration for tariff review and subsequent control period) and shall include:

- Short-term and long-term demand forecast, with inputs from the last approved load forecast
- Suggested areas/locations for capacity additions in generation and transmission keeping in view the economics of generation and transmission, losses in the system, load centre requirements, grid stability, security of supply, quality of power including voltage profile etc. and environmental considerations including rehabilitation and resettlement
- Integration of such possible locations with transmission system and development of state grid including type of transmission systems and requirement of redundancies
- Different technologies available for efficient generation, transmission and distribution
- Fuel choices based on economy, energy security and environmental considerations.

1.12.6.3 APTRANSCO, in preparing the state electricity plan, shall publish the draft plan and invite suggestions and objections there on from licensees, generating companies, the Commission and the public within such time as specified by the Commission.

1.12.6.4 APTRANSCO shall notify the plan after considering the comments of the Commission and all stakeholders, and obtaining the approval of State Coordination Forum and revise the plan incorporating directions, if any, given by the Forum while granting approval of the plan.

1.12.6.5 The state Electricity Plan would be used as a reference document by all stakeholders and also assist CEA in planning the National Electricity Plan or any other plan requiring inputs from the State.

1.13 Electricity Act- 2003:

Electricity Regulatory Commissions Act, 1998 provides for setting up of Central/ State Electricity Regulatory Commission with powers to determine tariffs, thus distancing Government from tariff determination.

1.13.1 Salient features of Electricity Act, 2003

1.13.1.1 Role of Government: Under section 3 of the act Central Govt. shall prepare a national electricity policy including tariff policy. Vide sections 4 & 5, Central Govt. will notify a National policy for rural areas permitting standalone systems based on renewal and Non-Conventional energy sources and formulate a National policy for bulk purchase of power and management of local distribution through User's association, Cooperatives, Franchisees and Panchayat Institutions etc. in consultation with the States.

1.13.1.2 Generation: Section 7 makes generation free from licensing and for non-hydro generation requirement of Techno Economic Clearance is done away with. Section 9 provides Captive generation free from controls. Open Access to Captive generation plants is permitted subject to transmission facility. Sections 61(1), 86(1) (e) provide for promotion of generation from Non-Conventional Sources/ Co-generation. Minimum percentage of power to be purchased from the renewable sources shall be fixed by the Regulatory Commissions.

1.13.1.3 Transmission: Sections 38 & 39 provide for establishment of transmission utility at centre and in the states to undertake planning and development of transmission system. Load dispatch shall be in the hands of a govt. company/organization with flexibility to keep transmission utility and load dispatch together or separately. Load dispatch function being critical for grid stability, shall maintain neutrality. Instructions of load dispatch shall be binding on both generators and distributors. Section 15(5) (b) allows appropriate Commission to issue license to private transmission companies after giving due consideration to the views of the transmission utility. Sections 27, 31, 38, 39, 41 prohibit trading of power by Load Dispatch Centre/Transmission Utility/Transmission Licensee to facilitate genuine competition between generators. Open access to transmission lines shall be provided to generating companies and distribution licensees under sections 38-40.

1.13.1.4 Distribution: Distribution license shall be issued by State Electricity Regulatory Commissions. Sections 7 & 12 permit distribution licensee to take up generation and

generating company to take up distribution. Section 62 directs Regulatory Commission to determine retail tariff.

1.13.1.5 Regulatory Commission/Appellate Tribunal: Under section 111 Appellate Tribunal will hear appeals against the orders of CERC/SERC. The Appellate Tribunal will also exercise general supervision and control over the Central/state Commissions.

1.13.1.6 Central Electricity Authority: CEA shall continue as the main technical Advisor of the Govt. of India/State Govt. with the responsibility of overall planning (Section 70). Section 73 delegates CEA to specify technical standards for electrical plants and electrical lines.

1.14 Planning and System Engineering:

1.14.1 Based on the long term planning decisions made and receipt of proposals from Discoms, system study group will conduct necessary system studies to determine the sequence in which the projects are to be taken up and the time by which these are required. Detailed studies should be carried out for prioritizing the projects as required by the system and the time of addition of these projects keeping in view the period required for execution and commissioning of the project.

1.14.2 Various stages in the execution of transmission projects and the time period for execution of each stage are given hereunder.

- i. Preparation of scheme and obtaining administrative approval from TRANSCO - 3 months (which includes obtaining the information like, preliminary survey for the route, approximate length of line, identification of land for substation etc.)
- ii. Obtaining finance clearance from funding agency, and investment approval from State Electricity regulatory Commission- 3months (both the activities can be taken up concurrently).
- iii. Carrying detailed survey for lines, acquisition of land for substations - 3months
- iv. Preparation of detailed estimate for technical sanction and calling for tenders and award of work- 3months
- v. Project execution period taking into consideration terrain conditions, seasons affecting the work and issues such as right of way, payment of tree & crop compensation, obtaining clearances from Railways, Road ways, P&T, environmental clearance, forest clearance and unforeseen contingencies - 12 to 18 months

1.14.3 Schemes for project can be classified as below.

a) System Improvement Schemes: are those which provide strength and support to the transmission network to give adequate level of performance parameters such as voltage and frequency.

Schemes viz., transmission lines, sub-stations, reconductoring, augmentation of transformer capacity (either by way of enhancing the capacity of the existing transformer or providing additional transformer), providing reactive power compensation (Shunt capacitors, shunt reactors/ statvars) can be classified under system improvement schemes. These will strengthen the transmission network in serving the power system with the anticipated load growth considered up to horizon year, with reliability and stability. A reliable and stable network is one which ensures availability of power supply to all loads under all operating conditions with the voltage levels at the busses of all EHV Substations in the specified limits.

b) Power Evacuation Schemes: Based on the generation addition plan and the time of addition of the generation, evacuation of power from the proposed new generating stations or from the existing generating plants where capacity is augmented; to the load center will be planned by TRANSCO.

Schemes prepared for evacuation of power from generating stations to load centers are classified under power evacuation schemes. After receipt of proposals for generation addition by various generating companies viz., GENCO, Power Grid and private generators and the likely time period by which these are planned to be added, the required power evacuation schemes shall be prepared by power system group.

c) Bulk Load Schemes Schemes prepared for extension of power supply at EHV level (i.e., 132 KV and above) to the individual consumers or a group of consumers through a particular unit (such as major lift irrigation projects; special economic zone/Industrial establishments etc) come under bulk load schemes.

The minimum demand for extending power supply at EHV level shall be above 10MW. However, where a consumer requests for extension of supply at EHV even though the contracted demand is less than 10 MW such request can also be considered. Depending on the load, appropriate voltage levels have to be selected considering the voltage regulation, power transfer capacity of transmission line proposed and the distance of the load from the source sub-station.

Impact of the prospective bulk load on the network has to be examined in detail from the point of view of adequacy of the system in meeting the bulk load. Normally bulk power may be extended radially from the nearest source substation. Where a prospective consumer requests for more than one source of power supply from reliability point of view, supply can be extended through a double circuit line from the nearest source substation. Alternately laying of two lines from two source substations up to the consumers point can be considered subject to technical feasibility and subject to consumer agreeing to bear the costs in respect of all the required arrangements. However, a switching station at the consumers point has to be erected where the two lines terminate and from the bus of the switching-station consumer shall be extended supply through a single line. In and Out of an existing line (LILO) shall not normally be considered except in the following cases.

- i. The line is a tie line, interconnecting two source substations or a floating line between two substations.
- ii. Line losses on account of LILO arrangements is less than or equal to the losses, if the supply is extended through independent radial lines.
- iii. When there is no possibility of laying a separate line.

The prospective consumer shall provide site to the extent required for this purpose. Prospective consumers shall also give an undertaking to the effect that ownership of the lines and the switching station executed for the purpose of extending power supply shall rest with TRANSCO.

Prospects of constructing a substation of appropriate voltage level at the switching station to meet the local and future loads coming up may be examined. Prospective consumer shall also give consent to permit TRANSCO for taking up improvements in the switching station if required by TRANSCO. In case the substation is not found feasible then the O&M costs for the switching station are to be borne by the prospective consumer.

While planning any Transmission projects for a particular horizon period, the period required for completion of the project as indicated earlier may be considered. Also Transmission system requiring additional of no. of transmission facilities spread over different zones in the region or in one zone itself within a given period, can be taken up for execution simultaneously. It is necessary that for a transmission facility required after two to two and a half years as per the planning studies; project activity should start right now.

1.14.4 Funding for transmission project.

Agencies funding transmission project to be taken up as planned, can be broadly classified into domestic funding agencies and external funding agencies.

1.14.4.1 Domestic Funding Agencies: eg. Banks, Insurance Companies, IL&FS, PFC, REC etc. Projects whose capital cost is small or medium say up to Rs.250 cores can normally be financed by the domestic financial institution.

Depending on the cost of particular project, TRANSCO can consider raising funds either from internal resources or borrowing from financial institutions. Each financial institution has its own eligibility criteria for extending loan to a project, such as Internal Revenue Return, Cost Benefit Ratio etc. Each financial institution has its own lending rate, lending period, moratorium and short closure terms. These institutes normally lend up to 80% of the estimated scheme cost, covering material, transport and labour portions of the scheme. Remaining amount is to be met by TRANSCO as counterpart funding or from their internal resources covering general expenses such as cost of land, insurance, taxes, duties, general administration and contingencies.

Security either in the form of Govt. guarantee covering the amount financed or in the form of pledging of assets to a tune of 110% of the finance is normally required to be given by the borrower. Different financial institutes have different limitations on finance. Projects unit together with finance wing can select a financial institute for funding a particular project depending on their suitability.

1.14.4.2 External Funding Agencies: eg. World Bank, JICA, DFID etc. These foreign agencies normally extend loans for major projects that contribute to growth in the sector in the form of improvement in efficiency, reliability, introduction of new technologies etc. Loans are mostly soft in nature i.e. lending rate will be very low and period of repayment will be long say 15 to 25 years. Extension of financial assistance will be up to 80% of the cost of scheme. Remaining amount shall be arranged by TRANSCO on its own.

Their norms for approval of finance for a project are stringent as compared to domestic funding agencies. These institutions involve with the Borrower at every stage of the project right from the appraisal stage till completion of the project.

External funding agencies can be relied upon in the case of major transmission projects such as bulk power evacuation schemes, improvement in efficiency and voltage regulation by addition of reactive compensation, modernization and improvement or reliability in major load centers (cities /urban areas), introduction of new technologies viz., GIS, underground cabling etc., where the project cost is substantially high and project duration is longer.

These institutions normally lend through Govt. of India and State Government. The proposals for such finance are therefore to be moved through Energy Dept., Finance Department of State Govt. and to be approved by Ministry of Power & Finance Dept, Govt. of India after which the proposals would be sent to these institutions for their consent.

Based on the value and duration of the project, finance wing will select appropriate funding agency. The construction unit will prepare scheme report (project report) according to the norms laid down by the selected financial agency and submit the reports to TRASNCO for approval.

Prior discussions with Directors in charge of Projects & Finance may be made for identifying a suitable financial agency.

1.14.5 Selection of projects for Execution:

1.14.5.1 Projects are to be taken up for execution in the sequence in which they are required to be added to the network as prioritized based on the load flow studies reports.

1.114.5.2 The selected projects as above for execution during a specific period are to be clustered into groups on a zonal or geographical area basis for the purpose of tendering.

1.14.5.3 Splitting up of projects(substations and connecting line, materials and labour) and awarding works to multiple agencies may often end up in mismatch resulting in delays in completion of project and often leading to dead investments i.e. without the asset put to beneficial use; having incurred substantial expenditure.

1.14.5.4 It will be advantageous to take up all components of a project having bearing on each other, in one package, through agency/consortium on a single responsibility basis so that the project can be put to beneficial use in time thus achieving the desired purpose.

1.14.5.5 After identification of the project proposed for execution based on the system needs, sequence and time of requirement; detailed project reports are to be prepared.

1.14.6 Salient features of a Detailed Project Report (DPR):

Technical details of various transmission elements viz., transformers and their capacities, no. of incoming and outgoing feeders in case of substations and voltage levels and length of lines, circuit size and configuration and no. of circuits in case of transmission lines etc. shall be incorporated in detailed project report. The DPR shall include

- a. Detailed estimate showing the cost of major items of the project
- b. A report on the need for the project, results of load flow studies and the technical feasibility.
- c. Internal Revenue Return/Cost benefit ratio of the project considered
- d. Reasons for selecting the proposed project among the various techno-commercial alternatives considered.
- e. Implementation schedule of the project
- f. Details of phase wise expenditure for executing the project
- g. Financial tie up for the proposed project.

1.14.6.1 Technical details: In case of EHV substation, voltage levels of SS, no of transformers and their capacity, no. of reactors and their type viz., line reactors/bus reactors, switchable/non switchable, no. of incoming and outgoing feeders, reactive compensation proposed if any such as series compensation/shunt compensation – their details, type of communication viz., PLCC, optical fibre etc.

For transmission lines, Voltage, no. of circuits, size and configuration of each circuit, type of ground wire and grounding, method of communication.

Detailed estimate shall cover the cost of all major components involved in the project. Typical example of a project comprising of a substation and a line is given below.

(a) Substations:

Extent of land required & cost of civil works (such as leveling, fencing, control room, switchyard, foundation for structures and equipment, drains and cable ducts).
 Cost of transformers (Number and capacity), Reactors (Number and capacity)
 Cost of Reactive compensation devices, switch gear (including Circuit Breakers, Instrument transformers, [CTs & VTs], isolators, LAS, marshaling boxes
 Cost of Control&Relay panels, communication PLCC/optic fiber (terminal equipments),
 Batteries and charging system, Cost of automation equipment, Cost of Earthing & lighting,
 Cost of auxiliaries such as generator sets for standby supplies, station supply devices, fire fighting system. Ex: emulsifier, repair bay

Cost of labor for erection, testing and commissioning

Cost of spares for O&M for 5 years

Cost of contingencies @ 3%

Cost of administration charges (covering, establishment, loss on storage, audit and inspection, T&P)

(b) Lines:

Cost of preliminary and detailed survey (Total Kilometres x Cost per kilometre) including cost of GPS survey if proposed.

Cost of steel required MT (MT per kilometre x Total kilometres).

Size and cost of conductor (Kilometeres x Number of circuits x number of conductors per phase in each circuit).

Size and cost of ground wire/OPGW – [if fiber optic communication is proposed] / kilometre x No. of kilometres

Note: A little extra over the actual length to be proposed for sag

Cost of civil works viz. soil investigation, foundation including re-enforcements, shoring and shuttering.

Cost of erection of towers, stringing including ground /OPGW

Cost of earthing

1.14.6.2 Need for the project: The need for taking up the proposed project, giving salient features of the project and how its implementation will strengthen/support the transmission system shall be explained. Improvement/benefits that will accrue to the system after the completion of the project have to be explained. Results of load flow studies conducted in support of the project have to be given. Cost/benefit ratio of the proposed project or Internal Revenue Return has to be compared to check whether they satisfy the norms for lending by various financial institutions.

Any Specific reasons for considering the proposed project, from among the various technical alternatives examined; such as whether it is on the least cost option basis or from point of view of system reliability/stability or any other basis, may be indicated in the report.

A chart giving the schedule for the execution of the project i.e., (Time to commence the work, Time for execution of various stages of all components of project, Period required for completion of project) shall be prepared.

Stage wise expenditure on the project and year wise requirement of capital shall be furnished. Proposed financial tie up for the project shall be indicated. Basis for selecting a particular financial agency and the terms of lending shall be mentioned.

Detailed project report as above shall be prepared by the Chief Engineer in-charge of construction and put up to Board through the Director in charge of projects for administrative approval.

If the project is going to be spread over long period, cost escalation shall be considered in the estimates and the budget required year wise shall be provided.

Where the cost of the project exceeds Rs.250 Crs., approval of Central Electricity Authority is to be obtained. Projects associated with 400 KV systems are however to be submitted to CEA for their clearance. Investment approval for projects costing more than 5 Crores has to be obtained from Regulatory Commission before taking up the work. Proposal for investment approval of Regulatory Commission should contain the detailed project report as explained above.

VOLUME - II

MANUAL ON DESIGN AND PROJECT AWARD

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2.1.Project Inception

2.1.1 Various steps in a project inception are:

- i) Selection of project – Classification – Zone/Area wise
- ii) Prepare a detailed project report on the lines explained earlier
- iii) Obtain Administrative approval
- iv) Approach identified financial agencies for financial tie up for the proposed project – giving details about the project, techno-economic feasibility in line with the norms set by utility along with commercial and other norms stipulated by funding agency
- v) Proposals along with detailed project report; details of funding agency and schedule of implementation shall be submitted to Regulatory Commission for information if the project cost is Rs.5 Crores or less and for investment approval if above Rs.5 Crores.

Note: schedule of implementation shall be properly assessed taking all issues into consideration

- vi) Proposal in respect of all 400 KV schemes and transmission schemes costing more than Rs.250 Crores are to be sent to CEA for their clearance (under section 68 of EA 2003).
- vii) Construction wing at head quarters will authorize Construction Units in the field to acquire land required (for Substation) and conduct preliminary / Reconnoitry / GPS survey for transmission lines, (for the connecting transmission lines / inter connecting transmission lines) proposed in the project. The construction units concerned in the field will initiate steps for acquisition of suitable land for the substations and for conducting preliminary surveys for transmission lines.
- viii) After conducting preliminary/GPS surveys, various route proposals containing salient features, such as, habitations, topography ,forest involved if any, railway/road crossings, telecom / major power line crossing etc are to be sent by the field units.
- ix) Route approval for the selected route is to be given by the Chief Engineer, construction and communicated to the SE/EE Construction in the field.

After receipt of route approval, construction unit (TLC Division) in the field shall carry out detailed survey including soil classification through reputed surveyors registered with APTRANSCO under direct supervision/coordination of one ADE/ AE, Electrical/Civil as may be nominated by the concerned Superintending Engineer/TLC and send the detailed survey report to construction wing at Head Quarter.

Simultaneously, the line profile also be finalized including type of towers and classification of foundations by the above said group of Engineers with the assistance of a reputed / approved professional Surveyor having soil testing expertise to avoid any deviations later or to keep the deviations to the minimum.

- x) TLC unit concerned shall also conduct survey of the identified land for Substation and submit contour maps and the site cum electrical lay out for the proposed substations to CE incharge of Construction at Head quarters.

The detailed contour levels of the proposed sub-station shall also be taken through a professional surveyor under direct supervision of ADE/AE, Electrical and (Civil) as nominated by SE/TLC concerned for finalization of the level of the Sub-station site. The sub-station yard level shall be at proximate road level. No deviation shall be allowed after such finalized level, after work is awarded.

- xi) In case of any deviation in the finalized levels of the substation, such deviation shall be permissible only with prior approval of the Chief Engineer (Civil) based on justification for such deviation up to 10% of the quantity of filling. Beyond this limit, approval is to be accorded by the committee of Technical Directors.
- xii) CE incharge of Construction at Head Quarters will finalize the levels for switch yard, control room, fencing etc taking into consideration future expansions if any; in consultation with CE/Civil and with the approval of Director concerned.
- xiii) Based on the information in items x & xi above, detailed estimate for the project shall be prepared by the CE incharge of construction in consultation with CE/Civil on civil items such as leveling, foundation, control room, fencing, internal roads & drainages etc and CE/ Telecom on items like PLCC, optic fibre, and interfacing panels in case of automation. Quantities of various items covered in detailed estimate shall be precise, based on the detailed survey reports and the scheme reports.
- xiv) The detailed estimate prepared shall be approved by CE/incharge of construction after obtaining clearance from the Director concerned; and accord technical sanction. If the detailed technical estimate cost exceeds by more than 10% of the Administrative Sanction, revised administrative sanction/ approval shall be obtained by the construction wing from the Board based on justification for such change in quantity, cost etc. prior to floating of tenders.
- xv) Bids for construction of the project will then be invited with the quantities & items covered in the detailed estimate, on turn key basis on e-procurement platform.
- xvi) Bids shall be processed and finalized following procedures laid down in the Purchase Manual.
- xvii) Contracts will be awarded after ensuring investment approval and other statutory approvals and financial tie up from the Financial Institutes.

2.1.2 All the steps above need not be taken up sequentially one after the other. Some of the steps may be clubbed and taken up simultaneously to avoid delays in project execution. For example, activities under steps iv, v & vi can be initiated simultaneously at Head Quarters. Steps in vii, viii & ix can be carried out by TLC units simultaneously in the field.

2.1.3 Action to acquire the land identified for Substation shall be initiated soon after the administrative approval; and land acquired before the work is awarded to save time and avoid delays and consequential escalations in costs during execution. Likewise, reconnoitery/GPS survey for transmission lines shall be carried out immediately after administrative approval and a route selected; so that detailed survey can be taken up immediately. While conducting survey, enumeration of trees and assessment of crop damage is made to compute compensation requirements. Also soil investigation may be made in different reaches of the line, where the earth strata are likely to vary. This will help in identifying and designing proper foundation for structures/towers and avoid major deviations in execution.

2.1.4 As the above works cost a small proportion of the total project cost, and carrying out these works before hand; will ultimately result in saving in time and cost over runs, they may be funded from the internal resources initially and adjusted after fund tie up for the project is made.

2.1.5 PREPARATION OF DETAILED ESTIMATE FOR THE PROJECT

2.1.5.1 The detailed estimate covers the cost of all the materials required for the project, labour, transportation, taxes, contingencies, establishment and general charges such as insurance, audit, loss on storage, tool & plant, spares for O&M, cost of land incase of SS, tree & Crop compensation in case of transmission lines etc.

2.1.5.2 Earlier Standard Schedule of Rates (SSR) was prepared at circle level by SE (TLC). Estimates were prepared based on these SSRs concerning each area. There used to be lot of variation in labour rates from place to place. When bids were called from head quarters for major projects, there were lot of variations in the offered rates for labour by the bidders, causing problems during execution.

2.1.5.3 Cost of materials & labour are to be reasonably accurate in the estimate as this will have a bearing on the other components in the estimate which are computed in percentages of the cost of material and or labour. Over valued estimate, may result in the utility sustaining losses and undervalued estimate may affect the quality of materials supplied and the works.

2.1.5.4 In respect of materials, a cost data shall be prepared and updated on an annual basis. The following are the guidelines in preparation of cost data for materials.

- Cost of pervious purchase of materials (Basic price + duties + taxes) updated with respective prevailing and accepted indices, statutory variations in duties, taxes and insurance, prevailing a month prior to preparation of detailed estimate.
- Prevailing market price. For this purpose quotation for the basic rates, taxes and duties may be obtained from various standard manufacturers

- Obtaining latest purchase rates duly updated with acceptable variation formulae for similar (and preferably identical) items from other power utilities in the neighborhood.

2.1.5.5 In respect of labour also, Schedule of rates for various components of labour need to be prepared on an annual basis.

2.1.5.6 With a view to standardize the schedule of rates for labour for various civil & electrical works in Transmission; APTRANSCO evolved a standard schedule of rates with effect from 2003-04. The following parameters form essential features in the preparation of SSR.

- Latest rates for labour for civil works of similar nature fixed by Govt. for Civil Engineering Departments like R&B, PWD, Irrigation etc.
- Rates for electrical works of similar nature to be obtained from other power utilities in the neighborhood and compared with the prevailing rates (Rates at which contracts were awarded earlier duly updated).
- Scattered nature of works like laying of transmission lines stretching over long distances in remote areas needing additional transportation of labour and material and storage etc.
- Importation of skilled labour for some of the works which are highly skilled in nature. Example: Transmission tower erection, Stringing and tensioning of Transmission line
- Extra allowances in terms of percentage of labour rates for carrying out works in Greater Municipalities, Municipal corporations, Municipalities, industrial areas, Agency areas etc.

2.1.5.7 Standard Schedule of Rates (SSR) for APTRANSCO is prepared on an annual basis. The latest SSR available at the time of preparation of detailed estimate has to be adopted. If latest SSR is not ready at the time of preparing the estimate, previous SSR updated on an interim basis and approved by Board may be adopted.

2.1.5.8 The cost data of materials and Standard Schedule of Rates for labour shall be prepared every year in the month of June, when the SSR of Govt will be ready. These rates may be updated at the time of preparation of estimate incase there are steep variations if any. Cost data and SSR will be prepared by the construction unit at head quarters and got approved by Board every year.

2.1.5.9 The detailed estimate prepared by the construction unit will be scrutinized and approved by Chief Engineer concerned after clearance from the Director.

2.2 DESIGN& ENGINEERING OF PROJECTS

After obtaining the administrative approval for the projects to be taken up in a sequential and time bound manner, designing of each project shall be made; as per the power system requirement arrived through studies.

2.2.1 SUBSTATIONS

Substations are important points for controlling supply of power on different routes by means of various equipment such as transformers, compensating equipment, circuit breakers, instrument transformers, isolators etc. The various circuits are joined together through these components to bus bar systems at the substations. Prime requisite of a good substation layout is that it should be as economical as possible in terms of land, material and labour. The layout should ensure desired degree of flexibility, reliability, ease of operation & maintenance and safety of operation and maintenance personnel. Site limitation is one of the important considerations in deciding the type of layout of a substation. It should be free from all obstructions for terminating high voltage transmission lines. Site should be accessible to the public road to facilitate transport of plant and equipment. While planning the layout and orientation of an EHV substation, provision should be made for installation of towers for incoming /outgoing lines and this aspect should be considered simultaneously and provision made accordingly in the construction of associated transmission lines. Provision for future extension of substation also shall be considered in the design of layout. The line and transformer bays sequence should be fixed minimizing the possibility of over loading bus-bars and connecting conductor.

2.2.1.1 ELECTRICAL CLEARANCE:

As per Indian Electricity Rules, all electric supply lines and apparatus shall be of sufficient rating for power, insulation and estimated fault current and of sufficient mechanical strength, for the duty which they may be required to perform under the environmental conditions of installation and shall be constructed, installed, protected, worked and maintained in such manner as to ensure safety of human beings, animal and property.

The clearances may also be lower, where it has been confirmed by operating experience that the over voltages are lower than those expected in the selection of the standard withstand voltages or that the gap configuration is more favourable than that assumed for the recommended clearances.

Clearances as per Indian Standard Code are provided for electrical equipment so that sufficient space is available for easy operation and maintenance without any hazard to operating and maintenance personnel working near the equipment and for ensuring adequate ventilation. These include the minimum clearances from live parts to earth, between live parts of adjacent phases' and sectional clearances between live parts and work section required for maintenances of an equipment. Besides, it is also necessary that sufficient clearance to ground is also available within the substation so as to ensure safety of the personnel moving about within the switchyard.

The minimum air clearance to ground and between phases are function of switching, lightning impulse withstand voltage, environmental condition and gap factor which depends

on electrode configuration. For voltage upto 245 kV, usually lightning over voltages are considered the governing factor whereas for 420 kV and higher voltage switching over voltage are considered the governing factor.

Recommended Clearances

Highest system voltage (kV)	Lightning impulse voltage (kV)	Switching impulse voltage (kVp)	Minimum clearances [^]		Safety clearances (mm)
			Between Phase and Earth(mm)	Between Phases (mm)	
36	170	-	320	320	2800
72.5	325	-	630	630	3100
123	450	-	900	900	3400
	550		1100	1100	3700
145	550	-	1100	1100	3700
	650		1300	1300	4000
245	950	-	1900	1900	4500
	1050		2400	2100	5000
420	1425	1050 (Ph-E)	3400*		6400
		1575 (Ph-Ph)	-	4200**	
800	2100	1550 (Ph-E) 2550 (Ph-Ph)	6400*	9400**	10300

*Based on Rod-structure air gap.

** Based on Rod-Conductor air gap.

[^]The value of air clearances are the minimum values dictated by electrical consideration and do not include any addition for construction tolerances, effect of short circuits, wind effects and safety of personnel, etc.

Notes:

- Safety clearances are based on the insulation height of 2.5 m which is the height of lowest point on the insulator where it meets the earthed Metal.
- The distances indicated above are not applicable to equipment which has been subjected to impulse test since mandatory clearances might hamper the design of the equipment, increase its cost.
- The values in Table refer to an altitude not exceeding 1000 m and take into account the most unfavourable conditions which may result from the atmospheric pressure variation, temperature and moisture. A correction factor of 1.25% per 100 m is to be applied for increasing the air clearance for altitudes more than 1000 m and upto 3000 m.
- No safety clearance is required between the bus-bar isolator or the bus-bar insulators. However, safety clearance is necessary between the section isolator or the bus-bar itself and the circuit breaker.
- For the purpose of computing the vertical clearance of an overhead strung conductor the maximum sag of any conductor shall be calculated on the basis of the maximum sag in still air and the maximum temperature as specified.

As an alternative to maintain safety clearances, earthed barriers may be considered to ensure safety of the maintenance personnel. The use of earthed barriers is quite common at lower voltages of 36 kV, 72.5 kV. However, as the voltage increases, the saving in space decreases and at 420 kV level, normally earthed barriers are not provided. In case of paucity of space where 2.50 m clearance is not available then localized earthed fencing with safety clearance can be considered.

2.2.1.2 INSULATION LEVELS:

All electrical equipment in a substation shall be designed to withstand power frequency voltage of network; temporary over voltages at power frequency caused by sudden loss of load and / or earth faults; switching over voltages and lightning over voltages.

Standard insulating levels are defined in IEC: 60071-(1, 2) or relevant IS. For equipment voltage upto 245 kV, IEC60071-1 specifies standard rated short duration power frequency and lightning impulse withstand voltages. For equipment voltage beyond 245kV, IEC60071-1 specifies standard rated switching and lightning impulse withstand voltages. The necessary insulation level depends on the insulation coordination, i.e., on the properties of different components of the network (mainly lines), the protection used against overvoltages (ZnO surge arrester are very effective), on altitude and also on the required reliability of the substation (permissible probability of flashover) and may vary in different parts of the same substation.

All EHV apparatus are generally protected against lightning as well as switching over voltage. The equipment used for protection are coordinated with protected apparatus to ensure safe operation as well as to maintain the stability of the Interconnected units of the power system.

2.2.1.3 SOME DEFINITIONS

Insulation Coordination: Selection of the dielectric strength (rated or standard insulation level) of equipment in relation to the voltages which can appear on the system for which the equipment is intended and taking into account the service environment and the characteristic of the available protective devices.

The primary objectives of insulation co-ordination are:

- To establish the maximum steady state, temporary and transient over-voltage levels to which the various components of a system may be subjected in practice.
- To select the insulation strength and characteristics of equipment, including those for protective devices, in order to ensure a safe, economic and reliable installation in the event of the above over-voltages.

Rated Insulation Level: A set of standard withstand voltages which characterize the electric strength of the insulation.

The selection of the rated insulation level consists of the selection of the most economical set of standard withstand voltages (U_w) of the insulation sufficient to prove that all the required withstand voltages are met.

Standard Insulation Level: A rated insulation level, the standard withstand voltages of which are associated to highest voltage (Um) as recommended in IEC.

Safety Clearance: Minimum clearance from any point on or about the permanent equipment where a person may be required to stand (measured from position of the feet) to the nearest unscreened live conductor in air.

“Earthed” or “Connected with Earth” : means connected with the general mass of earth in such manner as to ensure at all times an immediate discharge of energy without danger.

2.3 BUS-BARS:

Substations include bus-bars and are divided into bays. Outdoor bus-bars are either of rigid type or strain/ flexible type.

2.3.1 In the rigid type, aluminum pipes of grade 63401WP conforming to IS: 5082 are commonly used for bus-bars and for making connections to various equipment wherever required. The bus-bars and the connections are supported on pedestal mounted insulators. This leads to a low level type switch yard, wherein equipment and the bus-bars are spread out. Since the bus-bars are rigid, clearances remain constant. As the bus-bars and connections are not very high from the ground, maintenance is easy. Due to large diameter of pipes, corona loss is substantially less. Special care has to be taken in respect of Aeolian vibration. Commonly used sizes of pipes are given below.

System voltage (kV)	<u>Nominal Diameter</u>	
	External(mm)	Internal (mm)
72.5	42	35
145	60 60	52 49.25
245	89 89 101.6 101.6 114.3 114.3	78 74 90.1 85.4 102.3 97.2
400	114.3 114.3 127 127	102.3 97.2 114.5 109

2.3.2 Strain/flexible type of bus-bars is on overhead system conductors strung between supporting structures and strain/tension type insulators. The stringing tension may be in the range of 500-900kg per conductor/ sub-conductor (of a bundle conductor) for installations up to 132kV. For 220kV and 400kV installations, stringing tension may be in the range of 1000-2000kg per conductor/ sub-conductor (of a bundle conductor) depending upon span. Conductor tension, which strongly influences the design and weight of structure, has to be specified carefully with reference to span, ambient temperature, wind velocity and relevant soil conditions.

The design of structures can be economized by suitably locating spacers in bundle conductor bus-bars for 245kV and higher voltage substations.

Material commonly used for bus-bars and connections of strain/flexible type of bus-bars are ACSR/AAC. Commonly used sizes either as single conductors or as bundles are given below.

System Voltage (kV)	Type	Strands(Al / St) Dia (mm)	Diameter of complete Conductor (mm)
72.5	ACSR	30/7/2.79	19.53
	AAC	19/-/3.53	17.65
145	ACSR	30/7/3.00	21.00
	AAC	19/-/4.22	21.10
245	ACSR	54/7/3.18	28.62
		30/7/4.27	29.89
		54/7/3.35	30.15
	AAC	19/-/5.36	26.80
		37/-/5.23	36.61
400	ACSR	54/7/3.53	31.77

Bus-bar sizes should meet the electrical and mechanical requirements of the specific application for which they are intended.

2.3.3 Types of bus-bar schemes: Various types of bus-bar schemes generally in use are

- i) Single bus-bar, with or without sectionalizer
- ii) Main and transfer bus-bar
- iii) Double bus-bar
- iv) Double main and transfer bus
- v) Ring bus-bar and mesh bus-bar
- vi) One and a half circuit breaker
- vii) Double bus double breaker scheme

2.3.3.1 Selection of bus-bar scheme:

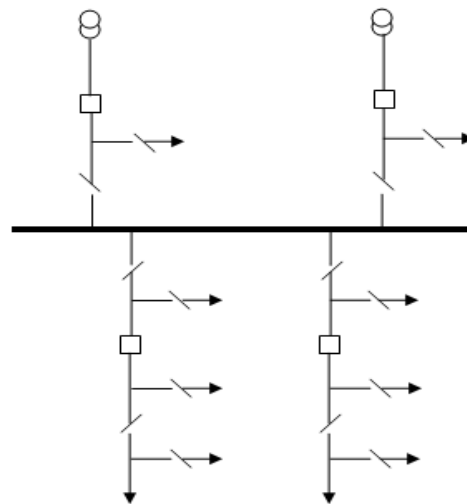
Factors influencing the selection of a bus-bar scheme in the substation design are operational flexibility, system safety, reliability, availability, ability to facilitate system control and cost. Single line diagrams of different types of bus-bar schemes are shown in the annexure. It is important to consider the degree of reliability of supply expected during maintenance or faults in selection of bus-bar scheme. Amount of redundancy to be provided so as to determine the equipment, which can be permitted out of use on account of maintenance or faults, should also be taken into consideration. Certain amount of sectionalisation has also to be provided in a substation so as to ensure that in the event of a fault, a large power source does not get disconnected. Future expansion of the bus-bar system at least in a foreseeable future may also be considered.

2.3.3.2 Single Bus-Bar Scheme: This is the simplest scheme, in which each circuit is provided with one circuit breaker [Fig.(A)]. This arrangement offers little security against bus bar isolator maintenance. The entire substation is lost in case of a fault on the bus bar or any bus-bar isolator and also in case of maintenance thereof. Another disadvantage is that in case

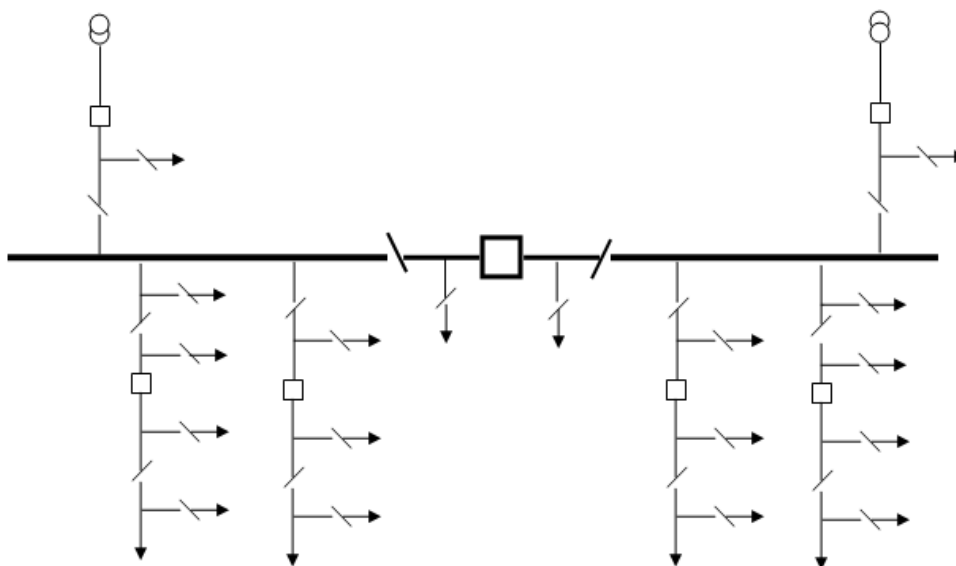
of maintenance of circuit breaker associated feeder has also to be shutdown. One of the methods for reducing the number of circuits lost in case of a bus fault is to sectionalise the bus as shown in [Fig. (B)].

The arrangement in [Fig. (C)] is a improvement over that shown in Fig. 6 (B), as additional by-pass isolators are provided to permit feeder circuit breakers to be taken out for maintenance without switching out the associated feeder. On occurrence of a fault on the feeder connected to bus bar through by-pass isolator, the other feeder on that bus section will also be lost.

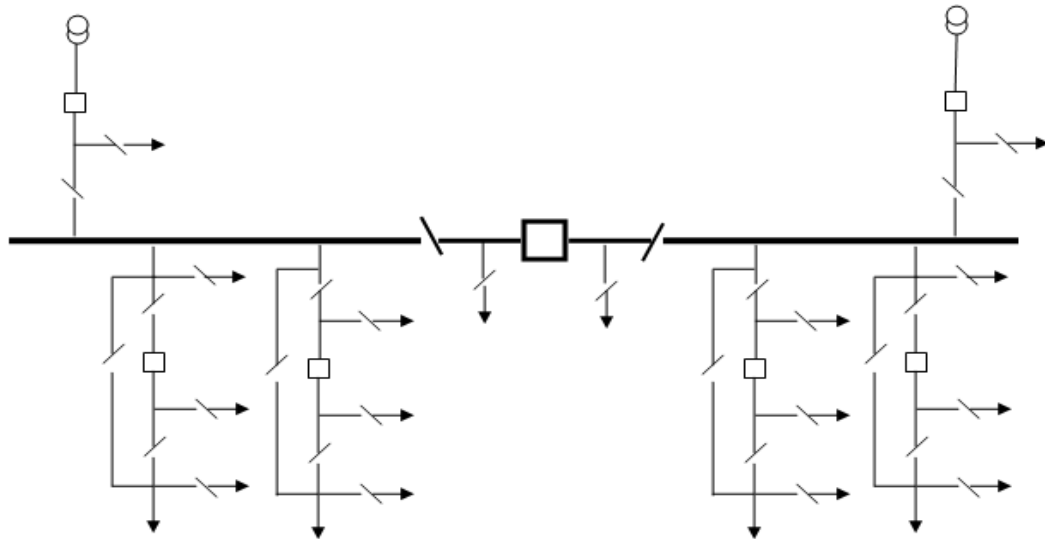
Different bus schemes shown below include two earth switches one on bus side and the other on feeder side for feeder breakers and one earth switch on bus side of transformer breaker. These earth switches are intended to discharge the concerned breakers before carrying out any works on these breakers. In the absence of earth switches earth discharge rods may be used.



(A) Single Bus-bar Scheme



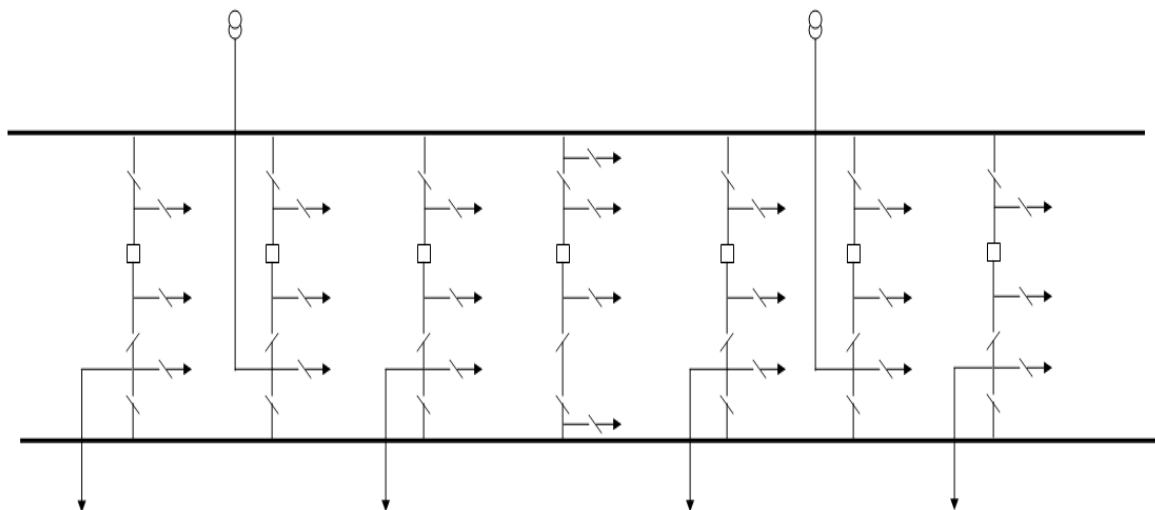
(B) Single Sectionalized Bus bar



(C) Single Sectionalized Bus-bar with by-pass isolators

2.3.3.3 Main and Transfer Bus Arrangement [Fig.(D)]: This is technically a single bus bar arrangement with an additional bus bar called "Transfer bus" energised from main bus bars through a bus coupler circuit, i.e., for 'n' number of circuits it employs n+1 circuit breakers. The additional provision of transfer bays and bus coupler circuit facilitates taking out one circuit breaker at a time for routine overhaul and maintenance without de-energising the circuit controlled by that breaker as that circuit then gets energised through bus coupler breaker and transfer bus bar. Each circuit is connected to the main bus-bar through a circuit breaker with isolators on both sides and through an isolator to the transfer bus-bar.

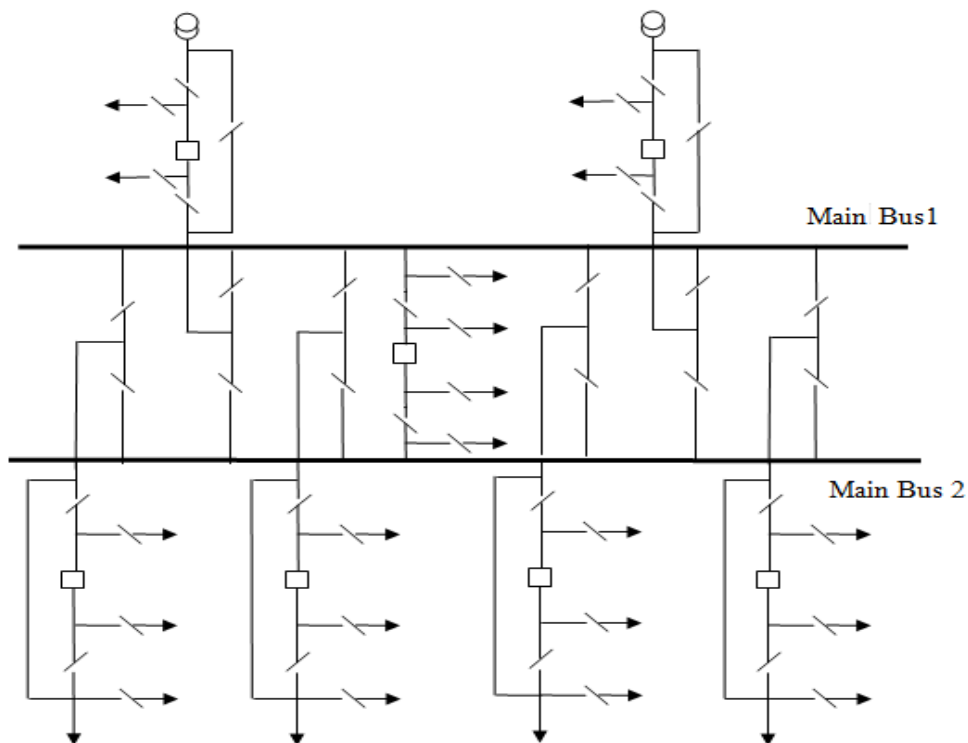
As in the case of single bus arrangement, this scheme also suffers from the disadvantage that in the event of a fault on the main bus bar or the associated isolator, there is a complete shutdown of the substation. Complete shut down can be avoided through sectionalizing the main bus with the provision of additional one single phase bus PT for synchronization in case of more than eight bays. This scheme has been used particularly for step-down substations, as bus-bar faults are rare.



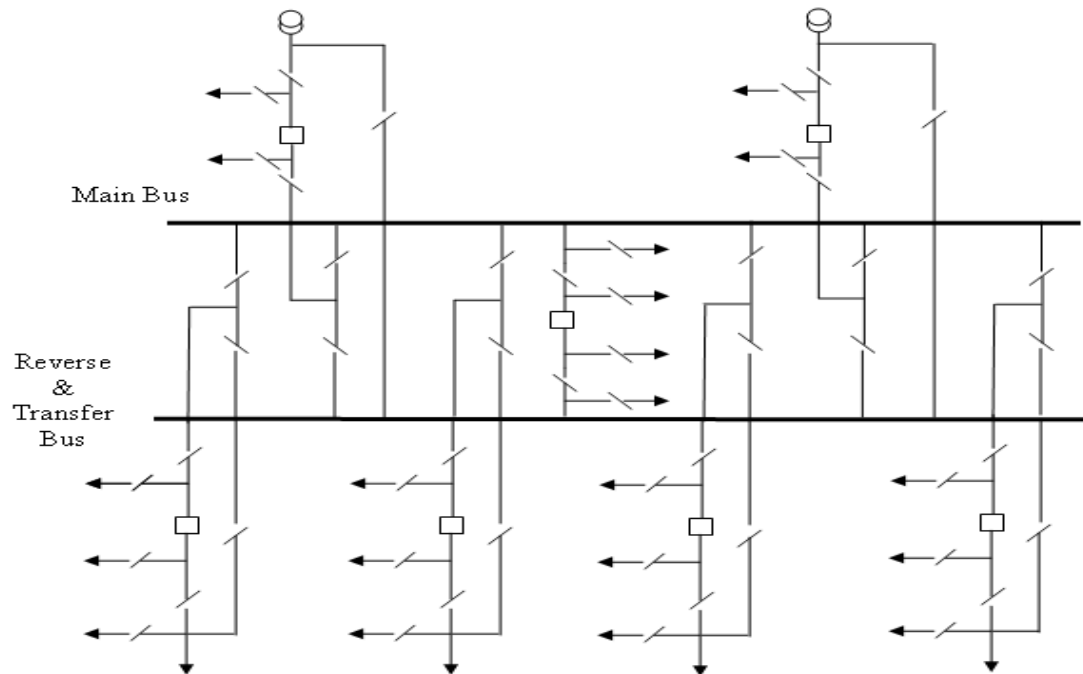
(D) Main and Transfer Bus Scheme

2.3.3.4 Double Bus-bar Scheme: In this scheme a double bus bar is provided and each circuit can be connected to either one of these bus-bar isolators as shown in [Fig. (E)]. Bus coupler breaker is also provided so that the circuits can be switched on from one bus to the other on-load. The scheme suffers from the disadvantage that when the circuit breaker is taken out for maintenance, the associated feeder has to be shutdown. This can be avoided by providing, a by-pass isolator across circuit breaker as shown in [Fig.(E)]. But under this condition all the circuits have to be transferred to one bus and protection of feeder has to be transferred to bus coupler. This scheme has the limitation that only one bus is available when any breaker has to be taken out for maintenance. The double bus-bar scheme with by-pass is available when any breaker has to be taken out for maintenance. The double bus-bar scheme with by-pass isolator across circuit breakers is very suitable for large generating stations as well as large grid substations forming part of a well inter-connected system wherein a variety of grouping of circuits is required. [Fig. (F)] shows another alternative of this scheme. In this alternative the by-pass isolators are connected to one of the main bus bars as shown. This scheme constitutes double bus-bar Scheme with main reserve and transfer bus-bars.

In both these schemes, use of temporary earthing device is called for during breaker maintenance. As temporary earthing drives can result in serious, accidents, if not removed, it is preferable to provide the isolators on either sides of the circuit breakers across which bypass isolators are provided with integral earthing switches having mechanical interlocking features.

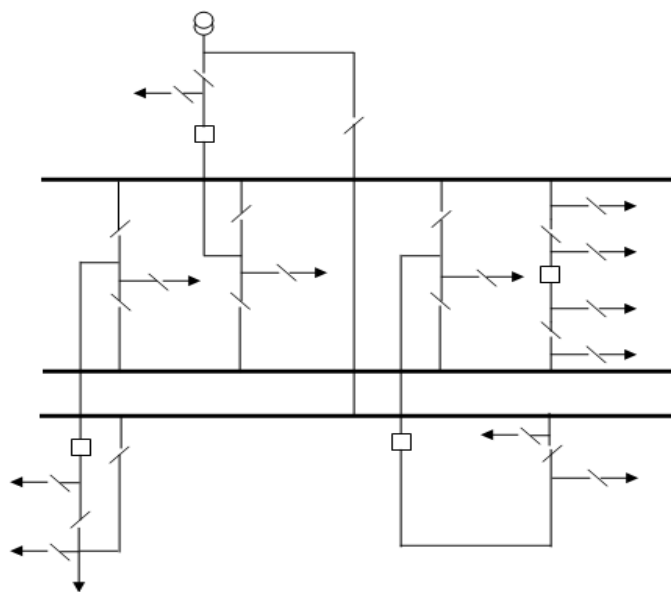


(E) Double Bus-bar System with By-pass isolators



(F) Main with Reverse and Transfer Bus System

2.3.3.5 Double Main and Transfer Bus-Bar Scheme: The limitation of scheme [Fig. (F)] can be overcome by using additional transfer bus, transfer bus breaker and isolators as shown in [Fig.(G)]. In this arrangement, the feeder, the breaker of which is to be maintained is transferred to the transfer bus, without affecting the other circuits. This scheme has been widely used for the highly inter connected power networks where switching flexibility is important and multiple supply routes are available. This scheme is also used for splitting networks, which are only connected in emergencies.



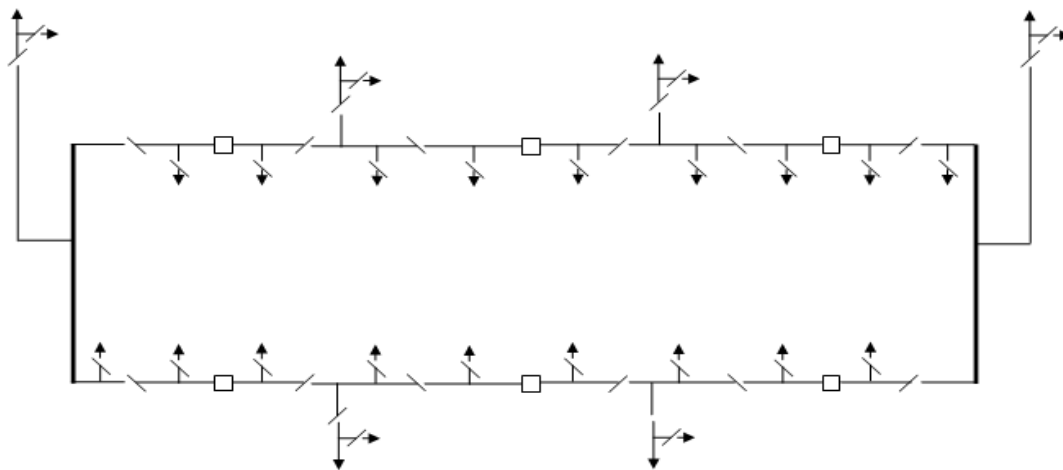
(G) Double main and transfer Bus-bar scheme

2.3.3.6 Mesh Bus-Bar Scheme [Fig.(H)]: Each circuit is controlled by two circuit breakers and therefore, any one circuit breaker can be taken out for maintenance without affecting the security of supply. A circuit fault also is cleared by opening of two breakers. In both cases

the ring is broken and the bus-bar is reduced to sectionalised single bus-bar scheme. In the case of a feeder fault, the circuit isolator can be opened, the faulty feeder disconnected and both the breakers closed which would close the ring. This system has got a number of advantages such as maintenance of a circuit breaker without loss of supply and without providing by-pass facilities, loss of only the faulty feeder in case of a feeder fault, and loss of only two circuits in case of a circuit breaker fault.

There are, however, some problems such as occurrence of a fault when a circuitbreaker is being maintained resulting in a double break in the mesh and capacity limitation of the equipment to pass the maximum current that may flow round the mesh. If these are provided for, it adds to cost of the station. In view of these problems, it is considered desirable to limit the number of circuits on the mesh.

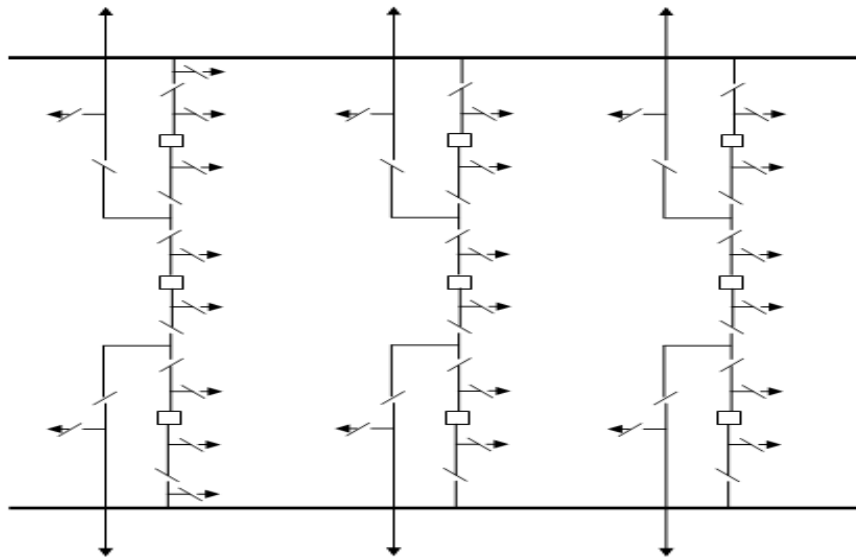
The mesh scheme is very suitable where the number of circuits is comparatively small and chances of future expansion are less such as substations associated with generating plants and also step-down substations operating at extra high voltages. This scheme has been used on many of our early installations. However, during the recent past there have not been many installations of this type as this scheme does not lend itself easily to further expansion.



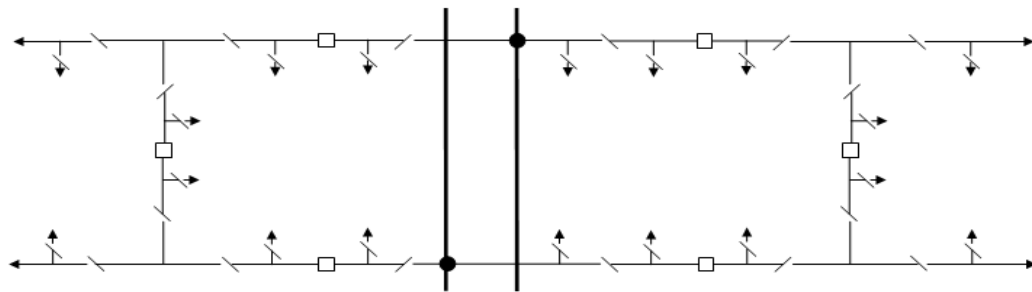
(H) Mesh Bus-bar System

2.3.3.7 One-And- A Half Breaker Scheme [FIG.(I &J)]: In this scheme three circuit breakers are used for controlling two circuits as shown in Fig.(I&J). Normally, both the bus-bars are in service.

A fault on any bus is cleared by the opening of the associated circuit breakers without affecting continuity of supply. Similarly, any circuit breaker can be taken out for maintenance without causing interruption. All load transfer is done by the breakers and therefore, the operation is simple. However relaying is somewhat more involved as the third breaker has to be responsive to troubles on either feeder in the correct sequence. Besides, each breaker has to be suitable for carrying the currents of two circuits to meet the requirements of various switching operations, which may in some cases increase the cost. The breaker and a half scheme is suitable for those substations which handle large amounts of power on each circuit. This scheme has been applied widely in the 420 kV systems.

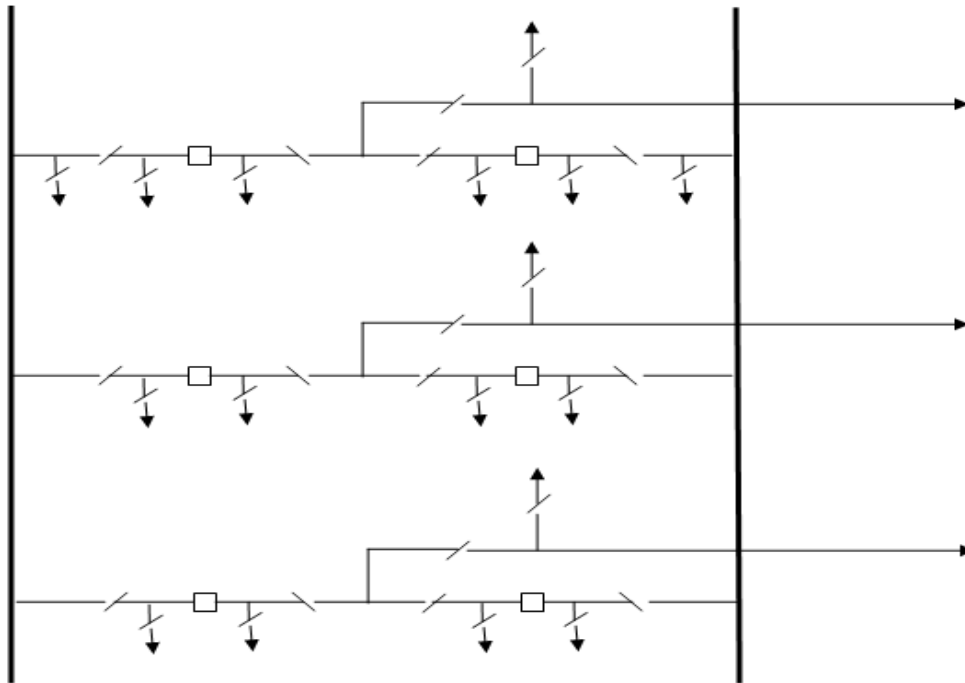


(I) One and half breaker Scheme



(J) One and half breaker scheme

2.3.3.8 Double-Bus And Double-Breaker Scheme: In this scheme two circuit breakers are used for controlling one circuit as shown in [Fig.(K)]. Normally both bus-bars are in service. Similar to breaker and half scheme, a fault on any bus is cleared by opening of the associated circuit breakers without affecting continuity of supply. Similarly any circuit breaker can be taken out for maintenance without causing interruption. All load transfer is done by breaker and therefore, the operation is simple and relaying is also simpler compared to breaker and half scheme. Because of increase in number of breakers per bay and higher cost, double bus double breaker scheme may be considered for those substations, which handle large amount of power.



(K) Double Bus Double Breaker System

2.4.1 TRANSFORMERS:

Anticipated load on the Substation upto horizon year may be considered for fixing power transformer capacities. A minimum of two numbers power transformers of suitable capacities shall be selected.

2.4.1.1 Transformer is the largest piece of equipment and it is therefore important from the point of view of station layout. One of the important factors governing the layout of the substation is whether the transformer is a three-phase unit or a bank of three single phase transformers. Space requirements with single phase banks are much larger than those with three phase ones. In the case of single phase banks it is usual to provide one spare single phase transformer installed in the yard, requiring additional space. Transformers up to 315 MVA, 400kV are available as three phase units. Transformers with larger capacities and medium capacity transformers where transport constraints restrict the movement limiting weight and size, will be normally single phase units.

2.4.1.2 In order to reduce the risk of spread of fire, large transformers above 100MVA capacity may be provided with stone pebble filled soaking pits and oil collecting pit. Also fire protection walls shall be provided in between the transformers. Road cum rail tracks also need to be provided for movement of transformer.

2.4.1.3 Transformers in transmission system normally have a vector group of YNyn0 for two winding transformers. Transformers of 100MVA rating and above and 220kV class and above and where transformation ratio is small, shall normally be auto transformers with a tertiary winding having a vector group of YNa0d11. The tertiary winding is intended for stabilizing purpose only. Tertiary windings for 220/132 kV auto transformers shall be of 11kV and that of 400/22kV auto transformers shall be of 33kV class. To withstand short

circuit stresses and higher transferred surge voltages the following special design features for tertiary windings shall be considered.

- a) Basic Insulation Level (BIL) of the tertiary winding shall be suitable for higher voltage class than that of the voltage class of tertiary winding to withstand transfer surges. Eg: 11kV tertiary winding will have BIL170kV peak and 33kV winding will have 250kV peak.
- b) Rating of the tertiary winding, shall be at least 1/3 rd of the rating of main transformer.
- c) Adequate cooling by way of ducts shall be provided to dissipate heat generated due to circulating currents and fault currents in the tertiary winding.
- d) Leakage reactance between primary to tertiary and secondary to tertiary shall be at least 35% and 25% respectively with only positive tolerances up to 10%, to reduce level of short circuit stresses and its impact on tertiary winding since it is closer to the core.

2.4.1.4 In case of auto transformers of 220/132 kV ratio, dispensation of tertiary winding altogether may be considered where there are balanced loads.

2.4.1.5 Provision for additional transformer and feeder bays (preferably with foundation laid) to be made to take care of likely future expansions.

2.4.2 Reactive Compensation Equipment:

Reactors required at the bus or line shall be provided as suggested by power system studies. Likewise the rating of shunt capacitors & the bus to which they are to be connected also to be fixed as per study reports.

Reactive compensation may be of switched or non-switched type as indicated by the system studies.

The non-switched type compensation usually comprises shunt reactors permanently connected to transmission line or to bus bars at the substations as per the requirements. Next to the transformer, shunt reactors constitute large pieces of equipment. These also can be in the form of single-phase units or three phase units.. Often another reactor called neutral grounding reactor, which is connected between the neutral bushing of the line shunt reactor and earth, is provided to facilitate single pole auto-reclosing. However in case of bus reactor neutral is solidly grounded. Since these equipment also contain oil, the provisions valid for transformers apply to shunt reactors too.

The switched compensation can comprise switched reactors, switched capacitors or thyristor controlled reactors and thyristor switched capacitors known as Static Var Compensations (SVC). These are selected according to the system requirements and connected directly to their own discrete transformers.

2.4.2.1 Shunt Capacitors:

Shunt Capacitors supply reactive power required at the bus to which they are connected. Reactive power is consumed by transmission lines due to the series inductance and by transformers due to self inductance. Transformers absorb reactive power in proportion to the load on the transformers up to a maximum, equal to 50% of their percentage impedance at rated load.

Eg: A 100 MVA transformer with 10% impedance will absorb 5 MVAR at rated load of 100MVA and 2.5MVAR at 50% load. Installation of shunt capacitors of appropriate capacity at various voltage levels viz; 11kV, 33kV and 132kV buses help in improving overall system power factor, maintaining optimum value of power factor at all levels. Capacitors provided at these buses supply reactive power requirement of power transformers and transmission lines to which they are connected.

KVAR rating of capacitor = $V^2 \times 2 \pi f C$

Reactive power delivered by the capacitors is proportional to the square of the voltage and the frequency. A lower bus voltage greatly reduces the available capacity of the capacitors.

If total required MVAR is connected in a single bank, the power factor may tend to lead at times due to load variation. Low power factor either lag or lead will result in increase losses and demand. Total requirement of Capacitors shall normally be installed in groups of smaller capacities and switched on/off in steps in proportion to the load in order to maintain optimum power factor.

Multi step switching of high voltage capacitors require additional associated equipment which is costlier. Alternatively requirement of MVAR compensation for base and peak load conditions can be worked out and capacitor banks numbering two or three of suitable capacity can be installed. Two/three step switching in/out can thus be achieved.

Capacitors can be connected in single star formation using Residual Voltage Transformer (RVT) or in double star formation using Neutral Current Transformer (NCT). The purpose of RVT/ NCT is to detect neutral displacement due to unbalance caused by the failure of capacitor units.

When a capacitor bank is switched on, there is an inrush current surge of high frequency which is transient in nature. To limit the inrush currents damping reactors are connected in series with capacitors.

Standardization of ratings for Capacitor banks and individual capacitor units will help in reducing the inventory costs and permit interchangeability.

2.4.2.2 Flexible AC Transmission Systems (FACTS): Flexible AC Transmission Systems (FACTS) technology is an evolving technology based solution for enhancing the power transmission capability of existing transmission system. FACTS is defined as "Alternating Current. Transmission systems incorporating power electronics and other static controllers to enhance controllability and increase power transfer capability." Thus, FACTS increases the flexibility of power systems, make them more controllable and allow increased utilization of existing network closer to its thermal loading capacity without jeopardizing the stability. FACTS technology can boost power transfer capability in stability limited system by about

20 to 30%. By the process not only capacity is increased but also design and installation cost is saved. Several types of FACTS controller devices e.g. Static VAR Compensator (SVC), Static Compensator (STATCOM), Thyristor Controlled Series Compensation (TCSC), Unified Power Flow Controller (UPFC), Inter-line Power Flow Controller (IPFC) etc. can be adopted to achieve the goal.

2.4.2.3 Static Var Systems: The following are the basic types of reactive power control elements, which make up all or part of any Static VAR system

- Saturated Reactor (SR)
- Controlled Shunt Reactor (CSR)
- Thyristor-switched Capacitor (TSC)
- Thyristor-switched Reactor (TSR)

Static VAR Compensators (SVCs) are shunt connected static reactive power generators and/or absorbers whose output are varied so as to control specific parameters of the electric power systems.

2.4.2.4 Series Compensation: Series capacitors are connected in series with the line conductors to compensate for the inductive reactance of the line. They reduce the transfer reactance between the buses to which the line is connected, increase maximum power that can be transmitted and reduce the effective reactive power losses. The series compensation can be variable type with control by Thyristor (also called as Thyristor Controlled Series Compensation — TCSC). Depending upon system requirement, a line can be compensated with fixed series compensation or fixed series compensation and TCSC.

The substation lay out should be such as to accommodate the required compensation equipments. Many-a-time only some of these may be required in the initial stage and may undergo alteration as the system develops.

2.4.3 Instrument Transformers:

Instrument transformers transform values of current and voltage in the primary system to values suitable for the measuring instruments, meters, protective relays etc. These also serve the purpose of isolating primary system from the secondary system.

2.4.3.1 Voltage Transformers (VT) may be of electromagnetic type or capacitor type. The electromagnetic type VTs are costlier than capacitor type. They are used where higher accuracy is required as in the case of revenue metering. Capacitor type is preferred particularly at higher voltages (400kV and above) due to lower cost and it serves the purpose of a coupling capacitor also for carrier equipment. For directional earth fault relays an additional secondary winding is required for connecting in open delta.

Capacitor voltage transformers are used for supplying voltage to the measuring instruments and relays. Simultaneously they are used as coupling capacitors for Power Line carrier Communication (PLCC). CVT consists of capacitor voltage divider and electromagnetic unit.

One set of voltage transformers is connected on the feeder side and one set on the bus side for providing two sets of voltages to two distance protection schemes with a change over switch

to select either of the voltages to the relays. Separate secondary windings shall be provided for metering and protection.

2.4.3.2 Current Transformers (CT) may be of bushing type or wound type. Bushing type CTs are normally accommodated within transformer bushings and the wound types are separately mounted. Wound type CTs come in dead tank and live tank (inverted primary) construction. A tap on the bushing of the CT shall be provided for measurement of Dielectric dissipation factor ($\tan \delta$).

Separate cores in the CT shall be provided for metering, protection, differential and bus bar protections. Metering CTs require higher accuracy over the normal operating current range. Protective CTs require specified accuracy for correct reproduction during the passage of abnormal current through primary due to a fault in the system. Main design parameters for CTs are

Rated primary current: It is the continuous current the CTs shall carry within the permitted temperature rise over the specified ambient including extended range of current i.e. from 120% to 200%. Accuracy shall be same in the extended range also.

Rated short time current: It is the maximum thermal current I_{th} which must be withstood by CT for 1 second. Maximum temperature permitted for oil insulated CT is 250 deg C. The dynamic withstand is calculated by the first current peak which can reach 2.5 times I_{th} . Peak value of dynamic current gives rise to the electromagnetic forces between the primary winding turns or arms of the hair pin. CT shall withstand both the thermal effects of short time current and forces due to the dynamic current.

Insulation level: CTs or VTs must withstand continuous operational voltage and also the over-voltages of the network which include AC one minute test voltage, lightning impulse withstand voltage, switching impulse withstand voltage as defined for 300kV and above system voltages and highest system voltage.

Pollution requirement: Pollution conditions are categorized as light, medium, heavy and very heavy, where minimum creepage distance of the porcelain weather casing shall be 16, 20, 25 & 31 mm/kV respectively. The creepage distance requirement is determined considering highest phase to phase voltage of the system.

Burden and accuracy on different secondary cores: Burden expressed as volt-amperes (VA) is the load (current coils of instruments/relays) connected to the secondary winding including secondary winding resistance and the connecting cable resistance. Errors in the CT are introduced by the exciting current in the form of ratio and phase displacement. To get high accuracy the exciting current shall be low. Since minimum error is generally reached between 50 – 75 % of rated burden, too high or too low burden may affect the accuracy.

Multiple ratios may be adopted on CTs, matching with different capacities of transformers/ different loading capacities of feeders, so that desired ratio of CT can be selected while augmenting the transformer/feeder without having to replace the CTs each time. Standard ratios adopted for various capacities are given in the table below.

Sl.No.	Transformer Rating	Voltage ratio	Desired CT	Ratio (Amps)
	MVA	kV	HV side	LV side
1	16 / 31.5 / 50	132/33	75-150-225/1or 100-200-300/1	300-600-900/1or 400-800-1200/1
2	80	132/33	400/1	1600/1
3	31.5 - 50	220/33	100-150/1	600-900/1
4	100 – 160	220/132	300-500/1	500-800/1
5	315	400/220	500/1	1000/1
6	16	132/11	75 - 100/1	900 – 1200/1

Secondary current rating is normally selected at 1 ampere for all cores. In respect of cores used for differential protection, depending on the type of connection to the relay viz. star/delta, rating of other than 1 amp say 0.5775amps.on secondary winding of this core may be provided. Likewise rating other than 1 amp for cores meant for bus-bar protection may be used considering overall bus ratio. However where numerical relays are employed for Differential/ Bus-bar protection, the relays take care of such mismatch in CT ratio. Hence there is no need for going for different taps on secondary windings of these cores.

2.4.4 Circuit Breakers:

Circuit breaker is a mechanical switching device capable of making, carrying and breaking currents under normal conditions and also making, carrying for a specified time and breaking current under specified abnormal conditions.

Types of circuit breakers in use

12kV & 36kV	:	Minimum oil, Bulk oil, Vacuum, SF ₆
72.5 kV	:	Minimum oil, Bulk oil, SF ₆
145 kV	:	Minimum oil, Bulk oil, Air Blast, SF ₆
245 kV	:	Minimum oil, Bulk oil, Air Blast, SF ₆
420 kV	:	Minimum oil, Bulk oil, Air Blast, SF ₆

However minimum oil, bulk oil and air blast circuit breakers are phased out with the advancement in technology. SF₆ breakers for 145kV and above voltages and vacuum circuit breakers for 11 and 33 kV are generally preferred.

Circuit breakers may be of live tank or dead tank design. Live tank breakers for outdoor substations have the interrupters housed in porcelain weather shields on the top of an insulated support column. Circuit breakers of dead tank type have interrupters housed in an earthed metal container with their connections taken out through porcelain bushings and the bushings may be used to house the current transformers.

Selection of rating of circuit breakers:

Rated voltage kV	Rated short circuit breaking current kA	Rated normal current (Amp)			
36	25	1250	1600	2500	
	31.5	1250	1600	2500	
145	31.5	1250	1600	2000	
	40		1600	2000	3150

245	31.5	1250	1600	2000		
	40		1600	2000	3150	
	50			2000	3150	4000
420	40		1600	2000	3150	
	50			2000	3150	4000
	63				3150	4000
800	40			2000	3150	

Continuous rating of the circuit breakers shall be equal to the current corresponding to the maximum power flow in the circuit/line, transformer. Short circuit breaking current (Rupturing current) shall be more than or equal to the maximum fault level at the Substation bus.

Rated operating sequence (Duty Cycle): The operating sequence denotes sequence of opening and closing operation which the breaker can perform. Operating mechanism experiences severe mechanical stresses during the auto re closure duty. The circuit breaker should be able to perform the following operating sequence.

- a) O - t - CO - T - CO
O- Opening operation, C – Closing operation, CO – Closing followed by opening
t – 0.3 sec. for rapid or auto- reclosure, T – 3 minutes
- b) CO - t – CO where t = 15 sec. for circuit breaker not to be used for auto-reclosure

Total Break Time (As per IEC: 62271-100):

145kV	60 ms to 100 ms
245kV	Not exceeding 60 ms
420kV	Not exceeding 40 ms
800kV	Not exceeding 40 ms

2.4.5 Control&Relay Panels:

2.4.5.1 Function of Protective Relaying: It is to cause a prompt removal from service of any element of a power system when it suffers a short circuit or when it starts to operate in any abnormal manner that might cause damage or otherwise interfere with the effective operation of the rest of the system. Relaying equipment is aided in this task by circuit breakers that are capable of disconnecting the faulty element when they are called upon to do by the relaying equipment. Relay processes and communicates adverse condition of equipments/line to be protected, automatically. Protective relays are activated by a single or combination of voltage, current and frequency.

Functional requirement of the relay:-

- i) Reliability: The most important requisite of protective relays is reliability since they supervise the circuit for a long time before a fault occurs; if a fault then occurs, the relays must respond instantly and correctly.
- ii) Selectivity: The relay must be able to discriminate (select) between those conditions for which prompt operation is required and those for which no operation, or time delayed operation is required.

- iii) Sensitivity: The relaying equipment must be sufficiently sensitive so that it operates reliably when required under the actual conditions that produces least operating tendency.
- iv) Speed: The relay must operate at the required speed. It should neither be too slow which may result in damage to the equipment nor should it be too fast which may result in undesired operation.

Control and Relay panels are required for control and protection of major equipment like transformers, reactors, capacitors and feeders in the substation. The C&R panels can be a single unit for both control and protection or two units for control and protection separately.

Control panel: shall contain the following:

Control switches for closing and opening of circuit breakers, isolators, earth switches, Indications (Semaphore/ mimic diagram) showing the status of these equipment Display of metering data such as voltage, current, MW, MVAR, Frequency, MWh and MVARh, through digital instruments

Audible annunciation and visual indications of events such as tripping on relay action, alarms for temperatures in case of transformers, low air/gas pressures, low gas density for circuit breakers

Interlock features preventing inadvertent operation of circuit breakers, isolatorsetc.

Relay panel: consists of various protective relays for transformers/ feeders, with associated auxiliary relays and communication features for inter trip and auto reclose wherever required.

2.4.5.2 Standard Protection Schemes followed in APTRANSCO:

(a) Transmission Lines:

400kV Lines: Main-I &Main-II distance protection schemes of numerical type suitable for 1-Phase / 3-Phase tripping with additional functions like Auto reclosure,Breaker failure protection(LBB), Over/Under Voltage and Over Current /Earth Fault are provided. These functions can be utilized depending on the requirement. Single phase single shot high speed Auto reclosure scheme is implemented whenever felt necessary.Carrier aided inter tripping schemes are implemented on all the lines. Two stage over voltage protection is used on all 400kV lines. For Stage-I, a separate relay is employed and for Stage-II, the built –in function available in Main-I&II is used.

220kV Lines: Main-I &Main-II distance protection schemes identical to 400kV lines are used. IDMT type Earth fault protection available in numerical Main-I&II is used for high resistance earth fault. Carrier aided inter tripping scheme is implemented on all the 220kV lines.

132kV Lines: 1No. numerical distance protection schemes and a separate backup Over Current/ Earth Fault scheme is used for 132kV lines.

Relay settings for Distance Protection:

Zone-1: Set to cover 80% the protection line. This is to take care of errors in instrument transformers, relay accuracy & line lengths. Time of operation is set as Instantaneous.

Zone-2: Set to cover 100% of protection line + 50% adjacent shortest line or 120% of protection line, whichever is higher. Time delay: 0.3 to 0.6 Sec.

Zone-3: Set to cover 100% of protection line + 120% of adjacent shortest line (or) 150% the protected line, whichever is higher. Time delay: 0.6 to 0.9 Sec.

Zone-4: Set to cover 100% of protection line + 120% of adjacent longest line (or) 120% Of Zone-3 reach whichever is higher. Time delay: 1.2 to 1.5 Sec.

Relay settings for backup Over Current & Earth Fault relays:

The plug setting is selected based on current carrying capacity of the transmission line conductor for grid lines and according to transformer capacity on radial lines. General over current plug setting for 132kV grid lines is 100% In with 600/1A.

The plug setting for Earth fault relay is set at 20% In for better sensitivity.

The Time Lever setting is selected to get actual time of operation equal to zone-2 time of the distance relay for grid lines. For radial lines it will be set maintaining time gradation with 132/33kV Power transformers for 33kV bus fault.

Instantaneous elements are being provided on 33kV feeders to ensure safety of the 132/33kV power transformers.

Over Voltage Protection:

Stage-I (low set) is set at 110% U_n with a typical time delay of 5 Sec. A time gradation of 5 or 6 Sec. is provided on the 2nd circuit of a D/C line.

Stage-II (High set) is set at 140% U_n with a time delay of 100msec. This stage is for operation during switching surges.

(b) Protection schemes of Power Transformers:-

Reliable, secure and fast protection system for the Transformers is essential to minimize the damage in case of an internal fault. Suitable backup protection scheme is to be provided to take care of uncleared system fault.

The following schemes are used for protection of Power Transformers.

- Differential Protection.
- Over flux Protection
- Restricted Earth Fault (REF) protection (for 315MVA ICTs)
- Backup O/C +E/F on HV & LV sides

- Protections and monitors built in to Transformer such as Buchholz relay, oil level indicator and Pressure Relief Device)

Settings Criteria:-

Differential protection: Generally the CT ratios on HV&LV are selected such that the relay currents on both sides are balanced. In the numerical relay, the ratio correction feature is available and unmatched CT ratios can be used on HV & LV side. A differential setting of 20 to 30% Id is adopted keeping in view tap changer range.

Overflux Protection: This function has to be set according to the transformer characteristics. In the absence of the above, the following settings are adopted

For alarm: 115% V_n/f_n , 2Sec.

For trip : 120% V_n/f_n , 5Sec. (Or) An inverse time characteristic curve is set for tripping

REF Protection: Identical CTs are provided on the phase side (HV&LV) and neutral side and the setting is selected such that through fault stability is maintained.

Backup O/C&E/F Protection scheme: The plug setting of O/C relay is selected based on full load current of Transformer. The plug setting of E/F relay is invariably set at 20% In. The time lever setting is set such that time gradation is maintained with feeder protection for feeder faults. However the actual time of operation for LV bus fault is set between 0.6 to 1.0 Sec.

The Instantaneous element is used in HV O/C relay and is set to operate only for transformer faults.

- (c) **Busbar Protection Scheme:** Busbar Protection scheme is required for high speed clearance of busbar zone faults by tripping all the circuit breakers connected to the faulty bus. Bus-bar protection scheme is provided in all the 400kV Substation and 220kV grid Substations.

This protection operates on differential current principle and provides independent zones of protection for each bus. It consists of continuous supervision for CT secondaries against any open circuits. On detection of open circuiting of CT secondaries, the effected zone of protection shall be blocked, giving an alarm, after a time delay.

Setting criteria: The CT supervision relay will be set such that it can detect CT secondary open circuit even in case of least loaded feeder.

In case of voltage operated high impedance type protection, the voltage setting of the differential element should be set above expected voltage developed across the relay during maximum through fault current condition.

In case of current operated relays to have through fault stability, the external resistance is set such that the voltage developed across relay and resistance combination is below the voltage required for forcing required relay operating current.

- (d) **LBB Protection:** In the event of any circuit breaker failing to trip on receipt of trip command from protection relays, all the circuit breakers connected to that bus will be tripped with minimum possible time delay through LBB Protection.

Each breaker will have a separate LBB relay housed in the C&R panel of that particular feeder/transformer.

A general current setting of 0.2A and a time delay setting of 200msec. is adopted for LBB protection.

(e) Reactor Protection : Shunt Reactors are used in EHV system to limit the over voltages due to capacitive VAR generation in long transmission lines.

Shunt reactors are used in 400kV system and connected (i) through isolator to a line and (ii) through circuit breaker to a busbar.

Protection schemes for reactors are similar to those used for transformers.

Setting Criteria:

- For differential relay, differential current setting of 10 to 20% I_n adopted.
- For REF relay, voltage setting of 10% to 20% U_n can be adopted, as through fault stability need not be considered.
- Backup O/C&E/F protection are set to operate for 1.2 x rated current with a time delay of about 0.5 to 1.0 Sec.
- For backup impedance relay 80% (single step) of reactor impedance is set with a time delay of 0.5 to 1.0 Sec.

2.4.6 SUBSTATION AUTOMATION:

During 70s protection was through electromechanical relays and the control of the CBs, isolators, and transformer tap changers were done manually. The real time status was available through analog meters mounted on the C&R panels. The reports and logs were prepared manually.

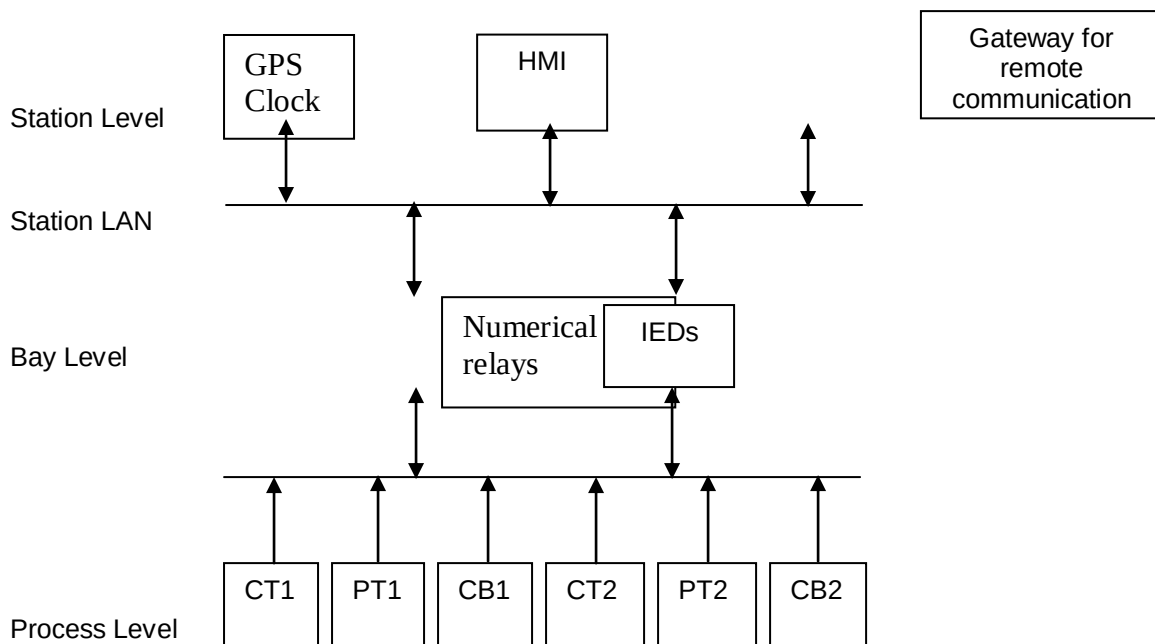
Static relays replaced the electromechanical relays during 80s. No major difference was there in the way the substation was monitored and controlled. Development in communication technologies made it possible to control and monitor substations from local and remote centers. Remote Terminal Units (RTUs) are being used for collecting and sending substation data to control centers and to receive and execute control commands from there. With the advent of numerical relays and bay controllers (also called Intelligent Electronic Devices i.e IEDs) the tasks of data collection and substation monitoring have changed. The basic inputs of current and voltage from CTs and PTs are taken and converted into digital format. This data is analyzed, reformed, computed and necessary logics and programmes are written to get necessary functionality, be it protection or control. Thus the processed data is communicated to local and remote control centres, in addition to control and monitoring system. This is the concept of substation automation. The objective of modern substation is to solve these tasks in a more efficient and economical way by using the state of the art technologies and to provide more functionality to the services rendered by the utility.

The automation feature in a substation is accomplished with the use of an architecture that typically consists of protection devices like numerical relays and bay controllers, control and monitoring devices like HMI and servers, connected to a high speed local

communication network like Ethernet local area network (LAN). This network provides a means for integration of these devices with the field devices using standard communication open protocols.

IEC 61850 is the present standard communication protocol being widely adopted in the substation automation systems. This standard defines the communication between the IEDs, system requirements and engineering requirements. Main features of IEC 61850 standard are interoperability and peer to peer communication. Interoperability is defined as the ability of two or more IEDs to operate on the same network or communication path exchanging information and using the information to execute specified functions. The advantage of peer (IED) to peer communication, through the LAN connection, is to eliminate the traditional hard wiring between protective devices reducing the installation and commissioning costs.

Typical architecture of an automated system is shown in fig.



Arrow direction indicates Data flow.

The SAS functions at three levels, viz., station, bay and process levels as shown in the above figure.

- The process level functionality is an interface to the primary equipment i.e CTs, PTs, circuit breakers isolators and on-load tap changers etc. The specified functions at this level include data acquisition, and issuing input/output commands.
- The bay level functionality is concerned with measurement of parameters and control of a defined subpart of the substation called as bay. IEDs mostly carry this functions.
- The station level consists of Human machine interface (HMI) as well as communication services for remote control centers.

Signals for substation automation: Analog inputs, Digital input and Digital output signals are required for communication to the local and remote (controlled and master) stations.

Analog inputs contain samples of current and voltage from various locations in the substation. These samples are used to calculate real power, reactive power and energy on that feeder.

Digital inputs are the status of various switches and breakers used to in the substation. This status indicates whether the switch has been is operated or not. A software program is used to read the status of any switch.

Digital outputs are used to control or to operate the switches and breakers in the substation.

IEC 61850 architecture facilitates distributed automation. In this distributed automation, control and protection devices are accommodated in an enclosure (bay kiosk), in the outdoor switch yard close to the equipment to control and monitor the bay equipment. This arrangement reduces the length of power and control cables required between outdoor equipment and control panels, reduces the size of the control room and cable ducts. Also this arrangement is more scalable. As such substation automation reduces cost of the project and completion period.

Benefits of Sub station Automation system :-

- SA provides more reliable on line information of the substation on one platform.
- Time synchronized information is available at a glance not only in the local station but also in the remote control centers. Present practice of data recording in log sheets was sometimes in question and in the event of fault occurrence the data recorded is either inadequate or not accurate enough to make a correct analysis. In the manual system if the operator is engaged with other important work, he may not be able to record the readings in time. Automation system keeps recording all the information continuously and automatically. Recording of trends, reports, events, alarms, transformer winding temperatures, SF6 gas pressures can be done automatically at required intervals.
- SA system works on LAN network which permits use of interface monitors at different user locations with different user authority levels. While majority of users have authority to view only, a few can be vested with authority to view and control, and a few can be authorized to view, control and engineer the system. SA system helps grid operating engineers to take correct decisions in the event of emergency. This system logs user's operations as an event and thus keeps a check on unintended operation or usage.
- The numerical relays have facility of recording disturbance reports in the event of any fault occurrence to an accuracy of 1ms. This helps to analyse the fault accurately and take corrective actions in lesser time. The DR information can be uploaded in to SCADA system automatically to access it by power system engineers for analysis. These reports can also be stored as records.
- Dynamic coloring of single line diagram (on the monitor) helps to visualize the operation of any equipment like CB, Isolator etc. In case of any occurrence this helps the operator to take corrective actions.

- The new system is highly reliable, spares to be maintained are less and self supervision feature assures that the system is healthy. It is possible to monitor closing and tripping time of the breaker which helps in taking decisions regarding shutdown maintenance programs to condition the equipment and thus increase the availability of supply.

SUBSTATION AUTOMATION WITH IEC61850 STANDARD:

Objectives:

- Improved network availability.
- Reduced quantity of equipment, wiring, and space.
- Real time status, equipment performance and event reports.
- Equipment condition monitoring data.
- Relays and other intelligent electronic devices (IEDs) communicate via local area networks (LANs) for operational integration.
- Relays, IEDs and data bases can be integrated with corporate WAN for non operational substation information access throughout the enterprise.
- Equipment monitoring IEDs evaluate and communicate operating data for major capital equipment.
- Redundant LAN network reduces inter panel control wiring, eliminates lock-out switches.
- The substation HMI replaces manual controls and metering.
- Coordinated substation and control center systems retain the substation events, disturbances, real time data information for reference during communication outages.
- Gives fast access to time synchronized fault and disturbance data for analysis and restoration of system failures.
- GPS based time synchronization signals connected to all IEDs achieve 1ms coordinated time tagging.

2.4.7 DISCONNECTORS AND EARTH SWITCHES (ISOLATORS):

Disconnect switches are mechanical devices which when open provide isolating distances meeting the specified requirements. These switches operate on no load and carry current under normal conditions and carry for a specified time short circuit conditions.

Earthing switch is a mechanical switching device for earthing parts of a circuit, capable of withstanding for a specified time short circuit currents, but not required to carry normal current of the circuit.

Types of switches in use for different voltage classes are given below.

36 kV	:	Horizontal double break
72.5 kV, 145 kV, 245 kV	:	Horizontal double break/ centre break
420 kV	:	Horizontal centre break/ Panto graph, double break
800 kV	:	Vertical break

Normally disconnecting switches (isolators without earth switch) are to be provided for transformers & bus VTs. Isolators with earth switch are to be provided for feeders/lines.

Type of isolators has great influence in bay width and level of substation. Using double break type of isolators compared to horizontal central break isolators, bay width can be reduced by 10-15%. Pantograph isolators are best suited for Double Main and Transfer scheme (with flexible bus arrangement). Vertical break isolators cause increase in height of levels, but are more economical for voltages more than 400kV due to lesser length of beam, bay width and lesser requirement of land.

2.4.8 Lightning Protection:

Substation has to be shielded against direct lightning strokes either by providing overhead shield wire or spikes (masts). The shield wire/masts provide coverage to the entire switchyard equipment. An angle of shield of 60° for zones covered by two or more wires/masts and 45° for single wire/mast shall be considered.

Apart from direct strokes, the substation equipment shall be protected against travelling waves due to lightning strokes on all the lines entering the substation. Lightning or Surge Arrestors are used for this purpose. Since power transformer is the costliest equipment in the substation, the surge arrestors shall be installed as near to the transformer as possible within the protective distance, on both sides of the transformer. Besides protecting the transformers, the surge arrestors also provide protection to the equipment on the bus side located within certain distance.

In the case of very large substations, where the surge arrestor connected to the transformer does not provide required protection to the other equipment, additional surge arrestors on the bus shall be provided. Surge arrestors shall also be provided on the lines entering the substation, before the line isolator.

Advances in material technology resulted in development of metal oxide gapless type surge arrestors. These have high energy handling and discharge capability, better protection level and low power loss under normal operating conditions and hence are widely used.

Typical technical parameters of surge arrestors are as follows:

Sl. No.	Item	765kV	400kV	220kV	132kV	33kV	11kV
1	System voltage kV	765	400	220	132	33	11
2	Highest system voltage kV	800	420	245	145	36	12
3	Rated arrestor Voltage kV	624	390/360/336	198/216	120	30	10
4	Nominal discharge current kA corresponding to 8/20 μ s wave shape	20	10	10	10		
5	Class	Class5	Class3	Class3	Class3	Class3	Class3
6	Pressure relief class	----- A -----					

2.4.9 Insulators:

Provision of adequate insulation in a substation is an important feature from the point of view of reliability of supply and safety of personnel. The substation design shall be so evolved that the quantity of insulators required is minimum commensurate with the expected security of supply. Special insulators with higher creepage distance shall be used where the level of pollution is high such as locations near sea, thermal power generating plant or an industrial plant etc. In case this does not suffice, washing the insulators by using live line equipment has to be done and this aspect has to be kept in mind while deciding the layout of the substation. Another method involves application of suitable type of grease or Room Temperature Vulcanization (RTV) compounds on the surface of insulators. This, however also requires cleaning of insulation, the frequency depending on the degree and type of pollution.

Creepage distances for different pollution levels as mentioned earlier shall be provided. Highest line-to-line voltage of the system forms the basis for determining the creepage distance requirement.

The following types of insulators are normally used:

(A) Bus Support Insulators

- i) Cap and Pin type
- ii) Solid core type
- iii) Polycone type

(B) Strain Insulators

- i) Disc Insulators
- ii) Long rod Porcelain Insulators
- iii) Polymer Insulators

2.4.10 Structures:

Steel is most commonly used material for structures. Steel is hot-dip galvanized to protect the structures against corrosion. Galvanizing has not been effective in substations located in coastal or industrial areas where the degree of pollution is very heavy. In such cases painting also may be needed. Special paints shall be used for this.

Cost of structures also is a major consideration while deciding the layout of a substation. In the case of strain/flexible bus-bar arrangement, cost of structures is much higher than in case of rigid bus type. Similarly the form of structures also plays an important part and the choice is usually between using a few heavy structures or a large number of smaller structures. While finalizing the design, size, and single line diagram of structures, safety clearance requirements should be ensured.

2.4.11 Power line carrier Equipment:

Carrier equipment required for communication, relaying and tele metering is connected to line through high frequency cable, coupling capacitor and wave trap. The wave trap is installed at the line entrance. Coupling capacitors are installed on the line side of the wave trap and are normally base mounted. Wave traps up to 145kV voltage can be mounted on the gantry structure on which the line is terminated at the substation. However wave traps for voltage levels of 245kV and above require separate supporting insulator stacks mounted on structures of appropriate heights.

2.5 Substation Auxiliary Facilities:

Design of a substation shall include auxiliary facilities such as earthing, cabling, oil handling system, fire fighting, crane and other unloading facilities, AC/DC distribution systems etc.

2.5.1 Earthing:

2.5.1.1 Provision of adequate earthing system in a substation is very important for safety of the operating personnel as well as for proper system operation and performance of the protection devices. The primary requirement of a good earthing system in a substation are:

- a) The impedance to ground should be as low as possible. In general it should not exceed 1 ohm for substations with high fault levels (EHV substation), 2 ohms for a 33kV substation, 5 ohms for distribution transformer structures and 10 ohms for tower footing resistance.
- b) The step and touch potentials should be within safe limits. Earthing system of a substation comprises of a mesh of earthing strips (earth mat) buried at a depth of at least 600mm below ground, supplemented with number of earth electrodes/ground rods at suitable points. In wet season, earth mat works as substation earth and in dry season earth electrodes have predominance as substation earth. Individual electrodes shall be designed in such a way that the earth resistance of each electrode is less than 3 ohms. Design of earth mat shall be such that its value in ohms is less than three divided by number of electrodes in switchyard, in order to keep touch and step potentials within limits.

Earthing is broadly divided as (a) system earthing(connection between part of plant in an operating system like neutral of a power transformer winding and earth), and (b) equipment earthing (safety grounding) connecting bodies of equipment to earth.

All the non-current carrying metal parts of the equipment in the substation should be connected to the earthing mat so as to ensure that under fault conditions, none of these parts is at a potential higher than that of the earthing mat. Ground rods maintain low value of resistance under all weather conditions which is particularly important for installations with high system earth fault currents.

All substations should have provision for earthing the following:

- a) The neutral points of equipment in each separate system. There should be independent earth for the different systems. Each of these earthed points should be

interconnected with the station earthing mat by two different diagonally opposite connectors to avoid common mode failure.

- b) Bodies of all the equipments, cable sheath and non-current carrying metal parts
- c) All extraneous metal frameworks not associated with equipment(structures, poles etc).
- d) Battery mid-point, tertiary winding and control panel
- e) Lightning arresters: These should have independent earthing which should in turn be connected to the station grounding grid or earthmat.

Soil Resistivity: or earth resistivity expressed in ohm-metre is the resistance of cubic metre of earth measured. Resistivity of a normal soil is about 10000 ohm-cm where as resistivity of copper is 1.6 micro ohm-cm. Resistivity of soil is influenced by the quantity of water held in it. In other words conduction of electricity through soil is due to water content present in it.

Touch Potential: is the difference in voltage between the object touched and the ground point just below the person touching the object when ground currents are flowing.

Step Potential: is the difference in voltage between two points, which are one metre apart along the earth when ground currents are flowing.

Equi Potential: Two separate points at same potential

Mesh Voltage: is the maximum touch voltage to be found within a mesh of ground grid.

Transferred Voltage: is a special case of touch voltage where voltage is transferred into or out of the substation.

The earthing of a substation fence has to be considered from the touch and step potentials point of view in the peripheral area outside the fence. Normally the earth mat has to be extended by 1m to 1.5m beyond the fence so as to ensure that the area in the vicinity of the substation fence is safe.

Where fenced area is large and mat area is small, fence earthing should be isolated from the main earth mat so that person touching the fence is protected from danger due to transfer voltage.

Earthing in a substation must conform to the requirements of the Indian Electricity Rules and the provisions of the relevant sections of latest IS: 3043 and IEEE Std - 80. The earthing system should be designed to have low overall impedance, and a current carrying capacity consistent with the fault current magnitude.

The major parameters which influence design of earth mat are:

- (a) Magnitude of fault current:
- (b) Duration of fault:
- (c) Soil resistivity:
- (d) Resistivity of surface material:
- (e) Shock duration:
- (f) Material of earth conductor, and
- (g) Earth mat grid geometry

Bare stranded copper conductor or copper strip used to find extensive application in the construction of earth mat in the past. However, on account of high cost of copper and the need to economise in the use of copper, current practice in the country is based on the use of steel conductor for earth mat.

In view of fast deterioration of GI pipe electrode, cast iron pipe electrode is preferred for earthing. The minimum distance between the electrodes shall be twice the length of electrode.

2.5.1.2 Design Procedure:

Methods for reduction of earth resistance: Sodium chloride (NaCl), coke and sand are the most common, popular and economical chemicals which are used to bring down the resistivity of soil. Aluminium sulphate is another chemical equivalent to sodium chloride. Other effective chemicals like Magnesium sulphate, calcium chloride or potassium chloride when mixed with soil brings down the resistivity, but are costlier.

Use of multiple electrode system, deep driven rod system, counterpoise earthing etc. are some of the other methods to reduce the earth resistance. Design calculations for each method are to be done in each case.

Use of Bentonite Compound: Bentonite compound reduces the earthmat resistance to $\frac{1}{4}$ level of its original. Bentonite consists of a clay which when mixed with water swells many times of its own volume. It absorbs moisture from the soil and retains it for a long time. Hence frequent watering to earth electrodes is not necessary. Bentonite may be used as a back fill material to surround vertical electrodes and also used to bed horizontal electrodes to improve the overall earth resistance. Bentonite treatment of soil results in appreciable reduction of resistance and low resistance remains constant over number of years. This is particularly more useful in soils where resistivity is too high i.e. 300 ohm-metres and above.

Periphery of earthmat in the switchyard should be laid with 75x8 / 100x16 mm MS flat so as to cover all pole structures and all metallic parts. Internal vertical and horizontal sections may be 50x6 / 75x8 mm MS flat.

Earthing of neutral terminal of power transformers shall be done at two points. One earth flat of size 75x8mm MS flat is directly connected to the earthpit and the earth pit inturn is connected to the earth mat. Second earthing of neutral is made to the earth mat with the support of 75x40x6mm MSchannel.

Bodies of all equipment and metal structures should be earthed 50x8mm MS flat to two sides of the earth mat diagonally opposite.

Lightning arrestor is to be connected one end directly to the earth electrode nearby individually and the earth electrode is inturn connected to earth mat.

Types of soils and their resistivity values

Type	Resistivity in Ohm-cm
Loamy, garden	500-5000
Clay	800-5000
Clay, Sand & Gravel mixture	4000-25000

Sand Gravel	6000-10000
Slates, Shell, Sans stone etc.	1000-50000
Crystalline Rock	20000-100000

Earth resistance of individual earth pits can be measured by disconnecting the earth connections to the electrode. This is possible if the connections are made to a common clamp which in turn is fixed round the pipe.

Maximum voltage is at the centre of electrode and it falls drastically within a radius of 150mm to some value and then remains constant to some extent. Hence the path up to 150mm radius from centre should be of very low resistivity material so that the discharge is very fast and resistance offered by the ground is very low. Hence the diameter of the charged electrode (electrode filled around with chemically charged materials like salt and charcoal etc) is generally kept as 300mm. The diameter can be increased if faster discharge is required but this will consume more material and space.

Separate and effective earthing should be provided to PLCC, Battery mid-point, in order to avoid flow of fault current through these equipment and for human safety. Ineffective earthing may affect the communication signaling in PLCC and may affect the performance of the battery.

2.5.1.3 New design concepts: New maintenance free earthing methods have been developed which use earth enhancing compound, electrodes and couplers. In place of salt and charcoal, a highly conductive, non corrosive earth enhancing compound (CONCRETE/CONTACT.GF) is used. This compound when in contact with the earth produces a gel having high conductivity in the electrode area and reduces the resistivity of earth and interacts with the earth homogeneously. This can be used with any type of soil. No topping up of water is required to maintain low resistance.

Copper coated nickel electrodes are used for faster dissipation of fault current. The electrodes can be driven deep into the earth with the help of sledge hammer. Total depth of the earth rods can be increased by joining them using compression couplers to reach the natural soil. Thus the electrode can be driven up to 30 to 40 feet using multiple rods and couplers against fixed lengths of 9 to 10 feet in a conventional earthing system. This type of earthing may be useful in areas where soil resistivity is very high and natural soil is at a very high depth.

Black Metal is spread in the switchyard mainly to provide high resistivity layer and to maintain moisture in the soil. Spread of metal in the switchyard obstructs running of persons in the switchyard and saves them from encountering possible high step voltage. In addition to the above this avoids formation of pool of oil in case of leakages from transformers, breakers etc. and to eliminate spreading of fire. The metal layer keeps the reptiles away and controls the growth of grass and weeds.

For detailed design of earth mat reference may be made to the latest edition of IEEE-80, CBIP Technical Report No. 5 on 'Steel Grounding Systems where Grounding Mat is not needed' and CBIP Publication No. 223.

2.5.2 Cabling:

Trenches and cable ducts are normally laid for cable runs. In very large substations, particularly those associated with power plants, tunnels have also been used. Except where cables enter and take off from trench, directly buried cables are generally avoided to facilitate locating faults easily.

The substation area should be properly sloped so that the rainwater is drained away from the cable trenches. Arrangements like pumping out of accumulated water if any in the trenches should be provided. Cable trenches should be provided with strong and effective covers. Cables should not be laid directly on the trench floor. At points of entry into indoor areas, termination chambers etc., waterproof and fireproof sealing arrangements should be made. Cable trenches should not run through oil -rooms.

Conduits should have the minimum number of bends in their run. Pull boxes to facilitate cable pulling should be provided at suitable locations. Conduits should be sloped and drained at low points. Care must be exercised to see that water does not accumulate within the conduits or drain into the equipment at the end.

In indoor areas, cable may be laid in racks supported on walls, ceiling or floor, floor trenches or clamped to walls or ceiling. Wherever a large number of cables are involved and conditions so permit, a system of racks is preferable as it gives quick access. Particular care should be taken in substation design to permit easy entry of cable in to switchgear with convenience of handling even afterwards.

Cable laying should be done in accordance with systematically prepared cable schedules. In major substation thousands of separate cables will be involved and quick tracing of defects will depend very much on the orderliness exercised while laying. All cable ends should be suitably labeled to facilitate easy identification.

Power cables and control cables should be segregated by running in separate trenches or on separate racks to prevent spread of fire from one to the other. Likewise AC and DC control cables shall also be segregated. Separate cables should be used for each CT and PT. In the case of 400 kV substations and substations having numerical/digital relays, shielded cables should be used for CT and PT circuits and armoured cables for other circuits. While arranging cable runs it should be kept in mind that the arrangement should be such that a fire at any point will not lead to complete shutdown of the whole substation for a long time. Flexible conduits should be used at terminal connections to motors, pumps, etc. The main trenches should be formed such that heavy current carrying conductors do not run parallel to the control cables. The cable ducts should be laid away from lightning arresters to minimize the effect of high discharge current flow.

In main trenches a heavy current carrying conductor should not be run parallel to control cables. This conductor should be clamped at suitable intervals to the support angles earthed to rod electrodes at every 20/25-meter intervals. This shield conductor drain all induced current and minimizes induction of high voltage in the control cables.

Power cables are placed in the top rack. Lower racks contain control cables. If unarmoured cables are used these should find place in the bottom most rack.

Multicore control cables should be PVC / XLPE insulated and colour coded. Adequate number of spare cores should be included in all control cables. Wherever fiber optic cable are used they should be armoured type.

Wherever insulated cables are used reference should be made to latest IS: 1554 and IS: 694. Earthing of cable sheaths, provision of earth continuity conductors etc., should be as per latest IS: 1255. "Code of Practice for Installation and Maintenance of Paper Insulated Cables" (upto and including 33 kV) and latest IS: 3043 Code of Practice on Earthing.

Wherever application demands, FRLS cables and fittings should be used. For mechanical protection, armoured cables are used in case these are laid on ladder type trays. For 400 kV switchyards, irrespective of the type of cable trays, armoured cable should be used. Armoured cables can be buried directly. However the unarmoured cables can be laid in conduits.

2.5.3 Oil Handling System:

Oil handling system is required for treatment of insulating oil in transformers, reactors etc. Details regarding handling and treatment of oil are given in latest IS: 1866 – “Code of Practice for Maintenance and Supervision of Insulating Oils in service”

2.5.4 Illumination System:

Good lighting in a substation is necessary to facilitate normal operation and maintenance" activities and at the same time to ensure safety of the working personnel. As per latest IS: 3646 (Pt. II) "Schedule for values of illumination and Glare Index" recommends values of intensity of illumination. Recommended values are given in the Table-1.

Out door switchyard average illumination level shall be 50 lux on main equipment and 20 lux on balance area of switchyard. In the out door switchyard, the area covered by transformer/reactor should have 50 lux.

Table – 1 Recommended Illuminator Values

Sl. No.	Particulars	Average illumination level Lux	Limiting Glare Index
1.	Control rooms:	200 to 300	19
	Vertical control panels	150	19
	Rear of control panels	300	19
	Control desks	150	25
	Switch houses		
2.	Battery room	100	-
3.	Carrier room	300	-
4.	Offices and reception	300	19
5.	Cloak rooms	100	-
6.	Workshop/Repair bay	300	25
7.	Test room	450	19
8.	Outdoor switchyard	20	-
9.	Stairs	100	-
10.	Corridors	70	16
11.	Approach roads	20	-

12	Pathways	20	-
13	Car parks	20	-
14	Conference room	300	19
15	Store room	100	-
16	Cable gallery/floor	70	-
17	AC plant/DG set room	150	-

The lighting system of a particular area whether outdoor or indoor should be designed in such a way that uniform illumination is achieved. As far as possible any dark spots should be avoided. This requires careful placing of the luminaires, selection of proper mounting heights and provision of sockets in the marshalling kiosks and mechanism boxes of circuit breakers/disconnect switches for providing supplementary lighting wherever required.

In outdoor switchyards, only the equipment/bus bar areas are illuminated. In outdoor area, luminaires should be directed as far as possible towards transformers, circuit breakers/disconnect switches, their mechanism boxes etc., where some operations may be necessary during emergency at night.

There are several classifications of the types of lighting such as direct, indirect, semi-indirect, diffusion, etc., The types of lighting or the combinations should be so chosen as would provide adequate level of glare-free illumination without creating undesirable shadows.

Direct lighting system is the most commonly used and it employs open dispersive reflectors, silver glass reflectors and angle reflectors. The simplest form of general diffusion fitting is the plain sphere of opal glass. The spherical form may be modified and any form, suitable for a given location may be used. The efficiency of the general diffusion fitting depends partly on shape but much more on the properties of the diffusing material used.

The typical indirect fitting is an opaque bowl with lamp suspended in it at such a depth that all the direct light from the lamp as well as from the bowl is emitted in the upper hemisphere. The semi direct fittings lie in between the indirect and the general diffusion fittings.

Flood light fittings are in essence, projectors with parabolic reflectors. There are two types of floodlights: the wide beam type and the narrow beam type. Wide beam type is suitable where accurate control is not necessary and the light is projected only over a short distance. The narrow beam type is used where light is required to be projected over longer distances.

The choice of lamps, i.e., incandescent, fluorescent, mercury vapour, sodium vapour halogen, compact fluorescent (CFL), LED etc., depends mainly on the nature of work, the number of hour of utilization annually, the cost of energy and the power available for illumination. Table below gives different types of lamps and fittings that may be used in different area of a substation.

The foremost criterion in the design of illumination system of indoor area such as control room, workshop, repair bay, offices, etc., is that illumination at the working height throughout the area should be as uniform as possible so as to avoid eye fatigue. In practice, complete uniformity of illumination is difficult to achieve and a ratio of the minimum intensity to the maximum equal to about 70 percent is usually considered acceptable.

Energy conservation requirement has to be kept in view while selecting type of lamp and type of fitting. While designing the lux level requirement Utilization coefficient factor may be considered to take care effect of dust, pollution etc. on reflectors used in the lighting fixtures.

Table: Typical Lamps & Fittings in Some Identified Areas

Sl. No.	Particulars of area	Type of lamps	Type of fittings
1.	Unloading-cum-repair bay	Mercury vapour sodium	High bay
2.	Store rooms, workshops	Fluorescent	Industrial
3.	Control room, offices carrier room	Fluorescent	Decorative
4.	Battery room	Fluorescent	Acid proof, Industrial
5.	Compressor room etc.,	Fluorescent	Industrial
6.	External lighting on building	Mercury vapour sodium vapour	Water tight flood light
7.	Outdoor switchyard	Mercury vapour sodium vapour	Water tight flood light
8.	Fence lighting	Mercury vapour sodium vapour	Post type water tight, flood light
9.	Roads	Mercury vapour sodium vapour	Post type water tight street light fittings

Emergency lighting is called for in case of AC supply failure in substations. In indoor installations such as a control room, switchgear rooms, etc., DC lamps connected to the DC supply system should be provided at suitable locations. These are brought into service in case of AC supply failure. These are normally wired through automatic changeover contactor at the DC distribution board. In workshops/ repair shops and machine hall, where mercury/sodium vapour lamps are employed, provision should be made for one incandescent lamp fitting of suitable power for a group of 4 to 6 mercury/sodium vapour lamps. This would avoid an extended total blackout in the event of a voltage dip or momentary interruption of AC supply, as the discharge lamps take a few minutes to give full light output again.

2.5.5 Crane Facilities:

Large substation sometimes has the facilities of repair bay along with a crane of adequate capacity for handling the heaviest equipment which is usually the transformer. Provision of a rail track should be made for movement of transformer from switchyard to the repair bay. Point for jacking pad should be provided at the transformer foundation, to facilitate 90° turn on the rail track for changing the direction of wheels.

2.5.6 Fire Protection Facilities:

In view of a large number of oil-filled equipments in a substation, it is very important that proper attention is given to isolation, limitation and extinguishing of fire so as to avoid damage to costly equipment, reduce chances of serious dislocation of power supply and ensure safety of personnel. The first step in this direction is that if fire occurs in any equipment it should be limited and isolated so that it does not spread to other equipments.

General guide lines are given below:

- i. The spacing of the equipment should be considered. Extra space is not usually provided for fire isolation, but the space available is taken into account in deciding other isolation measures.
- ii. Fire isolation walls should be provided between large oil-filled equipments such as two or more transformers placed adjacent to each other. These should be of adequate strength and of such size that the adjacent equipment is reasonably safe from fire risk due to burning oil flying from the equipment on fire.
- iii. In indoor areas automatic fireproof doors should be provided for rooms which house major oil-filled equipment. The rooms should also be constructed with a view to isolating the fire.
- iv. Soak pits or drain pits should be provided below large oil-filled equipment to drain off the burning oil falling below the equipment.
- v. Minor items of oil-filled equipment should be placed in beds of gravel or pebbles which will quench and prevent the spread of burning oil.
- vi. Care should be exercised that any prospective fire can be easily approached for quenching. In closed spaces and buildings attention should also be given to evacuation of personnel (Refer IS: 1646).
- vii. All oil pipes and cable trenches should be sectionalised by means of cross walls.

A well coordinated system of fire protection should be provided to cover all areas of the substation and all types of likely fires. The details of fire protection have to be worked out on the basis of size, type and location of the substation, accessibility and degree of attendance. Care should be taken that any fire can be fought from more than one source and dependence is not placed on single equipment for this purpose. The subject of fire safety involving electrical equipment is exhaustively covered in latest IS: 1646, IS: 3034 and CBIP Manual on Transformer.

Fire Fighting System: All substations should be equipped with fire fighting systems conforming to the requirements given in latest IS:1646 and Fire Protection Manual Part-I issued by Tariff Advisory Committee of Insurance Companies.

Trailer pumps where provided should draw their water supply from ground tanks of suitable sizes, the location and distribution of which shall be such that no item to be protected is more than about 90m away from any ground tank.

The more valuable equipment or areas forming concentrated fire risk should be covered by special fire protective systems. In this class are:

- a) Transformers, both indoor and outdoor
- b) Oil-filled Reactors
- c) Oil-filled switchgear
- d) Oil tanks and oil pumps
- e) Oil, grease and paint stores and
- f) Synchronous condensers.

It is necessary to provide efficient Fire Protection Systems in the Electrical Installations. Fire Protection System consists of Fire Prevention, Fire Detection & Annunciation and Fire extinction.

Fire Prevention: The safety and preventive measures applicable for substations as recommended by the relevant authorities must be strictly followed while planning the substations.

All fire fighting equipment and systems should be properly maintained. Regular mock drills should be conducted and substation staff made aware of importance of fire prevention and imparted training in proper use of the fire fighting equipment provided in various parts of the substation, control room building etc.

Fire Detection and Annunciation: Fire detection if carried out at the incipient stage can help in timely containment and extinguishing of fire speedily. Detection can either be done visually by the personnel present in vicinity of the site of occurrence or automatically with the use of detectors operating on the principles of fixed temperature, resistance variation, differential thermal expansion, rate of rise of temperature, presence of smoke, gas, flame etc.

Fire detectors of the following types are usually used:

- (i) Ionisation type
- (ii) Smoke type
- (iii) Photoelectric type
- (iv) Bimetal type
- (v) Linear heat detection type

Ionisation type detectors are used more commonly. However in areas like cable vaults, ionisation smoke and linear heat detection type detectors are used. Smoke type detector is effective for invisible smoke, and photoelectric type for visible smoke. Smoke type detectors incorporate LEDs, which start glowing in the event of fire.

Detectors are located at strategic positions and arranged in zones to facilitate proper indication of fire location, transmission of Audio-visual signals to Fire control panels and actuation of the appropriate Fire Fighting Systems. In the rooms with false ceilings, these are provided above the ceiling as well as below it. For the detectors located above the false ceilings, remote response indicators should also be provided.

Detectors are provided at the rate of one for a maximum area of 80 m² in the zones to be covered by the Fire Protection System

2.5.6.1 Fire Extinguishing:

The Fire Extinguishing Systems used for fire protection of the various equipments/building in substations are the following:

- (i) Hydrant system.
- (ii) High velocity water spray system.
- (iii) Portable fire extinguishers.
- (iv) Nitrogen injection fire prevention method for transformer

Hydrant System: Hydrant System is installed for the protection of the areas such as Control room, LT transformers and Diesel generator set building from fire. Hydrants are the backbone of Fire Fighting System as these can help fighting fires of all intensities in all

classes of fires and continue to be in service even if the affected buildings/structures have collapsed. These keep the adjoining properties/buildings cool and thereby save them from the serious effects of fire and minimize the risk of explosions.

The Hydrant System is supplied water from Fire Water Pump House. Fire Pump House is located by the side of Fire Water Storage Tanks constructed within the substation boundary limits. These tanks are made of RCC above ground such that these are easily accessible. Water from these tanks is pumped into the Fire Hydrant System with horizontal centrifugal pumps.

The Hydrant System essentially consists of a network of pipes, laid both above ground and underground, which feed water under pressure to a number of hydrant valves placed at strategic locations throughout the substation. Pressure in piping is maintained with the help of hydro-pneumatic tanks and jockey pumps.

Jockey pumps compensate for minor leakages also. The hydro-pneumatic tanks are pressurized with compressed air supplied by two air-compressors one of which works at a time and other acts as standby. Adjacent to the Hydrants, hosepipes, branch pipes and nozzles are kept in Hose boxes. In case of fire, the hoses with nozzles are coupled to the respective hydrants and water jet is directed towards the seat of fire.

On drop of pressure in the piping network below a preset value, the Hydrant pump starts automatically and continues to run till it is stopped manually after fire has been extinguished. The quantity of water to be available for fire protection and the number of fire water pumps depend on the total number of hydrants which are provided as per guidelines of Tariff Advisory Committee Manual, according to which substations fall in "Light Fire Hazard" category. The parameters of Fire Water Pumps as per TAC ceilings are given below.

- a. For the total number of hydrants upto twenty, one no pump of $96 \text{ m}^3/\text{hr}$ capacity with a pressure of 5.6 kg/cm^2 (gauge)
- b. For the total number of hydrants exceeding twenty upto fifty five, one no. pump of $137 \text{ m}^3/\text{hr}$ capacity with a pressure of 7.0 kg/cm^2 (gauge)
- c. For the total number of hydrants exceeding fifty five, upto hundred, one no. pump of $171 \text{ m}^3/\text{hr}$ with a pressure of 7.0 kg/cm^2 (gauge)

As per TAC guidelines, the jockey pump should have a capacity of $10.8 \text{ m}^3/\text{hr}$. and the hydro-pneumatic tank should have a capacity of 18 m^3 . The effective capacity of the Fire Water Tank should be not less than one hour of aggregate pumping capacity, with a minimum of 135 m^3 .

High Velocity Water (HVW) Spray System: This type of Fire Protection System is provided for Power Transformer, both auto and multi-winding and Shunt Reactors.

This system is designed on the assumption that one reactor/transformer is on fire at a time. For this assumption, the largest piece of equipment forms the basis.

High Velocity Water Spray System consists of a network of projectors arranged around the equipment to be protected. Water under pressure is directed into the projector network through a deluge valve from a piping network exclusively laid for the Spray System. Water leaves the projectors in the form of conical spray of water droplets travelling at high velocity.

The high velocity droplets bombard the surface of oil and form an emulsion of oil and water which does not support combustion. This emulsion converts a flammable liquid into a non-inflammable one. However, this emulsion is not of a stable character and therefore shortly after the water is shut off, oil starts to separate out from water which can be drained away, leaving the oil behind unimpaired.

The rate of burning of a flammable liquid depends upon the rate at which it vaporizes and the supply of oxygen to support combustion. It is the maximum when the rate of burning of the flammable liquid is the maximum and the surface of the liquid is near boiling point. The high velocity water spray system while forming an emulsion, intersperses cold water with the liquid, cools it and lowers down the rate of vapourisation which prevents further escape of flammable vapours. During passage of water droplets through flames, some of the water gets converted into steam, which dilutes oxygen in the air supporting the fire and creates a smothering effect, which aids in extinguishing the fire.

An automatic deluge valve triggered by a separate system of quartzoid bulb detector heads mounted on a pipe work array charged with water, at HVW spray mains pressure, initiates the HVW Spray System operation. When a fire causes one or more of the quartzoid bulbs to operate, pressure in the detector pipe work falls and this allows the deluge valve to open thereby permitting water to flow to all the projectors in the open pipe array covering the risk.

2.5.6.2 Water Supply to HVW Spray System

a) Two pumps are provided for HVW Spray System. Of these, one is electric motor driven and the other diesel engine driven. The capacity and head of the pumps is selected to protect the biggest risk. It has been experienced that each pump having a capacity of 410 m³/hr is usually adequate for the biggest risk in substations.

b) These pumps are located in Fire Water Pump House. Suitable connection with the Hydrant System is provided so as to allow flow of water from Hydrant System to HVW Spray System but not in the reverse direction.

Standby diesel engine driven pump is a common standby facility for HVW spray as well as Hydrant System.

These pumps are automatically started through pressure switches located sequentially in headers. However, stopping of the pumps is done manually after the fire gets extinguished. The values of pressure of running water and discharge density given below are recommended for HVW Spray System :

Running pressure at any projector at any instance	= 3.5 Bar (Min), 5.0 Bar (Max)
Discharge density on ground surface	= 6.1 lpm/m ²
Discharge density on other surface	= Not less than 10.2 lpm/m ²

Water for fire fighting purposes should be supplied from the water storage tanks meant exclusively for the purpose. The aggregate storage capacity of these a- s should be equal to the sum of the following:

One-hour pumping capacity of Hydrant System or 135 m³ which ever is more.

Half-an-hour water requirement for single largest risk covered by HVW Spray System.
The water storage tank made of RCC construction over ground should be in two parts.

Fire Water pumps located in the Fire Water Pump House should have pumping head suitable to cover the facilities for future stages also. The piping system should be designed to permit extensions without disruption in the existing system. The material of piping is mild steel as per IS: 1239/IS: 3589 medium grade. The piping laid underground is coated and wrapped against corrosion as per IS: 10221 and the piping laid over ground consists of galvanised mild steel.

All equipment and accessories, constituting the HVW Spray System, such as flow control valve, heat detectors, projector nozzles, piping, valves, fittings, instrumentation etc., should be of approved makes acceptable to TAC.

Portable Fire Extinguishers: are provided at suitable locations for indoor/outdoor applications. These extinguishers are used during early stages of localised fires to prevent them from spreading. Following types of these extinguishers are usually provided.

(i)	Pressurised Water Type	in 9.01 kg size
(ii)	Carbon Dioxide Type	in 4.50 kg size
(iii)	Dry Chemical Type	in 5.00 kg size
(iv)	Halon type	in 5.00 kg size
(v)	Mechanical foam Type	in 50 ltrs, 90 ltrs.

For the quantities of these types and their applications, the norms given in TAC manual should be followed.

The make of these extinguishers should also be acceptable to TAC.

Halon type fire extinguishers are now getting phased out on account of their negative effect on the atmosphere.

The transformers shall be protected by automatic high velocity water spray system or by carbon dioxide or BCF (Bromochloro-difluoromethane) or BTM (Bromotrifluoromethane) fixed installation system or Nitrogen injection and drain method.

Instrumentation and Control: Fire Protection System should include suitable instrumentation and necessary controls to render the system efficient and reliable. There should be local control panels for each of the pumps individually as also for the operation of deluge valve of the HVW Spray System. There should be a common control panel for the jockey Pump and Air Compressors. Main annunciation panel should be provided in the control room for the facilities provided in the control room and for repeating some annunciation from pump house.

2.5.7 DC AUXILIARY SUPPLY

DC Auxiliary supply is required for relays, instrumentation, closing and tripping of circuit breakers, emergency lighting, control board indications, etc. During normal operation, battery charger (rectifier bridge with Silicon diodes and Silicon control rectifiers) provides the required DC supply. However, to take care of failure of the AC supply (rectifier), a storage battery of adequate capacity is provided to meet the DC requirement. Normally, the storage battery merely keeps floating on the direct current system and supplies current in case of

failure of the rectifier in substation. It is desirable to provide duplicate rectifiers to meet the contingency of rectifier failure.

An arrangement shall be made to supply an uninterrupted DC supply to load wherever the battery charger is facilitated with float/trickle/boost charging.

The voltage commonly used for the DC auxiliary supply is 110 or 220 volts batteries for substations and 48 volts for PLCC. Conventional lead acid batteries of flooded type or valve regulated (VRLA) are used. VRLA batteries are maintenance free.

2.5.7.1 VRLA batteries: These work on Oxygen Recombination principle and do not require any topping up with distilled water during its life time. Pressure regulating valve is designed to relieve excess pressure from the cell. These batteries come in fully charged condition.

The battery consists of flat pasted positive(PbO_2) and flat pasted negative plates(Pb) between which an absorptive glass mat separator is sandwiched and all are housed in a polypropylene or ABS sealed container which has an outlet through a self resealing one way relief valve. The electrolyte used is sulphuric acid (Aqueous solution in immobilized state). The voltage per cell is 2 volts. The water loss is arrested by using special alloys in the plates, by keeping the charging voltage low and also by recombining the evolved electrolysis gases.

VRLA batteries do not produce acid fumes on charge. Being compact occupy very little floor area. They possess high discharge performance and hence a smaller capacity battery can do the same job as that of a large capacity tubular battery.

VRLA batteries however need a controlled temperature for proper operation. Their useful life is halved by every 8 deg.C increase in temperature.

2.5.7.2 Battery Charger: In a substation, the batteries are “Float” operated. This term applies to the method of operation in which battery remains connected to the load and the charger continuously. Voltage of charger is substantially constant and just higher than open circuit voltage of the battery. To keep the battery in a fully charged condition, the charger sends through the battery charging current of a few milli amperes at a voltage which is sufficient to compensate for local action and leakage losses.. The charger also supplies the entire DC load under normal condition.

The system basically consists of one float charger and one Boost charger with interlocking circuit and DC Distribution Board. The chargers are constant potential type and manufactured utilizing SCR/Diode Rectifier Bridge connected in full wave half controlled configuration. The Float Charger is rated to meet the load requirement and trickle current to the battery and boost charger is rated to meet the battery charging requirement.

Normally in the Auto/Manual float/Manual Boost selector switch when the switch is in AUTO position, Float Charger is ON, supplying both load and battery trickle charging current. Whenever battery requires boost charging, the same is achieved automatically through the battery charging path current sensing board relay changeovers. Provision is made to select both float and boost charging modes manually through Selector switch.

Capacity of the battery should be adequate to supply.

- (a) Momentary current required for the operation of switchgear.
- (b) The continuous load of indicating lamps, holding coils for relays contactors, etc.,
- (c) Emergency lighting load.

Complete DC equipment for a substation may be divided into three parts i.e., storage battery and accessories, charging equipment and distribution board.

In major substations, twin float-chargers and twin boost-chargers or with float cum boost charges with a suitable switching cubicle are generally used for reliability.

The distribution board has an incoming circuit from the DC battery and a number of outgoing circuits for closing and tripping, alarm and indication for control and relay panels. A separate circuit is provided for the emergency load normally fed from AC supply but is automatically switched on to DC supply in the event of AC power failure.

2.5.8 AC. Auxiliary Supply:

Both single and three-phase AC supply are needed in a substation for several functions such as:

Illumination. Battery charging, Transformer cooling system, Oil filtration plant, Transformer tap-changer drives, Air compressors, Power supplies for communication equipment Crane, Breakers/ disconnect switch motors, Fire protection system, Space heaters in cubicles and marshalling kiosks and Air-conditioning/ventilation equipment

Auxiliary Transformer: Design of AC auxiliary supply system must be such that it ensures continuity of reliable supply under all conditions. In a substation, it is normally provided from a station transformer, connected to the 11 kV or 33 kV station bus. Its capacity should be adequate to meet the demands of all the essential connected loads. Generally, two such transformers are provided in all major substations.

Alternate source of AC power supply should be available for charging of protective equipment in the event of failure of main AC auxiliary supply. A DG set shall be provided in major substations with Auto Main Fail (AMF) panel preferably. Change over scheme shall be provided in AC distribution panel, to feed important loads by DG set.

2.5.9 Ventilation:

Battery Room Ventilation: Exhaust fans should be provided. Further it is necessary to ensure sufficient air inlet to the battery room by providing blowers, if necessary. Exhaust alone without air inlet, will create a negative pressure in the battery room which will cause (a) Evaporation of electrolyte even at the normal room temperature and the fine spray of electrolyte will settle on cells, stands etc., reducing the electrical insulation of the battery from the ground, and (b) The hydrogen evolved from the battery may form an explosive mixture if the room pressure has reduced.

2.6 TRANSMISSION LINES:

Transmission lines are normally laid overhead using lattice structures fabricated with MS angles and galvanized. Lines are strung with aluminium cored steel reinforced conductor (ACSR) or all aluminium alloy conductor (AAAC) supported on the towers by porcelain disc insulator strings.

2.6.1 Survey: Selection of route using topo maps/ GPS and survey to identify the route, form basic input to the design of a transmission line. At the system planning stage, preliminary/reconnoitry survey has to be done on the proposed transmission line. After the project is administratively approved, detailed survey should be conducted to determine the line profile and tower spotting. Check survey should be done next to locate the towers on field either before or after award of contract.

2.6.2 Conductor : Proper size of the conductor is to be selected based on the maximum power anticipated and the voltage class. Use of bunched conductors (two and more) may be considered, where large amount of current is expected to flow in the circuit taking into consideration the effects of temperature gradient and sag & clearances to ground.

2.6.3 Towers : Transmission line towers are self supporting lattice towers. They are of four types.

- a) Tangent tower:- This is a suspension tower designed to support power conductor and ground wire(s) for extending the power line alignment in a straight line.
- b) 15° Small Angle Tower: - Fitted with two stacks of insulators per each phase duly connected by a jumper. This tower will facilitate deviation of line alignment up to 15°.
- c) 30°Medium Angle Tower: - This is similar to above angle tower but designed to take line deviation up to 30°.
- d) Large Angle Dead end Tower: - This tower is designed for use as terminal tower as well as an angle support capable of taking deviation up to 60°. All angle towers are used at cut point (Tension towers). In addition to the above towers, special structures may be used for river crossings and hill slopes.

Tower extensions to be fixed to the bottom of normal towers are also designed and fabricated for use on the lines wherever required. Normally 3Mtrs. and 6Mtrs. Tower extensions are used for raising the tower heights to 3Mtrs and 6Mtrs. respectively. Special tower extensions for 9Mtrs. and 12Mtrs. elevations are also used. In addition to these, hill side tower extensions are also designed and fabricated to facilitate erection of broad based towers in uneven hill ridges.

Type of tower at each location has to be decided and selected from the standard designs adopted for various voltage classes and wind zones. Special type of towers required for a specific location to suit a specific purpose may have to be designed.

Double circuit towers may be used even if a single circuit line is taken up initially, as this would help laying a second circuit later utilizing the same corridor without right of way problems. However, in respect of 400 KV line, as selection of a double circuit tower for laying a SC line initially may pose the problem of stability to tower due to unbalance; either proper anchoring of the towers be made or both the circuits are strung, depending on the need and economics. Due to acute right of way problems in obtaining corridor for future lines, it is suggested to opt for towers suitable for DC lines.

2.6.4 Design Parameters of Transmission Towers: The design of Transmission line towers

is governed by the stipulations of IS 802 (Part-I - Section 1 & 2) of 1995/92 use of structural steel in overhead transmission line towers was published in 1967 and subsequently revised in 1973, 1977 and 1995. Some of the major modifications made in revision 1995 are as follows:

1. Concept of maximum working load multiplied by the factors of safety as per I.E rules has been replaced by the ultimate load concept.
2. For assuring the loads on tower, concept of Reliability, Security and Safety have been introduced on the basis of IEC 826-1991 "Technical report on loading and strength of overhead transmission lines".
3. Basis wind speeds based on peak gust velocity averaged over 3 seconds duration, as per the wind map of India given in IS 875-(Part-3) - 1987 "Code of practice for design loads for buildings and structures (second revision)" are kept as the basis of calculating reference wind speed. Terrain and Topography characteristics of the ground are taken into consideration in working out the design wind speeds.
4. Wind loads on towers and conductors have been revised. These are based on the modified wind map of the country. Reference wind speed averaged over 10 minutes duration has been used for the determination of wind loads on tower and conductor.
5. Provisions for the temperature effects have been modified. In order to permit additional current carrying capacity in the conductor, the max., temperature in the ACSR conductor has now been permitted to be 75°C in any part of the country. For AAA Conductors, the corresponding max. temperature has been permitted to be 85°C.
6. Provisions for anti cascading checks have been included in the design of angle towers.

The towers to be used as supports for 132 KV, 220 KV and 400 KV Transmission lines are designed by adopting the following criteria.

Sl. No.	Description	132kV	220kV	400kV
1	Normal span (Mtr.)	320	380&350	400
2	Maximum weight span (Mtr.)	400/480	475/525	600
3	Minimum weight span (Mtr.)	125	200	320
4	a) Every day temperature b) Maximum temperature for conductor (ACSR) c) Maximum temperature for ground wire d) Minimum temperature	32°C 75°C 53°C 10°C	32°C 75°C 53°C 10°C	32°C 75°C 53°C 10°C
5	Protection or shield angle	30 deg.	30 deg.	20 deg.
6	Minimum midspan clearance between ground wire and top power conductor	6.1 Mtr.	8.5 Mtr.	9.0 Mtr.
7	Minimum ground clearance of the bottom most conductor	6.1 Mtr.	7.0 Mtr.	8.84 Mtr.
8	Minimum clearance of the live parts			

	<u>from the tower body</u> a) Suspension insulator string when deflected 0 deg 15 deg 30 deg 45 deg 60 deg	1.530 Mtr. 1.530 Mtr. 1.370 Mtr. 1.220 Mtr. 1.070 Mtr.	2.130 Mtr. 1.980 Mtr. 1.830 Mtr. 1.675 Mtr. ---	3.050 Mtr. (for deflection up to 22 deg)
	b) Jumper connection on angle towers when deflected Up to 10 deg Up to 20 deg Up to 30 deg	1.530 Mtr. 1.070 Mtr. 1.070 Mtr.	2.130 Mtr. 1.675 Mtr. --	3.05Mtr.(for deflection upto 20 deg) 1.86Mtr.(for deflection upto 40 deg)
9	Factor of safety for design of tower members a) under normal conditions b) Under broken wire conditions	1.02 1.02	1.02 1.02	1.02 1.02
10	<u>Broken wire conditions:</u> a) For tangent towers	Either ground wire or one of the power conductors broken	Either ground wire or one of the power conductors broken	Either ground wire or any one bundled power conductors broken
	b) For 15 deg and 30 deg angle towers	Ground wire and one of power conductors or any two power conductors broken.	Ground wire and one of the power conductors or any two power conductors broken.	Two ground wires and any one bundled conductor and one ground wire or one ground wire and two bundled conductors broken
	c) For 60 deg angle/dead end towers	Ground wire and any two power conductors or three power conductors broken.	Ground wire and any two power conductors or three power conductors broken.	One ground wire and any two bundled conductors or two ground wires and any one bundled conductor broken.

The various members of the tower can be classified into (i) main leg members including ground wire peak, (ii) Lattice member including transverse and longitudinal bracings, (iii) Horizontal and longitudinal belt members situated in the same horizontal plane as lower (compression) members of cross arms, (iv) Cross arm members and (v) redundant members and hip bracings.

The leg members are subjected to (i) Transverse forces due to (a) wind on conductors/ground wire (b) wind on tower (c) Force due to deviation in the alignment of power line at the tower location (d) Wind on insulators (ii) Vertical forces due to (a) weight of power conductors/ground wire (b) dead weight of tower (c) weight of man with kit and (d) weight of insulator strings, (iii) Longitudinal force due to tension in the broken conductor under broken wire condition only, and (iv) unbalanced vertical load under broken wire condition only.

The lattice members are to be designed for the stresses due to transverse loads, vertical loads, longitudinal loads and torsional loads under broken wire conditions. The horizontal and longitudinal belts are to be checked for torsion due to longitudinal load. The purpose of redundant members is to reduce the unsupported length of design members thereby increasing the allowable maximum stress in that member. The cross arm members are to be checked for vertical and transverse loads.

Anemometers shall be fixed on the top of the towers at an interval of 100 towers and/or at the highest point in the SubStations, in the areas of past history of collapse of towers due to whirl Wind conditions and particularly in the area classified as “Wind Zone-5” for recording adverse wind velocities. The cost of the same shall be incorporated in the estimate

2.6.5 Foundations: Standard designs for various types of foundations for different nature of soils are already in place. Based on the soil investigation reports and the applications (i.e., tangent/angle locations, normal/extended towers, narrow based towers, river crossings etc) & wind zones, proper type of foundations have to be selected from the standard designs available or if needed specially designed for a specific application.

2.6.6 Earthing: Earth pit at every location at the foot of the tower has to be constructed utilizing standard earthing practices, suitable to the nature of soil (soft, gravel, rocky etc) to ensure that the footing resistance does not exceed the limits prescribed.

All new 400 kV & 220 kV transmission lines shall be provided with OPGW (Optical Fibre Ground Wire) with PLCC back up for communications. Micro Wave (MW) communications as required shall also be provided. All new 132 kV transmission lines shall be provided with PLCC (Power line Carrier Communication) equipment. However, in addition to the above V-SAT communication facilities shall be provided at all EHV Substations.

2.7 Alternate designs for EHV substations and transmission lines:

2.7.1 Substations:

Requirement of space in a conventional substation is large due to statutory clearances and safety measures. Being located outdoor it is susceptible to pollution. In metro/urban areas space requirement for an EHV substation is at times either inadequate or available at a premium at the load centres. Places where there is a high risk of pollution and corrosion from industries/ marine and desert climates, cause damage to steel structures and the insulation in a conventional outdoor substation. Construction of a conventional outdoor substation may become a difficult task in underground substations for pumped storage and in some hydro

electric power stations. In all such cases solution lies in providing compact switchgear which occupies very little space as compared to a conventional station.

To day technologies using SF₆ gas-insulated switchgear (GIS) are widely adopted for construction of compact substations both indoor and outdoor depending on the requirement. Also where space is limited, outdoor compact metal clad switchgear with components of conventional design are used to minimize area requirement.

Phase to ground clearance in air for 132kV systems is 1200mm, compared to 80mm in SF₆ gas at 4.0 bar. Consequently the size of SF₆ insulated equipment is around 6% of that of air insulated equipment for this voltage class. Equipment size for SF₆ gas insulated equipment gets reduced to 30% for 33kV and below, to 15% for 66kV, to 6% for 132kV to 170kV and to 4 – 5% for >245kV.

Compact switchgear houses switchgear components like circuit breakers, dis-connecting switches, earthing switches and current transformers, in a standardized modular system surrounded by SF₆ gas in metal enclosures. This requires lesser bay width compared to a conventional bay.

2.7.1.1 SF₆ gas insulated switchgear:

For any single line diagram, there are usually a number of possible physical arrangements. The shape of the site of installation and the nature of interconnections, i.e., lines and/or cables are to be considered. GIS is available for double bus, single breaker arrangement and single bus with sectionalizer arrangement. Double bus arrangement is widely used and provides good reliability, simplicity in operation, easy protective relaying and excellent economy.

It is economical to adopt 3-phase enclosure up to 145 kV system voltage. For system voltages above 145 kV, single-phase enclosure designs are preferred. Functionally, the performance does not differ between 3-phase enclosure and single-phase enclosure of GIS but, it could depend on users' choice.

The GIS components like circuit breakers, load break switches, earthing switches, isolators, voltage transformers, current transformers, surge arresters and connectors are functionally separate modules of a standardized modular system.

The enclosure of GIS could be made of aluminium alloy or stainless steel. The selection of material largely depends on temperature rise considerations and permissible limits depending on emissivity (solar radiation) and/or temperature rise of conductor).

SF₆ is five times as dense as air. It is used in GIS on pressures from 3.5 - 7 bars absolute. The pressure is so selected that gas will not condense into liquid at the lowest temperature, the equipment may experience. This gas is about 100 times better than air in terms of interrupting arcs.

Cone or disc shaped insulators moulded from high quality resin support to active parts, in side the enclosures and serve as barriers between adjacent gas-filled compartments.

Silver-plated plus contacts provide connections between individual components and bolted flanges between the enclosures.

The operating mechanism for circuit breaker could be electro-hydraulically (hydraulic spring drive) operated or spring-spring operated for least maintenance.

The load break switches and high speed earthing switches are operated by motor charged spring mechanism and the safety earthing switches and disconnects are operated by motor operated mechanism. Manual operation of safety earthing switches is also possible as an alternative to motor operation.

Connectors enable straight line, 90 deg, 120 deg to 180 deg, four way and T-connections between various elements.

The modules include compensating units to permit lateral mounting, axial compensation, parallel compensation, tolerance compensation, vibration compensation etc. The lateral mounting units enable sections of switchgear to be removed and re-inserted without interfering with adjacent parts. Axial compensators take-up the changes, in bus bar length due to temperature variation. Parallel compensators are intended for accommodating large linear expansions and angle tolerances. Tolerance compensators are intended to take up manufacturing and assembly tolerances. Vibration compensators absorb vibrations caused by transformers connected directly to SF6 switchgear by oil/SF6 bushings.

Approximate space requirements for double bus lay out with vertical breaker scheme can be estimated approximately by assuming the width (3.0 m x 8.5 m x 8.0 m) leaving 1.5 m along the depth, for panels, 2.0 m for movement on either side along the length of bus. bar for 400 kV system

CONTROL CABINETS The elements for control, indication and alarms are contained in local control cabinets mounted close to bays. The elements normally mounted in the control cabinets consist of the following:

- (i) Mimic diagram with control switches for electrically operated breakers, load break switches, disconnects and earthing switches and indicators for all components provided with auxiliary switches.
- (ii) Local/Remote Selector Switches.
- (iii) Alarm facia with indicating lamps for monitoring operating system, gas density and auxiliary supplies.
- (iv) Contactors, timing relays etc.
- (v) Terminal blocks.
- (vi) Interior lighting, heater, cable glands.
- (vii) Lockable bypass switches for defeating the interlocks to facilitate maintenance work.

INTERLOCKS

GIS control cabinet includes electrical interlocks to prevent incorrect switching sequence and ensure correct operations of isolators, circuit breakers and earthing switches from local control cabinet or from the control room.

SAFETY LOCKS

Safety locks for locking the disconnects and earthing switches in the positions "Operation" or "Maintenance" are also provided. In the "Maintenance" position these locks interrupt the control circuits of motor drives for disconnects and earthing switches. In the manually operated earthing switches, these locks. in the "Operation" position do not permit engagement of manual operating handle with the earthing switches operating shaft.

SUPPORTING STRUCTURES

Depending on the design of installation, the GIS can be self supporting or erected on steel supporting structures of simple design anchored to the substation floor.

GROUNDING

The three enclosures of single phase GIS are required to be bonded to each other at the ends of GIS to ensure to prevent flow of circulating currents. These circulated enclosures currents cancel the magnetic field that would otherwise exist outside the enclosure out to conductor current. 3-phase enclosures GIS do not have circulating currents but have eddy currents in the enclosure and should also be multi point grounded. Although multi point grounding leads to some losses in the enclosure due to circulating current, multi point grounding results in many parallel path . for the current from an internal path to flow to the switchyard ground grid. The recommendations of manufacturers and multi point grounding concept normally ensures touch and step potentials within safe levels prescribed by IEEE 80.

The GIS should be extendable to meet the requirement of addition of bays in future. The side on which the extension is to be made should be provided with suitable extension bellows/flanges with blanking plates. The building that is to house the GIS should have space provision for future extension.

GIS TERMINATIONS

GIS terminations could be any of the following:

- SF6 to air bushings
- SF6 to cable termination
- SF6 to oil bushings for direct connection to transformer
- SF6 bus duct

All termination modules are commonly used to connect the GIS with transformer. Overhead lines could be connected to, GIS either through cables or through SF6 to air bushings. Type of terminations has also bearing on the size of substations. If cable or SF6 bus ducts are used, substation can be very compact. SF6 to air bushings, on the other hand, requires minimum clearance in air and thus requires more space and in addition, they are subject to environmental conditions. Especially in cities/ industrial areas where space is both restricted and expensive and the surrounding environment has impact on type of termination, preference should be for cable termination or SF6 bus duct. Selection of cable termination will have to be judiciously done keeping in view the specific requirement.

2.7.2 Transmission Lines:

Large corridors of about 27 to 52 metres wide are required for overhead transmission lines with conventional lattice towers. In view of rapid industrialization and urbanization, obtaining right of way for wide corridors is getting difficult day by day. Efforts are therefore on to limit the corridor width by reducing the base width of towers and using pole type structures or going in for multi circuit towers.

THE FOLLOWING IMPORTANT AND USEFUL CONCLUSIONS CAN BE DRAWN FOR PRLIMINARY UNDERSTANDING OF TRENDS RELATING TO POWER HANDLING CAPACITY OF ac TRANSMISSION LINES AND LINE LOSSES.

i) One 750kV line can normally carry as much power as four 400kV circuits for equal distance of transmission.

ii) One 1200kV Circuit can carry power of three 750kV circuits and twelve 400kV circuits for same transmission distance.

2.7.2.1 Multi circuit Transmission line: Since a multi circuit carries four single circuits/two double circuits corridor requirement gets reduced considerably compared with the corridor required for four single circuits or two double circuits. However, the capital outlays involved become heavy. Where growth of power demand is visualized from the present station and where take off for future lines could pose problems for right of way due to expansion/urbanization /industrialization, this option can be considered. This option has to be suitably selected considering the reliability aspects because of large chunk of power involved at extra high voltage.

2.7.2.2 Narrow Based Towers: These are lattice type towers employing smaller base width and reduced span length by suitably strengthening the tower members and the foundations. Due to the reduction in span length and increase in size of steel members and foundations, the total cost per km of transmission line with narrow based towers as compared to equivalent conventional system of towers is higher. However there is saving in land due to usage of lesser corridor. The cost saved in the land may or may not compare with the higher costs of narrow based tower line depending on the land value and its importance.

Factors considered in the design of narrow based towers and the foundations are similar to the ones considered for conventional towers.

Narrow based towers can be considered as an alternative to conventional towers in areas having limited corridor and in urban and industrial areas where it may be extremely difficult to get required corridor to maintain statutory clearances and there is scope for laying overhead line in a limited corridor without affecting statutory clearances.

2.7.2.3 Mono Poles: These are single poles tubular or polygonal in section made of galvanized steel, conical in shape with base diameter between 750mm to 1metre and 600 to 750mm at top. Mono poles need a still lesser corridor as compared to narrow based towers. They can be erected in areas with very narrow corridors as an alternative to underground cables which are costlier. They can be erected along the streets on either edge provided required statutory clearance is available.

Mono poles can also be erected on the middle of the road along road divider. The poles can be utilized for two circuits of transmission line on the top followed by sub transmission/ distribution lines underneath at a convenient height and further with street lights still below at required height.

Span length in case of Mono poles is less (say 150 to 200 metres) and require mass foundation to a greater depth. Hence are costlier compared to Narrow based towers for the same length. They can be considered in urban areas with severe corridor congestion as an alternative to Narrow based towers/ underground cables.

Corridor requirement for different transmission lines using different supports is given below.

Type of tower & Voltage	Power transmission Capacity (MW)	ROW required In metres	Normal Span (metres)
Conventional 132kV Double circuit	150	27	320
- do - 220kV Double circuit	450	35	350/380
- do - 400kV Double circuit	1000	52	400
+ / - 500kV DC	2000	70	400
Conventional 765kV Single circuit	2000	85	400
Narrow based 220kV multi circuit	800	30	250
Mono pole 220kV single circuit	200	12	180

2.7.2.4 Power transmitted versus Right-of-way width

In view of growing corridor congestion it makes sense to carry maximum power in the available corridor considering present and future load requirement. Concept of efficiency ratio of a line corridor expressed as power transmitted related to the width of right of way assumes significance.

$$\text{Efficiency ratio} = \frac{\text{Power transmitted}}{\text{ROW width}}$$

Power transmitted is proportional to the square of voltage, while the ROW width is nearly proportional to the voltage. Table below gives typical values. Efficiency ratio is measured in MVA/m.

Voltage(kV)	230	500	765
Power (MVA)	165	1000	2500
ROW width (m)	45	65	95
Efficiency ratio (MVA/m)	3.7	15.4	26.3

Efficiency ratio can be increased in several ways basically by increasing power transmitted in a given corridor, such as :

- Adopting higher voltage commensurate with the required loads
- Use of double or multi circuit lines, wher acceptable by reality or environmental considerations
- Line compaction
- Uprating lines (series compensation, use of FACTS, reconductoring, voltage increase)
- Use of DC transmission

2.7.2.5 Underground Cables: Laying transmission lines under ground with cables is the costliest option. Therefore it is limited to areas where there is not even a limited corridor and where a substation is an absolute necessity considering the dense load growth, in Metropolitan areas and heavy industrial zones. Underground cables have a long life of about 50 years and are reliable and virtually maintenance free.

Cross Linked Poly Ethene is the main insulation in an under ground (UG) cable. Single or three-core XLPE cable consists of a solid cable core, a metallic sheath and a non-metallic outer covering. The cable core consists of the conductor, wrapped with semiconducting tapes, the inner semiconducting layer, the solid main insulation and the outer semiconducting layer. These three insulation layers are extruded in one process and dry cured. The conductor of high voltage cables can be made of copper or aluminium and is either round stranded or single wires or additionally segmented in order to reduce the current losses.

The cable can be equipped with a longitudinal water barrier made of hygroscopic tapes or powder. The main insulation is cross-linked under high pressure and temperature. The metallic sheath shall carry the short-circuit current in case of failure. The cable can be provided with an embedded optic fibre for temperature monitoring. Finally, the outer protection consists of extruded Polyethylene (PE) or Polyvinylchloride (PVC) and serves as an anti-corrosion layer. Optionally it can be extruded with a semiconducting layer for an after-laying test and additionally with a flame-retardant material for installation in tunnels or buildings if required. Armour on the cable by single or double wire can be provided as required.

The following accessories are used for making the cable line through:

- Straight joints and joints with integrated screen separation for cross bonding
- Outdoor terminations with porcelain or composite insulators
- Screened separable connectors for switchgears and transformers
- Cable terminations for transformers and Gas Insulated Switchgears (GIS)
- Link boxes for earthing and cross-bonding
- Distributed Temperature Sensing (DTS) Systems with integrated optical fibre in metallic tube (FIMT)
- Integrated optical fibre cable for control and communication, as an alternative to separately installed cable for control and communication.
- Optical fibre cable. Especially suitable for 3-core submarine cables and for cables with a copper wire metallic screen.

Cables have a high service life of over 50 years. The service life of a cable is defined as its operating time. It is influenced by the applied materials, design, construction methods and the operating parameters. An increase of the operating temperature by 8 to 10°C reduces the service life by half.

An increase of the operating voltage by 8 to 10% reduces the service life by half.

Voltage level and transient voltages such as switch operations, lightning impulses, Short-circuit current and related conductor temperatures, Mechanical stress, ground ambient conditions like humidity, temperatures, chemical influences, Rodents and termites in the vicinity etc. have an influence on the service performance of the cable affecting the life.

Given the potential long lead time required to repair an underground transmission failure (potentially several weeks), two fully redundant circuits is reasonable to maintain operational integrity of the transmission system. The design of these circuits depends on the cable capacity and the cooling characteristics of the soil. When active, conductors produce heat that must dissipate in order to avoid permanent damage to the copper or the insulation of the conductors. Overhead conductors dissipate heat to the surrounding air and underground conductors dissipate heat to the surrounding soil. The air movement helps overhead conductors dissipate heat much better than soil, which is one reason why overhead conductors can be much smaller than underground conductors. Understanding the native soil's ability to transfer heat is vital, and soil studies would have to be performed to determine the proper makeup of backfill used to build an underground system.

The ability to cool underground cables is the primary driver in calculating the width of the right of way (ROW). A minimum separation is required between cables to avoid overheating the cables from heat generated by an adjacent conductor. The higher the capacity of the system, the greater the separation required between cables.

Minimum recommended clearances from other utilities are listed in Table below.

Utility	Clearance from Parallel Utilities	Clearance from Crossing Utilities
Steam (or any heat-producing utility)	12'	6'
Storm sewer	1'	1'
Water	1.5'	1.5'
Natural gas	1'	1'
Electric distribution(non-transmission)	10'	2'
Telecommunications	1'	1'

Cable layout and system design: The following data is required in designing and dimensioning the high voltage cable system:

- The type of cable insulation
- Nominal and maximum operating voltage
- Short-circuit capacity or short-circuit current and its duration in seconds
- Transmission capacity or nominal current
- Operating mode: permanent operation or partial load operation (load factors)
- Type of installation
- Ambient temperatures (incl. external effects)
- Proximity to other EHV cables

- Variation in number of cables (maximum 12 in number)
- Variation in depth of water table
- Variation in loading of cables (80% to 100%)
- Special thermal resistance of the ground

The calculation of admissible load currents (ampacity) and the cable temperatures is done in accordance with the IEC publication 60287.

Capacity, charging current: The operating capacity depends on the type of insulation and its geometry.

Inductance, Inductive reactance: The operating inductance in general depends on the relation between the conductor axis spacing and the external conductor diameter.

The three cables in a 3-phase circuit can be placed in different formations. Typical formations include trefoil (triangular) and flat formations. The choice depends on several factors like screen bonding method, conductor area and available space for installation.



Trefoil

Flat

Losses in cables

Voltage-dependent and current-dependent power losses occur in cables.

Voltage-dependent losses: Voltage-dependent power losses are caused by polarization effects within the main insulation

Current-dependent losses: The current-dependent losses consist of Ohmic conductor losses, Losses through skin effect, Losses through proximity effect and Losses in the metal sheath.

Ohmic conductor losses: The ohmic losses depend on material and temperature.

Losses through skin effect: The losses caused by the skin effect, meaning the displacement of the current against the conductor surface, rise approximately quadratic with the frequency. This effect can be reduced with suitable conductor constructions, e.g. segmented conductors.

Losses through proximity effect: The proximity effect detects the additional losses caused by magnetic fields of parallel conductors through eddy currents and current displacement effects in the conductor and cable sheath. In practice, their influence is of less importance, because three-conductor cables are only installed up to medium cross-sections and single-conductor cables with large cross-sections with sufficient axis space. The resistance increase through proximity effects relating to the conductor resistance is therefore mainly below 10%.

Losses in the metal sheath: High voltage cables are equipped with metal sheaths or screens that must be earthed adequately.

Sheath losses occur through circulating currents in the system, Eddy currents in the cable sheath (only applicable for tubular types) Resulting sheath currents caused by induced sheath voltage (in unbalanced earthing systems)

The sheath losses, especially high circulating currents, may substantially reduce the current load capacity under certain circumstances. They can be lowered significantly through special earthing methods.

Earthing methods, induced voltage

The electric power losses in a cable circuit are dependent on the currents flowing in the metallic sheaths of the cables. Therefore, by reducing or eliminating the metallic sheath currents through different methods of bonding, it is possible to increase the load current carrying capacity (ampacity) of the cable circuit. Along the metallic sheath voltage is induced as a function of the operating current. In order to handle this induced voltage, both cable ends have to be bonded sufficiently to the earthing system.

The following table gives an overview of the possible methods and their characteristics:

Earthing method	Standing voltage at cable ends	Sheath voltage limiters required	Typical application
Both-end bonding	No	No	Substations, short connections, hardly applied for HV cables, rather for MV and LV cables
Single-end bonding	Yes	Yes	Usually only for circuit lengths up to 1 km
Cross-bonding	Only at cross-bonding points	Yes	Long distance connections where joints are required

Both-end Bonding:

Both ends of the cable sheath are connected to the system earth. With this method no standing voltages occur at the cable ends, which makes it the most secure regarding safety aspects. On the other hand, circulating currents may flow in the sheath as the loop between the two earthing points is closed through the ground. These circulating currents are proportional to the conductor currents and therefore reduce the cable ampacity significantly making it the most disadvantageous method regarding economic aspects.

Single-end Bonding:

A system is single point bonded if the arrangements are such that the cable sheaths provide no path for the flow of circulating currents or external fault currents. One end of the cable sheath is connected to the system earth, and the other end is open. In such case, a voltage will be induced between screens of adjacent phases of the cable circuit and between screen and earth, but no current will flow. This induced voltage is proportional to the cable length and current. Single-point bonding can only be used for limited route lengths, but in general the accepted screen voltage potential limits the length.

In order to ensure the relevant safety requirements, the "open end" of the cable sheath has to be protected with a surge arrester. In order to avoid potential lifting in case of a failure, both earth points have to be connected additionally with an earth continuity wire. The surge arrester (sheath voltage limiter) is designed to deflect switching and atmospheric surges but must not trigger in case of a short-circuit.

Cross-bonding:

A system is cross-bonded if the arrangements are such that the circuit provides electrically continuous sheath runs from earthed termination to earthed termination but with the sheaths so sectionalized and cross-connected in order to eliminate the sheath circulating currents.

Along each section, a standing voltage is induced in between screen and earth, but no significant current will flow. The maximum induced voltage will appear at the link boxes for cross-bonding. In ideal cross-bonding systems the three section lengths are equal, so that no residual voltage occurs and thus no sheath current flows. The sheath losses can be kept very low with this method without impairing the safety as in the two-sided sheath earthing. Very long route lengths can consist of several cross-bonding systems in a row. In this case, it is recommended to maintain solid bonding of the system ends in order to prevent traveling surges in case of a fault. This method permits a cable current-carrying capacity as high as with single-point bonding but longer route lengths than the latter. It requires screen separation and additional link boxes.

This earthing method shall be applied for longer route lengths where joints are required due to the limited cable delivery length. A cross-bonding system consists of three equal *sections* with cyclic sheath crossing after each section. The termination points shall be solidly bonded to earth

In addition to cross-linking the sheaths, the conductor phases can be transposed cyclically. This is especially suited for very long cable lengths or parallel circuits.

Current Rating for XLPE Cable Systems: The XLPE cable should at least have a conductor cross section adequate to meet the system requirements for power transmission capacity. The cost of energy losses can be reduced by using larger conductor. Load losses in XLPE cables are primarily due to the ohmic losses in the conductor and the metallic screen. XLPE cables can be loaded continuously to a conductor temperature of 90°C. The dielectric losses in the XLPE insulation system are present also at no load current and depend primarily on the magnitude of the operating voltage. Dielectric losses in XLPE cables are lower than for EPR and fluid-filled cables. The continuous current ratings are calculated according to IEC 60287 series of standards and with the following conditions:

- One multi-core cable or one three-phase group of single-core cables
- Ground temperature 20°C
- Ambient air temperature 35°C
- Laying depth $L \geq 1.0$ m
- Distance "s" between cable axes laid in flat formation $70 \text{ mm} + \text{Dia}$
- Ground thermal resistivity 1.0 Km/W

Overload capacity: An XLPE-cable may be overloaded above 90°C and the conductor temperature may reach up to 105°C. Singular emergency overloads are not expected to produce any significant impact to the expected service life of the cable. However both occurrence and duration of these overloads should be kept at a minimum. Cyclic and emergency ratings can be calculated according to IEC publication 60853

Short-Circuit current capacity: For the cable system layout, the maximum short-circuit current capacity for both the conductor and the metallic sheath, have to be calculated.. Both values are dependant on

- the duration of the short-circuit current
- the material of the current carrying component
- the type of material of the adjacent components and their admissible temperature

Short-Circuit current capacity of conductors

Maximum admissible short-circuit currents I_{MS} for conductors with duration of 1 second for XLPE insulated cable with different conductors are given in the table below. (IEC 60949)

Conductor material (mm ²)	Copper 1 sec. , 90 , 250 °C	Aluminium
2500	358	237
2000	287	190
1600	229	152
1400	201	133
1200	172	114
1000	143	95
800	115	76
630	90	60
500	72	47
400	57	38
300	43	28
240	34	23

Short-Circuit current capacity of metallic sheaths

In addition to the above mentioned, the short-circuit current capacity of metallic sheaths depends on their layout. The short-circuit current capacity is different for tubular sheaths and wire screens, but generally the total short-circuit current capacity of a metallic sheath is the sum of the capacity of its components.

Metallic sheath types

The metallic sheath of high voltage XLPE single core cables has to fulfill the following electrical requirements:

- Conducting the earth fault current
- Returning the capacitive charging current
- Limitation of the radial electrostatic field
- Shielding of the electromagnetic field

Since high voltage XLPE cables are very sensitive to moisture ingress, the metallic sheath also serves as radial moisture barrier. There are several modes of preventing water and moisture penetrating into the cable and travelling within it along its length. Solutions for closed metallic sheathes can be based on welding, extruding or gluing.

Laying of Cables:

Laying of cables in a trench is the most laborious and important work involved in the installation of cable system. This involves excavation of a trench in dense city roads. The roads can be BT or CC or sides of the road. The excavation may involve cutting of hard rock. The trench has to be formed as per the approved drawing. It should be properly dressed and bottom of the trench shall be cleaned smoothly without any stones. Sand bed shall be formed. Then Rollers are placed as per requirement spaced in 5 m intervals. The cable drums placed on one side of the trench are prepared for pulling the cable by a winch placed on the other side of the trench with a steel rope. The cable shall be pulled by the winch smoothly in uniform speed after taking special precautions in road crossings/nala crossings/drain crossings and corners if any. The rollers shall be cleaned before the cable moves on them.

High voltage DC test on Sheath Insulation: After laying of cables, the cables shall be inspected for any deep scratches and repaired. Then the sheath insulation of the cable is tested by applying 10 KV DC with a DC test kit. It should stand for one minute. In case of any unidentified fault on the sheath, the cable sheath shall be tested with a Sheath Fault Locator.

Soil Thermal resistivity:

Life of the cable system and the value of the current capacity of a cable is directly linked to the effective dissipation of heat generated in the cables. This depends on the thermal resistivity of the soil in which the cables are laid. In case of places where thermal resistivity is high, a suitable thermal backfill material shall be placed around the cables for proper heat dissipation. This improves the current carrying capacity of the cable as well as increasing the life of the cable system. Thermal resistivity is a factor of nature of the soil, moisture present in the soil, density of the soil etc.

Measurement of the thermal resistivity shall be done in the field at the depth where the cables are to be laid. Or else the thermal resistivity measurement can also be done in lab as per IEEE guide.

Surveying:

A detailed survey shall be done to ascertain the following:

Cable route alignment, excavation of trial pits, fixing of joint bays, cable laying drawings, soil thermal resistivity measurements, road crossings, nala crossings, drain crossings, link boxes, earthing of joint bays, detailed route maps, marking of underground utilities, Cable and Accessories quantities, schematic drawing.

After finalization of detailed survey only, the cable and accessory quantities shall be finalized and ordered. All construction design drawings shall be produced for approval. Proposal for thermal backfill material shall also be made during the detailed survey.

Earthing of Joint Bays:

In the joint bay, the metallic sheaths of the cables on both sides of the joint have to be connected through by way of link boxes. For cross bonding joints this shall be through coaxial copper cables and for straight joints this can be a single core copper cable. Sheath voltage limiters shall be connected in between link box and earthing for cross bonding joints. Link box shall be connected to earth directly for straight through joints. From the link box earthing should be done by way of a single core copper cable of suitable capacity and earthed. There should be sufficient no of earth pits connected together for lowering the effective earth resistance so that during faults the fault currents pass to earth easily.

Tests on Cable Systems:

Testing methods and requirements for power cables with extruded insulation and their accessories for rated voltages above 150 kV and upto 500 kV are as per IEC 62067.

Testing methods and requirements for power cables with extruded insulation and their accessories for rated voltages upto 150 kV are as per IEC 60840.

The type of cable offered shall have been type tested as per standards to prove the process of manufacture and general conformity of the material to the specified requirements.

Pre-qualification test (PQ test) shall mean those tests made before supplying a type of cable system on a commercial basis, in order to demonstrate satisfactory long term performance of the complete cable system. Compliance to this test shall be insisted when inviting bids for cables and accessories.

Routine and acceptance tests should be done on sample cable and accessories at manufacturer's works to check that the components meet specified requirements.

Stage tests or tests during manufacture are to be carried out during the process of manufacture to ensure desired quality of the end product to be supplied.

Tests after installation are to be done to demonstrate the integrity of the cable system as installed.

Tests during installation

The cable shall be meggered before jointing. After jointing, complete cable system shall be tested before commissioning. The cable core shall be tested for

- a) Continuity
- b) Absence of cross phasing
- c) Insulation resistance to earth
- d) 10 kv DC voltage test for 1 minute on the outer sheath

Pre-Commissioning tests

- a) DC Voltage test on outer sheath at 10 KV for 1 minute (as per clause 5 of IEC 60229) between metallic sheath/ screen and external conducting surface.
- b) Conductor resistance of each completed circuit. Insulation resistance test, Capacitance Test
- c) AC Testing:
The installation shall be tested with AC voltage at power frequency.
(A power frequency voltage equal to $1.7 U_0$ applied for one Hour between each conductor and metallic sheath where U_0 is the RMS rated voltage at power frequency between the conductor and the earth or the metallic sheath.)
or
24 Hours AC testing, a voltage of U_0 may be applied for 24 hours.

Correction Factors for Various Laying Conditions

Ambient Air Temperature		Ground Temperature		Soil Thermal Resistivity		Depth of Laying	
Air Temperature ($^{\circ}\text{C}$)	Factor	Ground Temperature ($^{\circ}\text{C}$)	Factor	Soil Thermal Resistivity ($^{\circ}\text{Cm/W}$)	Factor	Depth of laying (in m)	Factor
20	1.2	15	1.08	0.7	1.14	0.50-0.70	1.09
25	1.16	20	1.04	1.0	1.0	0.71-0.90	1.05
30	1.10	25	1.0	1.2	0.93	0.91-1.10	1.03
35	1.05	30	0.96	1.5	0.84	1.10-1.30	1.01
40	1.0	35	0.91	2.0	0.74	1.31-1.50	1.00
45	0.94	40	0.87	2.5	0.67		
50	0.88	45	0.83	3.0	0.61		

Sample Continuous Current Ratings for some cables:

			In Air	
Cross-sectional Area (mm ²)	Direct buried	Pipe Duct	Trefoil	Flat (S=2D)
145 kV Copper Cable with Aluminium Sheath				
400	665	635	770	858
500	755	716	883	992
630	856	814	1011	1151
800	956	942	1137	1313
1000	1103	1093	1333	1555
1200	1185	1170	1439	1695
145 kV Copper Cable with Copper Wire Shield				
400	675	632	792	896
500	767	716	908	1033
630	872	811	1045	1200
800	979	932	1182	1374
1000	1145	1087	1420	1679
1200	1233	1212	1539	1801
145 kV Copper Cable with Lead Sheath				
400	684	636	808	904
500	780	727	924	1050
630	889	840	1077	1222
800	997	941	1222	1400
1000	1170	1100	1469	1681
1200	1264	1226	1599	1842
245 kV Copper Cable with Aluminium Sheath				
400	657	641	757	836
500	745	725	866	962
630	843	822	989	1111
800	943	916	1116	1268
1000	1090	1057	1310	1505
1200	1165	1131	1403	1631
245 kV Copper Cable with Copper Wire Shield				
400	668	634	779	863
500	759	719	895	998
630	864	842	1031	1159
800	970	944	1167	1326
1000	1131	1100	1390	1583
1200	1221	1185	1512	1733
245 kV Copper Cable with Lead Sheath				
400	676	638	793	871
500	770	745	914	1010
630	876	847	1054	1173
800	986	950	1196	1343
1000	1153	1108	1429	1606
1200	1243	1194	1552	1757

2.7.3 Materials:

2.7.3.1 Gas filled instrument transformers:

In oil filled CTs oil serves the purpose of insulation and cooling. Craft paper and aluminium foil are wrapped in alternate layers on the primary conductor which act as capacitors to grade the primary winding voltage within narrow bushing housing. The bushing is made of porcelain material. The outermost layer of aluminium foil is connected to earth through a tap. This tap facilitates testing of dielectric dissipation factor ($\tan\delta$) of the CT.

Quantity of oil in a CT is very less. Oil together with paper act as di-electric. The di-electric shall be perfectly dry. Absorption of moisture causes degradation of insulation resulting in partial discharges ultimately leading to failure. Failure of condenser graded bushing CTs (where bushings are of porcelain) will normally result in explosion and burning in oil filled CTs. The explosion may cause damage to the adjacent equipment viz. circuit breakers, isolators LAs, Transformer bushings etc.

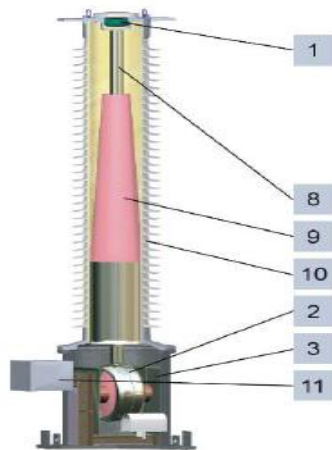
In a gas filled instrument transformer internal insulation medium is SF₆ gas with the following properties:

Excellent insulating properties, non-aging insulation and minimum risk of failures
Insulation is self healing and hence no insulation impairment through partial discharges
Non-toxic and non-flammable
Remote and online gas monitoring is possible
In place of porcelain insulator, the external insulation is provided by silicone rubber insulator (composite insulator) which has the following properties:

Insulator is shatter proof and explosion proof
Due to hydrophobic properties the insulator offers trouble free performance in heavily polluted conditions
No cleaning or hotline washing is required unlike in porcelain insulators, thus totally maintenance free
Creepage distance requirement is less compared to porcelain insulators
Light in weight, high mechanical strength of the fibre glass tube provides earth quake resistance and resistance against vandalism.
Gas filled instrument transformers are explosion proof and give good performance in highly polluted environment, thus saving cost of routine maintenance and avoid shut downs required for carrying out tan delta measurement tests.

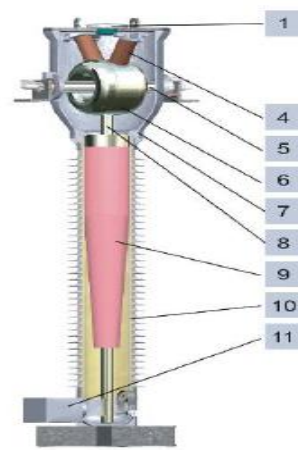
Gas filled units with composite insulators are available for voltage transformers, current transformers and combined voltage and current transformers. Diagrams showing these varieties are given below.

Voltage Transformer Type SVS



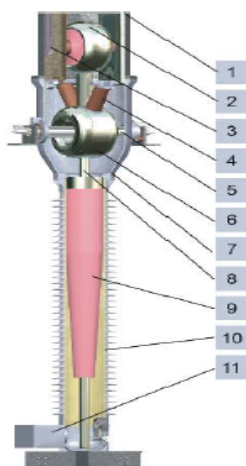
- Available from 72.5 to 800 kV
- Single high voltage coil design upto 800 kV ensures measurement accuracy
- Wide Ferro resonance-free design without use of an external damping device
- Suitable for line-discharging
- Ideal for power plants for tariff metering as accuracy does not depend on the system frequency
- Rupture Disc at the top makes it explosion proof
- Possibility of remote monitoring of insulation
- Completely maintenance free PT

Current Transformer Type SAS



- Available from 72.5 to 800 kV
- Low reactance bar type primary conductor provides optimal short-circuit performance
- Perfect transient response
- Well supported core housing avoids undue stress due to core weights on primary winding
- Rupture Disc at the top makes it explosion proof
- No fire risk
- Possibility of remote monitoring of insulation
- Freedom from capacitance and tan delta measurement
- Completely maintenance free CT

Combined Transformers Type SVAS



- Available from 72.5 to 800 kV
- Single high voltage coil design upto 800 kV ensures measurement accuracy
- Provides the advantages of a current and inductive voltage transformer at a competitive price
- Less foundation space required results in significant reduction in overall switchyard cost
- Savings in handling, installation and maintenance cost

1	Rupture Disc
2	HV Winding
3	Magnetic Core
4	Spacer
5	Primary Conductor
6	CT Cores
7	Head Housing
8	Outlet Tube
9	Capacitive Grading *
10	Silicone Composite Insulator
11	Terminal Box

All types of Current, Voltage and Combined Transformers are available for all insulation levels and meet the metering and protection classes according to international standards (IEC 60044).

Note: *Not required for 245 kV and below rated Current Transformer

Optical Current and Voltage Sensors: Optical sensing is the latest technology in sensing and indicating the primary current and voltage between 1amp and 63kAmps and up to 550kV with metering and protection accuracies.

Optical current sensors use light weight dry type insulator and window head design allowing pedestal mounting or suspension from a rigid bus. The sensor consists of two modules – one sensor electronics module and one current amplifier/ power supply module.

Optical voltage sensors employ an array of optical pockels within an advanced hollow core composite insulator. Wide separation of the high voltage and ground electrodes reduces dielectric stresses and eliminates the need for mineral oil, cellulose insulation or SF6 gas. The sensor is highly linear and features an electronically adjustable turns ratio spanning several voltage classes, enabling a single sensor to address a range of calibration applications. The sensor consists of three modules viz. sensor electronics, power supply and voltage amplifier.

Optical Voltage and Current Sensor combines the advantages of both the optical voltage and current sensors in one instrument maintaining the metering and protection accuracies.

2.7.3.2 New Generation Conductors:

Standard Conductors: There are four common types of standard conductors that have been used for many years: all-aluminum, aluminum conductor-steel reinforced, aluminum conductor- alloy reinforced, and all-aluminum alloy. Regardless of the type of metal used in the make-up of the conductor, the strands always are round and have a concentric lay. These conventional conductors have long, proven track-records of performance under specified conditions and certain types of applications.

All-Aluminum Conductor (AAC): AAC, manufactured with 1350-H19 aluminum, is a low-cost conductor that offers a conductivity of 61.2% IACS, or more, and good corrosion resistance. AAC has the highest conductivity-to-weight that makes AAC ideal for installations in urban areas limited in space where short spans with maximum current transfer are required.

Aluminum Conductor, Steel-Reinforced (ACSR): ACSR is used extensively on long spans as both ground and phase conductors because of its high mechanical strength-to-weight ratio and good current-carrying capacity. ACSR consists of all solid or stranded galvanized steel core surrounded by one or more layers of 1350-H19 aluminum. ACSR has equivalent, or higher thermal ratings in comparison with equivalent sizes of AAC.

Because of the presence of the steel core, lines designed with ACSR elongate less than other standard conductors, yielding less sag at a given tension. Therefore, the maximum allowable conductor temperature can be increased to allow a higher thermal rating when replacing other standard conductors with ACSR. The high tensile strength of ACSR allows it to be installed in areas subject to extreme ice and wind loading.

All-Aluminum Alloy Conductor (AAAC): AAAC, developed as a replacement for high strength ACSR conductors, is made of 6201-T81 aluminum alloy giving it comparable and, in some instances, improved qualities over both ACSR and AAC conductors. AAAC offers the combination of good conductivity, high tensile strength and excellent corrosion

resistance. The AAAC conductors have comparable thermal ratings, improved strength-to-weight ratio, lower electrical losses, and superior corrosion resistance. These factors make AAAC conductors prominent choices for distribution installations on the seacoast and other areas severally impacted by corrosion problems.

Aluminum Conductor, Aluminum-Alloy Reinforced (ACAR): ACAR, consisting of a mix of 6201-T81 and 1350-H19 strands of the same diameter, has an excellent balance between mechanical and electrical properties. These conductors exhibit excellent corrosion resistance and utilize simple termination hard-wares making them an excellent choice for many transmission line applications.

Transmission line network needs to be augmented to meet the growing demand. Construction of new transmission lines is becoming very difficult due to limitations on corridor and right of way and due to high costs involved in using narrow based towers/ Monopoles, in a limited corridor space. Laying of underground cables in places where even limited corridor doesn't exist, costs much more compared to Narrow based tower line/ mono-pole line.

Increasing the power transfer capacity of the existing line by the following methods can be considered in such cases.

- (a) Upgrading the conductor i.e.re-conductoring using conductor with better sag, temperature withstand properties.
- (b) Upgrading the line to next higher voltage class by replacing the existing conductor and insulators with conductor having better sag, temperature properties and with light weight long rod/ silicone rubber (composite) insulators of higher voltage class, maintaining same or less overall weight and clearances adequate for the higher voltage class. This may need upgrading of the connecting substations.

Upgrading the existing line by replacing with larger size conductor or by increasing no. of conductors per phase may need reinforcement of the existing towers, which may not be possible at times.

Line loadability is generally restricted by thermal/ stability limits. Current carrying capacity of a conductor depends upon diameter, resistance, surface condition and maximum permissible conductor temperature.

New generation conductors possess high conductivity, high temperature and low sag characteristics that facilitate increased loadability.

The construction of a conventional conductor can be adjusted to enhance its performance under certain conditions. It may be desirable to have an increase in the thermal rating of a conductor having the same diameter, increase the self-damping ability of the conductor to help dissipate Aeolian vibrations, or maybe even to allow for an increase in the line tension to yield reduced sag. The changes may come in the form of (1) differently shaped strands, (2) the degree of temper of the aluminum strands, (3) different types of coatings for corrosion protection of the steel core in composite cables, or (4) the modification of the geometric configuration of the conductor to produce a varying profile to the wind. These modifications may be used separately or in combinations to achieve the desired conductor properties for optimum performance.

These new type of conductors permit enhancement in loading from 30% to 100% over the existing capacity without the need for any reinforcement of steel towers. They are:

Trapezoidal-Shaped Wire Constructions: As the name suggests, Trapezoidal wire (TW), called Trap-wire, have strands shaped in the form of a trapezoid. Trap-wire constructions consisting of a homogenous metal may have all the strands trapezoidal shaped except the center wire. For non-homogeneous conductors, the multi-strand core may be composed of round strands of one material surrounded by the trapezoidal strands of a second metal.

Trap-wire is a compact construction having a reduced outer diameter of approximately 10% as compared to al. standard conductor of the same type with the same circular mil area. Due to the greater compactness of TW, more aluminum can be added while maintaining the same diameter of the standard conductor. The additional aluminum of approximately 20% to 25% reduces the resistance of the conductor, thereby increasing the current carrying capacity of the same diameter conductor by 8% to 10%.

Some modified conductors used to illustrate some of the advantages of TW are:

All-Aluminum Conductor/Trap-wire (AAC/TW): In comparison to standard AAC conductor, AAC/TW can be manufactured having the same cross-sectional area (resistance) or with a series of diameter spaced every 0.05 inch. AAC/TW, therefore, is useful for reducing the conductor diameter for a given resistance or decreasing the resistance for a given diameter. Table shows two possible AAC/TW alternatives to a standard 795 kcmil AAC “Arbutus”.

TABLE
COMPARISON OF AAC WITH AAC/TW ALTERNATIVES

Conductor Description	Diameter, in	Dc Resistance @ 20°C Ω/1000 ft
“Arbutus” AAC	1.026 (100%)	.0217 (100%)
“Arbutus”/TW	0.919 (89.5%)	.0217 (100%)
“Rainier”/TW	1.00 (97.4%)	.0188 (86.6%)

Aluminum Conductor, Steel-Reinforced/Trap-wire(ACSR/TW): ACSR/TW differs from conventional ACSR in that its aluminum strands are also trapezoidal shaped. ACSR/TW offers a reduced overall diameter or increased current carrying capacity for the same diameter conductor. Regardless of the diameter, the steel-to-aluminum ratios remain the same as comparable sizes of conventional ACSR. ACSR/TW constructions are grouped into “Type Numbers” that reflect the steel-to-aluminum ratio, expressed in percentages, ranging from 3 to 23.

Aluminum Conductor, Steel-Supported (ACSS): ACSS is a construction similar to standard ACSR except the aluminum strands are fully annealed (0-temper). Under typical operating conditions, ACSS essentially allows all the load to be carried by the steel core. Some of the major advantages of ACSS are:

- ACSS has a conductivity of 63% IACS or better due to the aluminum strands being “dead-soft” (fully annealed).

- Since the aluminum strands are dead-soft, the conductor may be operated at temperatures in excess of 200°C without loss of strength.
- Since the tension in the aluminum strands is normally low, the conductor's self-damping characteristics is high. This allows the conductor to be installed at high unloaded tension levels without the need for separate Stockbridge dampers.

These properties, along with decreased thermal elongation and creep elongation at elevated temperatures, make ACSS attractive for re-conductring existing transmission and distribution lines in up-rating application. ACSS is especially suitable for applications where high load currents are frequently encountered under contingency situations. Re-conductoring with ACSS may yield a potential increase of 100% in the static thermal rating for some lines.

Vibration Resistant Conductor (VR): VR cable is designed for use in overhead lines normally subject to aeolian vibration and galloping. VR conductor can be installed to higher tension levels without the need for additional dampers.

Self-Damping conductor (SDC): SDC in an ACSR construction is designed to limit Aeolian vibration by internal damping of the strands. The use of trapezoidal aluminum strands still results in a reduced conductor diameter for a given ac resistance per mile. Its high impact damping ability allows an increase of unloaded tension levels, resulting in reduced sag and possibly reduced structure costs. The reduced conductor diameter for a given ac resistance yields reduced wind and ice loading, thereby reducing structural loading.

Super-Thermal Resistant Aluminum Alloy Conductors, Aluminum-clad Invar Reinforced:

Hi-STACIR/AW, STACIR/AW is normally used to up-rate an existing transmission line by simply replacing the existing conductor without tower modification or reinforcement.

The conductor has aluminum strands of thermal resistant aluminum alloy (with Zirconium). The core is made of alloy of Iron-Nickel having low thermal coefficient of expansion ($1/3^{\text{rd}}$ that of steel), galvanized or aluminum clad, to allow smaller thermal expansion resulting in small conductor sag. The aluminum clad core improves the resistance against corrosion.

Aluminum conductor Invar reinforced is a completely different conductor compared to the conventional ACSR in capacity and thermal expansion keeping its size, weight and tensile strength. Aluminum conductor Invar reinforced can carry twice as much conductor as that of ACSR of the same size while maximum sag and maximum working tension are the same as those of ACSR. ACSR conductor can be replaced with this conductor without any need to reinforce the steel towers.

Super thermal resistant aluminum alloy wires used for conductor layer can continuously be operated up to 200 to 230°C without degradation. They can be used in heavy wind and snow, galloping area. Installation is easy adopting the same method and equipments as required for ACSR.

Materials for Bare Over head Conductor:

Material	Density Gm/ cm ³	Conductivity % IACS	Tensile strength MPa	Coefficient of thermal expansion X 10 ⁻⁶ / °C
copper	8.9	100	450	17
Aluminum	2.7	61	165	23
steel	7.8	9	1600	11.5
Alloy	2.7	52	325	23
Invar	7.1	14 - 23	1310 - 1170	3.7

2.7.3.4 Composite Insulators:

Composite Insulators (Polymer Insulators) are light in weight, most suitable for highly polluted/ saline environments. They are practically unbreakable and have superior anti-tracking properties. They are highly reliable and have a long life. Conventional ceramic insulators are brittle and lack in self cleaning property. Accumulation of solid pollutants with retention of water often leads to flash over of the insulators and breakdown. Composite insulators, because of the excellent hydrophobic property, are most reliable in highly polluted atmospheres.

The specially designed Polymeric material used in these Insulators have a self-cleaning property, achieved by molecular migration making it possible to maintain anti-tracking performance over an extended period. Surface hydrophobicity is maintained over a long period. Hence most suitable in a polluted environment. The composite FRP pultruded rod has a very high mechanical strength. Our special crimping technique allows this high strength to be maintained. In a typical comparison, the composite Insulator weights 25-30% of a ceramic Insulator. This ensures easy installation. These Insulators can be used at temperatures ranging from -50 deg C to +60 Deg C

Composite insulators consist of three main components – Fibre glass rod, Silicone rubber and Metallic end fittings. These are light in weight and come in strings for a particular tension and voltage class.

Fibreglass rod: This acts as a core. The reinforced fiberglass core shall be epoxy fiberglass rod having superior electrical performance and mechanical strength. The insulator core shall be mechanically and electrically sound, free from voids, foreign substances, and other manufacturing flaws.

Fiberglass Reinforced Plastic is of 22 mm or larger diameter shall be required for insulators of 3 m or longer to prevent excessive bending.

Housing (Sheath and Sheds): The fiberglass core of the polymer insulators support a housing made of high temperature vulcanized (HTV) Silicone Rubber. The Silicone elastomeric compound for housing shall have Si-O chemical backbone with fumed Silica and tracking control filler.

The housing shall be manufactured of 100 percent Silicone Rubber before fillers are added. The housing shall have shore' A' hardness of not less than 60. The track resistance of the material shall meet IEC 60587 method 1 class I A4.5 or 184.5 requirements.

The housing shall be multi step moulding of entire weather shed structure (sheds with the shank) on to the Fiberglass Plastic core rod instead of one-piece moulding. The material of sheath and sheds shall be the same.

The interface between the housing and rod shall be chemically bonded to prevent contaminants and moisture ingress. The bonding strength between the sheath and the rod shall be greater than the breaking strength of the polymer material itself.

The end fittings (electrodes) shall not be covered with the housing to prevent electrical puncture through the housing.

The minimum thickness of housing shall be not less than 3.0 mm.

Shed profile shall be in accordance with IEC Pub.60815.

The color of the housing material shall be gray, uniform and consistent.

Polymer insulator shall be designed to withstand high-pressure water washing with 3800 kPa, nozzle diameter 6mm and the distance of 3m from nozzle to polymer insulator.

End-fitting: The end fittings shall be designed to transmit the mechanical load to the core and to develop the uniform and consistent mechanical strength of the insulators

The material and the methods used in the fabrication of the end fittings shall be selected to provide good toughness and ductility. The metal shall be heat-treated appropriately to produce the minimum strength and ductility requirements.

Forgings and Castings shall be uniform in quality and without sharp edges or corners.

All ferrous material (except stainless steel) shall be hot-dip galvanized in accordance with ASTM A153. The galvanized thickness shall satisfy IEC Pub.60383-1 clause 26.2.2 after the crimping. Ball fitting shall be made of forged steel.

Assembly: The end fittings shall be attached to the core through crimping process (compression) so that end fittings uniformly transmit the mechanical load to the core. The end fittings of polymer insulators after complete assembly with the core and housing shall be coaxial with one another.

Sealing: The junction of the metal end fitting and housing shall be sealed to prohibit the entrance of the moisture and foreign materials.

Grading Ring: Polymer insulator rated at 150 KV and above shall have grading ring(s) attached. The RIV and corona performance of insulator with corona ring(s) shall conform to the requirement specified in IEC Pub.61109 Amendment 1.

2.8 Important Technical Specification for equipment:

After selecting a suitable design for the proposed project, detailed specification covering all technical and commercial aspects shall be prepared for inviting bids. Principal parameters and salient technical features of various substation & line equipment and materials are described here under.

Relevant Indian and International standards and codes governing the technical requirement, sampling and test procedures covering equipment and accessories are given in the annexure for reference. All the equipment/ materials shall normally conform to the latest issues of the relevant standards including amendments if any, unless explicitly modified whenever and wherever required.

2.8.1 POWER TRANSFORMERS

PRINCIPAL PARAMETERS:

Sl.No.	Item	Auto transformer with tertiary	Two winding transformer
1	Type of power transformer installation	3 Phase suitable for outdoor	
2	a) Voltage rating (HV/IV/LV) b) Capacity rating(MVA)	400/220/33 kV 220/132/11 kV 315 (400kV class) 160,100(220kV class)	132/33, 132/11kV 220/33,220/11kV 80, 50 ,31.5 ,25 (220 or 132kV class)
3	Type of mounting	---On wheels mounted on rails ---	
4	Suitable for system frequency	--- 50 Hz $\pm$ 5 % ---	
5	No. of phases	3	3
6	No. of windings	Two (Auto + tertiary)	Two (HV & LV)
7	Type of cooling	ONAN/ ONAF ONAN/ ONAF & OFAF	ONAN/ ONAF
8	MVA rating corresponding to cooling system a) ONAN cooling b) ONAF/OFAF cooling	60 % 100 %	60 % 100 %
9	Method of connection	HV - star IV – star LV – delta(tertiary)	HV – star(for 33kV) LV – star HV – star(for 11kV) LV – star or delta
10	Connection symbol	YNA0 d11	YNyn0 or YND11
11	System earthing	Solidly grounded neutral system	
12	Percentage impedance(%) voltage at normal tap and MVA base corresponding to HV/LV rating and permissible tolerance	12.5 $\pm$ 10%(315MVA) 10 $\pm$ 10 % (160 & 100MVA)	10 $\pm$ 10%(up to 25MVA rating) 12.5 $\pm$ 10%(above 25MVA rating)

13	Anticipated continuous loading of windings HV & LV	Not to exceed 110% of rated capacity	
14	Tap changing gear i. Provided on ii. Tap range iii. Tap step	On load IV side +10% to – 10% +25% to – 5%	On load HV side towards neutral end +5% to – 25%
15	Over voltage operating capability and duration	125% rated voltage for 60 secs 140% rated voltage for 5 secs.	
16	Maximum air core reactance of HV windings	20 %	20 %
17	Minimum knee point voltage	110 % rated voltage	
18	Max. flux density in any part of the core and yoke at rated MVA, frequency and normal voltage	1.6 Tesla	1.6 Tesla
19	Type of winding insulation HV/ LV winding	Graded for star winding Uniform for delta winding	
20	System short circuit level and duration for which transformer shall be capable to withstand thermal and dynamic stresses	For 400kV system 40kA/ 1 second 220kV system 40kA/ 1 second 132kV system 31.5kA/ 1second 33& 11 kV system 25kA/ 1 second	
21	Noise level at rated voltage and frequency (Max)	75 dB	
22	Permissible temperature rise over ambient temperature of 50 ° C Of oil measured by thermometer Of winding measured by resistance	50 ° C 55 ° C	50 ° C 55 ° C

Bushings:

Voltage rating	for 400kV class - 420kV	Neutral - 36kV
	220kV class - 245kV	Neutral - 36kV
	132kV class – 145kV	Neutral - 36kV
	33kV class - 36kV	Neutral - 36kV
	11kV class - 12kV	Neutral - 12kV

Current rating ----- As required -----

Insulation levels	Voltage class (kV)	Windings	Bushings
a) 1.2/50μs wave shape impulse withstand (kVp)	400	1450	1550
	220	950	1050
	132	550	650
	33	170	
	11	75	
b) Power frequency voltage withstand (kV rms)	400	630	
	220	460	
	132	275	
	33	70	
	11	25	

2.8.1.1 GENERAL TECHNICAL REQUIREMENTS

Duty Requirements: The transformers and all its accessories like CTs etc., shall be designed to withstand without injury, the thermal and mechanical effects of any external short circuit to earth and of short circuits at the terminals of any winding of values specified above for a period of 1 sec.

The transformer shall be capable of being loaded in accordance with IS: 6600 up to loads of 150%. There shall be no limitation imposed by bushings, tap changer etc.

The transformer shall be capable of being operated without danger on any tapping at the rated MVA with voltage variation of plus or minus 10% corresponding to the voltage of that tapping with normal temperature rise.

Radio interference: The transformers shall be designed with particular attention to suppression of maximum harmonic voltage. especially the third and fifth so as to eliminate wave form distortion and minimize interference with communication circuits.

The noise level, when energized at normal voltage and frequency with fans running shall not exceed, when measured under standard conditions, the values specified in NEMA, TR-I

Transformer shall be capable of operating under the natural cooled condition up to the specified load. The forced cooling equipment shall come into operation by pre-set contacts of winding temperature indicator and the transformer shall operate as a forced cooled unit, as ONAF/OFAF. Cooling shall be so designed that during total failure of power supply to cooling fans the transformer shall be able to operate at full load for at least ten (10) minutes without the calculated winding hot spot temperature exceeding 140 deg. C. Also stopping of two cooling fans should not have any effect on the cooling system. Transformers fitted with two coolers each capable of dissipating 50 per cent of the loss at continuous maximum rating shall be capable of operating for 20 minutes in the event of failure of the blowers associated with one cooler, without the calculated winding hot spot temperature exceeding 105 deg. C at continuous maximum rating.

Transformer shall be capable of withstanding thermal and mechanical stress caused by symmetrical or asymmetrical faults on any winding.

Transformer losses: are basically Iron losses(No load losses) due to excitation of the magnetic core, copper losses(load losses) due to current carried by the conductors and auxiliary losses due to power consumed by auxiliaries such as cooling fans, pumps etc.

The above losses can generally be specified or alternately the bidder can be requested to offer his best losses so that transformers with lowest losses and highest efficiency can be procured.

Clearances: The bottom most portion of any insulator or bushing in service is at an absolute minimum height of 2500 mm above ground level.

The transformer bay width in the sub station for 400kV will be 27000mm, 220 kV will be 17000 mm and 132kV will be 12000mm. Height of boom will be 11000 mm. These aspects may be noted while designing the transformer size.

2.8.1.2 CONSTRUCTION DETAILS:

Tank:

- a) Tank shall be of welded construction and fabricated from tested quality low carbon steel of adequate thickness.
- b) After completion of tank construction and before painting, dye penetration test shall be carried out on welded parts of jacking bosses, lifting lugs and all load bearing members.
- c) Tank stiffeners shall be provided for general rigidity and these shall be designed to prevent retention of water.
- d) The tanks shall be designed to withstand:
 - i) Mechanical shocks during transportation
 - ii) Vacuum filling of oil at 10 torr.
 - iii) Continuous internal pressure of 35 kN/m² over normal hydrostatic pressure of oil.
 - iv) Short circuit forces.
- e) The shields shall be such that no magnetic fields shall exist outside the tank. They shall be of magnetically permeable material. If required, impermeable shields shall be provided at the coil ends. Tank shield shall not resonate when excited at the natural frequency of the equipment.
- f) Each tank shall be provided with
 - Lifting lugs suitable for lifting the equipment complete with oil.
 - A minimum of four jacking pads in accessible position at 500mm height to enable the transformer complete with oil, to be raised or lowered using hydraulic or screw jacks.
 - Suitable haulage holes shall be provided.

Hydraulic jacks of adequate capacity are to be placed under the jacking pads for lifting the transformer during installation/removal on the plinth. The foundation in the area beneath the jacking pad needs to be sufficiently strong to bear the proportional weight of the transformer. To identify these areas (four nos. on four sides) on the transformer foundation plinth and to standardize the dimensions of plinth for transformers of specified capacity and voltage class, the dimensions of jacking pads for different groups of transformers may be fixed and indicated in the specification. This will avoid the need to re lay the foundation plinth while replacing the transformer with another make, minimizing the downtime.

Bell shaped tanks are available, where top 70% portion of the tank is fixed to the bottom 30% of the tank through flanges and gaskets. The whole tank resembles a bell, hence the name. This type of tank facilitates opening of the tank in the switchyard itself for detailed examination of core & windings, tap changers etc when needed without moving the transformer to the repair bay, thus saving the down time.

Tank Cover:

- a) The tank cover shall be sloped to prevent retention of rain water and shall not distort when lifted.
- b) Atleast two adequately sized inspection openings, one at each end of the tank shall be provided for easy access to bushings and earth connections. The inspection covers shall not weigh more than 25 Kg. The inspection covers shall be provided with two handles.
- c) The tank covers shall be fitted with pockets at the position of maximum oil temperature of MCR (Maximum Continuous Rating) for bulbs of oil and winding temperature indicators. It shall be possible to remove these bulbs without lowering the oil in the tank.
- d) Bushings, turrets, covers of inspection openings, thermometer, pockets etc., shall be designed to prevent ingress of water into or leakages of oil from the tank.
- e) All bolted connections shall be fitted with weather proof, hot oil resistant gasket in between, for complete oil tightness. If gasket is compressible, metallic stops shall be provided to prevent over-compression.

Axles and Wheels:

- a) The transformers are to be provided with flanged bi-directional wheels and axles. These shall be so designed as not to deflect excessively to interfere with the movement of the transformer. Wheels shall be provided with suitable bearings which shall be rust and corrosion resistant. Fittings for lubrication shall also be provided.
- b) Suitable locking arrangement along with foundation bolts shall be provided for the wheels to prevent accidental movement of transformer.
- c) The wheels are required to swivel and they shall be so arranged that they can be turned through an angle of 90 deg. when the tank is jacked up to clear of rails. Means shall be provided for locking the swivel movements in positions parallel to and at right angles to the longitudinal axis of the tank.
- d) The rail track gauge shall be 5'-6" (1676 mm) along longer axis as well as along shorter axis. There shall be one pair of rails in either axis, with the above gauge.
- e) To facilitate uniform distribution of transformer weight two Nos. props each on front & rear side along longer axis to be provided.
- f) The base of each tank shall be so designed that it shall be possible to move the complete unit by skidding in any direction without injury when using plates or rails.

Anti Earthquake Clamping Device:

To prevent transformer movement during earthquake, clamping device shall be provided for fixing transformer to the foundation. The arrangements shall be such that the transformer can be fixed to or unfastened from these bolts as desired. The fixing of the transformers to the foundations shall be designed to withstand seismic events to the extent that a static co-efficient of 0.3g, applied in the direction of least resistance to that loading will not cause the transformer or clamping devices as well as bolts to be over stressed.

Conservator Tank

- a) The conservator tank shall have adequate capacity between highest and lowest visible levels to meet the requirement of expansion of the total cold oil volume in the transformer and cooling equipment from minimum ambient temperature to 90 deg.C
- c) The conservator shall be fitted with magnetic oil level gauge with low level electrically insulated alarm contact.
- d) Conservator shall be provided in such a position as not to obstruct the electrical connections to the transformer.
- e) Separate conservator tank shall be provided for OLTC.

Pressure Relief Device: Adequate No. of pressure relief devices may be provided at suitable locations which shall be of sufficient size for rapid release of any pressure that may be generated in the tank and which may result in damage to the equipment. The device shall operate at a static pressure of less than the hydraulic test pressure of transformer tank. It shall be mounted direct on the tank. One set of electrically insulated contacts shall be provided for alarm/tripping.

Buchholz Relay: A double float type Buchholz relay shall be provided. All the gases evolved in the transformer shall collect in this relay. The relay shall be provided with a test cock suitable for a flexible pipe connection for checking its operation and taking gas sample. A copper or stainless steel tube shall be connected from the gas collector to a valve located about 1200 mm above ground level to facilitate sampling, with the transformer in service. The device shall be provided with two electrically independent ungrounded contacts, one for alarm on gas accumulation and the other for tripping on sudden rise of pressure. The contracts of relay shall be property housed, sealed and gasketed to make the arrangements water proof.

Temperature Indicator

Oil Temperature Indicator (OTI): Transformers shall be provided with a 150 mm dial type thermometer for top oil temperature indication. The thermometer shall have adjustable, electrically independent ungrounded alarm and trip contacts, maximum reading pointer and resetting device mounted in the cooler control cabinet. A temperature sensing element suitably located in a pocket on top oil shall be furnished. This shall be connected to the OTI by means of capillary tubing. Accuracy class of OTI shall be plus or minus 1.0% or better.

Winding Temperature Indicator (WTI): A device for measuring the hot spot temperature of the windings shall be provided (HV & LV). It shall comprise of the following:

- Temperature sensing element.
- Image coil.

- Auxiliary CTs, if required to match the image coil, shall be furnished and mounted in the cooler control cabinet.
- 150 mm dia local indicating instrument with maximum reading pointer mounted in cooler control cabinet and with two adjustable electrically independent ungrounded contacts (besides that required for control of cooling equipment), one for high winding temperature alarm and one for trip.
- Calibration device.

In addition to the above, the following indication equipment shall be provided for each winding.

- Signal transmitter
- Remote winding temperature indicator. It shall be suitable for flush mounting on RTCC panel. (this shall not be repeater dial of local WTI and shall operate by signal transmitter). The difference between local and remote WTI indication at any given time shall not exceed 1 deg. C. One RWTI with a four point selector switch shall be provided for all the windings (HV& LV).
- Auxiliary supply if required, in RTCC panel, for RWTI, shall be 220 V DC.
- Accuracy class of WTI shall be plus or minus 1.0% or better.

Earthing Terminals: Two (2) earthing pads (each complete with two (2) Nos. tapped holes, M 10 bolts, plain and spring washers) suitable for connection to 50 x 8 galvanized steel flat shall be provided each at position close to the two (2) diagonally bottom corners of tank.

Core: The core shall be constructed from high grade non-ageing cold rolled super grain oriented silicon steel laminations, of HI-B grade steel.

The insulation of core to bolts and core to clamps plates shall be able to withstand a voltage of 2 kV RMS for one minute.

Core and winding shall be capable of withstanding the shock during transport, installation, service and adequate provision shall be made to prevent movement of core and winding relative to tank during these conditions.

All steel sections used for supporting the core shall be thoroughly sand blasted after cutting, drilling and welding.

Each core lamination shall be insulated with a material that will not deteriorate due to pressure and hot oil.

The maximum flux density in any part of the core and yoke at rated MVA, voltage and frequency at any tap shall not exceed 1.6 tesla. A margin of 10 to 12.5% for over fluxing may be provided for the worst combination of voltage and frequency within the ranges specified.

Windings: The conductors shall be of electrolytic grade copper.

The insulation of transformer windings and connections shall be free from insulating compounds which are liable to soften, ooze out, shrink or collapse or be catalytic and chemically active in transformer oil during service.

Better insulating material shall be used and compression of the windings after drying out shall be carried out at a pressure exceeding one and a half to twice the force which can occur in the

transformer; to impart greater mechanical strength to the windings against heavy short circuit stresses.

Insulating Oil: The transformer oil shall conform to the parameters specified below. No inhibitors shall be used in the oil. The oil used shall be non - PCB (Poly Chlorinated Biphenyl) type.

Sl.no	Characterstic	Requirement	Method of Test
1	Appearance	Oil shall be clear and transparent and free from suspended matter or sediment	A representative sample of oil shall be examined in a 100mm thick layer at ambient temperature
2	Density@27°C max.	0.89gm/cm ³	IS – 1448
3	Kinematic viscosity @ 27°C max.	27 CST	IS - 1448
4	Interfacial tension @ 27°C max.	0.04 N/m	IS - 6104
5	Flash point Pensky Martin (closed) min.	140°C	IS - 1448
6	Pour point max.	- 10°C	IS - 1448
7	Neutralization value (Total acidity) max.	0.03mgKOH/gm	IS – 335 Appendix - A
8	Corrosive sulphur (in terms of classification of copper strip)	Non-corrosive	IS – 335 Appendix - B
9	Electric strength (Break down voltage) min a) New untreated oil b) After treatment	30kV(rms) {if the above value is not attained, oil shall be treated} 60kV(rms)	IS - 6792
10	Dielectric dissipation factor (tand) at 90°C max.	0.002	IS - 6262
11	Specific resistance (resistivity) a) at 90°C min b) at 27°C min	3.0*10 ¹² ohm-cm 500*10 ¹² ohm-cm	IS - 6103
12	Oxidation stability a) Neutralization value after oxidation max. b) Total sludge after oxidation max.	0.2mgKOH/gm 0.02 percent by weight	
13	Presence of oxidation	Oil shall not contain anti oxidant inhibitors	IS – 335 Appendix-D
14	Water content max.	10 ppm.	IS – 2362

15	Aging characteristics after 96 hours with catalyst (Copper) a) Resistivity i) 27°C ii) 90°C b) Tanδ at 90°C c) Total acidity d) Total sludge	0.25*10 ¹² ohm-cm (Min.) 0.02*10 ¹² ohm-cm (min.) 0.1 (max) 0.05mgKOH/gm (max.) 0.03% by weight (Max.)	As per ASTM - D 1934

Oil Preservation Equipment:

a) Conventional Conservator system: In this type of oil preservation system conservator shall be fitted with a dehydrating filter breather. It shall be so designed that:

- Passage of air is through a dust filter and silica gel.
- Silica gel is isolated from atmosphere by an oil seal.
- Moisture absorption indicated by a change in colour of the tinted crystals can be easily observed from a distance.
- Breather is mounted not more than 1400 mm above rail top level.
- Containers shall be of metal with glass enclosure along its periphery to ensure that the transparency to verify the color of dehydrating agent is maintained during operation directly under sunlight (ultra violet rays) for long life.

b) Diaphragm seal type constant oil pressure system : In this system contact of the oil with atmosphere shall be prohibited by using a flexible or nitrite rubber reinforced with nylon cloth air cell.

Diaphragm used shall be suitable for continuous operation in an atmosphere of 100 deg.C to which transformer oil is likely to rise.

The connection of the air cell to the top of the reservoir is by an air proof seal permitting entrance of air into the cell only. The Diaphragm of the conservator shall withstand the vacuum during installation and maintenance.

Bushings: Bushings of 132kV and above (EHV Class) shall be oil impregnated paper condenser type and 33kV and below shall be of plain porcelain. No arcing horns shall be provided on any bushings.

Condenser type bushings shall be provided with Oil level gauge; Oil filling plug and drain valve and Tap for measurement of capacitance/tan delta

Where current transformers are specified, the bushings shall be removable without disturbing the current transformers.

Bushings of identical rating shall be interchangeable.

Bushing turrets shall be provided with vent pipes which shall be connected to route any gas collection through the Buchholz relay.

Terminal Connectors:

Terminal connectors for HV & LV side shall be suitable for connecting required size and no of conductors specified and suitable for horizontal or vertical takeoff.

The short time rating of terminal connector shall correspond to the short time rating of respective bushing.

Bushing current transformers: It shall be possible to remove turret mounted CTs from the transformer tank without removing the tank cover. Necessary precaution shall be taken to minimize the eddy currents and local heat generated in the turret.

Neutral Earthing Arrangement: The neutral terminals of the star connected winding shall be brought to the ground level by a galvanized steel grounding bar which shall be supported from the tank by porcelain insulators.

The end of the GS bar shall be brought to the ground level, at a convenient point, for connection in the substation ground network through two (2) 50x8 mm galvanized steel flats. The connection shall be made by using two bolted neutral grounding terminals with necessary accessories.

Tap Changer - General Requirement: On Load Tap changer shall be provided towards the neutral end of HV winding for variation of HV voltage over a range (to be specified) to regulate voltage on LV side for a two winding transformer. In an Auto transformer the OLTC shall be provided on the LV side of Auto winding.

OLTC gear shall be motor operated for local as well as remote operation. An external hand wheel/handle shall be provided for local manual operation. This hand wheel/ handle shall be easily operable by a man standing at ground level.

On Load Tap Changing Gear (OLTC):

- The tap changer shall change the effective transformation ratio without producing phase displacement.
- The current diverting contacts shall be housed in a separate oil chamber not communicating with the oil in main tank of the transformer.
- The contacts shall be accessible for inspection without lowering oil level in the main tank and the contact tips shall be replaceable.
- The OLTC oil chamber shall have oil filling and drain plug, oil sampling valve, relief vent and level glass. It shall also be fitted with an oil surge relay the outlet to which shall be connected to a separate conservator tank.

Operating mechanism for on load tap changer shall be designed to go through one step or tap change per command. Subsequent tap changes shall be initiated only by a new or repeat command. Tap position indicators to indicate current tap position shall be provided.

Transformer load tap changer shall be equipped with a fixed resistor network capable of providing discrete voltage steps for input to the supervisory system.

Interlocking between manual and electrical operations shall be provided. Limit switches shall be provided to prevent overrunning of the mechanism and in addition, a mechanical stop shall be provided to prevent over-running of the mechanism under any condition.

The equipment shall be suitable for supervisory control and indication with make before break multi-way switch, having one potential free contact for each tap position. This switch shall be provided in addition to any other switch/switches which may be required for remote tap position.

Manual Control: The cranking device for manual operation of the OLTC gear shall be removable and suitable for operation by a man standing on ground level. Mechanical stops shall be provided to prevent over cranking of the mechanism beyond the extreme tap positions.

Electrical Control: A local control cabinet and a remote control cubicle shall be provided for electrical operation.

Remote Electrical Group Control: Remote control cubicle shall have provision for group control during parallel operation of transformers. For this purpose a four position selector switch having MASTER, Follower, Independent and OFF position shall be provided.

Master Position: If the selector switch is in MASTER position, it shall be possible to control the OLTC units in the FOLLOWER mode by operating the controls of the MASTER unit. Independent operation of the units under FOLLOWER mode shall not be possible.

Follower Position: When the selector switch is in FOLLOWER position control of OLTC shall be possible only from MASTER panel.

Independent Position: In this position of selector switch control of OLTC of individual unit only shall be possible.

Out of step relays with timer contacts shall be provided to give alarm and indication when tap positions of all transformers under group control are not in the same position.

Cooling Equipment and its Controls: The cooler shall be designed using 2x50% radiator banks mounted one on each side of transformer tank. Coolers shall with stand pressure conditions specified for tank. All coolers shall be attached and mounted on the transformer tank either direct or through header.

Each radiator bank shall have its own cooling fans / oil circulating pumps, shut off valves, lifting lugs, top and bottom oil filling valves, air release plug, a drain valve and thermometer pocket fitted with captive screw cap on the inlet and outlet.

One standby fan of at least 20% capacity shall also be provided and identified with each radiator block.

The exhaust air flow from cooling fan shall not be directed towards the main tank in any case.

Cooling Equipment Control (ONAN/ONAF COOLING): In addition to manual control facility for cooler fans, automatic operation control (switching in and out) of fans shall be provided (with temperature change) from contacts of winding temperature indicator. The setting shall be such that hunting i.e. frequent start stop operations for small temperature differential do not occur

Painting: The internal and external surfaces including oil filled chambers and structural steel work to be painted shall be shot or sand blasted to remove all rust and scale of foreign adhering matter or grease. All steel surfaces in contact with insulating oil shall be painted with two coats of heat resistant, oil insoluble, insulating varnish.

All steel surfaces exposed to weather shall be given a primary coat of zinc chromate, second coat of oil and weather resistant varnish of a colour distinct from primary and final two coats of glossy oil and Epoxy light gray paint in accordance with shade no.631 of IS-5.

The minimum thickness of each coat of outside painting of tank shall be 20 microns and the total thickness shall be minimum 80 microns.

2.8.2 INSTRUMENT TRANSFORMERS: Common to all instrument transformers (CTs, CVTs & IVTs)

2.8.2.1 General Technical Requirement: Core shall be high grade non-ageing silicon laminated steel of low hysteresis loss and high permeability to give high accuracy at both normal and over current/voltage.

Secondary terminals shall be brought into a compartment on one side of Instrument Transformer, for easy access. Secondary terminals shall be provided with short circuiting arrangements in case of CTs. Secondary taps shall be adequately reinforced to withstand normal handling without damage. Ratio taps shall be on secondary side.

The mounting of ITs shall be pedestal type and shall be suitable for mounting on steel structures or concrete pedestals. Necessary, flanges, bolts etc., shall be galvanized. Metal tanks shall be coated with at least two coats of zinc rich epoxy painting. All the ferrous hardware, exposed to atmosphere shall be hot dip galvanized. All the other fixing nuts, bolts, washers, shall be made out of stainless steel.

Internal insulation shall have higher electrical with stand capacity than the external insulation porcelain housing shall be in one single piece only without any metallic joints.

Note:

(i) The base dimensions of instrument transformers may be standardized and specified so as to facilitate mounting of any make of instrument transformer on the standard CPL structures (Structures meant for supporting CT, VT, CVT, and LAs) with ease and without any alterations to base plate. Secondary winding insulation shall be of class 'H' type.

(ii) All exposed metal parts such as tanks, hoods, hardware channels etc, shall be specially galvanized/painted with zinc rich epoxy paints to withstand effects of environment

particularly in medium and highly polluted areas. Creepages for porcelain shall also be suitably extended in highly polluted areas.

Temperature rise on any part of equipment shall not exceed maximum temperature rise mentioned below under the conditions specified in test clauses

Sl. No.	Nature of the part or of the liquid	Temperature Deg.C (max)	Temp.rise over a max. ambient temp. not exceeding 50°C
1.	Contacts in air: Silver-faced copper, copper alloy or aluminum alloy (see notes I & ii)	105	55
	Bare copper or tinned aluminum alloy	75	25
2.	Contacts in oil: silver-faced copper, copper alloy or aluminum alloy (see note ii)	90	40
	Bare copper or tinned aluminum alloy	80	30
3.	Terminals to be connected for external conductors by screws or bolts silver faced (see note iii)	105	55
	Bare	90	40
4.	Metal parts acting as springs (see note iv)	See Note iv	
5.	Metal parts in contact with insulation of the following classes:		
	Class Y: (for non-impregnated materials)	90	40
	Class A: (for materials immersed in oil or impregnated)	100	50
	Class E: in Air/ in Oil	120/ 100	70/ 50
	Class B: in Air/ in Oil	130/ 100	80/ 50
	Class F: in Air/ in Oil	155/ 100	105/ 50
	Enamel: Oil base	100	50
6.	Any part of metal or of insulating material in contact with oil except contacts	120	70
		100	50
7.	Oil	90	40

Note:

- When applying temperature rise of 55°C care should be taken to ensure that no damage is caused to surrounding insulating materials.
- The quality of silver facing shall be such that a layer of silver remains at the point of contact after the mechanical endurance test. Otherwise, the contacts shall be regarded as “bare”.
- The values of temperature and temperature rise are valid, whether or not; the conductor connected to the terminals is silver faced.
- The temperature shall not reach a value where the elasticity of the material is impaired. For pure copper, this implies to a temperature limit of 75°C.

2.8.2.2 CURRENT TRANSFORMERS (CTs):

Principal parameters: The current transformers shall conform to the following specific parameters:

Sl.No.	Item	Specification		
		400 KV	220 KV	132 KV
1.	Type of installation	Single phase, dead tank, oil filled, hermetically sealed and outdoor type.		
2.	Type of mounting	Pedestal type		
3.	System Frequency	50 Hz $\pm$ 5%		
4.	Highest system voltage (kv/rms)	420	245	145
5.	Current Ratio (A/A)	See Annexure		
6.	Ratio taps	On secondary side		
7.	Method of earthing	Efficient grounded neutral system		
8.	Rated continuous thermal current (A)	120% of rated current		
9.	Acceptable limit of temperature rise over the specified ambient temperature for continuous operations at rated current.	As per IS 2705		
10.	Accepted partial Discharge level at 1.1 time the rated voltage	10 PC(pico coulombs) at highest system voltage 5 PC at 1.2 Vm		
11.	1.2/50 micro second lighting impulse withstand voltage (kvp)	1425	1050	650
12.	1 minute dry power frequency withstand voltage for primary winding (kVrms)	520	460	275
13.	1 Minute power frequency over voltage withstand voltage for secondary winding (kVrms)	3	3	3
14.	Minimum total creep age distance of porcelain housing (mm)	10500	6125	3625
15.	Rated short time withstand current for	40	40	31.5

	1 sec. duration (kArms)			
16.	Rated Dynamic withstand current (kAP	100	100	78.75
17.	Type of insulation		Class A	
18.	RIV at 1.1 x rated voltage		Less than 500 micro volts	

The CTs shall be provided with suitable test tap for measurement of capacitance, tan delta as well as partial discharges, at site. A suitable caution plate shall be provided on the secondary terminal cover box indicating the purpose of test tap and necessity of its solid earthing before energizing the current transformer.

Number of cores on CT secondary and the current ratios are to be selected depending on application.

Example:

- (a) metering
- (b) Main protection
- (c) Backup protection
- (d) Different protection
- (e) Busbar protection

Metering: Ratio and phase angle errors are to be kept at minimum to get true output of CT in secondary. This can be done by proper selection of core material and size and type of winding. The CT shall give true output in the normal range i.e., from 0.1% to 120% of rated current. Under transient conditions (i.e., under fault conditions, when the current output from CT is many times the rated current) the heavy current flowing the metering circuit may develop heat and damage the meters/instruments. To avoid this, the CT shall be locked at a certain ratio, so that it gets saturated temporarily and does not give true output beyond this point, saving the meters from excessive heat and preventing damage. This ratio is called Instrument Security Factor.

Instrument security factor of 5 is normally specified.

Protection cores: These cores are connected to protective relay viz., over current, distance relays. The relays operate on the occurrence of overload/ phase to phase or phase to ground faults when heavy currents flow through them. All protection cores shall be able to produce undisturbed secondary current under transient conditions at all ratios. Under these conditions the CT shall deliver true output, without going into saturation. The number of times rated current that the CT can handle without getting saturated determines its suitability for a particular protection application. This is called the accuracy limit factor.

Thus for protection class CTs accuracy under normal range not significant. Accuracy of output under fault condition much beyond the normal range is of utmost importance for protection class CTs. Important parameters such as rated burden, knee point voltage and the maximum exciting current at knee point voltage, accuracy class and accuracy limit factor are to be mentioned for various cores of CTs for metering and protection applications. A table showing different class of CTs and these parameters are given in the table below:

Sl No.	Application	Output Burden VA	Accuracy class	Accuracy Limit factor	Minimum knee Point voltage (kpV) (Volts)	Maximum Exciting current at knee point voltage (mA)
1	Metering	20	0.2	-	-	-
2	Distance Protection Main	-	PS	-	$100I(R_{ct}+20)$	100
	Back up	-	PS	-	$100I(R_{ct}+20)$	100
3	O/L, E/L protection	20	5P	20	-	-
4	Differential protection	-	PS	-	$40I(R_{ct}+10)$	30
5	Bus-bar protection Main	-	PS	-	$80I(R_{ct}+10)$	30
	Check	-	PS	-	$80I(R_{ct}+10)$	30

Note: Separate cores shall be used for metering and protection. Separate secondary core shall be used for each protection application.

Eg: over current/ earth fault protection

Distance protection (Main)

Distance protection (Back up)

Busbar Protection (Main)

Busbar Protection (Check)

Differential protection

For transformers O/L,E/L and differential protection are used. Bus-bar protection main and check are used for transformers of 220kV and 400kV class.

For 33kV and 11kV feeders O/L,E/L protection is used.

For 132kV feeders Main distance protection and back up O/L,E/L protection is used.

For 220kV and 400kV feeders Distance protection main and back up and bus-bar protection main and check are used.

Primary winding shall normally consist of a single turn of suitable design with electrolytic high conductivity copper strips or aluminum tube of adequate area of cross section, to sustain the guaranteed short time as well as continuous thermal rating. The winding may be hair pin type or ring type.

2.8.2.3 Capacitor voltage transformers (CVTs):

Capacitor voltage Transformer is required for protection, metering, telecommunication (Voice, metering and control) purposes. Capacitor Voltage Transformer consists of graded capacitors and Electro Magnetic Unit. The EMU consists of compensation reactor, intermediate transformer, protective and damping devices. EMU is mounted in a hermetically sealed metal enclosure which shall also be used as a mechanical support for the

capacitor voltage divider. The capacitor voltage divider acts as a coupling capacitor, offering very low impedance path for carrier communication signals, to allow signals through them to power-line carrier communication cubicles.

The capacitor voltage transformers shall conform to the following specific parameters:

Sl. No.	Item	Specification		
		400kV	220kV	132kV
1	Type of installation	Single phase, oil filled, hermetically sealed, outdoor type		
2	Type of mounting	Pedestal type		
3	System frequency	50 Hz $\pm$ 5%		
4	Highest system voltage	420 kV	245 kV	145 kV
5	Voltage ratio			
	Rated primary voltage (kV)	400/ $\sqrt{3}$	220/ $\sqrt{3}$	132/ $\sqrt{3}$
	Secondary voltage (volts)			
	i. Winding i (metering)	110/ $\sqrt{3}$	110/ $\sqrt{3}$	110/ $\sqrt{3}$
	ii. Winding ii (protection)	110/ $\sqrt{3}$	110/ $\sqrt{3}$	110/ $\sqrt{3}$
	iii. Winding iii (protection)	110-110/ $\sqrt{3}$	110-110/ $\sqrt{3}$	110-110/ $\sqrt{3}$
6	a) Simultaneous output of secondary winding (VA)			
	winding-i	50	50	50
	winding-ii	200	200	200
	winding-iii	50	50	50
	b) Rated total thermal burden (simultaneous) VA	300	300	300
7	Accuracy class			
	Winding-I	0.2	0.2	0.2
	Winding-ii	0.5	0.5	0.5
	Winding-iii	3P	3P	3P
8	Method of earthing system	Effectively earthed		
9	1.2/50 μ s lightning impulse withstand voltage (kVp)	1400	1050	650
10	1 minute dry power frequency withstand voltage (kV rms)	500	460	275
11	Min. creepage distance of porcelain housing (mm)	10500	6125	3625
12	Rated voltage factor	1.2 continuous 1.5 for 30 seconds		
13	Limits of voltage error and phase displacement	Accuracy class	Percentage voltage error in minutes	Phase displacement
		Metering 0.2	± 0.2	± 10
		Protection 0.5	± 0.5	± 20
		Protection 3P	± 3	± 120
14	Rated total capacitance (pf)	4400 + 10% -5%	4400 + 10% -5%	4400 + 10% -5%

15	Acceptable limit of variation of total capacitance over the entire carrier frequency range	+ 50% and – 20% of the rated capacitance		
16	Equivalent series resistance over the entire carrier frequency range(ohms)	< 40	< 40	<40
17	Stray capacitance and stray conductance of low voltage terminal over the entire carrier frequency range	As per IEC- 350		
18	Standard reference range of frequency for which accuracies are valid	96% to 102% for protection 99% to 101% for metering		
19	Partial discharge level at rated voltage for capacitance divider (pico coulombs)	Less than 10		
20	1 minute power frequency withstand voltage: i. Low voltage terminal(HF) and earth terminal(kV rms) ii. Withstand voltage for secondary winding (kV rms)	----- 3 ----- ----- 3 -----		
21	Maximum temperature rise over ambient of 50 ⁰ C	As per IEC - 186		
22	Seismic acceleration (horizontal)	----- 0.1 g -----		
23	Type of insulation	----- Class A -----		

Separate windings for the secondary are to be provided for metering and protection. Normally one metering and one protection winding are sufficient for the purpose. Separate protection winding is required for connecting the potential coil of directional earth fault relays. This secondary winding is connected in open delta and the two leads of open delta are connected to the potential coil of directional earth fault relay.

In view of the graded capacitors in series with the electro magnetic unit, accuracies are affected beyond a certain frequency range. The range of frequency with in which the accuracies are valid for metering and protection classes are indicated in the principal parameters given above.

2.8.2.4 Voltage (Potential) Transformers:

Voltage Transformers serve the purpose of protection and metering. This is totally an electro magnetic unit. Graded insulation is provided for primary winding from phase to neutral point and the neutral point is grounded. Accuracies remain valid for a wide range of frequencies since entire voltage transformation takes place in a magnetic circuit.

Voltage Transformers are normally used up to 220 KV class only, due to constructional constraints and high cost of construction for higher voltage classes. Normally, VTs are used

on buses, for connecting various metering and protection applications of the transformers/feeders connected around the bus.

Principal parameters: The voltage transformers shall conform to the following specific parameters.

Sl.No	Item	220kV	132kV	33kV								
1	Type	Outdoor single phase, oil immersed and self cooled										
2	Mounting of tank	Bottom tank										
3	Highest system voltage	245kV	145kV	36kV								
4	Earthing of the system	Effectively grounded neutral system										
5	Frequency	50 Hz $\pm$ 5%										
6	Insulation level (primary)	460kV rms	275kV rms	70kV rms								
7	One minute power frequency withstand voltage secondary	3kV rms	3kV rms	3kV rms								
8	Impulse withstand voltage (peak)	1050kV	650kV	170kV								
9	Minimum creepage distance	6125 mm	3625 mm	900 mm								
10	Bottom most portion of the bushing at a height of (structure design to meet this requirement)	2500mm	2500mm	2500mm								
11	i) Secondary windings Secondary voltage volts Class of accuracy Rated burden (simultaneous) VA (indicative – to be decided as per the site conditions)	<table><tr><td>I</td><td>II</td></tr><tr><td>110 – 110/$\sqrt{3}$</td><td>110 – 110/$\sqrt{3}$</td></tr><tr><td>0.2</td><td>3P</td></tr><tr><td>150</td><td>50</td></tr></table>			I	II	110 – 110/ $\sqrt{3}$	110 – 110/ $\sqrt{3}$	0.2	3P	150	50
I	II											
110 – 110/ $\sqrt{3}$	110 – 110/ $\sqrt{3}$											
0.2	3P											
150	50											

2.8.3 Surge Arrestors (Lightning Arrestors):

Principal parameters:

Sl.No	Particulars	400kV	220kV	132kV	33kV
1	Nominal system voltage (kV rms)	400kV	220kV	132kV	33kV
2	Highest system voltage (kV rms)	420	245	145	36
3	1.2/50 micro second impulse voltage withstand level a) Transformers & Reactors (kVp) b) Other equipment and lines (kVp)	1300 1425	900 1050	550 650	170 170
4	Minimum prospective symmetrical fault current for 1 second at arrestor location (kA rms)	40	40	31.5	25
5	Dynamic over voltage withstand Voltage per unit (kV)/ Duration (Secs)	498/0.03 410/0.1 399/1.0 389/10.0 382/100.0	- 323/0.1 298/1.0 283/10.0 264/100.0 0		

6	System frequency (Hz)	50 ± 2.5			
7	Neutral grounding	Effectively earthed			
Technical requirements of metal oxide (gapless) arrestors					
1	Rated arrester voltage kV	390	216	120	30
2	Maximum continuous operating voltage MCOV (kV rms)	303	184	106	30
3	Installation	Outdoor			
4	Class	Heavy duty station class gapless			
5	Type of construction for 10kA rated arrester	Single column	Single column	Single column	Single column
6	Nominal discharge current corresponding to 8/20 μs wave shape (kA rms)	10	10	10	10
7	Type of mounting	Pedestal			
8	Connection	Phase to earth			
9	Long duration discharge class	3	3	3	3
10	Ratio of switching impulse residual voltage to rated arrester voltage	2	2	2	2
11	Minimum prospective symmetrical fault current for pressure relief unit (kA rms)	40	40	31.5	25
12	a)Terminal connectorsuitable for ACSR conductor size b)Take off	Single moose/ Zebra vertical	Single moose/ Zebra vertical	Single moose/ Zebra vertical	Single panther/ Dog vertical
13	Corona extinction Voltage (kV rms)	Rated voltage of the arrester			
14	Maximum radio interference voltage when energized at MCOV (micro volts)	1000	1000	1000	500
15	Whether insulator base and discharge counter with milli ammeter are required	yes	yes	yes	yes
16	Minimum creepage distance of arrester housing (mm)	10500	6125	3625	900

2.8.4 Isolator Metallic:

Principal parameters:

Sl.No.	Technical Parameters	400 KV	220 KV	132 KV	33 KV
1.	Rated frequency Hz	50 Hz			
2.	System neutral earthing	Effectively earthed			
3.	Number of poles	3			
4.	Temperature rise	As per relevant IS/IEC publication			
5.	Safe duration of over load				
	a) 150% rated current (minutes)	5	5	5	5
	b) 120% rated current (minutes)	30	30	30	30
6.	Rated voltage (kvrms)/highest system voltage (kvrms)	<u>400</u> 420	<u>220</u> 245	<u>132</u> 145	<u>33</u> 36
7.	Type of isolator	Horizontal single break/ Double break			
8.	Rated normal current	To be specified as required. Standard			

		capacities are 800, 1600, 2000, 2500 amps.			
9.	Rated short time withstand current (kArms) of main switch and earth switch for 1 second duration	40	40	31.5	25
10.	Rated dynamic withstand current KA	100	100	78.75	62.5
11.	Basic insulation level i) 1.2/50 micro second lighting impulse withstand voltage (+'ve or -'ve polarity) a) to earth (kvp) b) Across isolating distance (one terminal subject to lightning impulse (kVp) and opposite terminal subjected to power frequency (kvrms) voltage (as per IS) ii) Rated 1 minute power frequency withstand voltage (kvrms) a) Across isolating distance (kvrms) To Earth and between poles (kvrms)	1425 1425 610 520	1050 1200 530 460	650 750 315 275	170 195 95 70
12.	Minimum creep age distance of support and rotating insulator (mm)	10500	6125	3625	70
13.	Phase to phase spacing for installation (mm)	7000	4500	3000	1300
14.	Minimum clearances (mm) a) safety clearance b) live part to ground	2500 6400	2500 4900	2500 3800	2500 2820
15.	Rating of Auxiliary contacts	10 A at 220 V DC with breaking capacity of 2A DC with time constant not less than 20 ms			
16.	Operating type	12 secs or less	12Secs or less	Manual	Manual
17.	Rated Mechanical terminal load	As per relevant standards			
18.	Rated Magnetizing/ capacitive current make/break (A rms)	0.7	0.7	0.7	0.7
19.	RIV at 1 MHz & 1.1 rated phase to earth voltage	1000 micro volts			
20.	Type of insulator	Solid core			

Isolators 132 KV and above shall be a set of three individual poles double break, with one vertical break earthing blade per pole suitable for fixing on either scale of the poles; or without any earthing blade.

Isolators shall be complete with isolator blades (main and earth) supporting solid core insulation for fixed and rotating portion of blades complete base frame, linkages, operating mechanism, central control cabinet with all the devices such as motor, gear drive, auxiliary contacts and necessary terminal blocks. Material of earthing blades and contact shall be same

as that of main blades. Cross sectional area of earthing blades and contacts shall not be less than 50% of cross sectional area of main blades and contacts. Earthing blades shall have the same short time current rating (thermal and dynamic) as that of main blades.

In addition to operating the motor operator operating mechanism, electrically both locally and remotely, it shall be possible to operate mechanism manually for any emergency operation. Interlocks shall be provided to prevent the operation of isolator when the corresponding circuit breaker is “ON”. Earth switches also shall be manually operated by separate operating mechanism. Interlocks shall also be provided between earth switch and main switch to prevent the operation of earth switch when main switch is “ON”.

The operating mechanism shall be suitable to hold the isolator in close or open position and prevent operation by gravity, wind, short circuit forces, seismic forces, vibration, shock, accidental touching etc., 33 KV isolators shall be set of three individual poles double break, shall be complete with isolator blades (main) supporting solid core insulators for fixing and rotating portion of the blades, complete base frame, linkages, operating mechanism complete etc.

General requirement of Solid Core Insulators:

Description	400 KV	220 KV	132 KV	33 KV
No. of insulator units per stack	3	2	1	1
Height of each basic unit (mm)	1330+1330+1990	1150	1500 ± 2.5	508 ± 1
Total height of stack (mm)	3650± 2.5mm	2300 ± 3.5	1500 ± 2.5	508 ± 1
Pitch circle diameter	8 nos. 18mm dia holes on the base and 4 nos. 16mm dia holes on the top	4 nos. holes of 18 mm dia on the base and top suitable for 16 mm tapped for each unit	4 nos. holes of 18 mm dia on the base and top suitable for 16 mm tapped for each unit	4 nos. Holes tapped 12 mm
Top (mm)	127	127	127	76
Bottom (mm)	300	200	184	76
Total creep age distance mm	10500	6125	3625	900
Mechanical strength required minimum				
Canti lever (kN)	800 kg	6	6	6
Tension (kN)		110	80	40
Torsion (kN – M)	600 kg	4.5	4.5	2.5
Compression (kN)		220	160	90

Operating mechanism shall be equipped with manual operating device. It shall be possible to padlock manual operating handle both in open and close positions. Where ever gang operated, the operating mechanism shall be suitable for operation of all three poles simultaneously. The rated continuous current rating of isolators can be selected from the rating of equipment/or load on the line.

2.8.5 Control Cables: Cables can be PVC insulated and sheathed and either armored or unarmored for use on AC single phase or three phase (earthed or unearthed) systems of rated voltage up to and including 1100 V or DC systems of rated voltages up to 1500 V to earth, for operation in different Substations. Standard sizes of control cables are

2 core	1.5/2.5/4.0 sq.mm
4 core	1.5/2.5/4.0 sq.mm
6 core	1.5/2.5/4.0 sq.mm
10 core	1.5/2.5 sq.mm
12 core	1.5/2.5 sq.mm
14 core	1.5/2.5 sq.mm
19 core	1.5/2.5 sq.mm

Principal parameters: General purpose insulation cables shall be suitable for use where the combination of ambient temperature and temperature rise due to load results in conductor temperature not exceeding 70 deg. C for normal continuous operation and 160 deg. C for short circuit condition

The cables are normally buried directly underground, under dry or wet conditions. Suitable additives to prevent attack by rodents, termites shall be added to the outer sheath PVC compound. The outer sheath shall be so designed as to afford high degree of mechanical protection besides being resistant to heat, oils, chemicals, abrasion, weather conditions etc. Common acids, alkalis, contaminants, saline solutions etc. shall not have adverse effects on the PVC sheathing material.

The cables shall be capable of operating continuously under the system frequency variation of + or – 5%; voltage variation of + or – 10% and a combined frequency and voltage variation of + or – 10%. Stranded wires shall be preferred over single wire for conductor in each core. The wire in the conductor shall have the same nominal diameter before stranding. The number of wires in the conductor shall be not less than 3. Cores shall be identified by different colouring of PVC insulation.

Eg.	a)	2 cores	:	Red and Black
	b)	4 cores	:	Red, Yellow, Blue and Black
	c)	6 cores and above	:	Two adjacent cores in each layer blue and yellow, remaining cores gray

By numbers, in which case the insulation of all the cores shall be of same colour and numbered sequentially, starting with number 1 for the inner layer. The number shall be legible.

2.8.6 Battery&Batterycharger with DC Distribution Board (DCDB):

Battery for control and protection in a substation is normally flooded lead acid (conventional) type or Valve Regulated Lead Acid (VRLA) sealed maintenance free type.

The Battery shall be of 220 volts DC for indoor installation, for providing DC Supply to control, protection and other DC auxiliary power circuits in EHV substations. The batteries shall be capable of withstanding large discharge currents for operating various equipment.

The battery bank shall be complete with supporting teak wood stand and with all accessories including electrolyte, distilled water jars and trays, separators, cell insulators, spray arrestors, bolts and nuts, inter cell, inter row and inter bank connectors.

Principal parameters:

Description	220 V 400 AH	220 V 200 AH	220 V 80 AH
No. of cells per bank	110	110	110
Nominal voltage of each cell	2 volts	2 volts	2 volts
Nominal voltage of completed Bank (volts)	220	220	220
Type of plates in each cell	Tubular plate positive and pasted negative plates		
Capacity of batteries (in Amp. Hours at 10 hours rate to an end voltage of 1.85 V per cell)	400 AH At 27°C	200 AH At 27°C	80 AH At 27°C
Cell dimensions and designations in accordance with the standard	To be furnished by the supplier		
Proposed method of working	Float and Boost charge		
Arrangement system for the batteries	To be arranged in double row and double tier system.		

The battery shall be capable of operating satisfactorily (at reduced capacities) between 5°C to 50°C and in locations where the relative humidity varies between 12% and 100%.

The cell voltage shall not exceed 2.25 V with a continuous low rate floating charge and shall not be less than 1.85 volts at the end of emergency discharge.

The battery shall be operated without an intentional ground. For indicating the incidence and degree of a ground fault on the DC control circuitry, the mid point of the battery shall be earthed through an ammeter of high resistance. The resistance shall be so proportional that the current flowing under the worst earth fault shall not exceed 250 mA.

2.8.6.1 Battery charges and DC distributions Boards: Battery chargers comprise separate float and boost chargers suitable for 220 V of appropriate AH capacity conventional indoor type lead acid batteries, with DC distribution Boards.

Principal Parameters:

Sl. No.	Item	Specification
1.	Type of installation	Indoor
2.	AC voltage	3 phase 415 V + 10% to – 15% (for 220 V batteries)
3.	Frequency	50 Hz ± 5%

4.	Regulation	$\pm 1\%$
5.	Ripple content	Not more than 2%

2.8.6.2 Float Charger: Shall operate on 3 phase 415 volts supply, shall be capable of trickle charging the battery at about 2.15 volts per cell and simultaneously supplying a constant load in amps at 10% of the battery rating in an average ambient temperature of 50°C. Charger shall be provided with a regulator to facilitate controlling the cell voltage and to stabilize the output voltage within + or - 1% of the set DC value; for AC main supply voltage variation of +10 to - 15% and frequency variation of + or -5% and DC load variation of 0-100% and also when all the three variations occur simultaneously.

Float chargers shall be provided with automatic current limiting facility, such that when float charger output current exceeds 10% above the rated current, the float charger voltage should be brought down automatically so that the output current does not exceed the set value.

Float charger shall be of 3 phase full wave semi controlled thyristor bridge rectifier type with automatic voltage regulator unit and with necessary printed circuit Boards, transformers and relays etc.

2.8.6.3 Boost charger: Shall operate on 3 phase 415 volts supply, shall be capable of boost charging the battery up to a maximum cell voltage of 2.7 volts at a maximum charging current of 16A in a maximum ambient temperature of 50°C shall be capable of boost charging the battery from fully discharged condition to fully charged condition within 14 hours.

1 No. silicon blocking diode connected to 84th cell and DC positive bus to maintain continuity of DC supply to the DC bus in the event of AC failure while boost charger is in service and to avoid short circuit of 110th cell (last cell) positive and 84th cell positive. DC contactor of suitable rating for connecting 110th cell of the positive DC bus, inter locked with AC contactor provided in the boost charger.

The chargers shall have built in automatic voltage control and load limiting features. The voltage regulator shall automatically sense, monitor and regulate the DC voltage to within +1% of the set value from no load to full load and under AC input supply voltage and frequency fluctuations. Load limiting features shall automatically reduce the output voltage of the charger on loads more than the rated load.

The ripple content of the charger DC output shall not exceed 2% when the battery is not connected.

2.8.6.4 The DC Distribution Board shall be provided with 2 nos. bus bars made out of electrolytic copper of adequate capacity duly tinned, supported by bus bar supporters. These bus bars will be connected to 220 V DC 2 wire system consisting of 220 V battery or charger rated for 220 V DC output. The DC Distribution Board is meant to feed control circuits and other auxiliary DC equipment at the substation.

DC Distribution Board shall be provided with a double pole rotary switch for incoming DC supply and double pole ON/OFF rotary switches with required ratings for controls along with suitable HRC fuses with fittings for the rotary switches.

2.8.7 HT Electronic Meters:

Principal Parameters:

i)	Measurement Elements	Shall be 110 V AC, 50 Hz, 3 Phase 4 wire which can also be configured for use on a 3 phase 3 wire as well as 2 phase 2 wire (traction) system without affecting metering accuracy and other essential parameters.
ii)	Operating parameters for balanced/unbalanced loads a) operating voltage range b) operating frequency range c) operating power factor range	110 Volts AC (+20% - 30%) 50 Hz (+/- 5%) Zero lag – unity – Zero load
iii)	a) Operating current b) Minimum starting current	1 Amp basic (I _b), 120% I _b (Maximum) 0.1% I _b
iv)	Burden/Power Consumption	
v)	Accuracy class Active Energy Reactive Energy	To be specified.
vi)	Meterological	Full four quadrant measurement to IEC 687 class 0.2S and as per IEC 1268 (reactive) which implies 0.5S accuracy for reactive measurement
vii)	Type of installation	Indoor/outdoor
viii)	System of earthing	Solidly grounded
ix)	Energy measurement	Fundamental energy (rms values)
x)	Minimum requirements for display	Following real time parameters shall be available locally on the meter display. The energy meter Sl.No. shall be transmitted along with real time data. User shall be able to select locally (through optical port using CMRI) any combination or all of these parameters in the sequence mentioned below. 1) Energy meter Sl.No. 2) KW import 3) KW Export 4) KVAR lead 5) KVAR lag 6) R,Y,B phases voltages 7) R,Y,B phases current 8) Frequency 9) Average power factor 10) kWh import 11) kWh export 12) KVARH lag 13) KVARH lead 14) Demand 15) Date as per Indian Calendar (dd-mm-yyyy) 16) Real time in 24 Hrs format (Hrs-Mins-Secs)
xi)	Minimum requirements for data logging	Meter shall be base configured to log any combination or all of the parameters listed above. The meter shall be base configurable to log any or all combinations of pre defined sequence of the parameters listed above.

		The user shall be able to select those parameters and retrieve the logged data through optical port using common meter reading instrument (CMRI) as well as remotely over a galvanically isolated TIA/EIA – 485 communication port connected to remote server or local PC. The meter shall support open based access protocol (IEC 62056) using the RS-485 port for the remote access of data from billing centre or local dispatch centre over departmental communication network consisting of VSAT/MW/OFC or BSNL leads. The PC based software shall dynamically interact with the energy meters periodically (user defined anywhere from 10 Secs to 1 Sec) and download meter data over communication channel on to 7/PC. The design of meter shall ensure free operations and data access when similar multiple meters are connected in a loop area with a multi port communication protocol. The meters shall have sufficient memory to store at least eight (8) user selected survey parameters with 15 minutes inter action period and minimum 40 days storage data. Tentative (8) load survey parameters for storage are (i) KW export (ii) KW import (iii) KVA export (iv) KVA import (v)KVAR lead while KW export (vi) KVAR lead while KW import (vii) KVAR lag while KW export (viii) KVAR lag while KW import. The meter shall be MRI compatible and record the parameters on tri-vector mode in addition to ABT parameters and PRN format shall be compatible to energy billing centre data base. Each meter shall store the values of active energy (import), active energy (export), reactive energy lag and reactive energy lead separately at 24 hrs on last day of the month for a period of at least 12 months.
xii)	Logging period for parameters	Logging period shall be 15 minutes. The user shall be able to program the logging period for individual parameters from 1 minute to 60 minutes in 1 minute steps.
xiii)	Data storage	Data to be stored in a non volatile memory with a minimum retention period of 12 years.
xiv)	Pulse outputs	Type High intensity LED which can be utilized for test/accuracy check of KWh and KVARh measurements. No. of outputs per metering point - 1
xv)	Calendar	30 year calendar with automation leap year adjustment
xvi)	Data security	i) Message authentication algorithm capability ii) Independent security across communication channels

		iii) Encryption capability iv) mechanical seals and locks (sealing provision for terminal block, meter cover and communication ports)
xvii)	Indications	i) VT & CT equipment failure ii) Meter fault (self diagnosis) iii) Detection of abnormalities like missing potential, current and voltage unbalances, (magnitude as well as phase unbalances) phase sequence reversal, CT shorting (by-passing) display.
xviii)	Communications	For local communication one (1) optically isolated communication port (IR port) For remote communications – one (1) RS485 port
xix)	Display	Alpha – Numeric LCD with bright backlight. Automatic back light time out after 1 minute.
xx)	Software	The supply, software installation and testing of the following software is to be considered. i) To download the meter data with CMRI and ii) To retrieve the CMRI data or RS-485 data to a base computer and convert this data into standard ASCII format. iii) To retrieve the meter data over departmental captive communication network by a server located at the central station iv) The software shall be in the form of CD. Any further upgrades (licence copy) of software/protocol shall be made available free of cost. All of the parameters available in the register of the meter shall be user selectable (through optical port and RS-485).

The meter casing shall be of poly carbonate material to ensure higher reliability and longer life. Shall be resistant to vibration and shocks in normal transportation and shall withstand severe stresses likely to occur in actual service.

The Maximum Demand (MD) shall be monitored during each demand interval set with 15 minutes integration and the maximum of those in a month shall be stored. Whenever, MD is reset, the MD value so registered shall be stored along with data and time under the current integration period, the rising demand should be displayed continuously along with elapsed time. The registered demand and the number of times the MD is reset, shall also be displayed and the information stored.

MD Reset: The meter shall have provision for maximum demand resetting (a) Manually by operation of a button which is to be covered and sealing provision available for such a cover (b) Resetting shall also be possible through a hand held common meter reading instrument (CMRI). (c) provision for automatic resetting at the end of certain period and to allow to invoke this through CMRI with date and time.

Time of Day Tariff/Demand: Provisions in the meter shall be available for multi tariff metering (time of day metering/demand). Meter shall have a real time clock based on a

quartz crystal with a battery; independent of power supply. Meter shall be capable of being set into minimum of 8 time zones in 24 hours cycle to cover morning and evening on and off peak periods separately. TOD register shall be provided for active energy, reactive energy (lag & lead) and demand data.

Immunity to Electro Magnetic Disturbance: The meter design shall be such that conducted or radiated electro magnetic disturbance as well as electro static discharge do not damage or substantially influence the meter.

Tamper and fraud protection: The meter shall have features to prevent/detect common ways of tamper and fraud.

- a) Phase sequence reversal: meter shall work accurately irrespective of supply phase sequence.
- b) CT shorting/by passing: Meter shall be capable of recording shorting/by passing of any phase with time and duration.
- c) CT Polarity reversal: Meter shall register energy consumption correctly, even when the CT polarities are reversed; with provision to record date and time and total number of such occurrences for all phases during the above period.
- d) Missing potential, meter shall be capable of recording occurrences of missing potential phase wise, either due to a PT fuse blowing off or due to internal disconnection of a potential load and its registration with date and time along with total number of such occurrences, during the above period.
- e) Missing neutral: Meter shall continue to record accurately even if neutral of PT supply is disconnected.
- f) External Magnetic Influence: Meters shall not get influenced by any external permanent/electro magnets. The meter shall also be tested with the value of magneto motive force (mmf) applied for the meter as per the stipulation of CBIP report No.88 red with amendments April 99, September 99, and February 2002 for static Electronic Energy meters.

Tamper information: Minimum 50 events (occurrences and restoration) with date and time of event shall be recorded. The information shall be logged on first in first out basis and total number of tamper events during the period. All those information shall be available in simple and easily understandable format.

2.8.8 Control and Relay panels:

Principal parameters:

2.8.8.1 Transformer HV & LV control & relay panels: Following technical details of power transformers, current transformers and circuit breakers proposed on HV & LV sides shall be specified.

(a) Rated MVA (b) Voltage ratio (c) vector group (d) type of cooling (e) percentage impedance (f) over fluxing (g) Tapping range (h) fault levels on HV side and on LV side (i) CT ratios (j) No. of cores, accuracy class, burden and minimum knee point voltage (k) Circuit breakers – No. of poles; control voltage DC. Rating of close & trip coils. Break and make time in milliseconds. Minimum reclosing time.

2.8.8.2 Feeder control & Relay Panels: Technical details of feeder current transformers (details as given above for transformers) shall be specified. In addition, details of voltage transformers (VTs & CVTs) such as ratio, accuracy class, burden & no of windings and their purpose shall be specified.

2.8.8.3 Bus bar protection panels: Technical details such as over all CT ratio for bus bar protection, Number of cores and their ratios exclusively provided for bus bar protection, Bus coupler CT ratios and Type of bus bar arrangement shall be furnished.

2.8.8.4 Description of control & Relay Panels: Panels shall be simplex type with equipment mounted on the front of panel and having wiring access from the rear

Control & Relay panels shall be compatible to IEC-61850 protocol to facilitate up gradation to automation. The panel shall be vermin proof. Cable entry to the panels shall be from bottom through cable glands.

Dimensions of panel shall be uniform to present an aesthetic look. Standard dimensions adopted are 2250 mm height & 800 mm depth. Wiring of various equipment on in panel shall be with 1100 V grade, since core, stranded copper conductor wire with PVC insulation and shall be heat resistant grade and vermin and rodent proof. The minimum sizes shall be as follows:

- i) All circuits except CT circuits with are min stand 1.5 sqmm conductor.
- ii) CT circuit one 2.5 sqmm conductor

Mounting, panel internal wiring, terminal blocks and their arrangements, painting, mimic diagram, Name Plate and markings, Panel lighting and additional plug sockets and their location in the panel, earthing arrangements for the panel etc shall be specified. Various indicating instruments (voltmeter, Ammeter, MVAR meter, frequency meter, power factor meter) mounted on the panel shall be digital type; of 96 sqmm size; suitable for flush mounting. Instruments shall conform to IS: 1248 and shall have accuracy class of 1.0 or better. The design of the scale shall be such that it can read to a resolution corresponding to 50% of the accuracy class index.

Ammeters and current coils of watt and VAR meters shall continuously with stand 120% rated current and 10 times rated current for 0.5 sec without loss of accuracy. Voltmeters and potential coils of wattmeter & VAR meters shall with stand 120% of rated voltage for 0.5 Secs without loss of accuracy. Energy meters shall be static type (Refer to electronic meters specification – Technical requirements).

2.8.8.5 Relays: All relays shall conform to IS: 3231 or other applicable standards. Relays shall be flush or semi flush mounted on the front of panel. All protective relays shall be drawn out or plug in type/modular cases with proper testing facilities. Type of test facilities to be provided shall ensure testing of the relay, without the need to switch off the equipment/line protected.

All AC relays shall be suitable for operation at 50 Hz. AC voltage relays shall be suitable for 110 VT secondaries(phase to phase) and current operated relays for 1 Amp CT secondaries. DC auxiliary relays and timers shall be designed for 220 V DC and shall operate satisfactorily between 70% to 110% of rated voltage.

All protective relays shall be provided with at least two pairs of potential free isolated output contacts. All protective relays, auxiliary relays and timers except the lock out relays and inter locking relays specified, shall be provided with self reset type contacts. All protective relays and timers shall be provided with externally hand reset positive action operation indicators, provided with inscription as specified. Timers shall be electro magnetic or solid static type.

The static/digital relays shall meet the following requirement

- i. The printed circuit Boards (PCBs) shall be of fibre glass type and the contact shall be gold plated. All connections with the connector pegs shall be through wire wrapping. All solder joints on the printer circuit Boards shall be encapsulated or covered with varnish.
- ii. The components shall be rated to carry at least twice the normal expected loads. The resistors shall be of carbon composition or metal oxide type and the capacitors shall be plastic film or tantalum type. Relays shall be immune to voltage spikes. The relays must withstand the requirements of IEC 255-4 appendix E Class-III regarding HF disturbance tests, IEC-255-4 regarding impulse test at 5 KV and fast transient tests as per IEC: 801-4. Insulation barriers shall be provided to ensure that the transients present in CT and VT connections due to extraneous sources do not cause damage to static circuits.
- iii. DC to DC converter shall be provided in the protective relay whenever necessary in order to provide a stable auxiliary supply for relay operation. The relays shall be stable and stability protected against transient/induced over voltages and noise signals.

All equipments shall be of modular construction and the modules and sub units shall be of plug in type for easy replacement. The design shall permit fast recognition of defects and facilitate easy repair.

2.8.8.6 Annunciation system:

- a) annunciation system shall be provided on the control panel by means of visual indication and audible alarm to alert the operator to any abnormal condition/operation of protective devices. Annunciation scheme shall operate on 220 Volts DC.
- b) Visual annunciation shall be provided by a facia, flush mounted on the front of panel. The audible alarm shall be provided by two distinct buzzers/bells, one for trip and the other for non trip.
- c) Annunciation facia shall be provided separate for trip and non-trip circuits.
- d) Push buttons for acknowledging, resetting and testing the alarm and visual annunciation facia shall be provided on the panel.

Visual and audible annunciation for failure of DC supply to the annunciation system shall be provided. Annunciation shall operate on 240 V AC supply with separate fuses. On AC supply failure to the annunciation system for more than 3 seconds (adjustable setting) an indicating lamp and non trip alarms) shall sound. A separate push button for cancellation of this alarm alone shall be provided. Lamp shall remain lighted till the supply to the annunciation system is restored.

Position Indicators: Semaphore type position indicators shall be provided as part of the mimic diagrams on panels for indicating the position of circuit breakers, isolators/earth switches etc. The indicator shall be suitable for semi flush mounting with only the front disc projecting out and with the terminal connection for the rear. Their strips shall be of the same colour as the associated mimic.

Position indicators shall be suitable for either AC or DC operation (to be specified). When supervised object is in the closed position, the pointer of the indicator shall take up a positioning line with the mimic bus bars and at right angles to them when the object is in open position. When supply to the indicator fails, pointer shall take over intermediate position to indicate supply failure.

2.8.8.7 Synchronizing equipments: On EHV feeder control panels 1 No. synchronizing switch and 1 No. 12 pin synchronizing socket is to be provided (when ever required).

2.8.8.8 Trip circuit supervision relays: The scheme shall continuously monitor each trip coil in pre-close and after close of the breaker. The scheme shall detect

- i) Failure of DC supply to each trip coil
- ii) Open circuit of trip circuit wiring and
- iii) Failure of mechanism to complete tripping operation.

Two not indicating lamps to act in conjunction with trip circuit supervision relays for healthy trip indications of two sets of trip coils shall be provided.

2.8.8.9 High Speed Tripping relay: shall be DC operated and instantaneous (operating time not to exceed 10 Milli seconds). Shall have adequate hand resetting type contacts, preferably operated by push button. The resetting time shall be with in 20 milliseconds for self resetting relays.

Flag relays shall have: Hand reset flag indication and shall have necessary NO/NC contacts for each element/coil to meet scheme requirements.

2.8.8.10 Detailed Description of various protective relays: All the relays shall be numeric type unless otherwise specified.

(a) Transformer differential relay: Shall be rated for 1 ampere, triple pole high speed percentage biased differential type suitable for two/three windings as required. The relay shall

- i. have an operating time not more than 30 milliseconds at 5 times operating current setting of 20%.
- ii. have three instantaneous high set over current units.
- iii. have second harmonic restraint feature and fifth harmonic bypass/restraint feature and be stable under normal over fluxing conditions.
- iv. have an operating current setting of 20% or less
- v. have adjustable bias setting range of 20% to 50% and have two bias windings per phase
- vi. be stable for heavy through fault

- vii. include necessary separate inter posing CTs for angle and ratio correction or have internal features in the relay to take care of angle and ratio correction.

(b) Over fluxing relay: shall operate on the principle of voltage to frequency ratio and shall have inverse time characteristics compatible to transformer over fluxing withstand capability. The ratio shall be adjustable between 100 to 125 % of rated value and time delay continuously adjustable between 0.5 to 60 seconds. Tripping time shall be governed by V/F vs. time characteristic of the relay

Maximum operating time for the relay shall not exceed 3 and 1.5 seconds at V/F values of 1.4 and 1.5 times rated value, respectively. Relays may be provided on both HV and LV sides of the transformer of 220 KV voltage class and above. For 132 KV class and below the relay may be provided on HV side.

(c) Backup over current and earth fault relays on HV side: Triple pole non-directional Inverse Definite Minimum Time (IDMT) over current relay with instantaneous high set unit shall be provided for backup over current protection on the HV side. For faults on HV side involving heavy fault currents the high set units shall clear the fault instantaneously.

Directional IDMT earth fault relay with high set instantaneous unit with suitable settings shall be provided for back up protection on HV side. The over current and earth fault relays in addition to the above shall have self supervision, event recorder and disturbance recorder.

(d) Backup over current and earth fault relays on LV side: Triple pole non-directional IDMT over current relay with instantaneous high set and single pole non-directional IDMT earth faulty relay with instantaneous high set shall be provided for backup over current and earth fault protection on LV Side of the transformer. Separate high speed time relay shall be provided for LV protection.

(e) Auxiliary relays for transformer protection devices: Auxiliary relays required for bucholtz trip, OLTC surge relay trip, HV winding temperature trip, LV winding temperature trip, oil temperature trip, low oil level trip and pressure Relief valve (PRV) trip shall be provided. Each auxiliary relay shall have two pairs of contacts and one hand reset flag indicators.

(f) Local breaker backup protection relay: This scheme shall comprise of a breaker failure initiating relay associated with transformer protection schemes, a breaker failure relay which supervises the fault current flowing through the breaker being protected against failure and breaker failure time delay relay and breaker failure lock out relay.

The operation of both breaker failure initiating relay and breaker failure relay will initiate timer relay which in turn operates lock out relay. The lock out relay will have N/O contacts for annunciation and energization of bus bar protection trip relays (available in bus bar protection panels) for tripping all the breakers connected to the bus.

Breaker failure relay scheme shall be numeric with two over current and one earth fault elements, suitable for operation on 220 volts DC. The relay shall have an operating time of less than 15 milliseconds and a resetting time of less than 15 milliseconds. Shall have a setting range of 20% to 320% of rated current for over current and 20% to 80% for earth

fault. The relay shall have separate in-built timer with a continuously adjustable setting range of 0.1 to 1 sec on pick up.

(g) Inter Tripping Relays: Inter tripping relay to trip HV & LV breakers of the transformer to isolate the transformer from supply shall be provided. The inter trip relay shall be a high speed one and shall be provided with hand reset operation indicator and required no. of hand reset contacts.

(h) Under voltage relays for power transformers: The relay shall be suitable for operation on 110 volts AC and shall have a setting of 60% to 90% of nominal voltage in steps of 5%. The relay shall have 4 pairs of self reset contact (N/C contact).

Under voltage relay shall have provision to bypass the inter locking if any provided in the tap changer for the purpose of controlling the voltages

(i) Under frequency Relay scheme: shall consist of one number under frequency relay with df/dt feature, one no. timer relay and one no. trip relay with 6 N/O contacts hand resettable type. The relay shall be suitable for operation with 110 volts AC and 220 V DC supply. The relay shall have continuously adjustable setting range of 47 Hz to 50 Hz with an accuracy of 0.1 to 10 Hz per second in steps of 0.1 Hz/second. Relay shall not mal operate due to any abrupt change in supply voltage from VT secondary.

Each frequency relay shall have a timer relay with a range of 0.1 to 0.5 seconds and have 4 N/O contacts. One N/O contact will be connected to energize trip relay. The other 3 N/O contacts will be utilized for tripping the feeders directly. The trip relay shall have hand reset type 6 N/O contact for tripping 6 Nos. feeders.

(j) Bus Bar protection schemes: Depending on the type of bus-bar arrangement in the substation, single / two zone bus bar protection scheme may be provided. Size of the bus-bar protection scheme shall take into consideration possible extensions of transformer/ feeder bays in the substation in addition to the existing bays.

In a double bus arrangement each circuit (transformer/ feeder) can be connected to either bus I or bus II by means of isolators provided on each bus. All the equipment like individual tripping relays for all circuits (including bus coupler) and CT zone switching relays and auxiliary CTs for outgoing circuits(if required) shall be provided. Each trip relay shall have necessary N/O and N/C contacts as required. It should have built in feature of breaker failure protection and should also be possible to selectively enable/disable breaker failure function for each feeder.

The CT ratios and core details for bus bar protection of all circuits, including bus coupler shall be furnished so as to select a bus bar protection relay suitable for operation with main CTs having unequal magnetizing characteristics and unequal secondary resistance and unequal ratios. Based on the identical turns ratio of main CTs, no. of auxiliary CTs required if any to take care of mismatch of main CT ratios, for the bus bar protection scheme shall be provided separately. In a numerical bus bar protection scheme CT ratio correction is done through software without use of any external ICTs. Hence there is no need for auxiliary CTs. Zone CT selection shall be done through isolator replica without usage of external CT switching relays.

Bus bar protection shall be based on circulating current principle and shall not be affected by CT saturation in case of internal faults. The schemes shall remain insensitive to CT saturation during external faults

Bus bar protection features:

- i) Numeric, fast acting with operating time of less than one cycle
- ii) Triple pole type
- iii) Individual independent zone protection relay for each bus of the two zones
- iv) Each zone of bus bar protection with a check feature operating on different principle or independent additional check features common to all zones
- v) Detect both phase and earth faults
- vi) Sensitive for internal faults and stable for external faults with currents up to the short circuit ratings of switch gear, CT saturation, permissible CT errors, normal load flow and growing fault level.
- vii) Shall operate selectively for each zone of faults and trips the minimum number of circuits but all ensure isolation of fault completely and reliably.
- viii) The bus bar protection shall give clear zone indication and give visual and audible alarm. Necessary alarm and annunciation scheme shall be provided.
- ix) The protection scheme shall have continuous supervision for each zone over the various CT secondary pilot wires; so that in the event of open circuit, short circuit and crossed bus wires in the pilots, the relevant zone of protection shall be shorted and appropriate alarm initiated. The CT secondary circuit shall have sensitivity to detect open circuit of CT secondary of the least loaded circuit.
- x) Bus Bar protection scheme shall include continuous supervision of DC auxiliary supply and shall give necessary visual indication and alarm for DC fail
- xi) The scheme shall have built in automatic test facility.
- xii) Individual tripping relays for each breaker shall be provided.

(k) 220 kV line Protection:

The line protection relays are required to protect the line and clear the faults on line within shortest possible time with reliability, selectivity and full sensitivity to all type of faults on lines. The general concept is to have primary and back up protection having equal performance requirement except in respect of time of operation of basic relay without carrier facilities as provided by two main protections called Main-I and Main-II. Main I and Main II protection should not be duplicated.

The maximum fault current could be as high as 40 kA near power station but the minimum fault current could be as low as 20% of rated current.

The characteristics of starting and measuring relays shall be such that they work satisfactorily under these extremely varying conditions.

The protective relays shall be suitable for use with capacitor voltage transformers having non-electronic damping and transient response as per IEC/IS 3156. There shall be no additional delay

in relay operating time created intentionally to have stable operation. The power supply unit if provided as an integral part of relay scheme shall be fully rated with liberal design in capacity.

The DC supply for the relay shall be from DC/DC converters and these shall be amply and fully rated for all operating conditions in service. These DC/DC converters should be adequately rated and shall be suitable for operation from 180 V to 260 V DC.

Insulation barriers shall be provided to ensure that transients present in CT & VT connections due to extraneous sources do not cause damage to static circuits. The circuits must comply with IEC recommendation for impulse withstand values. The equipment shall also be protected against voltage spikes occurring in Aux. DC supply.

Main-I and Main-II protections for 220 kV and 400kV feeders are described hereunder

Main-I: Numerical distance protection shall be non switched type suitable for use with permissive under reach and over reach transfer tripping. The Relay shall have continuous self monitoring and diagnostic feature.

Main-II: Numerical distance protection. Main-I and Main-II protective relays shall not be duplicated.

Main I Protection :

The scheme shall have input transformation modules, analogue and digital filters, processing units A/D and D/A converters, DC supply modules etc. The sampling rate of analogue inputs, the processing speed and processing cycle of digital values shall be selected so as to achieve the operating time specified. Display on demand of various measured parameters, alarms, clock, relay identification, settings etc. during normal as well as fault conditions on individual phase basis shall be provided.

The offered scheme shall have continuous self monitoring and cyclical test facilities. The clock of this system shall be synchronized through time synchronizing system wherever it is available.

The system shall include MMI (Man Machine Interface) and serial/parallel ports for remote communication for each protective relay. MMI shall have facilities for setting alteration, display of all settings, scheme logics and any other requirements as per the software and hardware configuration of the system other than the menu driven alarms. Visual indication shall be provided for major trip alarms like phase and zone of operation. Power swing blocking/trip, Switch On To Fault(SOTF), Auto Reclose block etc.Carrier aided protection scheme, and all the relays, devices etc., shall be provided.

Distance protection scheme shall:

- Be modular in construction with high speed non switched distance relays for 3 phase systems to clear all types of line faults with in the set reach of the relay. Have 6 non switched measuring elements for each zone of protection (3 for phase to phase faults and 3 for phase to earth faults).
- The basic scheme (without considering carrier protection features) shall have Zone-I operating time up to trip impulse to breaker (complete protection time including the trip relay operating time) of not more than 40 Milli Seconds.

- Operate on carrier blocking principle and or carrier inter trip (with facility to change over to carrier inter trip at site)
- Suitable shaped characteristic to prevent relay operation during maximum load conditions without reducing the reach of relays.
- Shall be suitable for operation with either bus PT or line CVT supply. Quick change over facility for changing over of potential supply from line VT to bus PT or vice versa shall be provided.
- Have two independent continuously variable time setting range of 0-3 seconds for Zone-2 & 0-5 seconds for Zone-3. The measuring relay shall have wide setting ranges and the reach of relay for Zones 1, 2, and 3 should be able to cover line lengths of 0.5 KM to 200 KM.
- Have a maximum resetting time of less than 35 milli seconds.
- Have residual compensation with suitable variable setting range.
- The setting/reach should not be affected by mutual coupling effect of D/C line or nearby parallel circuits.
- Operate instantaneously when circuit breaker is closed to Zero-volt 3 phase fault.
- Be suitable for single and three phase tripping
- Have a continuous current rating of two times rated current. The voltage circuit shall be capable of operation at 1.2 times rated voltage. The relay shall also be capable of carrying a high short time current of 70 times rated current without damage during a period of 1 sec.
- Be selective between internal and external faults
- Incorporate three high speed trip relays for single phase faults and a fourth high speed trip relay for multi-phase faults. Each of these trip relays shall have adequate contacts to meet the complete scheme requirement. These trip relays shall be self reset type.
- Include power swing blocking protection which shall
 - i. be of triple pole type
 - ii. have suitable setting range to encircle the distance protection described above
 - iii. have a continuously adjustable time delay on pick up of setting range 0-2 seconds.
 - iv. block tripping during power swing condition
 - v. be possible to select the power swing blocking in zone 1,2 or 3 or any combination of zones

- Include fuse failure protection which shall
 - Monitor all the three fuses of CVT and PT and associated cable against open circuit
 - inhibit trip circuits on operation and initiate annunciation
 - have an operating time less than 7 milli seconds
 - remain inoperative for system earth faults
 - have sufficient no. of contacts one for alarm and others for blocking the tripping.
- Suitable no. of potential free contacts (if required multiplied through reed relays only) be provided on each distance scheme for carrier tripping, auto re-closing, fault locator, disturbances recorder, and data acquisition system.

Open circuit protection:

Necessary protection relays for detecting single phase/2 phase open circuiting of feeders and to trip the feeder circuit breaker shall be provided, either separately or as a built in feature of Main-I & Main-II protection schemes.

Auto re-closing relays shall be either included in Main I and Main II as a built-in feature or provided separately, but shall be available for Main I and Main II relays even if one of them is not in operation.

- i. Have single phase and three phase re-closing facilities
- ii. Have a continuously variable single / three phase dead time of 0.5 to 5 seconds
- iii. Have facilities for selecting check synchronizing or dead line charging features. It shall be possible at any time to change the required feature by reconnection of links.

(a) Include check synchronizing relay which shall

- i. Have a time setting variable between 0.5 to 5 seconds.
- ii. have a response time within 200 milli seconds with the timer disconnected
- iii. have a phase angle setting not exceeding 35 deg.
- iv. have voltage difference setting not exceeding 10%

(b) Include dead line charging relay which shall

- have two sets of relays and each set shall be able to monitor the three phase voltage.
- have one set connected to the line CVTs with a fixed setting of 20% of rated voltage

- have one set connected to the bus VTs with a fixed setting of 60% of rated voltage
- incorporate necessary auxiliary relays and timers to give comprehensive scheme
- (c) Incorporate a separate pole discrepancy relay with timing range of 0.1 to 1 sec
- (d) Auto reclosure of the line shall take place only when fault is cleared in first zone by the main protection.
- iv. Incorporate auto re-closure lockout relays to prohibit auto re-closure under the following conditions
 - a. tripping due to operation of bus bar protection
 - b. tripping immediately after the manual closer of line breaker
 - c. tripping for faults in second and 3rd zone as backup
 - i. when tripping takes place after a power swing condition
 - ii. in the event of trip on pole discrepancy
 - iii. when carrier is out of service.

Local breaker backup protection scheme: This scheme shall comprise of a breaker failure initiating relay associated with each protective system viz., Main-I and Main-II, breaker failure relay which supervises the fault current flowing through the breaker being protected against failure and breaker failure time delay relay and breaker failure lockout relay.

Details of the relay are described earlier.

Distance to Fault Locator: shall be electronic or microprocessor based, online type suitable for breaker operating time of 2 cycles i.e. measurement time for fault locator shall not exceed 2 cycles (40 ms), with built in test facility. The relay shall display in percent of line length or kilometers without requiring any further calculations. Shall have an accuracy of 3% or better under all conditions including presence of remote end feed, predominant DC component in fault current, high fault arc resistance and severe CVT transients.

The relay shall have facility for remote data transmission. The following information shall be provided by the relay by means of printer/equivalent device

- Nature of fault and phases in which fault is involved
- distance to fault in terms of line length
- magnitudes of pre-fault currents and voltages and magnitude of fault currents and voltages for further analysis

Main II protection: shall be provided with fourth zone back up timer with independent timing range of 0.5 to 5 seconds. The fourth zone setting shall have the facility to set for directional or

non-directional operation and shall operate on carrier inter trip feature. All other features shall be similar to Main-I protection described above.

EHV Line Protection for 132kV and below: The detailed description for Main-I and back up protection for 132 kV and below feeders is given here under.

a) The Main-I distance protection shall be of Numeric type with features such as basic operating time, powerswing block, fuse failure protection, switch on to fault(SOTF), fourth zone backup timer, and distance to fault locator etc. similar to that of Main-1 protection for 220kV feeders.

b) Back up protection shall be of numeric type with 3 Nos. IDMT directional overcurrent relays with high set and 1 No. IDMT directional earth fault relay with high set

2.8.9 LT AC Panels:

The LTAC panel shall comprise of sheet steel clad dust and vermin proof compartmentalized cubicle type panel. The panels shall be of floor mounting and free standing type and suitable for indoor installation. Panels shall have standard dimensions viz. height and depth to match with the control and relay panels and width as required to accommodate incoming, out going and spare circuits.

Each compartment is to be segregated and closed on all sides except for the bus bar/cable connector opening.

Feeders above 63 A shall be connected by bus bar links. Switches of 63 A and below to be connected by PVC copper wires using suitable crimped, copper lugs of Dowells make.

Bus bars - Three Phases, Neutral aluminum PVC sheathed Phase size 62 x 10 mm, Neutral 31 x 10 mm. Aluminium alloy used for bus bars shall be equivalent to E91E quality of IS 5082. Bus bars shall be supported on unbreakable non-hygroscopic insulated supports. Bus bars to be fully shrouded.

Incoming MCCB - MCCB with clearly marked ON-OFF positions with rotary mechanism provided with front handle shaft and door interlock.

Switch fuse units - Combination switch fuse units double break mechanism AC 23 duty rating with door inter- lock and pad locking mechanism.

Earthing shall be done for all the equipment and the panel. The minimum size of earthing bus shall be 3x25 mm copper.

Construction of panels shall be such that it is possible to add more incoming/outgoing circuits by suitable and easy extensions.

2.8.10 Circuit Breakers:

2.8.10.1 Principal Parameters:

Sl. No.	Item	Requirements			
		400 KV	220 KV	132 KV	33 KV
2.	Maximum system voltage kv	420	245	145	35
3.	Continuous current rating (A) rms	2500	2500	1600	1600
		(only indicative ,to be specified depending on requirement)			
4.	Type	3 pole outdoor SF6 gas			3 pole out door vaccum
5.	Mounting	Hot dip galvanized lattice steel support structure, bolted type			
6.	No. of Poles	3	3	3	3
7.	Type of operation	Individually Operated single poles		3 pole gang operated	
8.	Phase to phase spacing in the switch yard for breaker mm	3400	2100	1300	400
9.	Required ground clearance from the lowest live terminal (mm)	6400	5000	4000	2800
10.	Height of concrete plinth (mm)	150	150	150	150
11.	Minimum height of the lowest part of the support insulator from ground level (mm)	2500	2500	2500	2500
12.	Operating mechanism	Spring/ Pneumatic/ Hydraulic			
13.	Auto re-closing	Single & three phase		Three phase	
14.	Rated Operating duty cycle (min)	0 – 0.3 Sec – CO – 3 min - CO			
15.	First pole to clear factor (type of tripping)	1.3	1.3	1.3	1.3
16.	Closing time max (ms)	150	150	150	150
17.	Max. Total break time (ms)	Less than 3 cycles or 60 ms			
18.	1.2/50 micro second impulse withstand voltage to earth (kVp)	1425	1050	650	170

19.	1 minute power frequency with stand voltage kVrms	610	460	275	70
20.	Rated breaking current capacity				
	i) line charging at rated voltage at 90° lead PF (A)rms	600	125	50	—
	ii) Small inductive current (A)rms without switching over voltage exceeding 20 As	0.5 to 10			
	iii) cable charging current	250	250	160	100
	iv) short circuit currents				
	a) AC component kA rms	40	40	31.5	25
	b) % DC component	Corresponding to minimum opening time as per IEC - 56			
	c) Duration of short circuit in Secs	1	1	1	1
21.	Rated short circuit making current capacity (kA)	100	100	78.75	62.5
22.	Maximum acceptable difference in the instants of closing/opening of contacts				
	i) with in a pole (ms)	2.5	5	5	
	ii) Between Poles open (ms)	3.3	3.3	10	10
	iii) between Poles close (ms)	5.0	5.0	--	--
23.	Minimum creep age distance of support insulator (mm)	10500	6125	3625	900
24.	i) Rating of auxiliary contacts ii) No. of auxiliary contacts	10 A at 220V DC 10NO and 10NC as spare	10 A at 220 V DC 10 NO and 10 NC as spare	10 A at 220 V DC 10 NO and 10 NC as spare	10 A at 220 V DC 10 NO and 10 NC as spare
25.	Breaking capacity of auxiliary contacts with circuit time constant with circuit time constant not less than 20 ms	2A DC	2A DC	2A DC	2A DC

26.	Noise level at Base and up to 50 meters	140 db (max)	75 db (max)	75 db (max)	75 db (max)
27.	Seismic acceleration (horizontal)	0.1 g			
28.	Minimum corona extinction voltage (kV)	320	156	92	92
29.	No. of closing & tripping coils	Two trip coils and one close coil with anti pumping arrangements			

Technical requirements: 132 KV and above voltage level circuit breakers shall be normally Sulpha Hexaflouride (SF6) type and 33 KV and below voltage level shall be vacuum type.

220 KV and above level SF6 circuit breakers shall comprise of three identical single pole units and are meant for single pole tripping and re-closure. In this case, pole discrepancy features shall invariably be provided. 132 KV & 33 KV breakers shall be three pole gang operated.

Breakers shall be complete with bases, control cabinet, support structure for breaker and control cabinet, terminals, compressed SF6 gas, operating mechanisms (Pneumatic/Hydraulic/Spring operated) in complete shape. For 220 KV and above breakers one control cabinet for each breaker and one control box for each pole shall be provided with all the required electrical devices mounted therein.

Circuit breaker shall be suitable for hot line washing, current density for terminal pads shall be 1.6 A/Sqmm for copper pads and others 1.0 A/Sq mm.

Breaker making and breaking contacts shall have adequate thermal and current carrying capacity for the duty specified. Provision shall be made for rapid dissipation of heat generated by the arc on opening.

Where main and arcing contacts are provided, main contacts shall be the first to open and the last to close and arcing contacts shall be the first to close and last to open, so that there will be little contact burning and wear Tips of arcing and main contacts shall be silver plated or have tungsten alloy tipping.

SF6 gas shall not leak from the breaker at more than 1% per year for a minimum period of 10 years. Also the integrity of the vacuum in the bottle of vacuum circuit breakers shall be intact for a minimum period of 5 years.

2.8.10.2 Porcelain Housing: Shall be of single piece construction without any joint or coupling. Shall have high mechanical and dielectric strength.

2.8.10.3 Additional Requirements: The circuit Breakers shall be single pressure type and single break. In the interrupter assembly there shall be a product box for absorbing SF6 decomposition products and moisture.

Each pole of SF6 circuit breaker shall form an enclosure filled with SF6 gas independent of the other poles. Facility for monitoring SF6 gas density of each pole and regulating by

pressure switch shall be provided. The density monitors shall be adequately temperature compensated.

There shall be alarm and trip setting contacts for SF6 gas pressure indicator. In the first step a warning alarm will be given when the SF6 gas pressure falls below a preset value for alarm (low pressure alarm).

In the second step, when the pressure continues to fall beyond this value, after pressure falls further beyond a preset value, the trip signal shall be initiated and breaker shall open and remain under lock out.

Means for pressure relief shall be provided in the gas chamber of circuit breaker to avoid damages or distortion, when pressure increases in the breaker are abnormal.

There shall be provision in the breaker to attach an operation analyzer for testing the breaker's condition.

The circuit breaker shall be totally restrike free under all duty conditions and shall be capable of performing specified duties without opening resistors.

2.8.10.4 Operating Mechanism and Associated equipments: The circuit breaker shall be suitable for local and remote operation electrically. In addition there shall be provision for local mechanical control (emergency trip).

The operating mechanisms shall be designed for satisfactory, maintenance free operations for at least 10 years, under all operating conditions. As far as possible, the need for lubricating the operating mechanism shall be kept to the minimum or eliminating altogether if possible. The operating mechanism shall be non-pumping (and trip free) electrically and mechanically/pneumatically under every method of closing.

Control: Breaker shall be provided with two independent trip circuits, valves and coils each connected to a different set of protective relays. Capacitor Trip Device (CTD) shall be provided for breakers controlling transformers, Reactors, shunt capacitors etc for automatic tripping of the breaker, along with flag indication when there is no DC supply. Suitable relay for monitoring DC voltage supply to the control cabinet shall be provided. The pressure switches used for interlock purposes shall have adequate contact ratings to be directly used in the closing and tripping circuits. When the DC supply to interlock circuit fails, it is essential that the breaker trips in order to protect the switchgear and transformers etc. from any possible faults arising at that time.

The connection must be such that capacitor provided for this purpose gets charged from the DC source from the battery of the station and the capacitor supply is released to the tripping circuit as soon as DC supply fails. It shall be possible to close the breaker, after this tripping only after restoration of DC supply.

Motor Operated Spring Charging Mechanism:

Spring operated mechanism shall be complete with motor opening spring, closing spring and other necessary accessories to make the mechanism a complete unit. Breaker operation shall be independent of motor, which shall be used only for charging closing spring. Motor rating

shall be such that it takes less than 15 seconds for fully charging the closing spring. Closing operation shall compress the opening spring (i.e., charging the opening spring) to keep it ready for tripping. Mechanism shall be provided with means for charging the closing spring by hand. Interlock shall be provided between electrical and manual charging of spring.

Pneumatically Operated Mechanism:

Individual compressor unit (ICU) shall be provided for pneumatically operated circuit breakers.

The ICU shall be provided with air piping and accessories, local air receivers, control valves, stop valves, tees, pressure reducers, filters, coolers, drain ports etc.

The capacity of air receiver shall be adequate for two C- O operation at the lowest pressure for auto re-closing duty without refilling.

The air compressor shall be of air cooled type, complete with cylinder, lubrication, drive motor and slide rails. Total running time of compressor shall not exceed 4 Hrs in a day. Normal running air charging shall not exceed 15 minutes.

The compressor shall run and stop automatically to maintain required pressure in the air receiver. Independently, adjustable pressure switches with potential free, ungrounded contacts to actuate lockout devices shall be provided. This lockout device with provision for remote alarm indication shall ensure prevention of operation of circuit breaker, when ever the pressure of the operating mechanism is below the preset value for satisfactory operation of the breaker.

Hydraulically Operated Mechanism: Shall comprise of operating unit with power cylinder, control valves, high and low pressure reservoir, motor etc. The Hydraulic oil used shall be fully compatible for the specified temperature range. The oil pressure switch controlling the pressure in the high pressure reservoirs, shall be provided with remote alarm in the control room for continuous monitoring of low pressure, high pressure etc.

The operating mechanism shall be capable of performing open close open operation, without the compressor motor running under AC supply failure condition. Trip lock out shall be provided to prevent operation of circuit breaker below the minimum specified hydraulic pressure. Alarm contact for loss of Nitrogen shall also be provided.

2.8.11 ACSR Conductor:

2.8.11.1 Principal Parameters:

Sl. No.	Parameter	Panther	Zebra	Moose
a.	Stranding and wire diameter	30/3.0 mm Aluminum 7/3.0 mm steel	54/3.18 mm Aluminum 7/3.18 mm steel	54/3.53 mm Aluminum 7/3.53 mm steel
b.	Number of stands			
	i) Central steel wire	1	1	1
	ii) 1 st steel layer	6	6	6
	iii) 1 st Aluminum layer	12	12	12
	iv) 2 nd Aluminum layer	18	18	18
	v) 3 rd Aluminum layer	--	24	24
c.	Sectional area of Aluminum (sq mm)	212.10	428.9	528.5
d.	Total sectional area (sqmm)	261.5	484.5	597.0
e.	Over all diameter mm	21.0	28.62	31.77
f.	Approximate weight (kg/km)	974	1621	2004
g.	Calculated maximum DC Resistance at 20 ⁰ C (Ohm/km)	0.139	0.06868	0.05552
h.	Minimum ultimate tensile stress (UTS) (kN)	89.67	130.32	159.6
i.	Modules of elasticity (GN/ Sq mm)	80	69	70.3
j.	Co-efficient of linear expansion per deg. C	17.8×10^{-6}	19.3×10^{-6}	19.3×10^{-6}

Details of Aluminum strand:

a.	Minimum breaking load of strand before standing (kN)	1.17	1.29	1.57
b.	Minimum breaking load of strand after standing (kN)	1.11	1.23	1.49
c.	Max. DC resistance of strand at 20 ⁰ C Ohm/km	4.079	3.626	2.921
d.	Diameter mm Strand/Max/Min	3.0/3.03 2.97	3.18/3.21 3.15	3.53/3.57 3.49
e.	Mass kg/km (at nominal die)	19.11	21.47	26.45

Details of Steel Strand:

a.	Minimum breaking load of strand before stranding (kN)	9.29	10.43	12.86
b.	Maximum breaking load of strand after stranding (kN)	8.83	9.91	12.22

c.	Diameter mm (strand/max/min)	3/3.06 2.94	3.18/3.24 3.12	3.53/3.60 3.46
d.	Zinc coating testing	3 dips of 1 min each	3 dips of 1 min each	3 dips of 1 min each
e.	Minimum weight of zinc coating (gm/sq mm)	250	250	250
f.	Mass of steel-strand at normal diameter (kg/km)	55.13	61.95	76.34

2.8.11.2 General Technical Requirements: The ACSR conductor shall be suitable for direct installation in air supported on suspension insulator strings or anchored through tension insulator strings at the cross arms of transmission line Towers. The conductor shall be suitable for satisfactory operation under the tropical climate condition, given in general terms and conditions.

Joints in wires: Aluminum wires: Joints shall not be permitted in the outer most layer of ACSR conductor in order to ensure a smooth conductor finish and reduce radio interference levels and corona losses on the EHV lines. Joints in the inner layers may be permitted but no two such joints shall be less than 15 meters apart in the complete stranded conductor. Jointing shall be only through cold pressure bult welding.

Galvanized steel wires: There shall be no joints except those in the base rod or wire, before final drawing, in steel wires forming the core of the steel reinforced aluminum conductor; in order to avoid reduction in the breaking strength of the conductor that may occur as a result of failure of joints.

Successive layers of ACSR conductors shall have opposite directions of lay, the outermost layer being right handed. The wires in each layer shall be evenly and closely stranded.

2.8.12 Earth Wire:

High tensile Galvanized steel wire with multi-standards (usually 7/3.15 mm or 7/3.66 mm) is used as earth wire on EHV Transmission Lines as well as stay wires on other lines.

Principal Parameters: the wire shall be high tensile galvanized standard steel wire. 7/3.15 mm wire is used on lines up to voltages of 220kV and on 400 KV lines. 7/3.66 mm wire is used.

No. of Strands	7/3.15	7/3.66
Inner layer	1	1
Outer layer	6	6
Over all diameter mm	9.45	10.98
Total sectional area sq mm	54.57	73.65
Approx weight kg/km	428	583
Minimum breaking load of single wire before stranding kN	8.57	
Minimum breaking load of earth wire kN	56.98	68.4
Directional of lay of outer wire tensile grade of wire	Right hand Grade 3	Right hand Grade 3
Minimum Tensile strength N/sq mm	1100	
Minimum percentage of elongation	4	

Minimum mass of zinc coating (Heavily coated wire) gm/sq m	275	
Testing of uniformity of zinc coating	4 dips of 1 min. duration each	
Diameter of individual strand (Standard/max/min)	3.15/3.21/3.12	3.66/3.75/3.57
Lay length (Std/max/min) mm	160/175/152	181/198/165
Final modules of elasticity kg/sq mm	19330	19330
Co-efficient of linear expansion	11.5×10^{-6} per deg C	11.5×10^{-6} per degC

Standard length of earth wire is 2000 meters per drum.

2.8.13 Optical Fibre Ground Wire (OPGW & OFAC):

Optical Fibre Ground Wire is a combination of a ground wire and a wire intended for communication and protection (optic fibre) joined together to form a composite wire. The OPGW serves as a ground wire for protection of EHV transmission line and the fibres embedded in it serve as carrier for communication and protection systems.

Definitions:

- I. OPGW- an optical fibre unit embedded in the core or first layer of the ground wire, whose shield wire consists of one or more layers of aluminium clad steel/aluminium alloy wires.
- II. OFAC- fibre optic approach cable including all dielectric cables suitable for cable trench/buried duct installation, with heavy duty thermosetting jacketing and shall contain optical wave guide fibres. the approach cable shall be installed between the terminal joint boxes suitable for opgw and fibre distribution frame installed at the substation.
- III. Optical Waveguide Fibres - optical fibres embedded in the opgw/ofac - which would serve as medium for the proposed optical communication system.
- IV. Termination Joint Box - outdoor box to terminate/splice the opgw/ofac-fibre optic approach cable in an organized manner. The box shall be located on the terminal gantries at each end of the lines.
- V. Shield Wire Joint Box - outdoor box to terminate / splice the opgw/opgw in an organized manner.
- VI. Distribution Rack/Termination Box - the indoor rack/box for termination of the ofac and connection to the OLTE.

2.8.13.1 General Technical Requirement:

OPGW: The standard length of OPGW is 3.4 km. The communication system being established over the OPGW and associated accessories and hardware shall be integrated with the OLTE. OPGW shall contain 24 Nos. Dual Window Single Mode (DWSM) optical fibres in conformity with ITU-T recommendations G-654. OPGW shall be loose buffer or tight

buffer type. The fibres shall be embedded in a water tight aluminium/aluminium alloy (AA) wires. If stainless steel tube is used in contact with the AA or AS wires, there shall be no galvanic corrosion.

The design of OPGW shall be similar to the galvanized stranded steel earthwire. The OPGW shall with stand without change in its characteristics, a fault current of 20 kA or more for 0.1 second (short circuit dissipation power equal to $40 (KA)^2 \text{ sec}$ without exceeding the maximum allowable temperature of OPGW for short circuit duration as specified taking OPGW temperature before short circuit as 53° C. The temperature rise, measured in the core of OPGW shall not exceed 75% of the OPGW maximum rated temperature.

The OPGW shall be used to provide lightning protection to the transmission line and shall withstand a lightning current of 200 kA (peak) without change in its characteristics.

Requirement of metallic wires: The protective optic unit shall be surrounded by concentrically stranded metallic wires. The properties of the metallic wires shall be in conformity with ASTM-415 and 416. The surface of the OPGW shall be free from all imperfections such as nicks, indentations, excess of lubricants etc. Adjacent wire layers shall be stranded with reverse lay directions. The direction of lay of the external layer shall be right hand. The wires in each layer shall be evenly and closely stranded around the underlying wires or around the central core.

For Aluminium clad steel wires, the Aluminium covering on each individual steel wire shall be continuous and uniform and shall provide sufficiently strong bonding strength at the boundary between Aluminium layer and steel core.

2.8.13.2 General information of OPGW & OFAC (Optical waveguide fibres): The single mode optical wave guide fibres shall have characteristics in accordance with the International Telegraph and Telephone Consultative Committee (CCITT) - Red Book (1984) – Volume-III. FASCICLE III. 2 –International Analogue Carrier System. Transmission Media, Characteristics. Recommendations G.211 – G.653 (Study Group XV and EMBD) and G-654 or equivalent standards with the following preferred sizes:

1.	Number of optical fibres in OPGW / OFAC	24
2.	Mode	Single
3.	Optimized wavelength (nm)	1550
4.	Mode field diameter	8 to 9.5 at 1550 nm
5.	Deviation in mode field diameter	$\leq 10 \%$ of the nominal value
6.	Outside (Clad) diameter (μm) :	125 +/- 2
7.	Cladding non-circularity :	<2%
8.	Mode field concentricity error (μm) :	<1.0 μm at 1550 nm
9.	Cut-off wavelength :	It should satisfy ITU-T Rec.G.653 in the 1550 nm Wavelength region

10.	Screening level (tensile proof test)	
	a) loose buffer design	1.0%
	b) tight buffer design	1.2%

The offered single mode fibre shall be at dispersion minimized at a wavelength around 1550 nm for use in 1550 nm window. The maximum attenuation coefficient of any individual fibre shall not exceed 0.25 db/km in the 1550 nm region at 20 deg. C. The additional attenuation introduced for 100 turns of uncabled optical fibres (loosely wound) with 37.5 mm radius mandrel and measured at 1550 nm at +20 deg. C shall be less than 0.5 db compared to the initial value measured before winding. The additional temporary attenuation compared to the initial value measured at + 20 deg. C due to temperature cycling (-20 deg. C to + 80 deg. C) shall be less than 0.05 db/km. Temperature rise on account of short circuit current shall be less than 0.25 db/km.

The above increase in attenuation shall be only temporary. There shall be no measurable increase in the fibre attenuation after normalcy is restored. The attenuation of the fibres embedded in the OPGW shall be distributed uniformly throughout its length so that there are no point discontinuities in excess of 0.05 db. The fibre lengths in each reel shall be continuous. No splice of fibre within a reel of OPGW shall be accepted. The optical wave guide fibres shall be completely protected from water penetration and environmental conditions.

2.8.13.3 Fibre splice loss: The splicing loss of any two fibres in any case shall not exceed 0.10 db/splice. Ageing shall not cause increase of the nominal optical attenuation at ambient temp. at 1550 nm by more than 0.05 db/km of fibre over a period of 25 years.

Chromatic dispersion: A single mode optical fibre cable (ITU-T Rec.G.653) shall have following dispersion characteristics.

a)	Zero dispersion wave length	1550 nm
b)	Maximum tolerance on the Zero dispersion wavelength	+/- 15 nm
c)	Maximum chromatic dispersion coefficient in operation window from 1525 to 1575 nm wavelength region	≤ 3.5 PS/ nm x km

Fibre Material: The fibre shall be manufactured from high grade silica and doped as necessary to provide required transmission performance. The chemical composition of the fibres shall be specifically designed to minimize the effect of hydrogen on the transmission properties. The fibres shall be heat resistant.

Fibre coating: The fibre core and cladding shall consist of silica (SiO₂) glass. In order to prevent damage to optical fibre the optical fibre shall be suitably coated. The coating must provide a sufficient mechanical protection while splicing optical fibres. The number of coatings shall be as per design of OPGW. The fibre coating shall be easily strippable during splicing and termination with a mechanical stripping tool. Stripping shall not induce any mechanical stress or notches that could weaken the optical fibre.

Fibre identification: Each optical fibre for identification shall be colour coded corresponding to sequential numbering. The colours and numbering shall be in accordance

with relevant International / Indian Standards in vogue. The colour shall be integrated in the fibre coating and shall be homogeneous.

Filling of OPGW (Filling compound): The loose buffer or tight buffer type OPGW shall be offered and the interstices between the optical fibres shall be filled with a suitable water proof compound if required. The filling compound shall be non-hygrosopic, electrically non-conductive, homogenous and free from any metallic or foreign particles. The compound shall be compatible with all the OPGW components; it may come in contact with, and shall inhibit generation of hydrogen within the OPGW. It shall not adversely affect the colour of fibres and shall be non-toxic for the skin and readily removable with an appropriate solvent that is non-toxic and non-allergic. The filling compound shall remain stable for temperature variations from – 20 deg.C to + 80 deg.C in continuous operation.

Requirements of core protection tube: The OPGW shall be of tube core construction. The core tube shall be made of Aluminium, Aluminium Alloy or stainless steel and shall protect the Optic Fibres from mechanical and thermal loadings.

The optical core, including the optical fibres, shall be contained and protected by a tube, that is continuous, fully sealed, water tight and without mechanical joints. The tube shall have sufficient resistance in order to protect the optical fibres against radial compression transmitted by the metallic wires of the external layers.

The internal surfaces of the tube shall be smooth, the internal and external surfaces of the tube shall be circular and the tube thickness shall be constant. No tube joints shall be allowed in finished OPGW.

2.8.13.4 Fibre optic approach cable: shall be loose or tight buffer type with 24 Nos. Dual window single mode optical fibres. The fibre optic approach cable shall be suitable for direct burial in the cable ducts and on cable trays. The cable shall comprise of a tensile strength member, fibre support/bedding structure, core wrap/bedding, armouring and over all impervious jacket. No intermediate joints shall be permitted in any run of approach cable between its two termination points. The cable sheathing shall have additive to prevent rodent attack.

2.8.13.5 Installation of OFAC:

Installation in cable trenches and on cable trays: Each OFAC shall be pulled in HDPE pipe of 75 mm diameter and required thickness (mm) placed in cable trench (separate trays for OFACs).

Burial: In the case of direct burial the OFAC shall be installed in HDPE pipe of 75 mm diameter and required thickness (mm) to a depth of 1.0 m . The pipe shall be embedded in M 15 concrete with cover of 37.5 mm (150 mm overall) and the trench filled with excavated material and hand compacted.

Pigtail cords: The pigtail cords will be used for the interconnections of the approach cables with the respective optical terminal equipment. The optical fibres of the pigtail cords and approach cable shall be fusion spliced and protected in an approved type terminal box. On the optical equipment side, FC-PC type optical connectors shall be used. Insertion loss shall not exceed 0.5 d B and **return loss shall not be less than 35 d B.**

2.8.13.6 Associated Hardware for OPGW/OFAC:

Suspension clamp: Preformed Armour grip suspension clamp shall be used. The total drop of the suspension clamp from the center of the attachment to the center point of the OPGW shall not exceed 150 mm. The aluminium alloy retaining rods shall be used. The suspension clamp shall have a breaking strength of not less than 25 KN and shall have slip strength of 12 to 17 KN.

Deadend clamp: The dead end clamps shall be aluminum alloy and of bolted type using armour rod. The dead-end clamps shall include all necessary hardware for attaching the same to the tower strain plates. Dead-end clamps shall allow the OPGW to be continuous through the clamp without cutting and jointing. The dead-end clamp shall have slip strength not less than 0.95 times the OPGW rated tensile strength. The clamp shall have a breaking strength of not less than the OPGW. The clamp shall be capable of carrying the maximum current for which the OPGW is designed without overheating or loss of mechanical strength.

Grounding the jumper assembly at suspension and tension towers: The bolted clamps shall attach the OPGW to the structures. The clamp shall have two parallel grooves for the OPGW, One on either side of connecting bolt. The clamps shall be such that clamping characteristics do not adversely change if only one OPGW is installed. The tower attachment plates shall locate the OPGW on the inside of the tower. It shall be attached directly to tower legs/cross arm without drilling or any other modification to the tower. At splice locations the OPGW shall be coiled on the tower close to the splice box.

Vibration dampers: 4R-stock bridge type vibration clampers shall be used. The damper shall have aluminium/Aluminium Alloy clamp capable of supporting the damper during installation and maintain the damper in position without damaging or crushing the OPGW or causing fatigue under the clamp. Armour or patch rod may be provided if necessary to reduce clamping stresses on the OPGW. The armour rod shall be made of Aluminium alloy. The messenger cable shall have 19 strands of galvanized or stainless steel with a minimum strength of 135 Kg/sq.mm and of sufficient size to prevent subsequent drop of weights in service. The messenger cable shall be at the ends to prevent corrosion. The damper weight shall be hot dip galvanized steel or cast iron. The castings shall be free from cracks, shrinkages, inclusion and blow holes. The vibration damper shall restrict the OPGW dynamic strain to 150 micro strains under normal/Aeolian vibration conditions. The dampers shall not be dynamically overloaded during operation to prevent damper fatigue. It is considered that at tension tower locations two dampers shall be installed on OPGW on each side of the tower and at suspension locations one damper shall be installed on each side of the tower.

Joint boxes: OPGW/SHIELD WIRE /OPGW-OFAC Terminal Joint boxes shall be sturdy, weather proof conforming to IP55 and shall include all necessary hardware to retain, terminate, protect and splice the 24 fibres, as well as suitable clamps for fixing to the tower without any need for drilling holes in the tower/substation gantry structure.

The distribution rack/termination boxes in the communication rooms shall be free standing,

vermin proof, watertight conforming to IP55 and shall be made of hot dipped galvanized steel. The distribution rack shall have the facility for different cable clamping locations and suitable for all types of cable.

Termination/ Splicing: The OPGW/OFAC shall be terminated/spliced at the splice locations using joint boxes which shall be located approximately 10 m (minimum 5m) above ground level. Spare length of 15 m of optical fibre shall be coiled and attached to the tower near the joint boxes.

Fusion splicing shall be done using automatic fusion splicing equipment designed for the fibre type. Fibre ends shall be prepared for splicing using methods and tools recommended. Cleanliness and accurate cleaving of fibre ends shall be ensured before splicing.

The accurate alignment of fibre cores, prior to splicing shall be verified using a technique that monitors the optical power transmitted across the splice interface. Fusion splicing shall be commenced only after manipulations of fibre alignment have maximized the transmitted power.

Single splice loss shall not exceed 0.1 dB. Finished splices shall be supported within the joint box by means of suitable clips or restraints. It shall be possible to remove and replace the splice in the support device without risk of damage to the splice or fibre.

Each fusion splice shall have a spare length of fibre of approximately 1m associated with it. This excess fibre shall be coiled neatly and clipped (or otherwise retained) within the joint box.

2.8.14 Solid Core Insulators:

Consists of porcelain part secured in a metal case to be mounted on the supporting structures. Porcelain shall be sound and homogenous, free from defect, laminations and other flaws or imperfections which might affect the mechanical or dielectric quality. The insulators shall withstand any shocks to which they may be subjected by the operation of any of the associated equipment. Stresses due to expansion and contraction in any part of the insulator shall not lead to breaking.

2.8.15 Porcelain Disc Insulators:

The insulators shall be suitable for operation in tropical climate in which they will be subject to the full rays of the sun and inclement weather and shall be able to withstand wide range of temperature variations. The humidity may be as high as 100% during rainy season and as low as 10% during dry season.

Reference atmospheric conditions for which insulator characteristics shall be expressed for the purpose of comparison are given below.

Ambient temperature	20 Deg C
Barometric pressure	1013 Millibars
Absolute humidity	11 gms. Of water per cubic Metre corresponding to 60% relative humidity at 20°C

2.8.15.1 General Requirements:

Insulators shall be of Type B. Type B insulator is one in which the length of the shortest puncture path through solid insulating material is less than half the length of the shortest flashover path through air outside the insulator.

The disc insulators shall be of ball and socket type. The ball and socket of the disc insulator shall be galvanized and mechanically strong. The sockets shall be made of malleable iron. These shall be free from cracks, shinks, air holes, burrs and rough edges.

Porcelain: The porcelain used shall be ivory white, non-porous of high dielectric, mechanical and thermal strength, free from internal stresses, blisters, laminations, voids, foreign matter, imperfections or other defects which might render it in any way unsuitable for insulator shells. Porcelain shall remain unaffected by climatic conditions, ozone, acid, alkalis, zinc or dust. The manufacturing shall be by the wet slip process and an impervious character obtained by thorough vitrification.

Porcelain Glaze: Surfaces to come in contact with cement shall be made rough by sanding. All other exposed surfaces shall be glazed with ceramic materials having the same temperature coefficient of expansion as that of the insulator shell. The thickness of the glaze shall be uniform throughout and the colour of the glaze. The glaze shall have a good visible lustre, smooth on surface and be subject to satisfactory performance under extreme tropical climatic weather conditions and prevent ageing of the porcelain. The glaze shall remain under compression on the porcelain body throughout the working temperature range.

Cap and Ball Pins: Ball pins shall be made with drop forged steel and caps with malleable cast iron. They shall be in one single piece and duly hot dip galvanised. They shall not contain parts or pieces joined together, welded, shrink fitted or by any other process from more than one piece of material. The pins shall be of high tensile steel, drop forged and heat-treated. The caps shall be cast with good quality black heart malleable, cast iron/ spheroidal graphite iron/drop forged steel and annealed. Galvanising shall be by the hot dip process with a heavy coating of zinc of very high purity.

Zinc Sleeve: For Anti-fog type disc insulators, Zinc sleeves shall be provided on the shank of the ball pins. The zinc to be used for making sleeve shall be 99.99% pure or as per latest acceptable standards. The Zinc sleeves shall be fixed at the top position of the neck of the shank of the ball pin. The length of the shank of the ball pin shall be suitably chosen to ensure easy fixing into the socket of the next disc insulator. The zinc sleeve shall cover the top neck portion of the shank of the ball pin to a minimum extent of 20 mm and embedded into the cemented portion up to an extent of 10mm.

The thickness of the sleeve shall be 5mm. The Zinc sleeve shall be clamped and fused together with the pin without forming any gap between the sleeve and the pin. Any gap will cause corona discharge due to the moisture and the insulators with this defect will be rejected outright.

Security Clips: Security clips for use with ball and socket coupling shall be in accordance with IS 2486 (Part III & IV) and made of suitable material of stainless steel or copper alloy or Phosphor-bronze. The security clips shall provide positive locking of the coupling. The logs of the security clips shall be spread after installation to prevent withdrawal from the socket.

Cement: Cement to be used as a fixing material shall be quick setting, fast curing Portland cement. It shall not cause fracture by expansion or loosening by contraction. Cement shall not react chemically with metal parts in contact with it and its thickness shall be as small and as uniform as possible.

2.8.15.2 Required rating and electrical Characteristics

Sl. No.	Characterstics	Type of insulators			
		70KN B&S type normal Disc insulators	120KN B&S type normal Disc insulators	70KN B&S type Anti-fog disc insulators	120KN B&S type Anti-fog Disc insulators
1	Type description	Ball& Socket type normal disc insulators		Ball & Socket type Anti-fog type disc insulators	
2	Colour and surface of porcelain portion	BROWN GLAZED			
3	Ferrous parts	As per IS – 2629 & 2633 with latest editions			
4	Check clip provided in the socket	‘W’ type clip with Phosphor Bronze	‘R’ type clip with stainless steel	‘W’ type clip with Phosphor Bronze	‘R’ type clip with stainless steel
5	Ball pin	Drop Forged Steel			
6	Socket fitting	Malleable Cast Iron / Spheroidal Graphite Iron			
7	Ball pin designation	16 mm	20 mm	16 mm	20 mm
8(a)	Diameter and spacing of insulators (in mm)				
	(i) Diameter	255	280	255	280
	(ii) spacing	145	145	145	145
(b)	Tolerances				
	(i) Dia + /-	(0.04d + 1.5) mm where ‘d’ is the dia of shell			
	(ii) Spacing + / -	(0.03 S + 0.3) mm where S is the spacing of disc			
9	Minimum failing load of the insulator (Kg)	7000	11500	7000	11500
10	Minimum total creepage distance in mm	295	320	435	435
11	Minimum protected creepage distance in mm	175	215	240	240
12	Combined Mechanical and Electrical strength in Kgs	7000	11500	7000	11500
13	One minute power frequency withstand voltage (kV) Dry	75	75	80	80
14	One minute power	45	45	45	45

	frequency withstand voltage (kV) Wet				
15	Flashover power frequency voltage (kV)				
	Dry	80	80	85	85
	Wet	45	45	50	50
16	Visible discharge voltage (kV)	9	18	9	18
17	Puncture voltage (kV)	120	120	140	140
18	Impulse flashover voltage (kV)				
	Positive	125	125	125	125
	Negative	130	130	130	130
19	Standards to which the porcelain insulator shall be manufactured and tested	IS – 731 – 1971 with latest amendments			
20	No. of units for suspension / tension string				
	132 kV	9	10	9	10
	220 kV	13	14	13	14
21	Rated Voltage of each insulator (kV)	12	12	12	12

2.8.15.3 TYPE AND RATING OF INSULATOR STRINGS:

Particulars of disc insulators and insulator strings of porcelain Anti-fog with Zinc sleeve of 120kN&160kN rating for 400kV system.

Sl. No	PARTICULARS	DOUBLE SUSPENSION STRING	SINGLE SUSPENSION AND PILOT STRING	SINGLE “V” SUSPENSION STRING	DOUBLE TENSION STRING FOR ANGLE TOWERS	DOUBLE TENSION STRING FOR ROAD, RAIL CROSSINGS AND T.TS
1.	No. of Standard discs	2x23	1x23	2x23	2x23	2x24
2.	Size of Porcelain Disc Insulators	305 x 145	305 x 145	305 x 145	305 x 170	305 x 170
3.	E & M strength each string (kN)	2x120	120	2x120	2 x160	2x160
4.	Ball and Socket Designation (mm)	20	20	20	20	20
5.	Creepage distance of each porcelain	460	460	460	470	470

	Insulator Disc (mm)					

NOTE: AT MAJOR CROSSINGS

Suspension Towers : 120 kN 2X24 Discs.

Angle Towers : 160 kN 2X24 Discs.

STRING CHARACTERISTICS:

The Characteristics of complete porcelain string shall be as follows:

S.No.	Details	Single / Pilot / Single “V” Suspension	Double Tension
1	Lighting impulse withstand voltage (dry) kV peak	1550	1550
2	Power Frequency withstand voltage (wet) kV rms	680	680
3	Switching impulse withstand kV (peak)	1050	1050
4	RIV at 1 MHz at 305kV (rms) MV	1000	1000
5	Corona extinction voltage kV	320	320
6	Voltage distribution across the string	9%	10%
7	Mechanical failing load kN	1 x 120	2 x 160
8	No deformation load kN	1 x 96	2 x 120

Ball and Socket Insulators are assembled to 132kV, 220kV and 400kV suspension and tension hardware. Important design aspects and other details are given in the table below.

Sl. No.	Description	132 KVlines	220 KV lines	400 KV lines
1.	Type of insulators	Ball and socket type disc insulator	Ball and socket type disc insulator	Ball and socket type disc insulator
2.	Dimensions of insulators of suspensions string	255mmx 145mm	280mm x 145mm	280mm x 145mm
3.	Dimensions of insulators for tension string	280mm x 145mm	280mm x 145mm	280mm x 170mm
4.	Number of insulator disc per single suspension string	9 nos.	13 nos.	23 nos.
5.	Number of insulator disc per double suspension string	2 x 9 nos.	2 x 13 nos.	2 x23 nos.
6.	Number of insulator discs per single tension string	10 nos.	14 nos.	24 nos.
7.	Number of insulator discs per each double tension string	2 x 10 nos.	2 x 14 nos.	2 x 24 nos.
8.	Electro Mechanical strength for tension string insulator	7000 Kgs.	7000 Kgs.	11,500 Kgs.
9.	Electro Mechanical strength for suspension	11,500 Kgs.	11,500 Kgs.	16,500 Kgs.

	string insulator			
10.	Total creepage distance of each disc insulator for suspension strings	280mm	280mm	315 mm
11.	Total creepage distance of each disc insulator for tension string	280mm	280mm	330mm
12.	Minimum impulse dry withstand voltage (wave of 1 x 50 Micro second) for each disc insulator (I.E.C standard)	110KV	110KV	120KV
13.	One minute power frequency withstand voltage for each disc insulator	70 KV (dry) 40KV (wet)	70KV (dry) 40 KV (wet)	70KV (dry) 40 KV (wet)
14.	Power frequency puncture voltage per each disc insulator	110 kV (Suspension strings) 140 kV (Tension Strings)	110 kV (Suspension strings) 140 kV (Tension Strings)	140 kV (Suspension strings) 140 kV (Tension Strings)
15.	Size and designation of ball pin shank for suspension string discs	16mm	16mm	20mm
16.	Size and designation of ball pin shank for tension string discs	20mm	20mm	20mm
17.	Maximum Radio Influence Voltage at 10 KV (RMS) for each disc insulator	50 Micro Volts at 1 MHz	50 Micro Volts at 1 MHz	50 Micro Volts at 1 MHz
18.	Corona extinction voltage for complete (RMS) string both suspension and tension strings	-	-	320KV
19.	Maximum RIV for complete string both volts suspension and tension strings	-	-	500 Micro volts

2.8.16 Galvanized Transmission line Towers, Extensions and Tower Accessories:

2.8.16.1 Principal Parameters: The steel used for fabrication of tower parts of normal type, tower extensions, stubs, stub templates etc., shall be of mild steel of tested quality as per latest versions of IS-2062. Steel sections used in the design of towers shall be in conformity to IS-802. Dimensional and mass tolerances of the various sections shall conform to the appropriate values stipulated in IS-1852. No individual member shall be longer than 6000 mm.

The following sizes of steel sections are used in the design of towers with tolerances as per IS-1852-1985.

2.8.16.2 Equal Angles

i) 200x200x20/16

viii) 75x75x8/6/5

ii)	150x150x20/16/12	ix)	70x70x5
iii)	130x130x12/10	x)	65x65x6/5
iv)	110x110x10/8	xi)	60x60x5/4
v)	100x100x10/8/6	xii)	55x55x5/4
vi)	90x90x8/6	xiii)	50x50x6/5/4
vii)	80x80x8/6	xiv)	45x45x6/5/4

Unequal Angles 45x30x4/5
Plates

i)	25mm thick	vi)	8 mm thick
ii)	20mm thick	vii)	6 mm thick
iii)	16mm thick	viii)	5 mm thick
iv)	12mm thick	ix)	4 mm thick
v)	10mm thick	x)	2 mm thick

2.8.16.3 General Technical Requirements:

The towers shall be of self-supporting type, built up of lattice steel sections or members. The towers shall be fully Galvanized structures built up of structural mild steel sections. All members shall be connected with bolts, nuts and spring washers.

The stubs shall mean a set of four stub angles fully galvanized and shall include cleats.

Superstructure shall mean the Galvanized tower assembly above the stubs which includes structural members like angle sections, cross arms, Earth wire peak, gusset plates and pack washers.

Extensions shall mean the galvanized tower assembly above the stubs, which includes structural members for maintaining adequate ground clearance.

Hangers for attaching suspension strings, 'U' bolts for attaching ground wire suspension assemblies are required for completing the towers in all respects.

The 200x200x20 section if any to be used for leg members shall be of HT steel of tested quality as per IS: 2602-2006 or any revision thereof. High Grade Electrolytic Zinc of 99.95% purity shall be used for galvanizing fabricated material.

Extensions: The towers shall be suitable for adding 3, 6, 9, 12, 18, 25 metres extensions for maintaining adequate ground clearances without reducing the specified factor of safety in any manner.

Tower Accessories: Insulator strings and Earth wire clamp attachments

- For attachment of suspension insulator strings, a swinging hanger on the tower shall be provided so as to obtain requisite clearance under extreme swinging conditions and free swinging of the string. The hanger shall be fabricated (forged) to withstand an ultimate tensile strength of 7,000 Kgs for 132 kV, 220kV towers and 14,000kgs for 400kV towers. The hanger set shall be hot dip galvanized and shall comprise of the forged hanger rods, bolt etc.,

- For earth wire at suspension towers suitable 'U' Bolts shall be provided to accommodate the hook of the Earth wire suspension clamps. The 'U' bolt shall be hot dip galvanized and shall comprise of a 'U' bolt with nuts and spring washers.
- For the attachment of tension insulator strings a tension D-shackle on the angle tower shall be provided and to obtain requisite clearance at bottom and middle cross arms an extension link is required. The D-shackle shall be fabricated (forged) to withstand an ultimate tensile strength higher than the details mentioned in (a) above. The D-shackle along with extension link set shall be hot dip galvanized.

2.8.16.4 Details of Tower Fabrication Workmanship: The tower structures shall be accurately fabricated to bolt together easily at site without any strain on the bolts.

The diameter of the holes shall be 17.5 mm (for a 16mm diameter bolt plus 1.5 mm.)

All steel sections before any work is done on them, shall be carefully leveled, straightened and made true to detailed drawings by methods which shall not injure the materials so that when assembled, the different matching surfaces are in close contact throughout. No rough edges shall be permitted anywhere in the structure.

Drilling and Punching: Before any cutting work is started, all steel sections shall be carefully straightened and trued by pressure and not by hammering. They shall again be trued after punching and drilling.

The maximum allowable difference in diameter of the holes on the two sides of plates or angle is 0.8 mm i.e., the allowable taper in punched holes should not exceed 0.8 mm in diameter.

Erection mark: Each individual member shall have an erection mark conforming to the component number given to it in the fabrication drawings. This mark shall be marked with marking dies of 16mm size before Galvanizing and shall be legible after Galvanizing.

The erection mark shall be A-BB-CC-DDD where -

A	-	Owner code assigned to the Bidder (Alphabet).
BB	-	Bidder's Mark (Numerical)
CC	-	Tower type (Alphabet)
DDD	-	Number mark assigned by Purchaser (Numerical)

Abbreviation of suppliers name shall be separately marked on each tower member with marking dies of 16mm size.

Bolt Arrangement: The minimum bolt spacing and rolled edge distance and sheared edge distances of sections from the centers of the bolt holes to be maintained are given below.

Dia of bolts (mm)	Hole dia spacing (mm)	Min. bolt distance (mm)	Min.rolled edge distance (mm)	Min.sheared edge distance (mm)

16	17.5	40	20	23

2.8.16.5 Allowable Stress: Structural steel angle sections manufactured according to the latest IS: 802 (Part V & VI) and tested according to the latest edition of IS: 2062 or any revision thereof and having yield strength of not less than 255 N/mm. Sq. shall be used in the fabrication of tower members.

2.8.16.6 Proto Inspection: Proto assembly of each type of tower, extension, and stub setting template shall be done by the supplier and offered for inspection before taking up mass fabrication of the structures required.

Two sets of shop drawings/sketches for stub, superstructure, and all extensions for all types of towers shall be furnished for verification before inspection of proto type. Copies of structural drawings and shop drawings/sketches, Bill of materials for each type of tower/structure shall be furnished after inspection of proto type.

2.8.17 Hot dip Galvanized Bolts& Nuts and Washers for Transmission line Towers:

2.8.17.1 Principal parameters:

Bolts: The dimensions of the Bolts shall be as given in table-I of IS-12427. Preferred length, size, combinations as well as Grip ranges shall be as given in table-II of IS: 12427. Prior to Hot-dip galvanizing, the bolt threads shall conform to tolerance class-8 (G) of IS-4218 (Part-6)-1978 and the latest revision if any.

Nuts: The dimensions of the standard nuts shall be as given in Table-I of IS-1363 (Part-3) - 1992:

Spring Washers: The dimensions of the spring washers shall be as given in Table-1A of IS-3063-1994.

Flat Washers: Flat Washers shall be of 40 mm. dia. round of thicknesses 4 mm, 5 mm, 6 mm, 8 mm, 10 mm and 12 mm suitable for 16 mm dia. Bolts for use in transmission line towers.

2.8.18 Hardware Fittings&Accessories for Transmission lines suitable for ACSR Conductors&HTGS Wire:

Principal Parameters: Conductor hardware fittings shall be suitable for single/double suspension insulator strings and single/double tension insulator strings.

Insulator string Characteristics: Characteristics of the complete string shall be as follows:

Sl.No.	Details	220kV				132kV			
		Suspension		Tension		Suspension		Tension	
		Single	Double	Single	Double	Single	double	Single	Double
1	Lightning impulse withstand voltage (dry) kV peak	1050	1050	1050	1050	650	650	650	650
2	Power frequency withstand voltage (wet) kV rms	460	460	460	460	280	280	280	280
3	Mechanical failing load – kgf.	7000	14000	11500	23000	7000	14000	11500	23000
4	No deformation load - kgf	4690	9380	7705	15410	4690	9380	7705	15410

The suspension hardware suitable for ACSR Conductor shall consist of the following.

For single Suspension Hardware:

1. Ball Hook - Drop forged steel to class 4 as per IS-2004
2. Socket eye - Drop forged steel to Class 4 as per IS-2004
3. Arcing horns - Tubular steel (Tower side & Line side)

Ball and Socket Fittings: The dimensions of the ball and socket shall be in accordance with standard dimensions stated in IS: 2486 (Part-II).

Ball Fittings: Ball fittings shall be made of class IV steel as per IS: 2004 or steel of equivalent grade forged in one piece. They shall be normalized to achieve the minimum breaking strength specified. Before galvanization of ball fittings, all die flashing on the shank and on the bearing surface of the ball shall be carefully removed without reducing the dimensions below the requirements.

Socket Fittings: Socket fittings shall be made of class IV steel as per IS: 2004 or steel of equivalent grade and shall be forged in one piece. They shall be normalized to achieve the minimum breaking strength specified.

Security Clips (Locking Devices): Socket fitting shall be provided with security clip in accordance with IS:2486 (Parts III & IV) to provide positive locking against unintentional disengagement of socket from the ball of the insulator.

The hole for the security clip shall be on the side of the socket opposite to the socket opening. The hole for the clip shall be countersunk. The clip shall be of such design that the same may be engaged by a hotline clip puller to provide for disengagement under energized conditions. The security clip shall be made of phosphor bronze conforming to IS: 7814 or of brass conforming to IS 410 with a minimum hardness of 160 HV for Split Pins and 150 HV for W-Clips.

Arcing Horns: Arcing Horns of fixed type and adjustable type should be with double bolt fixing arrangement

Suspension Assembly: For ACSR Conductor the suspension assembly shall include armour grip suspension clamp. The suspension clamp along with standard preformed armour rods set shall be designed to have maximum mobility in any direction and minimum moment of inertia so as to have minimum stress on the conductor in the case of oscillation of the same. The suspension clamp along with standard preformed armour rods set shall have a slip strength as per relevant standards. The suspension assembly shall be smooth without any cuts, grooves, abrasions, projections ridges or excrescence which might damage the conductor.

Armour Grip Suspension Clamp: The armour grip suspension clamp shall comprise of retaining strap, support housing, elastomer inserts with aluminium reinforcements and AGS preformed rod set. The armour grip suspension clamp shall be so manufactured that it shall minimize the static and dynamic stress developed in the conductor under various loading conditions as well as during wind induced conductor vibrations. It shall allow slipping of the conductor under unbalanced conductor tension in adjacent spans and broken wire conditions. It shall also withstand power arcs and have required level of Corona/RIV performance.

Elastomer cushion shall be resistant to the effects of temperature from -40 deg.C to +75 deg.C, ozone, ultraviolet radiations and other atmospheric contaminants likely to be encountered in service. The physical properties of the elastomer shall be of approved standard. It shall be electrically shielded by a cage of AGS preformed rod set. The elastomer cushion shall be so designed that the curvature of the AGS rod shall follow the contour of the neoprene cushion and shall not leave any gap between the two when installed.

The support housing of AGS clamp shall be forged out of aluminium alloy of type 6061 or equivalent. It shall be duly heat treated to achieve the specified tensile properties and to maintain consistent material characteristics during service.

AGS Preformed Armour Rods : The AGS Preformed Armour rod set suitable for ACSR Conductor shall be used to minimise the stress developed in the conductor due to different static and dynamic loads because of vibration due to wind, slipping of conductor from the suspension clamp as a result of unbalanced conductor tension in adjacent span and broken wire conditions. It shall also withstand power arcs, chafing and abrasion from suspension clamp and localised effect due to resistance losses of the conductor.

The preformed armour rod set shall have right hand lay and the inside diameter of the helics shall be less than the outside diameter of the conductor to grip the same tightly. The surface of the armour rod when fitted on the conductor shall be smooth and free from projections, cuts and abrasions etc.

The pitch length of the rods shall be less than that of the outer layer of ACSR conductor and the same shall be accurately controlled to maintain uniformity and consistently reproducible characteristic wholly independent of the skill of linemen.

The length and diameter of each rod shall be as per the values given below. The tolerance in length of the rods in completed set should be within 13 mm between the longest and shortest rod. The ends of armour rod shall be parrot billed.

Description	MOOSE	PANTHER
i) Breaking strength	35 kg/mm ²	35 kg/mm ²
ii) No. of rods per set	12	11
iii) Diameter of rod with tolerances (mm.)	9.27 +0.0 or -0.1	6.35 +0.0 or -0.1
iv) Length of rod with tolerances (mm.)	2235 +0 or -51	1520 +0 or -38

The number of armour rods in each set shall be twelve for 'MOOSE' conductor and eleven for 'PANTHER' conductor. Each rod shall be marked in the middle with paint for easy application on the line.

The armour rod shall not lose their resilience even after five applications.

The conductivity of each rod of the set shall not be less than 40% of the conductivity of the International-Annealed Copper Standard (IACS).

Deadend Assembly: The dead end assembly shall be of compression type with provision for compressing jumper terminal at one end. The angle of jumper terminal to be mounted should be 30 Deg. with respect to the vertical line. The area of bearing surface on all the connections shall be sufficient to ensure positive electrical and mechanical contact and avoid local heating due to copper losses. The resistance of the clamp when compressed on the conductor shall not be more than 75% of the resistance of equivalent length of conductor.

The compression length shall be clearly marked on each dead end assembly designed for continuous die compressions and shall bear the words "**compress first**" suitably inscribed near the point on each assembly where the compression begins. It shall bear identification marks "**compression zone**" and '**non-compression zone**' distinctly with arrow marks showing the direction of compressions and knurling marks showing the end of the zones. Tapered aluminium filler plugs shall also be provided at the line of demarcation between compression and non-compression zone. The letters, number and other markings on the finished clamp shall be distinct and legible.

The assembly shall not permit slipping of, damage to or failure of the complete conductor or any part thereof at a load less than 95% of the minimum UTS of the conductor

The outer sleeve shall be made out of EC grade aluminium 99.5% pure. The steel sleeve shall be made of mild steel rod.

Suspension Hardware for Ground wire: used for suspending ground wire at all tangent/suspension towers and shall be suitable for supporting the GSS ground wire of size 7/3.15 mm for 220 kV and 132kV lines and 7/3.66 mm for 400kV lines.

The suspension clamps shall conform to the latest version of IS: 2486 and shall have adequate area of support for the ground wire. The groove of the clamp shall be smooth, finished in a uniform circular or oval shape and shall slope downwards in a smooth curve to avoid edge support and hence to reduce the intensity of bending moment on the ground wire. The clamping piece and the clamp body shall be clamped by at least two "U" bolts of size not less than 10mm with 3mm thick lock washers on each of its limbs. Suspension clamp shall be provided with inverted type of "U" bolts. One limb of the "U" bolt shall be long enough to accommodate the lug of the flexible steel bond.

The complete assembly of the suspension clamp shall have a slip strength of not less than 15 kN and not more than 17 kN. The ultimate tensile strength of the assembly including components shall not be less than 70 kN.

Tension Hardware for Ground wire: Tension hardware shall be used at all tension towers for anchoring the 7/3.15mm or 7/3.66 mm galvanized steel ground wire. The hardware assembly shall comprise of compression type tension clamp and two "D" shackles. The tension clamp shall be attached to the horizontal strain plate of the tower body by means of a "D" shackle.

These clamps shall give adequate area of support without any slip to the ground wire under normal working tension and vibration conditions.

The complete tension hardware assembly shall be so designed as to avoid undue bending in any part of the clamp and shall not produce any hindrance to the movements of the clamp in horizontal and vertical direction.

The slip strength of tension clamp assembly shall not be less than 95% of the ultimate strength of the ground wire. The ultimate strength of the clamp and individual components shall not be less than that of ground wire.

2.8.19 Accessories for Conductor:

Mid-span Compression Joints for Power Conductor: This shall be suitable for joining the two ends of MOOSE ACSR conductor for 220kV/400 kV lines and PANTHER ACSR conductor for 132kV lines. The joint shall have conductivity more than the conductivity of an equivalent length of the conductor. The joint shall not permit slipping of, damage to, or failure of the complete conductor or any part thereof at a load of not less than 95% of the ultimate tensile strength of the conductor. The electrical resistance of the joint, after installation, shall not exceed 75% of the measured resistance of the equivalent length of the conductor.

The components of the joint for ACSR conductor shall consist of steel and aluminium sleeves for joint compression of the steel core conductor and aluminium conductor respectively. The steel sleeve shall not crack or fail during compression. The Brinell Hardness number of the steel sleeves shall not exceed 200. The steel sleeve shall be hot dip galvanised. The aluminium sleeve shall be manufactured and extruded out of EC grade aluminium with a purity of not less than 99.5%. Tapered aluminium filler plugs shall be provided at the line of demarcation between compression and non-compression zones. The dimensions and dimensional tolerances of the mid span compression joint shall be as per the values given below.

Description	MOOSE	PANTHER
<u>(I) Diameter of Sleeves (mm)</u>		
a) Before Compression (Inner Diameter)		
i) Aluminum	34 + or – 0.5	23 + or – 0.5
ii) Steel	11 + or – 0.5	9.45 + or – 0.5

<u>(Outer Diameter)</u> i) Aluminum ii) Steel	54 + or – 1 24 + or – 0.5	38 + or – 0.5 18 + or – 0.5
b)After Compression <u>(Corner to Corner)</u> i) Aluminum ii) Steel	53 + or – 0.5 23.4 + or – 0.5	37 + or – 0.5 17.4 + or – 0.5
<u>(face to Surface)</u> i) Aluminum ii) Steel	46 + or – 0.5 20.2 + or – 0.5	32 + or – 0.5 15.1 + or – 0.5
(II) Length of Sleeve (mm) a) Before Compression i) Aluminum ii) Steel	735 + or – 5 305 + or – 5	610 + or – 5 203 + or – 5
b) After Compression i) Aluminum ii) Steel	785 + or – 5 330 + or - 5	650 + or – 5 225 + or - 5

Repair Sleeves for Power Conductor: Repair sleeve shall be used for repairing the conductor when a few strands of the aluminium conductor in the outermost layer are damaged with scratches, kinks, abrasions, nicks or cuts. Sleeve shall be of the compression type. The sleeve shall be manufactured and extruded out of EC grade aluminium having a purity of 99.5%. The sleeve shall be in two halves with a seat provision for sliding of the keeper piece. The edges of the seat as well as of the keeper piece shall be so rounded that the conductor strands are not damaged during installation. The outer body of the sleeve shall be smooth, even and with rounded off edges. The compressed conductor with the repair sleeve shall not permit damage or failure of the conductor at a load of not less than 95% of the ultimate tensile strength of the conductor. The electric resistance of the repaired portion of the conductor shall not exceed 75% of the measured resistance of an equivalent length of the conductor.

The dimensions and dimensional tolerance of the repair sleeves shall be as per values given below.

Description	MOOSE	PANTHER
Diameter of Sleeves (mm)		
<u>a) Before Compression</u>		
Outer Diameter	54 + or – 1	38 + or – 1
<u>b) After Compression</u>		
i) Corner to Corner	53 + or – 0.5	37 + or – 0.5
ii) Surface to Surface	46 + or – 0.5	32 + or – 0.5
a) Before Compression	305 + or – 5	241 + or – 5
b) After Compression	330 + or - 5	271 + or - 5

Twin Spacer for power Conductor: The spacer shall be designed to maintain the bundle spacing of 450mm under all normal operating conditions and to effectively control sub span

oscillation to a negligible limit. The spacer shall restore the nominal spacing after any extraordinary loads. The spacers shall be of the armoured grip type or the bolted grip type. The spacers shall meet the following requirements:

- i. Spacer shall restore normal spacing of the sub conductors after displacement by wind, electro-magnetic and the electrostatic forces under all operating conditions including the specified short circuit level without permanent deformation/damage either to the conductor or to the assembly itself.
- ii. For spacer requiring retaining rods, the retaining rods shall be designed for the specified conductor size. The rods shall be made of high strength special aluminium alloy of type 6061 or equivalent aluminium alloy having minimum tensile strength of 35 kg/mm². The ends of retaining rods should be ball ended. The rods shall be heat-treated to achieve specified mechanical properties and give proper resilience and retain the same during service.
- iii. Four number of rods shall be applied on each clamp to hold the clamp in position. The minimum diameter of the rods shall be 7.87 +/-0.1mm and the length of the rods shall not be less than 1100mm.
- iv. Where elastomer surfaced clamp grooves are used, the elastomer shall be firmly fixed to the clamp. The insert should be forged from aluminium alloy of type 6061 or equivalent aluminium alloy having minimum tensile strength of 25 kg/mm². The insert shall be duly heat treated and aged to retain its consistent characteristics during service.
- v. Elastomer, if used, shall be resistant to the effects of temperature upto 75 deg. C, ozone, ultraviolet radiation and other atmospheric contaminants likely to be encountered in service. It shall have good fatigue characteristics. The physical properties of the elastomer shall be of approved standard.
- vi. The spacer assembly shall have electrical continuity. The electrical resistance between the sub-conductors across the assembly in case of spacer having elastomer clamp grooves shall be suitably selected by the manufacturers to ensure satisfactory electrical performance and to avoid deterioration of elastomer under all service conditions.
- vii. The clamp grooves shall be in uniform contact with the conductor over the entire clamping surface, except for rounded edges. The groove of the clamp body and clamp cap shall be smooth and free of projections, grit or other material, which cause damage to the conductor when the clamp is installed.
- viii. For the spacer involving bolted clamps, the slip strength of the clamp is maintained between 2.5kN and 5kN. The clamp when installed on the conductor shall not cause excessive stress concentration on the conductor leading to permanent deformation of the conductor strands and premature fatigue failure in operation.
- ix. The spacer shall not damage or chafe the conductor in any way which might affect its mechanical and fatigue strength or corona performance.
- x. The spacer assembly shall not have any projections, cuts, abrasions etc., or chattering parts which might cause corona or RIV.
- xi. The spacer tube shall be made of aluminum alloy of type 6061 or equivalent aluminium alloy. If fasteners of ferrous material are used, they shall conform to and

be galvanised conforming to relevant Indian Standards. The spacer involving ferrous fasteners shall not have magnetic power loss more than one watt at 600 Amps 50 Hz alternating current per sub conductor.

- xii. The spacer assembly shall be capable of being installed and removed from the energised line by means of hot line techniques.

Twin spacer for Jumpers: Jumpers at tension points shall also be fitted with spacers so as to limit the length of free conductor to 3.65m and to maintain the sub conductor spacing of 450 mm. It shall meet all the requirements of spacer used in the line except for its vibration performance.

Vibration Dampers for Power Conductor: The vibration damper in association with spacers shall effectively control Aeolian vibrations as well as sub span oscillations to acceptable limits. The vibration dampers shall be of either 4R type or stock-bridge type for being used at all suspension and tension points at each and every span to damp out the vibrations of the conductors to the level specified.

The clamp of the vibration damper shall be made of aluminium alloy. It shall be capable of supporting the damper during installation and prevent damage or chafing of the conductor during erection or continued operation. The clamp shall have sufficient grip to maintain the damper in position on the conductor without damaging the strands or causing premature fatigue to the conductor under the clamp. The groove of the clamp body and clamp cap shall be smooth, free of projections, grit or other materials, which could cause damage to the conductor when the clamp is installed. Clamping bolts shall be provided with self locking nuts and designed to prevent corrosion of the threads or loosening during service.

The messenger cable of the damper shall be made of high strength steel with a minimum strength of 136 kg/sq.mm. It shall be post formed in order to prevent subsequent droop of weight in service and to maintain consistent flexural stiffness of the cable while in service. The messenger cable shall be suitably and effectively sealed to prevent corrosion.

The damper mass shall be made of hot dip galvanized mild steel/cast iron or a permanent mould cast zinc alloy. All castings shall be free from defects such as cracks, shrinkages, inclusions and blowholes etc. The inside and outside surfaces of the damper masses shall be smooth.

The damper assembly shall be electrically conductive to reduce radio interference

The vibration damper shall be capable of being installed and removed from energized line by means of hot line technique. In addition, the clamp shall be capable of being removed and reinstalled on the conductor at the design torque without shearing or damaging of bolts, nuts or cap screws.

Technical Requirements for 4R Vibration Dampers for ACSR Conductor

Description	MOOSE	PANTHER
a) Total weight of each damper (kg.)	6.5 + 0.3 or - 0	4.5 + 0.3 or - 0
b) The number of dampers required per span for various span lengths and their spacing	2 for Single 4 for Twin	2

2.8.20 EARTH WIRE ACCESSORIES:

Mid-Span compression Joint for Ground wire: The mid span compression joint for ground wire is to be used for joining of two lengths of Galvanized Steel Stranded (GSS) Ground Wire of size 7/3.15 mm or 7/3.66 mm.

The joint sleeve shall be made of high strength hot dip galvanized steel tubes and shall be easily compressible with a 100 MT capacity hydraulic compressor. The clamp shall not permit slipping of, damage to, or failure of the complete ground wire or any part thereof at a load of not less than 95% of the ultimate tensile strength of the Ground Wire. The joint shall have conductivity more than the conductivity of an equivalent length of ground wire.

Flexible Steel Earth Bond: The flexible steel earthing bond shall be made of flexible steel cable having 34 sq. mm. copper equivalent area. The length of steel cable shall not be less than 500 mm. Two steel connecting lugs shall be press jointed to the either ends of the flexible steel cable. The complete assembly shall also include one 16mm dia 40mm long HRH M.S. bolt hot dip galvanized, with nut and lock washer.

Fasteners: All fasteners shall be hot dip galvanized conforming to IS: 6639 All bolts and nuts shall have hexagonal heads, the heads being forged out of solid truly concentric, and square with the shank, which must be perfectly straight.

Fully threaded bolt shall not be used. The length of the bolt shall be such that the threaded portion shall not extend into the place of contact of the component parts.

All bolts shall be threaded to take the full depth of the nuts and threaded enough to permit the firm gripping of the component parts but not further. It shall be ensured that the threaded portion of the bolt protrudes not less than 5 mm and not more than 10 mm when fully tightened.

Flat washers and spring washers shall be provided wherever necessary and shall be of positive lock type. Thickness of washers shall conform to IS: 2016.

To obviate bending stress in bolt, it shall not connect aggregate thickness more than three times its diameter.

2.9 General Specification Terms:

The following general clauses common to every equipment/material described above, may be included in the specification to the extent appropriate for the equipment/material proposed to be purchased.

2.9.1 Climatic Conditions: The Equipment / material shall be suitable for satisfactory continuous operation under the following tropical conditions:

a) Maximum ambient air temperature (in shade)	45 ⁰ C
b) Maximum ambient air temperature (under sun)	50 ⁰ C
c) Minimum ambient air temperature	7.5 ⁰ C
d) Maximum daily average ambient air temperature	35 ⁰ C
e) Maximum yearly average ambient air temperature	30 ⁰ C

f) Maximum relative humidity	74% to 100 %
g) Minimum Relative humidity	10%
h) Altitude above M.S.L.	Up to 1000M
i) Average No. of thunder storm days per annum	50
j) Average No. of dust storm days per annum	Occasional
k) Average No. of rainy days / annum	90
l) Average Annual Rain fall	925mm
m) Maximum rainfall per annum	120 Cms
n) Normal tropical monsoon period	4 months
o) Maximum wind pressure	150 kg/Sq.M.
p) Seismic level (horizontal acceleration).	0.1 g

Note: Moderately hot and humid tropical climate conducive to rust and fungus growth. The climatic conditions are also prone to wide variations in the ambient conditions. Smoke is also present in the atmosphere. Heavy lightning also occurs during June to October.

2.9.2 Quality Assurance Plan: The bidder shall furnish the following information along with the bid. Information shall be separately given for each type of material offered.

- i. The structure of organization.
- ii. The duties and responsibilities assigned to staff ensuring quality of work.
- iii. The system of purchasing, taking delivery and verification of material.
- iv. The system for ensuring quality of workmanship.
- v. The quality assurance arrangements shall conform to the relevant requirement of ISO-9000, 9002 or 9003 as applicable.
- vi. Statement giving list of important raw materials, names of sub-supplies for the raw materials, list of standards according to which the raw material are tested, list of tests normally carried out on raw material in the presence of contractors representative, copies of test certificates.
- vii. Information and copies of test certificates in respect of bought out items.
- viii. List of manufacturing facilities available.
- ix. Level of automation achieved and list of areas where manual processing exists.
- x. List of areas in manufacturing process, where stage inspections are normally carried out for quality control and details of such tests and inspections.
- xi. List of testing equipment available with the bidder for final testing of material specified and test plant limitation, if any vis-à-vis the type. Special acceptance and routine tests specified in the relevant standards. These limitations shall be very clearly brought out in a Schedule of Deviations from the specified test requirements.

The successful bidder shall within 15 days of placement of order submit the following information to the Purchaser.

- i. List of the raw material as well as bought out accessories and the names of sub-suppliers selected from those furnished along with the offer.

- ii. Type test certificates of the raw material and bought out accessories if required by the Purchaser / Engineer.

Routine test certificates of bought out accessories and central excise passes for raw material shall be produced at the time of routine testing, if required by the Purchaser and ensure that the quality assurance requirements of specification are followed by the sub-contractor.

The Quality Assurance Programme shall give a description of the Quality System and Quality Plans with the following details.

i) Quality System:

- The structure of the organization.
- The duties and responsibilities assigned to staff ensuring quality of work.
- The system of purchasing, taking delivery & verification of materials.
- The system of ensuring of quality workmanship.
- The system of control of documentation.
- The system of retention of records.
- The arrangement of contractor internal auditing.
- A list of administrative and work procedures required to achieve contractor's quality requirements. These procedures shall be made readily available to the Purchaser for inspection on request.

ii) Quality Plans:

- An outline of the proposed work and programme sequence.
- The structure of contractors' organizations for the contract.
- The duties and responsibilities ensuring quality of work.
- Hold and notification points.
- Submission of engineering documents required by this specification.
- The inspection of the materials and components on request.
- Reference to contractors' work procedures appropriate to each activity.
- Inspection during fabrication / construction.
- Final inspection and test.

Training of Personnel: The Supplier shall provide necessary facilities for training personnel (No. of personnel to be trained shall be decided by purchaser), at their works/principals works

relating to design, manufacture, assembly and testing and operation and maintenance, free of cost.

2.9.3 Packing and Forwarding: The equipment shall be packed in crates suitable for vertical/horizontal transport, as the case may be and suitable to withstand handling during transport and outdoor storage during transit. The Bidder shall be responsible for any damage to the equipment during transit, due to improper and inadequate packing and handling. The easily damageable material shall be carefully packed and marked with the appropriate caution symbols. Wherever necessary, proper arrangement for lifting, such as lifting hooks etc., shall be provided. Any material found short inside the packing cases shall be supplied by the Bidder at no extra cost.

Each consignment shall be accompanied by a detailed packing list containing the following information:

- a) Name of the consignee.
- b) Details of consignment.
- c) Destination.
- d) Total weight of consignment.
- e) Handling and unpacking instructions.
- f) Bill of material indicating contents of each package.

2.9.4 Supervision of Services: To be specified depending on the need for supervision of installation, testing and commissioning.

2.9.5 Type Tests: All the equipment offered, shall be fully type tested by the bidder as per the relevant standard. The type tests must have been conducted on similar or higher capacity not earlier than **five years as on the date of bid opening**. The bidder shall furnish one set of the specified type test reports for each equipment offered along with bid.

2.9.6 Acceptance and Routine Tests: All routine tests as stipulated in the relevant standards and acceptance tests as agreed by the purchaser and the supplier shall be carried out by the Supplier in the presence of Purchaser's representative

2.9.7 Additional Tests: The Purchaser reserves the right for carrying out any other tests of a reasonable nature at the works of the Supplier/laboratory or at any other recognized laboratory/research institute in addition to the above mentioned type, acceptance and routine tests at the cost of the Purchaser to satisfy that the material complies with the intent of this specification.

2.9.8 Inspection: The inspection may be carried out by the Purchaser at any stage of manufacture. The Supplier shall grant free access to the Purchaser's representative at a reasonable time when the work is in progress. Inspection and acceptance of any equipment under the specification by the Purchaser shall not relieve the Supplier of his obligation of furnishing equipment in accordance with the specification and shall not prevent subsequent rejection if the equipment is found to be defective.

The supplier shall keep the Purchaser informed in advance, about the manufacturing programme so that arrangement can be made for inspection.

The Purchaser reserves the right to insist on witnessing the acceptance/routine testing of the bought out items.

No material shall be dispatched from its point of manufacture unless the material has been satisfactorily inspected and tested.

The supplier shall give 15 days (for local supplies)/ 30 days. (In case of foreign supplies) advance, intimation to enable the purchaser to depute his representative for witnessing acceptance and routine tests.

All charges in connection with inspection by purchaser's personal such as travel, accommodation and incidentals shall be borne by the Purchaser.

2.9.9 Documentation: All drawings shall conform to International Standards Organization (ISO) 'A' series of drawing sheet/Indian Standards Specification. All drawings shall be in ink and suitable for micro filming. All dimensions and data shall be in S.I. Units.

2.9.10 Drawings and Documents: The Bidder shall furnish relevant descriptive and illustrative published literature pamphlets and the following drawings for preliminary study along with the offer.

- General outline drawings showing dimensions and shipping weights, quantity of insulating media, air receiver capacity etc.,
- Sectional views showing the general constructional features of main components of equipment/material with lifting dimensions for maintenance.
- Schematic diagrams of equipment
- Structural drawing, design calculations and loading data for support structures.
- Foundation drilling plan and loading data for foundation design.
- Type test reports.

The Supplier shall within 2 weeks of placement of order submit four sets of final version of all the above drawings for Purchaser's approval. The Purchaser shall communicate his comments/approval on the drawings to the Supplier within two weeks of receipt of drawings. The supplier shall, if necessary, modify the drawings and resubmit four copies of the modified drawings for Purchaser's approval. The purchaser shall communicate approval within two weeks of receipt of modified drawings.

The Supplier shall furnish printed copies of drawings and literature along with reproducibles and also digital formats (CDs). In addition bound manuals covering erection, commissioning, operation and maintenance instructions in English Language and all relevant information and drawings pertaining to the main equipment as well as auxiliary devices shall also be supplied. Marked erection drawings shall identify the component parts of the equipment as shipped to enable Purchaser to carryout erection with his own personnel. Each manual shall also contain one set of all the approved drawings, type test reports as well as acceptance reports of the corresponding consignment dispatched.

The manufacturing of the equipment shall be strictly in accordance with the approved drawings and no deviation shall be permitted without the written approval of the Purchaser. All manufacturing and fabrication work in connection with the equipment prior to the approval of the drawing shall be at the supplier's risk.

Approval of drawings by the Purchaser shall not relieve the supplier of any of his responsibility and liability for ensuring correctness and correct interpretation of the drawings for meeting the requirements of the latest revision of the applicable standards, rules and codes of practices. The equipment shall conform in all respects to high standards of engineering, design, workmanship and latest revisions of relevant standards at the time of supply and Purchaser shall have the power to reject any material which, in his judgment, is not in full accordance therewith.

Additional data to be furnished along with the offer: Nature of data relevant to the equipment required if any, shall be specified. Eg. Functional drawings for various components, designed curves for temperature, pressure, density etc. data on the capabilities of equipment in terms of time and no. of operations under different conditions etc.

2.9.11 Test Reports:

- i) Two copies of acceptance test reports shall be furnished to the Purchaser. One copy will be returned, duly certified by the Purchaser and only there after the material be dispatched.
- ii) All records and routine test reports shall be maintained by the supplier at his works for periodic inspection by the Purchaser.
- iii) All test reports of tests conducted during manufacture shall be maintained by the Supplier. These shall be produced for verification as and when requested for by the Purchaser.

2.9.12 Mandatory Spares and Tools: as required for each equipment / as recommended by the manufacturer shall be considered.

2.10 Tendering and Awarding of Contracts:

2.10.1 Various components of Transmission Projects include survey, leveling, construction of civil works, supply of various equipment/ materials, erection, testing and commissioning. Bids can be invited for each of the above works individually or for the whole project in a single bid on turnkey or semi turnkey basis.

A Project where bids are called for, evaluated and contracts awarded for individual components in that project, will be executed by independent Agencies. Multiple Agencies are to be pursued to complete the entire project as per given schedule. The construction unit will have to coordinate various activities in the project with different contractors/ suppliers for progress of different works and supply of materials with respect to the time frame and monitor works closely to achieve the target set for completing the whole project. This

requires timely matching of material/equipment supplies with progress of works. Any mismatch in supply of materials as per plan or in execution of various works in the project or in both; will result in time overrun of the project. The expenditure incurred on an incomplete project will remain as dead capital yielding no return.

In a turnkey project single agency will be liable for execution of the whole project. Timely completion of whole project will not only benefit the contractor in improving his business prospects but also will benefit the department in putting the project to beneficial use, reducing the time overruns and consequential cost overruns.

Tendering for all major projects such as EHV substations, Transmission lines, Augmentation of Transformers, Reactive power compensation works and major R&M works are done by centralized procurement wing at Corporate Office.

2.10.2 Invitation for bids shall cover general, commercial and technical specifications concerned with the work as given under.

Volume-1:

Shall contain a Notice Inviting Tenders covering project name and nature of work, estimated cost value, type of contract, contract schedule, bid security, bid closing, submission and opening dates, eligibility criteria etc.

Bid documents containing instructions to the bidders, financial, General conditions of the contract and special conditions if any for the subject contract, various schedules, formats, price schedules for equipment/ materials and works etc. shall be furnished in this volume.

Volume -2:

shall contain the following schedules

- a) Technical specifications for equipments/materials and works
- b) Price schedule for equipment/materials, works covering all construction and erection works
- c) Total schedule of rates
- d) Schedule giving programme of supply of materials and works giving a bar chart for various activities covering the project works.

Conventional tendering was followed in APTRANSCO till 2006. The steps followed in manual tendering for purchase of goods / award of works or for both are given below.

- a. After receipt of indents, notice inviting tenders would be issued for publication in News papers having wide circulation giving details about the name of the project, nature of work, details of work, Estimated cost value, bid security, eligibility criteria, etc. requesting the bidders to purchase bid documents. Generally two part bid system

is followed wherein bids would be invited in two parts – first part containing technical experience, financial turnover etc forming qualification criteria and the second part the prices.

- b. Compiling of bid document manually, getting them approved, printing of no. of copies of bid document (required as per the expected no of bidders) and sale of bid documents.
- c. Submission of bid documents duly filled up by prospective bidders (filling up all schedules, computing total offer, enclosing various documents in support usually making a bulk volume)
- d. Bid opening manually on the scheduled date and time and reading out important bid contents of all bids received; in the presence of bidders present
- e. Preparation of comparative statement of eligibility requirement for qualification evaluation and circulation for approval.
- f. After approval, preparation of comparative statement of prices of qualified bidders, computation of various loadings taxes and duties and circulation to heads in technical and financial wings (Chief Engineer, FA&CCA).
- g. Physical checking of the statements with reference to original copies by the finance wing and communication of their remarks.
- h. Preparation of no. of copies of approved evaluation statements and circulation to Stores Purchase committee
- i. Award of contract as per the recommendations of the committee.

All the above steps are done manually. The entire tendering cycle normally requires about 100 to 120 days.

Number of transmission projects taken up commensurate with the growth in generation and load demand has been on increase in the recent past. Conventional tendering requiring longer tendering cycle and handling large no. of tenders due to piecemeal tendering had an impact on planned execution of projects.

As per directives of Government of A.P., electronic procurement (e- procurement) has been introduced in APTRANSCO in 2006 for purchase of goods/ services of value of ten lakh rupees and above. Tenders for a project as a whole (eg. A substation and connecting line) are invited on a total turnkey basis except Power transformers in order to reduce the no. of tenders handled and to condense the time for tender process with a view to achieve the planned targets for projects.

2.10.3 E- PROCUREMENT:

E-Procurement is a software package through which goods or services (works) can be purchased using internet. The net connects buyers and suppliers. E-Procurement is about carrying conventional tendering through electronic medium.

AP Technological Services through M/s.C1 India Ltd. provides necessary platform for registering purchasers to publish their bids and contractors to submit their bids from any part of the country, instantly. This provides adequate time for bidders to submit their bids on line without the need for delivering bids either personally or through post.

Tender Management software helps both buyers and suppliers to reduce the cycle time, unnecessary paper work and simultaneously maintain transparency in the entire process. Different tendering practices such as Single part bid, Two part bid for works, for products, EPC/ Turnkey project modules in two part bids, Auction of materials and reverse auction can be adopted on e-procurement platform.

2.10.4 Tendering procedure on e-procurement platform:

Various stages of tendering include indents initiation and approval, create and publish Notice Inviting Tenders (NIT), submission of bids on line, online opening of technical bids, evaluation of technical bids, online opening of price bids, evaluation of price bids and scrutiny by finance wing.

Initiator (normally AE/ADE) will be authorized to initiate indents, prepare bid documents, create and publish NIT.

Next approver (normally DE) will verify the indents, NIT put up by initiator and will edit if required and approve the same with his remarks and send to final approver (normally SE)

SE will verify the indents, NIT and edit or mark to others for review if required and give final approval.

Initiator then issues NIT for publication on line on e-procurement platform and simultaneously intimates through e-mail to the registered bidders.

The registered bidder logs in secure mode and submits technical and price bids, encrypting price bid only. Bidder also enters all details such as commercial terms and conditions, bid security, C1India transaction fee, and attaches all documents as required by the department.

At the scheduled date and time for bid opening, Tender Inviting Authority (SE) will login for assigning tender activities (i.e. pre qualification, technical and price bid opener.)

Next, the initiator logs in and completes pre qualification evaluation, evaluation of technical and commercial terms and submits to next approver. Next approver verifies and sends it to final approver with his remarks.

Final approver verifies and edits or reviews if required and approves the file.

After approval of the prequalification bids, the tender inviting authority (SE) decrypts price bids. Next the initiator logs in and evaluates the price bids and submits to next approver. Next approver verifies and puts up to final approver along with his remarks. Final approver verifies and edits or reviews if required and approves.

Approved statement is then sent to CE in charge of purchase and to FA&CCA. After their verification and approval the same will be sent to tender inviting authority (SE) who will

arrange for circulation to the stores purchase committee for decision. Contract will be awarded to the bidder as decided by the committee.

E-Procurement has secure features in that all activities, transactions and changes in configuration are logged and log report is made available to all concerned. Log of the activities is available at data base level also. All designated users, approvers, tender inviting authority and the heads of technical and financial wings are provided with access keys such as user ID, password, digital key and encryption key according to their responsibilities. All the registered bidders are provided with digital keys and encryption keys. No unauthorized person can have access to data. All sensitive data is encrypted. All the price bids received against a tender are encrypted at data base level. Further log in and passwords of all users and suppliers are also encrypted at data base level. The system prevents viewing the commercial bid of a supplier till the technical evaluation of the tender is complete and the date and time specified for opening commercial bid is due.

Minimum Hardware and Software requirements for user work station:

2.10.5 Hardware requirement

- A system with minimum P-III processor
- 64 MB RAM or above
- Ethernet based network interface
- Modem or mode of connecting internet for web based uses.
- UPS for power backup

2.10.6 Software requirement

- Windows based operating system – Windows98. Release2, windows WT, Windows2000 professional, Windows XP
- Web browser, Internet Explorer 5.5 or above
- Latest antivirus running on the system.
- Connectivity: Connect to the Internet via Dialup modem or any other mode (ISDN modem/ cable connection/leased line etc.) Open the web browser and type www.eprocurement.gov.in Click on Tender, log in and follow the link.

Note: Reference to E-Procurement Manual may be made for detailed procedure

2.10.7 Turnkey projects:

Bids for a project can be invited on a piecemeal basis i.e. for equipment/materials directly from manufacturers, for only labour works, for substations, for lines, for other works, for part material supply and labour, or for entire project covering substation and line on a total turnkey basis or semi turnkey basis.

Advantages and limitations of turnkey projects are given hereunder. Difficulties and constraints in each type of tendering were explained earlier. Merits and demerits of turnkey projects are given hereunder.

Advantages:

- 1) Project is executed by a single agency. Hence monitoring and coordination becomes easy.
- 2) Planned delivery of materials i.e. materials in proportion to the work in progress can be arranged, ensuring uniform investment in proportion to the progress.
- 3) Mismatch between material supply and works is prevented.
- 4) Completion of entire project as scheduled enables beneficial use of the asset created,

Limitations: Project cost may go up since the materials specific to the project being small in number, are procured in retail by the contractor at higher costs as compared to the costs at which these are procured in bulk covering a cluster of projects, by the department.

In case of purchase of equipment/materials in bulk by the department separately, delivery of goods shall be suitably programmed to match with the progress of works in the projects covered. Every effort shall be made to coordinate the procurement of materials and their delivery with the award of contract for labour and the progress of related works. If the materials are supplied in advance or if the connected works do not progress as scheduled, even though the materials are received as per schedule, the inventory of stores piles up resulting in locking up of capital in addition to curtailing the warranty and likely damage to goods due to storage for longer period.

In order to reduce the burden due to payment of extra amount for the equipment in case of turnkey projects, a cost data on the cost of various equipments/materials may be prepared carefully arriving at the prevailing costs. The following alternatives may be considered.

- a) Cost of goods purchased earlier by the department, shall be updated using approved IEEMA / any other Indices.
- b) Latest costs of various goods may be obtained from reputed manufacturers
- c) Cost of similar goods purchased by the neighboring utilities may be obtained

Higher of the costs obtained as above may be adopted considering the prevailing market trend. To this margin between bulk and retail cost say 10% may be added to get the latest cost data. The rates obtained in the cost data may be taken as internal bench mark for supply of goods in case of turnkey projects. The limits in the bids may be fixed accordingly.

Power Transformers/Reactors are the costliest and major elements in a project. Due to their bulky size and heavy weight, they are normally delivered at site. These are normally required in the last quarter of the project. In view of this, it would be better if the transformers/reactors required for various projects to be taken up for completion in a specific period, are procured by the department with deliveries so scheduled that they are received at designated time. The remaining project as a whole can then be awarded on turnkey basis.

2.10.8 ANNEXURE

List of Standards and Codes governing equipment and Materials:

Sl. No.	Description of the Equipment	Standards applicable
1	Power Transformers	IS-2026, IEC-76
2	Bushings for AC Voltages above 1000 V	IS-2099, IEC-137, BS-223
3	Specification for large bottom porcelain for use in electrical installation	IS:5621
4	Dimensions of porcelain transformers bushings	IS:3347
5	Fittings and Accessories for power transformers.	IS-3639
6	Insulating oils for Transformers and switch gear.	IS-335, IEC-296, BS-148
7	Three phase Induction motors	IS-325 , IEC-34
8	Industrial cooling fans	IS-6272
9	Guide for loading of oil immersed transformers	IS-6600
10	Gas operated relays	IS-3737
11	Code of practice for selection, installation and maintenance of transformers	IS-1886, IS 10028-Part-II & III
12	Current Transformers	IS-2705 part-I to IV, IEC-185
13	Capacitor voltage Transformers	IS:3156 (Part –IV), IEC:186
14	Potential Transformers	IS 3156 (Part –I to III), IEC 186
15	Coupling capacitor divider	IEC:358
16	Coupling capacitors and capacitor dividers	IS:9348
17	Lighting arrestors for AC system	IS:3070 Part-I to III
18	Arrestors without gap for AC system	IEC 99-Part 4
19	Circuit Breakers for AC system	IS:2516, IEC:62271-100 Ed 1.0 (2001)
20	Acceptance of new supply of sulphur Hexa fluoride.	IEC-376
21	Synthetic Testing of High Voltage alternating current Circuit Breakers	IEC-60427
22	Pressurized Hollow Column Insulators	IEC-61264
23	Isolators and earthing switches for voltages above 1000 V AC system.	IS: 9921 , IEC 129, IS:1818
24	Air break switches, Air break disconnectors and fuse combination units for voltages not exceeding 1000 VAC or 1200 V DC.	IS:4064
25	Electro Technical Vocabulary secondary cells and batteries	ISS:1885/1986(Part VIII)
26	Stationery cells and Batteries Local Acid Type with tabular positive plates.	ISS:1651/1991 (Third revision)
27	Water for storage Batteries	ISS:1069/1964
28	General requirement and methods of test of lead acid storage Batteries	ISS:8320/1982
29	Stabilized power supplies DC output	ISS:7204/1980

30	PVC insulated (heavy duty) electronic cables for working voltages up to and including 1100 Volts	IS: 1554 (part-I)
31	PVC insulation and sheath of electric cables	IS:5831
32	Conductors of insulated cables	IEC 228
33	Conductors for insulated electric cables and flexible cords	IS:8130
34	methods of test for cables	IS:10810
35	Recommended current ratings for cables (PVC insulated light duty cables)	IS:3961 (part-V)
36	Energy meters	IS:13010, IS:722 (part-I to IX) IEC 521, BS 3T
37	AC transformer operated watt hour and VAR hour meters class 0.2S and 0.5S	IS:14697/1999
38	Static watt hour meters for class 0.2S & 0.5S	IEC:687/1992
39	AC static electrical energy meters. Alternating current static watt hour meter for active energy (class 1 and 2) Alternating current static VAR hour meter for reactive energy (class 2 & 3) Alternating current static VAR Hour meter for reactive energy (class 2 & 3)	CBIP Technical Report No.88 (Revised in July 1996 read with amendments issued in April 99, Sep 99 and Feb 2002) IEC 1036, IEC 1268
40	Indicating instruments	IS:1248, IS:2419, BS 89
41	Electrical relays for power system protection	IS:3231, IEC 255 part I to III, BS 142
42	Specification for static protective relays and tests	IS:8686, IEC: 255 (Part V & VI) IEC 801-4
43	Communication protocol	IEC 62056
44	Control switches (LV switching devices for control and auxiliary circuits).	IEC 337, IEC 337 – 1 IS 6875
45	MCCBs and Load Break switches having a breaking capacity of 30 KVA at 415 volts.	IS:2516
46	Fuse switching units	IS:4047
47	HRC cartridge fuse links for voltage above 650 volts.	ISS:2208/1962
48	HRC cartridge fuses	IS:9224 (part II)
49	Boxes for the enclosures of electrical accessories (part II Boxes made of insulating material)	IS:5133/1969
50	Insulation co-ordination	IEC-171
51	Marking & arrangements for switch gear, bus bars, main connections and auxiliary wiring.	IS-375
52	Common clauses for high voltage switchgear and control gear standards	IEC-694
53	Factory built assemblies of switchgear and control gear for voltages upto and including 1000V AC and 1200 V DC.	IS:8623
54	Low Voltage switchgear and control gear	IEC 439

	assemblies	
55	General requirement of switchgear and control gear for voltages not exceeding 1000 V	IS:4237
56	Degree of protection provided by enclosures for low voltage switchgear and control gear.	IS:2147
57	Aluminum alloy Bars	IS:5082
58	Copper strips for electrical purpose	IS:1897
59	Code of practice for phosphate treatment of iron and steel.	IS:3618 IS:6005
60	Guide for marking of Insulated conductors	IS:5578
61	Graphic symbols Ref – abbreviations	IS:2032
62	Marking and arrangement for switchgear, bus-bar, main connections and auxiliary wiring.	IS:55788 IS:11353
63	Seamless High Carbon steel cylinders for permanent and high pressure liquefiable gases.	IS: 7285
64	Indian Electricity Rules	IE 1956
65	Electrical clearances	IEC 71
66	Insulation co-ordination for equipment of 100 KV and above	IS:2165
67	Degrees of protn. provided by enclosures for low voltage switch gear and control	IS-2147
68	Classification of degree of protection provided by enclosures of electrical equipment	IS:12063
69	Degree of protection provided by enclosure for rotating electrical machinery	IS: 4691
70	Colors for ready mix paints	IS-5
71	Current Transformers Measurement of PDs and Tan Delta	IEC-44(1)
72	High Voltage testing techniques	IEC-60
73	Method of High Voltage testing for equipment	IS:2071 part-I to III
74	Partial discharge measurement	IEC-270
75	Structural steel (standard quality)	IS:2062
76	Mild steel and medium tensile bars and hard drawn steel wire for concrete reinforcement	IS:432
77	Code of practice for use of structural steel in overhead transmission line Part I : Loads and permissible Stresses Part II : Fabrication, Galvanizing, Inspection	IS:802
78	Structural Steel Micro Alloyed (Medium And High Strength Quality)	IS:8500
79	Code of practice for Design Part I & II Installation & Maintenance of Section of Overhead Power Line	IS:5613
80	<u>Transmission Tower Bolts</u>	IS-12427
81	Hexagonal bolts for steel structures	IS:12427
82	Hexagonal Bolts for Steel	IS: 6639

83	Hexagonal Bolts & Nuts	IS: 3138
84	Dimensions for nominal lengths & thread length for bolts, screws and studs.	IS: 4206
85	Plain washers	IS: 2016
86	General requirements for plain washers and lock washers	IS-5369
87	Specification for heavy washers for steel structures	IS: 6610
88	Testing of washers	IS-6821
89	Fastness spring lock washers for screws with cylindrical heads.	IS: 6735
90	Technical Supply Conditions for Threaded Steel Fasteners	IS-1367part 1 to 13
91	Single coil rectangular section spring lock washers	IS-3063
92	Methods for sampling of fasteners	IS-2614
93	High quality spring steel	IS-4072
94	Danger Notice Plates	IS:2551
95	Specification for zinc	IS:209-1992, BS : 3436
96	Recommended practice for hot dip galvanizing of iron and steel.	IS:2629, ASTM-A 153-82
97	Method of testing uniformity of coating on zinc coated articles.	IS:2633
98	Hot dip zinc coatings on structural steel and other applied products	IS: 4759
99	Electro plated coating of zinc on iron and steel	IS: 1573
100	Hot Dip galvanized coatings on round steel wires	IS: 4826, ASTM A-472729 BS: 443
101	Methods of Determination of weight of zinc coating of zinc coated iron and steel articles.	IS:6745 BS:443
102	Method of chemical Analysis of slab zinc	IS:406
103	Aluminum conductors steel reinforced for overhead transmission purpose.	IS: 398 (Part II & V) IEC: 1089, BS: 215 (Part II)
104	AAA Conductors	IS: 398 (Part IV)
105	Reels and Drums for Bare conductors	IS 1778, BS: 1559
106	Method for tensile testing of steel wire	IS:1521, ISO/R89
107	EC grade Aluminum rod produced by rolling	IS:1841
108	Aluminium alloy 6201-T 81 wire for electrical purposes.	ASTM-398 M-82
109	Hard drawn aluminium clad steel wire.	ASTM-B415-81, IEC 1232
110	Concentric lay stranded aluminium clad steel	ASTM-B416-81
111	Concentric lay stranded aluminium alloy 6201-781 conductors	ASTM-B 399 M-82
112	Zinc coated (galvanized) steel core wire for aluminium conductors steel reinforced (acsr).	ASTM-B 498M-83
113	International electro technical vocabulary	IEC-50-(1975)
114	Optical fibres. Part-1: generic (1987) specification	IEC-793-1
115	Optical fibre, cables,	IEC-794- Part-1., E1, E3,

	E1 – tensile performance of optical fibre cable E3 – crush strength test on optical fibre cable E6 – bending test on optical fibre cable F1 – temp cycling test on optical fibre cable F5 – longitudinal water tightness test on optical fibre cable	E6, F1, F5
116	EC grade Aluminum rod produced by continuous casting and rolling	IS: 5484
117	Specification for galvanized stay strand.	IS: 2141-1992
118	Method for wrapping test for metallic wire	IS:1755-1983
119	Fibre optic test procedures series (FOTP.S)	RS-445
120	Standard optical wave guide fibre (1984) material classes and preferred sizes	RS-458-A
121	Fibre optic connector terminology	RS-440 (1978)
122	Generic specification for fibre optic connectors	RS-475 (1961)
123	Standard fibre optics, definition of terms.	IEEE 812-1984
124	Standard construction of composite fibre optic overhead ground wire (opgw) for use on electric utility power lines.	IEEE 1138-1994
125	Porcelain insulators for overhead power line with a nominal Voltage greater than 1000 V	IS:731-1971, BS-137 (I & II), IEC : 60383- (Part-I)-1993, (Part-II) 1992
126	General requirements & Tests for Insulators	IS : 2486, Part-I-1971, BS : 328-1973
127	Dimensional requirements for Insulators	IS : 2486 Part-II-1974 IEC : 60120-1984
128	Locking devices for Insulators	IS : 2486 Part-III, IEC 372(2)
129	Characteristics of string insulator units	IS:3188-1980, IEC : 60305
130	Method for RIV test on High Voltage Insulators	IEC-8263
131	Methods for switching Impulse test on HV insulators	IS : 8269-1976, IEC : 60506-1975
132	Thermal Mechanical performance test and Mechanical performance test on Insulator units.	IEC : 60575-1977
133	Guide for selection of insulators in respect of pollution conditions	IS : 13134 – 1992 IEC : 60815 – 1986 & IEC : 60273 - 1990
134	Artificial Pollution tests on HV Insulators to be used on AC systems	IS : 8704, IEC : 60507 - 1991
135	Metal fittings of insulators for overhead power lines with nominal voltage greater than 1000v general requirements and tests. (Hardware for Transmission line)	IS 2486 1993- (Part-1 to III)
136	Stockbridge Vibration Dampers for overhead power lines	IS 9708 - 1993
137	Conductors and earth wire accessories for overhead power lines Armour rods, binding wires and tapes.	IS 2121-1981 (Part-I to III)

138	Technical supply conditions for threaded steel fasteners	IS : 1367 - 1980
139	Method of Impulse Voltage testing	IS : 2071 (Part-II) - 1974
140	Specification for white heart malleable iron castings	IS : 2107 - 1977
141	Specification for black heart malleable iron castings	IS : 2108 - 1977

Reference Abbreviation	Name and address
IEC	International Electro Technical Commission Bureau de la commission, Electro Technique international, 1, Rue de Vercimbe, Geneva, Switzerland
ISO	International Organization for Standardization, Danish Board of standardization Auvehogvej -12, DK- 2900, Heel Prup, Denmark .
IS	Inchain Standard, Bureau of Inchain standards , Manak Bhavan, 9, Bahadurshah, Zaffer Marg, New Delhi – 110 002.
BS	British Standards, British Standards Institution, 101, Pentonville Road, N-19-ND-UK.

VOLUME - III

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3.1 PROJECT MANAGEMENT

After award of contract, CE (construction) at Corporate office will assign the project execution to the construction unit in the field SE (TLC). The SE will authorize one of the Executive Engineers to take up the work, who will be the Project Manager. The EE will be assisted by ADE/AE of electrical and civil wings in the execution of the project.

The Projects Construction unit at head quarters shall ensure that the approved schemes are completed as per the schedule and within the given time frame. In case of any deviations where extra items are found absolutely necessary during execution of the scheme, the EE/TLC in the field in-charge of the work, shall submit the details with full justification for such deviation / new item to Headquarters without any delay: The CE/Construction shall approve such deviations based on the justification. However, the CE/Construction shall submit a monthly return on the above to the Committee of Technical Directors for their review and seek ratification of the action taken by them. In case the cost is expected to exceed 10% over the sanctioned scheme cost, then the CE/Construction shall submit a report immediately and obtain approval of the Board.

APTRANSCO has been adopting Enterprise Resource Programme (ERP) in the following modules.

- 1) Project Management and Execution
- 2) Finance Management
- 3) Stores Management and Inventory Control
- 4) Operation and Maintenance management

Upon award of contract, execution and monitoring of the project are carried out by both field and headquarters units through Enterprise Resource Planning system (ERP).

3.1.1 About ERP: It is an IT tool useful in optimizing the resources available, be it man power, material, finance technology etc. The ERP is aimed at bringing in more transparency, accountability; unhindered data flow across the functions, availability of data and help in forecasting, and to cut-down delays. Implementation has initially been taken up in four areas viz., (i) Project Module (ii) Material Module (iii) Maintenance Module and (iv) Finance Module. The entire APTRANSCO has been connected through an intranet and any licensee in APTRANSCO can access the data through his login and pass word. Thus any user with requisite authority can view all the data and find out the stock position from all the stores, raise the indent for material, get the allotment, view the project progress and process all the financial activities for payment .

(i) Project Module: The project module is aimed at facilitating smooth implementation of the project giving necessary time lines, alerts and to transparently transfer the entire data across the organization for all the concerned to view. The project implementation can be viewed pictorially and PERT techniques can be applied to quickly complete the

projects. This module also provides strict material control as well as budget control. The day today progress of the works can be updated from the field immediately and can be viewed from any where in the state. The material indents also can be raised, allotted and the expenditure booked to the project.

(ii) Material Module: The material module basically covers the functionality of the procurement and material management. The material management process consists of planning and procurement of materials, receipt and storage of material and issue of material. The planning and procurement process consists of identification of material requirement on a periodic as well as continuous basis, selection of appropriate vendor for supply of the required material, raising of Purchase Orders on the required material, placing of orders and following up for receipt of the material. Receipt of materials process has been segregated into the following sub-processes.

- a) Centralized Purchases and Receipt from other stores.
- b) Devolutions
- c) Localized Purchases.

(iii) Maintenance Module: The maintenance module is aimed at improving the O&M of the equipments. All the equipments are identified by a unique ID and they are tracked based on this unique ID. The maintenance schedules and periodicity against each equipment are stored in the database. As per the periodicity, the mail will be triggered to all the concerned to take up the work. The steps to be followed for each of the preventive activity are also stored in the database. Thus whenever an activity of preventive maintenance is triggered, it gives all the necessary steps involved in the work and the user will be able to update the information with the no. of resources used, the works which were carried, material consumed etc. Likewise data can also be entered in case of breakdowns. Thus the history of the equipment from the date of commissioning will be available with all details such as no. of years served, preventive maintenance details, material consumed for preventive maintenance, the persons who attended preventive maintenance, the time taken for preventive maintenance activity, similarly for breakdown maintenance. This will help in planning the maintenance works and estimating for repair and maintenance.

(iv) Finance Module: All the payments and payment processes like raising of LOAs, passing LOAs, passing of bills, check measurement, creation of balance sheet, profit & loss account, budgetary control, capitalization, inventory valuation , project expenditure monitoring are tracked through this module.

Construction of Transmission Projects:

TRANSMISSION LINES:

Major steps in a transmission line construction are a) appropriate selection of route adopting most suitable technical procedures, and b) geo-technical investigations.

3.2 Important Technical specifications for Line Works:

The specification covers check survey, distribution of all the material to work locations, setting to work, erection, testing, commissioning of EHV Transmission lines.

Length of the line and the quantities specified in the Schedule against various items may vary depending upon the actual site conditions and also the changes / deviations in the alignment of the line that may have to be carried out depending upon the right of way, forest clearance, PTCC Clearance and other problems that may arise in the course of execution of the contract. The contractor shall execute works to the extent required and shall have to complete the work as a whole (i.e. the Transmission line which is the ultimate work to be put into use). The contract shall specify his role and responsibility for all such deviations in quantities arising due to changes in alignment or other reasons.

3.2.1 Route: The actual route of the transmission line shall depend on the results of the survey carried out by APTRANSCO and is also subject to the approval of the Power Telecommunication Coordination Committee.

In case of any deviation found necessary at the time of execution of works in the finalized profile, number/ type of finalized towers etc., the same shall be placed immediately before the committee of technical Directors for approval

3.2.2 Topography: Along the route of the transmission line the altitude varies from sea level to about 1000 meters above mean sea level. The topography of the terrain is fairly plain having hilly terrain, cultivated fields, gardens, and small thick jungles.

3.2.3 Type of Construction: The line shall be constructed on self-supporting galvanized lattice steel towers suitable for assembly at site by bolt connections. The conductors shall be in vertical formation for DC or DC/SC line and in horizontal formation for a SC line. Continuous earth wire shall be provided above the conductors for effective shielding etc. The line shall initially terminate on terminal towers situated at a distance of not more than $1/3^{\text{rd}}$ of normal span from the out-door substations at either end. From the terminal towers, the line shall be connected to the terminal structures in the sub-stations.

3.2.4 Permits and Priorities: The contractor shall make his own arrangements in using private roads, pathways, etc., in connection with the construction work. The contractor shall himself arrange for permits required for the operation of the vehicles used in construction works. The APTRANSCO may, however assist the contractor in obtaining controlled commodities necessary for the execution of the works.

3.2.5 Cement and Reinforcement Rods: The cement and steel reinforcement rods required for the work have to be supplied by the contractor. Ordinary Portland cement of Grade-43 manufactured as per IS-8112 of 1989 shall only be used. Storage, certification, delivery and testing of the cement shall conform to IS-8112 with latest amendments. IS Certification mark is obligatory. Cement procured from major/ approved cement manufacturing plant (M/s.Raasi, M/s.Vishnu, M/s.Andhra Cement Company, M/s.ACC, M/s.CCI, M/s.L&T, M/s.Coromandal, M/s.Priyadarshini, M/s.Madras Cements, to name a few) with the approval of APTRANSCO shall be accepted. Reinforcement Steel shall conform to IS 1786 and shall be procured from standard manufacturers i.e. TISCO, SAIL & VSP for use in tower foundations.

3.2.6 Materials required for the work: In case of a turnkey contract, the Successful bidder shall supply all the material as required in the specification for erection of the line. The material shall be delivered at the site stores. The contractor will be responsible for proper handling and maintenance of the materials up to the time of handing over of the completed works to APTRANSCO and return of surplus materials if any, at APTRANSCO's stores.

After completion of the Check Survey, the contractor has to furnish actual quantity of material required for each item covered in Schedule and proceed to procure the requisite quantity of material only. Should however, on completion of all the works, any surplus materials for which payments have been made by APTRANSCO are lying with the contractor, all such material shall be handed over to the Engineer at the APTRANSCO's stores. This shall be done within two months after completion and handing over of the line. If the materials are not returned within this period and / or in the opinion of the Executive Engineer in charge of the work, are not in a fit condition for use, such surplus materials will be treated as sold to the contractor at the rate equal to the stores issue rate plus 10% centage charge or at the prevailing market rates plus incidental charges, whichever is higher, and recoveries made accordingly. The 10% retention amount against the contract will be released only after all the balance materials are handed over at APTRANSCO's stores in proper shape and material accounts are rendered.

The contractor shall ensure safety for the materials lying with him for erection purpose. The contractor has to insure the materials during erection and ensure safety of the materials till the line is handed over for operation

3.2.7 Loss of Material in Erection: The following maximum additional quantities of materials may be permitted, to cover damages and losses during erection.

- i) Disc insulators required : Up to 1% of the quantity.
- ii) Conductor and earth wire : Up to 1% of the route length of the line.

(The 1% wastage includes additional lengths required to account for sag and jumpers).
- iii) Bolts and Nuts, washers and Hardware & accessories : Up to 2% of the quantity required for conductor & earth wire.

3.2.8 Standard specifications: Unless specifically mentioned, works shall be carried out in accordance with relevant Indian standards and A.P.S.S. or any revision thereof which may be issued during the currency of the contract, and all the clauses relating to materials and workmanship, responsibilities, liabilities, commencement of works, completion delays and extensions, suspension works, and forfeitures etc., as provided in the A.P.S.S. shall be binding.

The Indian Standard specification (IS) mentioned below or International Standards as amended up to date shall be applicable to the material and process used in the manufacture of towers and tower accessories.

Sl. No	Indian Standards (IS)	Title	International & Internationally recognised Standard
1	IS:2-1960	Rules for rounding off numerical values.	
2	IS:209-1992	Specification for Zinc	ISO/ R/ 752 ASTM B 6 BS: 3436- 1986
3	IS:278-1991	Specification for Galvanized Steel Barbed wire	ASTM A131
4	IS:432-1982	Mild steel & medium tensile steel bars & hard drawn steel wire for concrete reinforcement.	
5	IS:456-1978	Code of practice for plain & reinforced concrete	
6	IS:802(Part I/ Sec-I)-1995 Sec-II)-1992	Code of practice for use of structural steel in overhead transmission line towers: Materials and loads Permissible stresses Section – I : Materials and Loads Section – II : Permissible stresses	ASCE 52 IEC 826 BS 8100
7	IS:802 (Part-2)-1990	Code of practice for use of structural steel in overhead transmission line: Fabrication, galvanizing, inspection and packing.	ASCE 52
8	IS:802 (Part-3) – 1990	Code of practice for use of structural steel in overhead transmission line: Tower Testing.	ASCE 52 IEC 652

9	IS:808-1991 Part-V Part-VI	Dimensions for hot rolled steel beams, column channels & Angle sections. Equal leg angles Unequal leg angles	
10	IS:1367(Part-1)-1992	Technical supply conditions for threaded steel fasteners	
11	IS:1573-1991	Specification for Electroplated coatings for zinc on iron and steel.	
12	IS: 1893-1991	Criteria for earthquake resistant design of structures	
13	IS:2016-1992	Specification for Plain washers	ISO/R887-1968
14	IS: 2062-1992	Specification for Structural general purposes	
15	IS:2551-1990	Danger notice plates	
16	IS : 800 – 1991	Code of Practice for general building construction in steel	CSA 6.1
17	IS:2629-1990	Recommended practice for hot dip galvanizing of iron and steel	
18	IS: 2633-1992	Method of testing uniformity of coating on zinc coated articles	ASTM A123 CSA G164
19	IS:3063-1994	Specification for single coil rectangular section spring washers for bolts, nuts and screws	DIN-127 1970
20	IS:3757-1992	High strength structural bolts	
21	IS: 4091-1979	Code of practice for design and construction of foundations for transmission line towers and poles	
22	IS:4759-1990	Specification for Hot dip zinc coatings on structural steel and other allied products	
23	IS: 5358-1969	Specification for Hot dip galvanized coating on fasteners	
24	IS:5613-1993 (Part-2/) Section.1 Section.2	Code of practice for design, installation and maintenance of overhead power lines: (<u>up to 220kV</u>) Design Installation and maintenance	
25	IS:5613-1989(Part-3/Sect-1 Section-2	Code of practice for design, installation and maintenance of overhead power lines: (400kV lines) Design Installation and maintenance	

26	IS:6610-1991	Specification for Heavy washers for steel structures	
27	IS :875 –1992	Code of practice for design loads/ other than earthquakes for Buildings & Structures	
28	IS :1852 1993	Rolling & Cutting tolerances of Hot Rolled steel products	
29	IS :3043 –1991	Code of Practice for earthing	
30	IS : 6623-1992	High Strength structural nuts	
31	IS:6639-1990	Specification for Hexagonal bolts for steel structures	
32	IS: 6745-1990	Specification for Methods for determination of the weight of zinc coating on zinc coated iron and steel articles	
33	IS:7215-1991	Specification for Tolerance for Fabrication of steel structures	
34	IS:8500-1992	Specification for weldable structural steel (Medium and High Strength Quality)	
35	IS:10238-1989	Step bolts for steel structures	
36	IS: 12427-1988	Transmission tower bolts	
37		Indian Electricity Rules	
38	Publication No. 19 (N)/ 700	Regulation for Power Line crossings for Railway tracks – 1987	
39	C B I& P Publication No 268	Transmission line Manual	
40		ASCE Manual-72	

The standards mentioned above are available from:

Abbreviation	Name and address
BS	British Standards, British Standards Institution, 101, Pentonville Road, N1 9ND United Kingdom,
IEC/CISPR	International Electro-technical Commission. Bureau Central de la Commission, Electro Technique International, 1 Rue de Verembe, Geneva, Switzerland.

BIS	Bureau of Indian Standards, Manak Bhavan, 9, Bahadur Shah Zafar Marg, New Delhi – 110 001, India
ISO	International Organization for Standardization, Danish Board of Standardization, Danish Standardizing Sraat, Aurehoegvej-12 DK-2900, Heelstrup, DENMARK.
NEMA	National Electric Manufacture Associate, 115, East 44th Street, New York NY 10017, U.S.A.
JIS	Japanese Standards Association 1-24 Akasaka 4-Chome, Minato-ku, Tokyo, Japan
DIN	Deutsches Institute flir Normung Burggrafen Strance 4-10 Post Farh 1107 D-1000, Berlin 30 (GERMANY)
ASTM	American Society for Testing & Material 1916, Lace Street Philadelphia, PA 1903 1187 USA

3.2.9 QUALITY ASSURANCE PLAN:

The Contractor shall invariably furnish Quality Assurance Plan giving the following information along with his offer. Information shall be given for each type of equipment offered separately.

- Statement giving list of important raw materials, names of sub suppliers for the raw material, list of standards according to which the raw material are tested, list of tests normally carried out on raw material, copies of test certificates.
- Information and copies of test certificates as in (i) above in respect of bought out items.
- List of manufacturing facilities available.
- Level of automation achieved and list of areas where manual processing exists.
- List of areas in manufacturing process, where stage inspections are normally carried out for quality control and details of such tests and inspections.

The material shall conform in all respects to high standards of engineering, design, workmanship latest revisions of relevant standards at the time of ordering and Purchaser shall have the power to reject any work or material which in his judgment is not in full accordance therewith.

Sub vendor items: For the entire sub vendor items the following are to be furnished at the time of sub vendor approval after the award of contract.

- i. Quality Assurance Plan
- ii. Drawings.
- iii. Type Test reports conducted not earlier than five years.
- iv. Guaranteed Technical Particulars.

3.2.10 Materials to be supplied by the Contractor – Standards to be complied with:

The following shall be the standards for materials to be supplied by the bidder, for erection of the lines.

Sl.No.	Indian standard Specification	Title
1.	IS-8112 of 1989 of Latest issue	Ordinary port land cement of grade 43
2.	IS-1786	Tor steel for reinforcement
3.	IS-456	For concrete aggregates
4.	IS-383	For sand for use in rendering, plastering and mortar
5.	IS-1239 (part-I)	Hot dip galvanized M.S.Pipe and galvanizing conforming to ISS-2633/1986
6.	IS-5613 (Part-II)	Danger Boards, phase plates, Bird Guards and Number plates
7.	IS-3043	Pipe earthing
8.	IS-2062-1992	Steel for General structural purpose - For M.S.Flat 50 x 6mm for earthing of tower lines.

- a) The material shall be procured from the regular suppliers of APTRANSCO
- b) The material shall be procured after taking approval of concerned SE/TLC/APTRANSCO
- c) In respect of tower accessories, the contractor has to use the material on the line only after approval by SE/TLC.

Body Extensions: The towers have to be designed so as to be suitable for adding 3M, 6M, 9M, 12M, 18M & 25M body extensions for maintaining adequate ground clearance without reducing the specified factor of safety in any manner. The strength of tower members for all loading cases is adequate with and without extensions.

Leg Extensions: To spot the tower in the hilly terrain leg extensions/Hill side extensions for all types of towers ranging from 1.5M to 9.0M suitable to be fitted to normal towers to plus six metres towers as well as with other extensions shall be provided.

3.2.11 TOWER ACCESSORIES

Step Bolts and Ladders: Each tower shall be provided with step bolts conforming to IS: 10238 of not less than 16mm diameter and 175mm long spaced not more than 450mm apart and extending from 3.5 metres above the ground level to the top of the tower. For double circuit tower the step bolt shall be fixed on two diagonally opposite legs up to top of the towers. For single circuit tower the step bolt shall be fixed on one leg up to waist level and on two diagonally opposite legs above waist level up to top of the towers. Each step bolt shall be provided with two nuts on one end to fasten the bolt securely to the tower and button head at the other end to prevent the feet from slipping away. The step bolts shall be capable of withstanding a vertical load not less than 1.5 KN. For special towers, where the height of the super structures exceeds 50 meters, ladders along with protection rings as per the Purchaser approved design shall be provided in continuation of the step bolts on one face of the tower from 30 meters above ground level to the top of the special structure. From 3.5 m to 30 m height of super structure step bolts shall be provided. Suitable platform using 6 mm thick perforated chequered plates along with suitable railing for access from step bolts to the ladder and from the ladder to each cross-arm tip and the ground wire support shall also to be provided. The platform shall be fixed on tower by using counter-sunk bolts.

3.2.12 Number, Danger, Circuit and Phase Plates: Each tower shall be fitted with a danger plate, number plate & 2 sets of phase plates for double circuit tower. The transposition towers should have provision of fixing phase plates on both the transverse phase. Circuit plates (set of 2) shall be provided on all the Double Circuit Towers. Danger plates shall conform to IS: 2551-1990 in all respects, except that the plate shall be of vitreous enameled Red with letters, figures and the conventional skull and bones in white.

The number, circuit and phase plates shall conform to IS: 5613 (Part 3/section-1)-1989. The corner edges of the danger, number & circuit plates shall be rounded off to avoid sharp edges.

The letters of number & circuit plates shall be red enameled with white enameled background.

Anti -Climbing Device: Towers are to be provided with anti-climbing devices as per drawing and conform to IS: 5613 (Part 3/section-1) -1989.

Necessary holes, as shown on the fabrication drawings, are to be provided on the tower members for installation of the anti-climbing device.

The barbed wire used shall be of TYPE - A and SIZE -1 as per IS-278, 1991 (latest). The barbed wires shall be given chromating dip as per procedure laid down in IS: 1340.

Bird Guards: The bird guards for suspension towers shall be made of galvanized iron sheet and shall conform to IS: 5613 (Part-3/Section-1)-1989.

Statuary Requirements: Statutory requirements as laid down in the 'Indian Electricity Rules 1956' or by any other statutory body applicable to such structures shall be satisfied/observed.

3.2.13 Ground Clearance: The minimum ground clearance from the lowest conductor shall be considered as given in the following table. The provisions made for considering the ground undulations, errors in stringing, is 150 mm extra.

System Particulars

a)	Line Voltage (kV)	400	220	132
b)	Highest system voltage (kV)	420	245	145
c)	Number of circuits	2	2	2
d)	Frequency (Hz)	50	50	50
e)	Neutral	Effectively earthed	Effectively earthed	Effectively earthed
f)	Number of sub conductors	4 or 2	2 or 1	1
g)	Bundle arrangement	Square/ Horizontal	Horizontal	-
h)	Bundle spacing	450	450	
i)	Basic insulation level BIL kV(RMS) (peak)	1550	1050	650
j)	Power frequency withstand voltage wet (kV) rms	680	460	275
k)	Switching Surge withstand voltage wet kV peak	1050	NA	NA
l)	Corona extinction voltage: Dry condition kV rms	320		
m)	Radio interference voltage at one MHz for phase to earth voltage of 266kV rms dry	1000 volts		
n)	Short circuit level KA	40	40	31.5
o)	Maximum temperatures deg C Conductor Earth-wire	75	75	75
		53	53	53
p)	Power line crossing			
	i) Another power line (mm)	5490	4580	3050
	ii) Telecommunications line (mm)	4480	3050	2750

iii)	Railway line (mm) Above track (mm) Above crane (mm)	17900 6000	15400	14600
iv)	Major roads	As per IE rules – 1956 12.2	12.2	12.2

Clearances of live parts to Tower Members: The minimum clearances between the live parts, tower and cross-arm members are given below.

Clearances	400kV	220kV	132kV
Minimum ground clearance from power conductor (mm)	8840	7050	6100
Provision for survey and sag errors (mm)	150	150	150
Minimum phase to phase distance (mm)	4000		
Minimum vertical midspan clearance between power conductor and earth wire in still air (mm)	9000	8500	6100
Swing angles and minimum clearance from live to earthed metal	20°	30°	30°
Suspension insulator string in still air and when deflected upto 22 degrees from vertical (mm)	3050	1830	1370
Suspension insulator when deflected by wind up to 44 degrees from the vertical (mm)	1860	1675	1220
Jumpers in still air and when deflected up to 20 degrees from the vertical (mm)	3050	1675	1070
Jumpers when deflected by wind up to 40 degrees from the vertical (mm)	1860	-	-
Tension insulator string (mm)	3050	-	-

The minimum weight spans shall be verified by the Designs division, based on actual spans and deviations and such issues that may arise, before deciding on next type of tower or extension.

3.2.12 INSULATOR STRINGS AND EARTH WIRE CLAMP ATTACHMENTS: For the attachment of suspension insulator strings a suitable hanger on the tower has to be provided so as to obtain required clearance under extreme swinging conditions and free swinging of the string. The hanger has to withstand the highest possible load that may be imposed on it.

- a) Earth wire peak/ cross arms have to accommodate the shackle of the suspension clamp.

- b) At tension towers, strain plates of suitable dimension on each cross arm tip and top of the earth wire peak; have to be provided for taking the D-Shackles of the tension insulator strings or earth wire tension clamps as the case may be.

3.2.13 Shield Angle: The angle of shielding is defined as the angle formed by the line joining the center lines of the earthwire and power conductor/outer power conductor, in still air, at tower, to the vertical line through the center line of the earthwire. The drop of 150 mm on account of earthwire suspension assembly has to be considered while calculating the minimum angle of shielding.

Limit for shield angle for 400kV lines is 20° and for 220 and 132kV lines is 30°. No. of shield wires (earth wires) depends on these limitations. Normally two wires are provided for 400kV lines and one no. wire is provided for 220 & 132kV lines for shield.

3.2.14 Fabrication: Mild steel and high tensile steel should not get mixed up during fabrication and as such identification mark shall be embossed on each and every H.T. Steel section.

All parts of the towers shall be cut to correct lengths and fabricated in accordance with the shop drawings approved by the purchaser. Welding of two or more pieces to obtain the length of member specified shall not be allowed. Members shall be straight to the permissible tolerances to ensure proper fitting before being laid off or worked and after galvanizing.

The tower members shall be accurately fabricated to bolt together easily at site without any undue strain on them or the bolts.

The diameter of the hole shall be equal to the diameter of bolt plus 1.5 mm. No angle member shall have the two leg flanges brought together by closing the angle. All parts of the towers shall be accessible for inspection and cleaning. Drain holes shall be provided at all points where pockets or depressions are likely to hold water.

All similar parts shall be made strictly inter changeable. All steel sections before any work is done on them, shall be carefully leveled, straightened and made true to detailed drawings by methods which will not injure the materials so that when assembled the adjacent matching surfaces are in close contact throughout. No rough edges shall be permitted in the entire structure.

3.2.15 Bolts, Nuts and Washers: All tower members shall be joined together with Bolts and nuts. The redundants of first two (2) panels from ground level shall be connected with Anti-theft bolts and nuts along with spring washers whereas the balance joints shall be connected with hexagonal bolts & nuts. All hexagonal bolts and nuts shall conform to IS – 12427. They shall have hexagonal head and nuts.

Anti-theft bolts and nuts shall have round tapered heads with hexagonal shear nuts. They shall conform to IS: 12427 and IS: 1367 for property class 5.6/5. The bolt shall be of 16/24

mm diameter and of property class 5.6 as specified in IS: 1367 (Part-III) and matching nut of property class 5.0 as specified in IS: 1367 (Part-VI).

Nuts for hexagonal bolts should be double chamfered as per the requirement of IS: 1363 Part-III. It should be ensured by the manufacturer that nuts should be over-tapped beyond 0.4mm oversize on effective diameter for size up to M16.

Nuts for Anti-theft bolts should be round tapered with hexagonal shear nuts. The hexagonal portion of shear nuts shall break away at specified torque recommended by the supplier to ensure proper tightening of members and the fasteners shall not be opened subsequently with tools. The tightening torque and shearing of anti-theft nuts shall be verified during proto-assembly.

Fully threaded bolts shall not be used. The length of bolts shall be such that the threaded portion will not extend into the plane of contact of the member. All bolts shall be threaded to take the full depth of the nut and threaded enough to permit firm gripping of the members, but not beyond. It shall be ensured that the threaded portion of each bolt protrudes not less than 3 mm and not more than 8 mm when fully tightened. All nuts shall fit and tight to the point where the shank of the bolt connects to the head.

Flat and tapered washers shall be provided wherever necessary. Spring washers shall be provided for insertion under all nuts. These washers shall be steel electro galvanized, positive lock type and 3.5mm in thickness for 16mm dia bolt and 4.5 mm for 24mm bolt.

To avoid bending stress in bolts or to reduce it to minimum, no bolt shall connect aggregate thickness of members more than three (3) times its diameter.

Spacing of Bolts and edge distance: The minimum spacing of bolts and edge distances shall be as given below:

Bolt diameter (mm)	Hole diameter (mm)	Minimum bolt Spacing (mm)	Minimum edge Distance	
			Hole center to rolled or sawn edge	Hole center to sheared cut edge
16	17.5	40	20	23
20	21.5	48	25	28
24	25.5	60	33	38

Not more than two diameters of bolt shall be used on any one tower. Step bolts are excluded from this requirement.

Locking Devices: Spring washers designated as B-16-IS-3063 Electro galvanized shall be provided for insertion under all nuts. These washers shall be of steel and electro-galvanized, conforming to IS: 1573-1986 and positive lock bolt as per IS: 3063-1972. Washers of the following thickness shall be provided under all nuts.

Bolt Diameter (mm)	Thickness of spring washers (mm)
16	3.5
20	4.0
24	4.5

Check Assembly of Towers: Before proceeding with the mass fabrication of any type of tower, the contractor shall fabricate and assemble at his works for inspection by the purchaser or his authorized representative, one tower of each type as finally approved by the purchaser for checking the fabrication accuracy and workmanship (Proto assembly). The prototype assembly made on the ground in the horizontal position shall be adequately supported to prevent distortion and over-stressing of members. Proper fit shall be accomplished without extraordinary effort to align bolt holes or to force members into position. For the check assembly, bolts and nuts shall be not more than finger tight.

3.2.16 Check Survey: The Contractor shall carryout check survey. After the approved profiles are received, the contractor must fix up locations based on the approved spans indicated in the profile / tower schedule and only conspicuous variations in the chainage and physical features as indicated in the profile and as actually noticed during check-survey must be brought to the notice of the APTRANSCO's Engineer for taking remedial action. If the site of a tower location is not suitable for locating a tower, the location will have to be shifted suitably keeping in view the limitation of span and this will be decided by the Executive Engineer.

3.2.17 Stub setting and Foundations:

Excavations for Foundations in different soils, setting of stubs, laying of foundations to be carried out is described in construction of transmission lines

The contractor shall undertake full responsibility for the correct setting of stubs in accordance with the approved methods of the exact locations and alignment and in precisely correct level. Stub setting templates shall be used for proper setting of stubs.

Cement concrete foundations shall be constructed complying with the foundation drawings to be furnished to the contractor. The type of foundation to be laid at each location will be decided by the Executive Engineer after inspection of site and for this purpose the locations must be excavated for dry type foundations initially and offered for inspection. Foundation at a location shall be laid only on receipt of written communication from the Executive Engineer indicating the type of foundation to be laid.

In case, foundations of types other than those mentioned are found necessary in the course of execution of contract, such foundations shall have to be laid only on communication of drawings for such foundations by the Engineer.

APTRANSCO shall reserve the right to uncover and examine any foundation if it is found to be not in accordance with the specification. The contractor shall be required to open up and rectify all defective foundations if any and backfill at his sole expense and cost.

Cement concrete footing shall be used for all types of towers in conformity with the present day practices followed in the country. They will be mostly pyramid, stepped and chimney type. In very loose soils and wet locations R.C.C type of foundations may have to be provided to suit actual conditions. All the four footings of towers will be similar. Bidders shall quote for concreting including cost of dewatering.

In case of river crossings it may be necessary to use well foundations or other special type of foundations based on actual conditions.

3.2.18 Classification of Foundations: Classification of soil shall be made according to IS: 200 (Part I) 1974 for footing cast in open pits. The Foundation Drawings as finalized by the Civil Engineering Wing for various soil conditions suitable for different Types of Towers being deployed in the construction shall be followed. When in the opinion of contractor, the classification of soil and foundation design for a particular location given by the Executive Engineer differs from his own assessment; the contractor may submit his reasoning and analysis for examination by CE (Civil), APTRANSCO. The foundation work at this location shall commence only after specific approval from CE (civil).

3.2.19 Foundation Concrete:

(a) Pad Concrete: The cement concrete used for the base/pad of foundations shall be of 1:4:8/ 1:3:6 mix with 40mm well graded hard broken granite metal.

(b) Foundation Concrete: The cement concrete used for the foundations (frustum/stepped and chimney) shall be of 1:2:4 mix ratio with 20 mm hard broken granite metal.

The sand used for the concrete shall be composed of hard silicon materials. It shall be clear and of a sharp angular grit type and free from earthy or organic matter and deleterious salts. The aggregate shall be of clean broken hard granite or other stone specified or approved by the Engineer. It shall be of hard, close grained quality. It shall also be as far as possible cube like, preferably angular, but not flaky, perfectly clean and free from earth organics or other deleterious matter. 20 mm aggregate shall be of size as will pass through 20 mm square mesh measured in clear.

The water used for mixing concrete shall be fresh, clean and free from oil, acids and alkali. Saltish or blackish water should not be used.

Methods of concrete mixing, conveyance and depositing of concrete, curing and back filling are explained in construction of lines.

In special cases, the APTRANSCO Engineer at site may authorize use of quick setting or rapid hardening compound in certain foundations.

As the uplift strength of the foundation depends upon proper consolidation of backfilled earth, extreme care shall be taken in this regard with special emphasis. Thereafter both the backfilled earth and exposed chimney top shall be kept wet for the remainder of the prescribed time of 14 days. The backfilling of foundations shall be so carried out that after one monsoon the level of the backfilled earth does not go below the surrounding ground level. However if any foundation settles below ground level after one monsoon it would be filled up by the contractor to be in level with the surrounding ground at his expense. The Stub setting templates shall be opened only after the completion of backfilling.

After backfilling, about 150 mm high earthen embankment along the sides of excavation pits will be made and sufficient water will be poured in the backfilled pits so that standing water remains above the backfilled earth for at least 24 hours. The uncovered concrete chimney above the backfilled earth shall be kept wet continuously for 14 days after concreting by providing wet empty gunny bags fully wrapped around the concrete chimney for curing and ensuring that the bags are kept wet by frequent pouring of water on them. The excavated earth left over should be spread within the four legs of the tower location.

3.2.20 Earthing: Tower footing resistance (TFR) of each tower after it has been erected and before the stringing of the earthwire shall be measured during dry weather. Each tower shall be earthed and the tower footing resistance shall not exceed 10 ohms. Pipe type earthing and counter poise type earthing wherever required shall be done in accordance with the latest additions and revision of

IS : 3043	Code of practice of Earthing
IS:5613	Code of practice for Design, Installation and maintenance (Part-III/section 2) of overhead power lines

The provision of holes on stubs shall be made as per approved earthing drawings. The earthing will vary depending on soil resistivity.

Pipe Earthing: At locations where pits can be excavated, the towers shall be earthed by pipe earthing. The grounding shall be effected by making about 325 mm dia and 3850 mm deep pit at a distance of not less than 3650 mm diagonally away from the stubs and filling in the pits with finely broken coke having granule sizes not more than 25 mm thick. The coke shall be maintained up to a distance of 150 mm from the pipe on all sides. The top edge of the pipe shall be at least 600 mm below the ground level. The steel strip shall be buried not less than 600 mm deep from the ground level. The earth flat shall be of G.I. Pipe shall be of 25mm dia and 3050mm long class-B, with 6mm holes at 150mm apart and GI flat shall be 50x6mm, 4050mm long.

Counterpoise Earthing: In locations of high resistivity soils especially in rocky locations special earthing arrangement shall be employed in the form of counterpoise

earth to bring down the tower footing resistance to 10 ohms. The counterpoise earth shall consist of 4 Nos. 7/3.15mm galvanized steel wires running radially from all the four tower legs for a distance of about 15 to 70 meters. The galvanized steel wire shall be connected to the tower legs by galvanized steel lugs forged or compressed at its one end, complete, with 16 mm (5/8") dia bolts and nuts, required for connecting the earthing to the tower and the other ends of the earthwire shall be connected to an electrode of 20mm dia and 600mm long, and the counterpoise shall be buried radially from the tower base at 600 mm below/ground level. The lugs should be preferably covered in chimney portion of the foundation to avoid pilferage.

For soil resistivity less than 1500 Ohm-meter, earthing shall be established by providing 4 length of 30 meter counterpoise wire (Total 120m length wire). Otherwise for soil resistivity greater than 1500 Ohm-meter, earthing shall be established by providing 4 length of 70m counterpoise wire (Total 280 m length wire)

3.2.21 ERECTION OF TOWERS:

Procedure for tower erection, insulator hoisting, conductor paving, stringing of conductor and earth wire and clipping is given under construction of transmission lines.

All the bolts & nuts in the towers up to the height below the bottom cross arm level including the bolt connecting the cross bracings at the bottom cross arm level, shall be seam welded in the upper half round portion (25mm length) of the bolt & nut circumferentially by using 10 gauge welding rods. This shall be done immediately after the tower is erected and its verticality is checked and found to be within the limits. After seam welding, one coat of zinc rich paint shall be applied on the seam-welded surface matching the galvanized portion of the tower to prevent rusting.

Each tower shall be fitted with number plate, danger plate and phase plate. Anti climbing devices shall be provided on towers erected at all railway crossings, important road crossings etc. Bird guards shall be provided on suspension towers. These accessories shall conform to the relevant standards.

(a)Insulator Hoisting: Suspension insulators shall be used on all tangent type towers in the line and tension insulators on all angle type towers.

For ensuring insulation co-ordination, the suspension or tension strings on approach and terminal towers near the substation ends up to a length of 1.5 kilometers shall be provided with adjustable arcing horns on tower side and fixed arcing horns on line side, keeping the arcing gap as may be stipulated by the Engineer at site.

(b)Stringing of Conductor and Earth wire: Before commencement of stringing, the contractor shall submit stringing charts for the conductor and earth wire showing the initial and final sags and tension for various temperatures and spans along with equivalent spans in the line, for approval by the Engineer.

The contractor shall be entirely responsible for any damage to the towers or the conductor during stringing. He shall also be responsible for proper distribution of the conductor drums as per drum schedule to keep the numbers and lengths of cut pieces of the conductor to the minimum.

The earth wire shall be strung and securely clamped to the towers before the conductors are drawn up, in the order of the top conductor first, then the middle and the bottom conductor at the end. It shall be ensured that all the conductors of one section should be identically tensioned.

During pulling out operation the tension in each conductor and earth wire shall not exceed the approved working tension of the conductor at the actual prevailing temperature. After being pulled, the conductor and earth wire shall not be allowed to hang in the stringing blocks for more than 96 hours before being pulled to the specified sag. During the time the conductors and earth wire are on the stringing blocks, before sagging in, it shall be ensured that the conductors and earth wire are not damaged due to wind, vibration or other causes.

The conductor shall be pulled up to desired sag and left in travelers for at least one hour after which the sag shall be rechecked and adjusted, if necessary, before transferring the conductors from the travelers to the suspension clamps. The conductors shall be clamped within 36 hours of sagging in. Pre-stressing of conductor is not required. Instead, the conductors should be strung to sag of one inch per foot less than the sag (in feet) shown on the final sag charts provided by the erection contractor in case of 132 & 220kV lines. A temperature compensation of $- 26^{\circ}\text{C}$ shall be made in initial stringing charts in case of 400kV and above lines. i.e. a temperature equal to prevailing temperature $- 26^{\circ}$ is to be considered to arrive the tension at prevailing temperature at the time of stringing, towards creep compensation, when conductors are not pre-stressed.

In respect of bundle conductors the adjustment of the sub-conductor sag by means of sag adjustment devices provided in the insulator string shall not be permitted at the time of stringing of conductors. The sag adjustment plates shall be kept in fully open position at the time of stringing of conductor.

Dynamometers shall be used in checking the tension in the conductors and earth wire and these instruments shall be periodically checked with a standard dynamometer. The sag shall also be checked when the conductors have been drawn up and transferred from aerial rollers to the insulator clamps.

The stringing block, when suspended on the transmission structure for sagging, shall be so adjusted that the conductor on the traveler will be at the same height as the suspension clamp to which it is secured.

The suspension insulator assemblies shall normally assume vertical position when the conductor is clamped. Sagging operation shall not be carried out under wind, extremely low temperature, or other adverse weather conditions, which prevent satisfactory sagging.

Any departure from the correct sag in any span shall not exceed 4 per cent. The sag of any conductor shall not depart by more than 3 percent from the mean sag of all the conductors in the same span.

3.2.22 Execution of works at Power line and Railway Crossings: Works such as erection of towers underneath an existing power line and paving out of conductors and earth wire and stringing the power line crossing span or a railway crossing span, will have to be done only after receipt of approval from the concerned officer, which, sometimes, may not match with the programme of the contractor. In such cases, the contractor shall be prepared to execute such works as and when approvals are received.

3.2.23 The following general terms form part of the specification:

- a) APTRANSCO shall provide approved profiles, tower schedules, foundation drawings, Bill of materials, and other technical particulars and vendors list for procurement of materials.
- b) The contractor shall procure the materials as per specification from the approved vendor list and execute the works as per the approved profiles. It is the responsibility of the contractor to complete the works in full shape and handover to APTRANSCO in fully operational condition within the time specified in the contract.
- c) All the material such as transmission line towers including stubs & cleats, templates, tower accessories, bolts, nuts, spring washers, flat washers, ACSR conductor, disc insulators, HTGS earth wire, hardware & accessories for conductor & earth wire, etc. are to be supplied by the successful bidder.
- d) The successful bidder shall execute the line works of conducting check survey and fixing up tower locations as per approved profiles, laying of foundations, erection of towers including accessories, stringing of conductors & earth wire, testing and commissioning of the lines.

3.3 SURVEY:

As transmission lines have to traverse a long distance, the topographical & geographical nature of the terrains play significant role in the project cost and implementation time. Hence, it is essential that at the planning stage itself various alternative routes and technical solutions for transmission lines are examined in detail. For undertaking such studies, one of the major requirements is obtaining adequate information regarding physical constraints, environmental factors etc. along the route so that optimum solutions are found. Subsequently, during implementation of the project, it is required to obtain elaborate details about terrain, soil conditions, constraints etc. of the route for proper resource planning, costing etc. as well as reduction in implementation time.

Presently, conventional methods of survey like walk over survey, preliminary survey and detailed survey are carried out at various stages from planning of the project to implementation, which are time consuming tasks. As manual methods are used for these surveys, which are conducted in not so friendly terrains, there is possibility that the results do not reflect adequately the true picture of the terrain in great details.

Modern methods to conduct route survey using remote sensing, aerial survey, GPS based survey, etc are available today. These techniques are said to have edge over conventional techniques in terms of credibility of data but are expensive, require lot of expertise, specialized equipment and may have certain other limitations.

Safety clearances as per Indian Electricity Rules (1956) as amended from time to time are to be maintained from any earthed object in the vicinity of the transmission lines. The clearances from the line conductor to the ground as well as to adjacent objects are ruled by the sag of the conductor that takes the form of a catenary, which increases with the span length between two adjacent locations. The atmospheric conditions like ambient temperature, solar radiation, wind velocity etc as well as power flow influences the sag. The conductor also swings under heavy wind and it is required to maintain clearances under such conditions. Hence placing of intermediate supports at appropriate intervals becomes essential. Further, the line has to take deviations from the straight line route at certain locations along the route to maintain necessary clearances from permanent establishments, to avoid forest areas wherever possible, if not, minimize involvement of reserve forests and minimize major crossings. Transmission line should not involve any human rehabilitation and should avoid wildlife sanctuaries, national parks, monuments of cultural or historical importance etc.

When routing of line through forest areas can not be avoided, it should be aligned in such a manner that tree cutting requirement is minimum.

The transmission line requires a right of way along its route to keep minimum clearances from earthed objects. All objects within this zone are to be cleared. Normal power transfer capacities and right of way requirements of transmission lines of various system voltages is shown in the table below.

Sl.No.	System Voltage	Power flow per circuit	ROW requirement
1	132 kV AC	85 MVA	27 m
2	220 kV AC	200 MVA	35 m
3	400 kV AC	800 MVA	46-52m
4	800 kV AC	2500 MVA	72-92m
5	500 kV HVDC Bipole	2000 MW	52m

Surveys are done by the construction units in the field taking into consideration the following, to optimize the costs and to reduce implementation time:

a) Site conditions

1. Minimum number of river crossing towers

2. Accessibility i.e. approachability to the site from construction as well as from law and order point of view
3. Type of soil - loose hills areas prone to landslides, type of terrain - benching and revetment requirement, requirement of leg extensions, area of submergence as well as river meandering.

- b) Power line crossings, railway and road crossings etc, clearance from habitation
- c) Environmental clearance, minimum forests, areas of archaeological importance, national parks and wild life sanctuaries.
- d) Shortest route clearing various objects

Various stages in a transmission line project requiring map study/ surveying and the types of surveys associated are detailed below:

3.3.1 System Planning Stage

For effective power transfer with good reliability, security and economy, different alternatives are studied at the system planning stage; for example, different voltage level of transmission lines, different routes of transmission lines, different connecting points etc. Therefore the routing and the cost of transmission line projects depends on factors like terrain conditions (plain, hilly), soil conditions, river crossings, power line crossings, railway crossings, reserved forests, agricultural fields etc through which the line traverses. At present, general routing and estimation of cost of each alternative at planning stage is done with reference to certain empirical rules as well as forest and physical maps. As these maps are not updated frequently, percentage error in assessment may be large. Even though this may not largely affect the selection of alternatives it will be prudent to identify more accurate and faster methods of collecting details at planning stage itself so that a large number of possible alternatives can be examined. The requirement generally would be to have updated information on maps so that the planning engineers can study various line routes and then identify and recommend cost effective solutions.

3.3.2 Project Feasibility Stage

After conducting system planning studies and identifying suitable transmission system, feasibility reports for the transmission line projects are to be submitted for techno-economic clearance from the CEA and investment approval from the Government. At the project feasibility stage, detailed elaboration of the project is done for the technical details, BOQ, cost and implementation schedules of the project.

The type of surveys adopted at feasibility stage is generally ruled by time constraints for fast track projects. Reconnaissance forms the most important aspect of transmission line survey as the cost of line is influenced by the route chosen. Best route selected gives the following benefits:

Line construction cost can be brought down.

Any possible delay/hindrance likely to occur during the execution of work can be avoided after taking due care of various statutory provisions while selecting the route alignment.

Approvals from PTCC, Railways, Civil Aviation, Forest authorities etc can be obtained faster.

Construction targets can be realistically fixed, which will help in judicious planning of materials flow, cash flow and manpower requirements.

Considerable time can be saved during construction of line, if selection of river crossing points, route along hill sections and power line crossings etc. are properly made.

3.3.3 Map Study: After drawing various feasible alternative routes within 10kms. of the Bee line on the survey of India topographical maps (1: 50000 scale), a comparative study is done on the basis of the following data.

Route length

Nos. and type of angle points in each proposal indicating the angle of each deviation as measured on the map.

Nature and no. of major crossings

Deviation in the line due to civil/military aerodromes and other industrial installations.

Approach to the line in general for construction

Reaches through protected or Reserve Forests

Continuous long stretches in paddy fields

Close parallelism with Telecom and Railway block circuits

3.3.4 Walkover Survey: Walkover survey is carried out in the alternate routes selected on the map. Walkover survey means going over the area covering the routes proposed and collecting the features observed other than those existing on the map. The following additional features are also checked.

- Power lines, communication lines
- Expanding villages and towns
- Rich gardens and plantations
- Reserve forests and high tree areas
- National parks and wildlife sanctuaries
- Archaeological monuments
- Aerodromes, Radar centers etc.
- Steep sloping terrain, areas prone to landslides, soil instability etc.
- Prohibited areas declared under statutory regulations.

Modern methods of route survey: Route survey can be carried out in any of the following modern methods.

- Electronic distance measuring technique (EDM). Accuracy in this method is up to 1PPM

- Total Station: Measures the distance and angle through measuring technique in one system.
- Global Positioning System (GPS)
- Remote Sensing Technique
- Air borne Terrain Mapping Technique.
- Remote sensing technique and terrain mapping techniques are technologically economical.

3.3.5 PRELIMINARY SURVEY: Most suited route proposed after conducting walkover survey, is further studied before taking up preliminary survey. The main objective of preliminary survey is to transfer the route to ground with such deviations as may be necessary as per field constraints. It includes fixing angle points of towers, route alignment, identification of major crossings, general classification of soils, measurement of route length etc with conventional instruments like Tapes and Theodolites. Bill of quantities is estimated based on these results and cost estimates are prepared. Preliminary survey does not include detailed soil investigations for locations along the route.

3.3.6 DETAILED SURVEY: After completing preliminary survey and approval of feasibility report, Administrative approval shall be obtained. After receipt of administrative approval/ instructions from construction wing at headquarters, the field construction unit (SE TLC) shall arrange to carry out detailed survey of the route. Detailed survey consists of precisely determining the no. and types of towers with extensions required if any, special towers required, no. and types of foundations, special foundations etc. Detailed survey includes taking of levels in different sections of the line, each section being the portion between two angle points. The levels are plotted on a graph sheet on a scale 1:200(vertical) and 1:2000(horizontal). These profiles are again examined for tower spotting.

3.3.7 Profiling

The complete survey along the route can also be carried out using modern surveying equipments viz. total stations, GPS, digital theodolite, long range scanners etc. Reference levels at every 20 meters along the route are to be recorded. R/L at other undulations along the route as well as in the route plan and other details enroute viz. crossings, buildings & structures, trees & other infrastructure Etc shall also be recorded. Areas along the route, which are not suitable for tower spotting, shall also be marked.

The complete profiling details shall be digitized and the data shall be prepared & stored in the format compatible to computer-aided tower spotting software.

A printed/plotted output of the digitized profiling shall be reviewed before taking up computer-aided tower spotting.

3.3.8 Tower Spotting Requirements: For spotting of towers on the profiles, 1) tower spotting requirements and 2) sag template are needed.

Tower spotting requirements include

- 1) Maximum value of sum of adjacent spans
- 2) Limitation of individual span on considerations of separation distance

- 3) Maximum permissible weight spans for different deviation angles
- 4) Whether or not vertical loads acting upward can be applied and
- 5) Normal values of wind span and weight span. These are derived from the tower designs.

While profiling & spotting the towers, the following shall be considered:

- **Span:** The number of consecutive spans between the section points shall not exceed 15 spans or 5 Km in plain terrain and 10 spans or 3 Km in hilly terrain. A section point shall comprise of tension point with B/ C / D or DB/ DC/ DD type.
- **Extension / Truncation:** Individual span shall be as near to the normal minimum design span as possible. If during tower spotting it is found that, due to undulations of the ground profile, the ground clearance becomes insufficient when using normal height towers, the height of such towers may be increased by the use of standard body or leg extensions designed for this purpose. In case of locations where the ground clearance is available, truncated towers may be employed. Including too many extensions in a particular reach may weaken the stability of the line in that particular reach.
- **Loading:** There shall not be any upward force on suspension towers under normal working conditions and the suspension towers shall support at least the minimum weight span as provided in the designs. In case uplift is unavoidable, it shall be examined if the same can be overcome by adding standard body extensions to the towers, failing which tension towers designed for the purpose shall be employed at such positions.
- **Railway Crossings:** Railway crossings shall be supported on Dead End Type Towers on either side depending on the merits of each case and shall be constructed in conformity with the specification laid down by the Railway Authorities. The angle of crossing shall be 90 degrees. However deviation to the extent of 30 degrees may be permitted under exceptionally difficult conditions.

The following are the important features of the prevailing regulations.

- i) The maximum crossing span shall be 300m or 80% of the design span, whichever is lesser.
- ii) The distance between the leg of the crossing tower and the edge of the nearest railway track shall be tower height + 6 metres.
- iii) The minimum ground clearance above rail level of the lowest portion of any conductor under condition of maximum sag shall be maintained at 17.9 metres.
- iv) The minimum clearance between the jib of a railway crane and the bottom conductors shall be 6.0m.
- v) No crossing shall be located over a booster transformer, traction, switching station, traction sub-station or a track cabin location in an electrical area.

Minimum distance of the supporting structure for the crossing span from the centre of the nearest railway track shall normally be the height of the structure above ground level plus 6 metres.

3.3.9 Railway tracks are categorized as follows:

Cat A: Tracks electrified on 1500 V DC

Cat B: Tracks electrified at 25kV AC or likely to be electrified in near future

Cat C: Un-electrified tracks

Minimum clearances between the overhead line and railway track for Cat A and C

	BG (inside stn limits)(metres)	BG (outside stn limits) (metres)	MG or NG (inside stn limits)(metres)	MG or NG (outside stn limits)(metres)
Up to 11KV	10.0	7.6	8.6	6.3
Above 11KV – 33KV	10.0	7.6	8.8	6.4
Above 33KV – 66KV	10.3	7.9	9.1	6.7
Above 66 KV – 110KV	10.6	8.2	9.5	7.0
132 KV	10.9	8.5	9.8	7.3
220KV	11.2	8.8	10.0	7.6
400KV	13.41	10.97	12.19	9.76

Minimum clearances between the overhead line and railway track for Cat B for all gauges

	inside stn limits(metres)	outside stn limits(metres)
Unto 11kV	Only by cable	Only by cable
Above 11kV to 33KV	12.5	10.5
Above 33KV – 66KV	13.0	11.0
Above 66 KV – 110KV	13.7	11.7

132 KV	14.0	12.0
220KV	15.3	13.3
400KV	20.57	18.57

3.3.10 Highway Crossings:

Roads should be crossed preferably at right angles. Crossing towers should be located outside the road boundaries. Frequent crossing of the same road should be avoided. In such cases efforts shall be made to keep the route on the same side of the road. Minimum distance from the centre of nearest tower to road edge should be 1.5 times the tower height to have sufficient tower falling distance.

At all National Highways, tension towers shall be used. The crossing span shall not exceed 250 metres. The ground clearance at the roads under maximum temperature and still air shall be 12.2metres.

3.3.11 River Crossing:

In case of major river crossing in planes, tower shall be of suspension type using double suspension strings and the anchor towers on either side shall be dead end type.

Clearance required by the navigation authority shall be provided. For non-navigable rivers, clearance shall be reckoned with respect to the highest flood level.

3.3.12 Power Line crossings:

Rule87 of Indian Electricity rules 1956 states that a) When an overhead line crosses or is in proximity to another overhead line, guarding arrangements shall be provided so as to guard against the possibility of their coming into contact with each other.

- a) No guarding is required when an EHV line crosses another EHV, High voltage, medium or low voltage line.
- b) Where two lines cross, the crossing shall be made as nearly at right angles as the nature of case admits and as near the support of the line as practicable and the support of the lower voltage line shall be erected below the upper voltage line provided that the angle of crossing of power lines shall not be less than 60 degrees.

Where the proposed line is to cross another line of the same voltage or different voltage, angle tower with suitable extensions shall be used. In order to reduce the height of the crossing towers, it may be advantageous to remove the ground-wire of the line to be crossed (if this is possible and permitted by the owner of the line to be crossed).

Minimum clearance in metres between lines crossing each other:

		132kV	220kV	400kV	765kV
1	132 kV	3.05	4.58	5.49	7.94

2	220 kV	4.58	4.58	5.49	7.94
3	400kV	5.49	5.49	5.49	7.94
4	765kV	7.94	7.49	7.94	7.94

Where a proposed transmission line is to be taken parallel and in close proximity of existing power lines, adequate lateral clearance of minimum 300 metres may be provided to minimize induction effect to facilitate construction and maintenance in cross country reaches.

When locating terminal towers of proposed line near terminal tower of existing power line, it should be ensured that adequate electrical clearance between cross arms are available (minimum phase to phase clearance should be maintained).

Factors of safety of towers, clearances above ground of the lowest conductor, clearances from buildings for EHV lines, proximity to aerodromes, line crossings etc. are covered under the Indian Electricity Rules 1956.

Towers shall have a factor of safety of 1.5 based on the crippling load.

Clearance above ground of the lowest conductor of 33kV line shall not be less than 5.18 metres. Clearance shall raise by additional 0.3 metres for every 33kV or part thereof rise in line voltage.

Minimum clearance along or across any street shall not be less than 6.1 metres.

No conductor of an overhead line crossing a tramway or trolley-bus using trolley wires shall have less than 3.05 metres clearance.

On the basis of maximum sag, vertical clearance above the highest part of the building immediately under a line shall not be less than 3.66 metres plus 0.3 metres for every additional 33kV or part thereof.

Horizontal clearance between the nearest conductor and any part of the building, on the basis of maximum deflection due to wind pressure, shall not be less than 1.83 metres plus 0.3 metres for every additional 33kV or part thereof.

3.3.13 Details enroute:

All topographical details, permanent features, such as trees, buildings etc., 13m for 132kV, 18m for 220kV, 26m for 400kV /400kVHVDC and 46m for 765 kV on either side of the alignment shall be detailed on the profile plan.

3.3.14 Sag Template

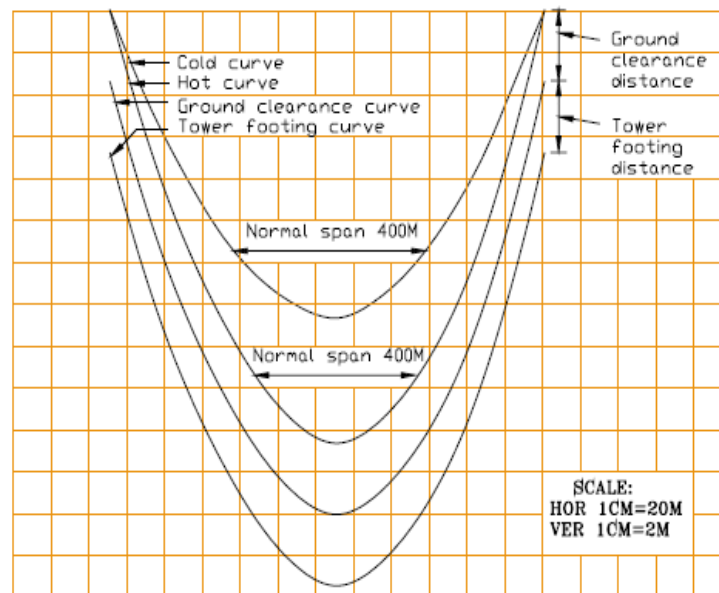
It is a very important tool for the surveyor by the help of which Tower spotting can be done. Depending upon the maximum specified permissible temperature of the conductor and zero wind condition the ground clearance is to be maintained by the line. Similarly under the specified minimum temperature of the conductor surface, with zero wind condition, the tower tensions should be within the specified limits. The sag template curves are first prepared on tracing paper and the blue print is taken out from

the tracing. Their replicas on Acrylic sheets are prepared with the itching process. The Acrylic sheets are normally 2.5 to 3 mm thick.

The sag templates have the following curves itched on them.

- ‘Cold or Uplift Curve’ showing sag of conductor at specified minimum temperature and zero wind.
- ‘Hot’ or ‘Maximum Sag Curve’ showing maximum sag of conductor under zero wind and maximum temperature and sag tolerances are also allowed to take care of stringing error, conductor creep or snow incidences.
- Ground clearance Curve drawn parallel to hot curve and at a distance equal to specified minimum ground clearance.
- Tower footing Curve for normal tower drawn parallel to hot curve under ground clearance curve and separated by a distance equal to maximum sag at design span.

In erecting an overhead line all the spans cannot be kept equal to normal design span because of the profile of the ground and proper ground and object clearance considerations. A constant tension is calculated which will be uniform throughout the Section (from one tension tower to other tension tower), however the sags in individual spans will vary according to their respective spans. The ‘Cold and Hot’ Template Curves are plotted as parabola, to the same scale as the survey chart for the minimum and maximum sags for the normal span mentioned in the specification.



Application of Sag Template for Tower Spotting

The Sag Template is an important tool for correct spotting of the towers after the detailed survey work is completed. The following are the steps to be followed for correct application of sag template.

- The acrylic sag template is applied to the ground profile by moving the same horizontally while always ensuring that the vertical axis is held vertical with reference to graphed lines of the tracing paper below.
- The structure positions are marked where the tower footing curve just touches the profile, while the ground clearance curve is just clear and above the profile to the left or right of the centre line up to a distance equal to maximum cross area spread on either side.
- Besides normal ground clearance, the clearances between power conductor and objects like, other power or telecommunication lines, houses, trolley wires, roads, railway tracks, canal embankments etc., shall be checked.
- Extra clearance can be obtained either by reducing the span or providing extension to tower body, depending on which alternative is most economical.
- The weight span on either side of a tower can be easily obtained by marking the low points of sags (Null Point) in two adjacent spans and then reading the distance between the two.
- On inclined spans, null point may be outside the span. This indicates that the total weight of conductor is taken up by the higher tower and the lower tower is being pulled up by a force equal to the weight of conductor between lower support and the null point.
- Should the upward pull of the uphill span become greater than downward load of the next adjacent span, actual uplift will be caused and the conductor would tend to wing clear of the tower upwards.

The following may be adopted to check whether a tower is under uplift or not

- The Template is applied horizontally until the tops of alternate supports coincide with the Cold Curve.
- If the support is under uplift and has to be extended so as to be above it and in case requisite standard body extension do not suffice for doing this, tower which is designed to take uplift will have to be used.
- However, for the stability of the line it is not desirable to place a tower in such a position where it is always under permanent uplift condition.
- In case it becomes mandatory due to route compulsion, the cross-arms of the tower subjected to up lift shall be designed to take the extra upward pull.
- The intermediate spans shall be as near as possible to the normal design span.
- In case an individual span becomes too short on account of undulations in ground profiles, one or more line supports of the Section may be extended by inserting standard body extensions.

- Even if the line does not deviate for a long run, sections have to be provided after every 12 to 15 tangent towers. (i.e. 3 to 4 km. length).
- For this purpose a small angle tension tower designed for 15° should only be used. It is mandatory to afford better stability of the line against Transverse wind forces and to facilitate easy stringing. Besides 15° angle tension tower is most economical amongst the standard angle tension towers.

Use of computer for preparing sag template and the tower spotting

Before taking up the tower design on hand, Sag and Tension charts are required to be prepared. These charts indicate the values of sag and tension of conductor and the earth wire at Maximum temperature, minimum temperature and every-day temperature under 100%, 66% and 0% wind pressure. Normally, in plain terrain in India the maximum, minimum and every-day temperatures are considered as 0°C, 75°C and 32° C. These values may change in the region experiencing snow or Sub-Zero temperatures. If the conductor is required to carry large block of power, the maximum surface temperature of conductor can be taken up to 95°C. For Earth wires the maximum temperature is taken as 53°C

Based on the sag tension charts, the sag template curves can be plotted on the computer through a specific programme. The full scale print out of the curves is then used to prepare the Acrylic Sag Template by itching process.

The final output of detailed survey is in the form of tower schedule showing the type of tower with associated angle of deviation, span length, wind and weight spans, associated foundations along with its classifications, geological and geotechnical, data and any crossing involved in that span. The profile rolls and tower schedules finalized and approved shall be issued to contractor to proceed with check survey along the proposed alignment of the line.

Detailed survey also includes final alignment and pegging of line/direction/angle points at locations, trial pit excavation and detailed soil investigation where required. Further trees/shrub jungles and crops likely to come in the right of way clearance of the finalized line shall be enumerated during detailed survey to compute the extent of damages and compensation payable, so that payment of compensations are not delayed during construction preventing stalling of work. Soil resistivity readings are taken for every 1 kilo metre along the line in detailed survey.

3.3.15 Limitations of Conventional methods of Map study/ Surveying: Apart from taking considerable time, the conventional methods have the following limitations.

Topographical maps used for survey can be very old and do not contain recent changes in inhabitation pattern, vegetation coverage and water bodies etc.

Process of elimination is done at the ground itself which increases the number of angle locations and length of line.

Surveying staff do not have bird's eye view of the present ground condition. This may particularly result in large inaccuracies in estimation of quantities for civil works (benching and revetment) in terrains with large undulations.

There is every possibility of error in recording ground data and subsequent transfer on the route map.

3.3.16 Probable solutions for fast and reliable surveying: The following procedure at each stage of transmission line project will provide fast and reliable surveying solutions.

(a)Route planning and fixing of alignment: Data Input – Survey of India maps, Satellite data, Railway maps, land use maps, settlement maps etc are used as input for data base preparation.

GIS – Above inputs through GIS are used to update Survey of India topo sheets. Other specific maps may also be created.

Using computer run algorithms or linear programming techniques optimal transmission line route may be finalized.

On this output from GIS domain post field work is done and locational latitude and longitude of the deviation points are identified on ground using Geographical Position System (GPS)

Further in terrain having large undulations, stereoscopic satellite imageries may be used selectively to interpolate contours and digital terrain model can be used to select the route in hilly regions.

(b)Detailed survey: Aerial photography can be used as a reliable tool to record precise elevations and plan measurements of the selected route. Permission from Ministry of Defence is required for carrying out aerial photography. Flight has to be arranged on selected route. Photographs taken need to be transferred to studios for processing and detailed measurements. The same can later be verified on ground for authentication.

Once the ground profile in digital form is obtained, the estimation of various types of earth works involved viz. Benching; revetments etc can be made using software.

Appropriate techniques for obtaining soil conditions, subsoil conditions, water tables, treacherous terrain conditions etc for accurate estimation of civil works need to be explored.

When satellite imagery is used for preliminary survey there may be some error due to the shadow effect. In the above case it was found sometimes difficult to differentiate between forests and other greenery. Thus exact boundaries could not be demarcated.

Resolution plays an important part in interpreting satellite images. Power line crossings cannot be identified in the satellite imageries of 23.5m/4.88m resolution. Higher resolution may help reveal ground conditions more closely.

Ground profile and subsoil data cannot be accessed through satellite imageries.

Digitization of complete topographical maps rather select features would provide a complete replica in integrated environment.

Satellite data with 1 metre resolution will be preferable. However overall cost economics shall be worked out since this data will be costlier but will completely avoid field works.

3.3.17 Statutory Clearances in Construction:

Major statutory clearances in transmission line construction are

- Forest clearance
- PTCC clearance
- Clearances from Railways, Roadways, Navigation and Aviation Authorities
- CEA clearance
- Clearances from Local bodies and Defence authorities

Strict adherence to statutory provisions under various acts of centre and state is mandatory in the construction of Substations and transmission lines. Obtaining statutory clearances is a must for energizing newly constructed transmission system.

(a) Forest Clearance:

Forest conservation act came into existence on 25-10 1980, to protect forest lands from encroachments and to safeguard environment. Any diversion of forest land for non-forest purpose has to be approved by ministry of environment and forests (MOEF) under Central Govt. on compensation of loss of forest area / vegetation in the wake of diversion of forest land. Felling of trees in the forest land will be carried out only after approval of MOEF.

Section 2 of the act defines forest area as land covered under all reserved forests, protected forests or any other area recorded as forest in Govt's records irrespective of the ownership.

Reserved forests are natural forests having rich biodiversity. No activity is permitted in these forests without specific approval.

Protected forests are those which come up through plantation and regeneration. All activities are permitted in these forests unless something is specifically prohibited.

Dense forests are those where canopy density is more than 40%.

Open/Degraded forests are those where canopy density is less than 40%.

Plantations carried out under social forestry schemes or under compensatory afforestation schemes are covered under protected forest.

Steps in proposal formulation and approval under forest conservation act 1980:

Proposals for laying transmission line in a forest area to be submitted in a prescribed form given in FC Rules 2003 shall contain the following.

- Brief details like short narrative of project for which forest land is required.
- Total length of transmission line and the length passing through forest area.

- No. of transmission line towers and area covered by each tower, height of tower and the line.
- Towers to be erected in the forest area and right of way
- Extent of forest area to be diverted, legal status of forest land
- Whether the forest land needed for the purpose is minimum, whether no alternate alignment is possible.
- Whether forest land forms part of National park, wildlife sanctuary, Bio sphere reserve or forms part of the habitat of any endangered species of flora and fauna.

Where routing of transmission lines through forest areas cannot be avoided, these should be aligned in such a way that it involves least amount of tree cutting.

As far as possible, route alignment through forest areas should not have any line deviation.

Right of way requirements for different voltage lines on forest land are as follows:

Line voltage (kV)	Maximum right of way (metres)
11	7
33	15
66	18
110 - 132	22 - 27
220	35
400(DC - SC)	52
800	85
500 (HVDC)	52

Below each conductor, width clearance of 3mtrs. would be permitted for taking tension stringing equipment. Trees on such strips should be felled. After stringing work is completed, the natural regeneration will be allowed to come up. Felling/pollarding/pruning of trees will be done with the permission of the local forest officer, whenever necessary to maintain clearance. One outer strip shall be left clear to permit maintenance of transmission line.

In the remaining width the right of way up to a maximum of 85metres (for 800kV lines) trees will be felled or lopped to the extent required, for preventing electrical hazards by maintaining the following clearances:

Voltage (kV)	Minimum clearance between Conductors and trees (Mtrs.)
11	2.6
33	2.8
66	3.4
110 – 132	3.7 – 4.0

Sag and swing of the conductors are to be kept in view while working out minimum clearance mentioned above.

Where forest growth consists of coconut groves or similar tall trees, widths of right of way greater than those indicated above may be permitted in consultation with CEA.

Proposals for forest clearance:

Shall be submitted to Nodal officer in the prescribed proforma giving the above details. The Nodal officer will forward it to concerned Divisional Forest Officer to formulate the proposal.

Following the above, a joint inspection of Transco and forest authorities is carried out to assess the loss of vegetation. Enumeration of trees and shrubs is made species wise. These details form critical parameters for cost-benefit analysis to be done by forest authorities.

Transco shall give a certificate that they will provide cost of compensatory afforestation, net present value and royalty for timber and for operational cost for extraction of timber from project site.

Suitable degraded forest land / alternate land shall be identified for preparation of compensatory afforestation (CA) scheme. CA shall be done over equivalent area of non-forest land. The identified land shall be contiguous to or in proximity of reserved forests or protected forests. Where non forest land for CA is not available in the same district, non forest land anywhere in the state as near as possible to the site of diversion shall be identified.

Where non forest land is not available or available to a lesser extent than forest area being diverted, CA is carried out over degraded forest twice the area being diverted.

The proposal bearing the above details is then resubmitted by Divisional Forest Officer to the Nodal Officer through Conservator of Forests. Nodal officer after examining the proposal forwards it to Principal Chief Conservator of forests, and then to Secretary (Forests) of the state Government.

The State Government recommends the proposal to the concerned regional office of Ministry Of Environment and Forests (MOEF) if the area involved is 40 hectares or less and to MOEF, New Delhi if the area is more than 40 hectares for processing and approval.

Regional MOEF approves the proposal if the area is up to 5 hectares. In case of the area above 5ha and up to 40ha, Regional MOEF processes the case in the State Advisory Group (SAG) and recommends the proposal to MOEF New Delhi for minister's approval.

MOEF New Delhi directs the Regional MOEF to conduct inspection of the site, where the forest area involved is more than 100Ha. If the area in question is significantly rich in wild life, special recommendation of Chief Wildlife Warden of the state is sought. Proposals containing the above details are then submitted to Forest Advisory Committee

(FAC) of MOEF for its views. The committee is headed by Director General of forests, with Addl.DG, Addl. Commissioner (Soil Conservation, Ministry of Agriculture), 3-non official experts one each in Mining, Civil Engg. and Development economics as Members. The committee after deliberations gives its views for approval or otherwise on the proposal. With these details proposal is submitted to the Minister of Environment and Forests. Approval of Minister marks the in principle or first stage clearance of proposal.

When the stipulated conditions like funds to the State Forest department for raising of CA are met, on such a certificate from the State Government, Govt. of India conveys its final or second stage approval.

(b) PTCC Clearance:

To solve the problems of inductive interference and to resolve any conflict of interest in regard to location and working of power and telecom line, Govt. of India constituted a central standing committee of coordination of power and telecom lines in May 1949 called Power & Telecom Coordination Committee. The committee comprises of members from Telecom, Railways, army, Ministry of Energy and State Transcos.

Due to proximity and parallelism of telecom and power lines, the performance of telecom lines is adversely affected. They are subject to dangerous induced voltages in the event of earth faults on power lines. To avoid induction, transmission line route is selected in such a way that line alignment remains away from telecom lines as far as possible.

PTCC clearance is required for crossing of any P&T line as per the laid down procedure.

On completion of preliminary survey, proposal is submitted in the prescribed forms accompanied with all the system data and route maps of transmission lines. All the telecom lines falling in the vicinity of the power line (8 kms on either side) are marked along with the computations of induced voltages.

Depending on the magnitude of induced voltage protective measures are taken for the affected telecom circuits. Protective measures to be taken for various induced voltage levels are given in the following table.

<u>Induced voltage levels</u>	<u>Protective measures</u>
Up to 430 V	No protection required
430 – 650 V	Adequate no. of Gas discharge (GD) to be Provided by Telecom authorities at their cost
650 – 2000 V	GD tubes to be provided by later entrant
More than 2000 V	Re- Engineering to be done

(c) Proximity to Aerodromes: Overhead lines shall be erected in the vicinity of Aerodromes only after the route of proposed line is approved by airport authorities.

Details such as flying tunnel limits, areas of aerodromes, landing strips etc. should be collected from the appropriate agencies.

As per the circular of Directorate of Air Routes and Aerodromes, overhead HT/LT lines shall not be permitted within 3.05kms of an airport. Beyond the radius of 3.05kms and up to 15.24kms from an airport (having runway of 5000 ft or more) construction is permitted subject to painting of all structures above 35 metres with day and night marking.

Advance action shall be taken by the SE/TLC In consultation with CE/construction, headquarters to obtain the statutory clearances from Power & Telecom Coordination Committee (PTCC) for new Transmission lines routing, permission from Railways for crossing of transmission lines over the railway tracks and from Civil. Aviation Authorities for Towers to ensure that there shall be no hold up of works for want of these clearances / permissions.

3.3.18 CHECK SURVEY FOR TOWERS:

Check survey shall be conducted to locate and peg mark the tower positions on ground conforming to the approved profile and tower schedule using GPS, Total Station, and Digital Theodolites etc. In the process, it is necessary to have the pit centres marked according to the excavation marking charts. The levels, up or down of each pit centre with respect to the centre of the tower location shall be recorded at intervals of 2 metre using Total station/GPS/ Digital Theodolites and digitized contour plans shall be made and recorded for determining the amount of earthwork required to meet the approved design parameters.

Changes in the preliminary tower schedule after detailed survey, if required, shall be carried out by the contractor and he shall thereafter submit a final tower schedule for the approval of owner. The tower schedule shall show position of all towers, type of towers, span length, type of foundation for each towers and the deviation at all angles as set out with other details.

3.3.19 RIGHT OF WAY, CUTTING / TRIMMING OF TREES, ETC.

Any lopping or trimming of tree branches obstructing the line of sight during survey shall be the responsibility of the contractor. Clearing of obstructions falling in the right-of-way as per IS: 5613 (Part 3/Section 2)-1985 and lopping or trimming of the portion of the trees falling within the minimum electrical clearance zone shall be the responsibility of the Purchaser

Clearance from ground, buildings, trees and telephone lines shall be provided in conformity with the Indian Electricity Rules, 1956 as amended up to date.

The contractor shall count, mark and put proper numbers with suitable quality of paint at his own cost on all the trees that are to be cut by the owner at the time of actual execution of the work as detailed below. Owner shall not pay any compensation for any loss or damage to the properties or for tree cutting due to contractor's work.

To evaluate and tabulate the trees and bushes coming within right of way on either side of the central line alignment, the trees will be numbered and marked serially from angle point 1 onwards and the corresponding number will be painted on the stem of trees at a height of 1 metre from ground level. The trees list should contain the following:

- a) Girth (circumferences) measured at a height of 1 meter from ground level.
- b) Approximate height of the tree with an accuracy of + 2 metres.

- c) Name of the type of the species/ tree.
- d) The bushes and shrubs encountered under the r.o.w. for lines should also be evaluated with their type, height, girth and area in square meters, clearly indicating the growth in the tree/ bush statement.

On fixing of the line route after carrying out the detailed survey, a detailed enumeration of area of land and the number of trees with classification, likely to be affected in the corridor on construction of transmission lines, shall be assessed by the EE/TLC concerned. The details of extent of land, crop & trees likely getting affected, owner particulars, crop/tree, classification in the identified areas duly certified by local Revenue Authorities, etc, shall be prepared in the prescribed format by the EE/TLC and a provisional estimate shall be finalized for including in the technical estimate. At the time of taking up the excavation of foundations, tower erection, paving & stringing of line, the Crop/Tree Compensation Forms, as prescribed, shall be got filled up by the land owners and consolidated statements along with assessed tree compensation shall be furnished to Chief Engineer (Construction projects) at Headquarters, to facilitate processing the case for payment without delay and to avoid any hindrance to the construction programme on account of non-payment of crop compensation to the land owners in time.

3.3.20 Survey Report.

Complete bill of quantities (BOQ) of the transmission lines shall be furnished in the survey report.

Each angle point location shall be shown with detailed sketches showing existing close by permanent land marks such as specific tree(s), cattle sheds, homes, tube wells, temples, electric pole/ tower, telephone pole, canal, roads, railway lines etc. The relative distance of land marks from the angle points and their bearing shall be indicated in the sketch. These details shall be included in the survey report.

Information with regard to infrastructure details available enroute, identification and explanation of route constraints, etc shall also be furnished in the Survey report and shall inter-alia include the following:

- Information regarding infrastructural facilities available along the final route alignment like access to roads, railway stations, construction material sources (like quarry points for stone, sand and availability of construction water) labor, existing transport facilities, fuel availability etc., shall be furnished in the survey report.
- All observations which the contractor thinks would be useful to the construction of the transmission lines mentioned under scope of the work are to be reported.
- Suggestions regarding the number of convenient zones (line segments/ portion) in which the entire alignment can be divided keeping in view the convenience of owner are to be pointed.
- Working months available during various seasons along the final route alignment, with period, time of sowing & harvesting of different type of crops and the

importance attached to the crops particularly in the context of way leave problems and compensation payable shall be stated by the contractor.

- Availability of labor of various categories and contractors of civil works shall be reported.
- Some portions of the line may require clearance from various authorities. The contractor shall indicate the portion of the line so affected, the nature of clearance required and the name of the concerned organizations such as local bodies, municipalities, P & T (name of circle), Inland navigation, Irrigation Department, Electricity Boards and Zonal Railways, Divisional Forest Authorities etc.
- All the requisite data for processing the case of statutory clearances such as PTCC, Forest and Railway shall be provided along with the report.
- The contractor shall also collect details pertaining to pollution levels envisaged along the transmission line.

3.3.21 Soil Resistivity: Soil resistivity along the alignment, shall preferably be measured in dry weather by four electrodes method keeping inter electrode spacing of 50 meters. For calculating soil resistivity, formula $2\pi ar$ (where $a = 50$ meters, $r =$ megger reading in ohms, $\pi=3.14$) shall be adopted. Measurements shall be made at every 1km along the route. In case soil characteristics change within 1 km, the value shall also be measured at intermediate locations. The megger reading and soil characteristics shall also be indicated in the soil resistivity results.

3.4 Soil Investigation: Classification of foundation at each location shall be made after soil investigation. For each type of tower different types of foundations are to be designed suitable for different soils.

Soil investigation is made to ascertain the composition and type of soil. Various types of soils are given below.

- 1) Normal Soil: Vegetable or organic soil, turf, sand, ordinary gravel, clay, mud, black cotton soil, soft soil and loose morram.
- 2) Hard Soil: Hard gravel, hard morram, kankar, lime stone, and stone matrix.
- 3) Soft Rock: Decomposed rock, laterite or soft disintegrated rock which generally requires chiseling, wedging and hammering, besides the use of pickaxe or crowbar and spade.
- 4) Hard Rock: Hard rock is the one which has to be excavated by drilling and blasting.
 - a) Any rock or boulder, of a volume of more than 3cu.m per each boulder, of the excavation for which blasting is required.
 - b) Hard rock requiring blasting as described above but where blasting is prohibited for any reason, then excavation is carried out by chiseling, wedging or any other agreed method.

Detailed geo-technical investigation at specified number of tower locations need to be done to provide sufficiently accurate information, both general and specific about the

substrata profile and relevant soil and rock parameters at site on the basis of which the foundation of transmission line towers can be classified and designed rationally

Detailed soil investigation shall be carried out at all important locations such as the crossing of railway lines, national highways, power lines, and location identified by the purchaser. Boring of trial holes or excavation of test pit to at least 3 metres depth or more is to be made depending upon the design depth of foundation proposed in the bid and bore log data including depth of the ground water with table shall be furnished. Data regarding variation of subsoil water table along the proposed line route shall also be ascertained.

Special care shall be taken for locations where marshy soils are encountered and Contractor in such cases shall ensure that specified numbers of vane shear tests are performed and the results correlated with other soil parameters.

Wherever possible, contractor shall obtain information and review existing local knowledge of neighbouring streams, water resources, abandoned under ground works, nearby quarries, unlined wells, excavations, records of test pits, boreholes, recent land fills, land slides etc., types of foundations adopted and the behaviour of existing structures, particularly those similar to the present project. Study of the general topography of the surrounding areas will often help in the delineation of different soil types.

3.4.1 CODES AND STANDARDS FOR GEOTECHNICAL INVESTIGATION

All work shall be carried out in accordance with the following Indian Standards and Codes

Indian Standards (IS)	Title	International and Internationally Recognised Standard/ Code
IS : 1080	Codes of Practice for Design and Construction of Simple Spread Foundations.	
IS: 3025	Methods of Sampling and testing (Physical and Chemical) for Water used in Industry	
IS : 1498	Classification and Identification of Soils for General Engineering Purposes.	ASTM D 2487 ASTM D 2488
IS : 1888	Method of load tests on soils	
IS : 1892	Code of Practice for Subsurface Investigation for Foundation.	
IS : 1904	Code of Practice for Design and Construction of Foundation in Soils: General Requirements	
IS : 2131	Method of Standard penetration test for Soils	ASTM D 1586
IS : 2132	Code of Practice for Thin Walled Tube Sampling of Soils	ASTM D 1587
IS : 2720	Method of Test for Soils (Relevant parts)	ASTM D 420

IS : 2809	Glossary of Terms and symbols relating to soil engineering	ASTM D 653
IS : 2810	Glossary of Terms and symbols relating to soil engineering	
IS : 4078	Code of practice for indexing and storage of drill cores.	
IS : 4434	Code of practice for In-situ Vane Shear test for soils	ASTM D 2573 ASTM D 4648
IS : 4453	Code of Practice for exploration by pits, trenches, drifts and shafts	
IS : 4464	Code of practice for presentation of drilling information and core description in foundation investigation	
IS : 4968	Method for subsurface sounding for soils, dynamic method using cone and bentonite slurry	
IS : 5313	Guide for core drilling observation	
IS : 6403	Code of practice for determination of allowable bearing pressure on shallow foundation	ASTM D 194
IS : 6926	Code of practice for diamond core drilling for site investigation for river valley projects.	
IS : 6935	Method of determination of water level in a bore hole.	
IS : 7422	Symbols and abbreviations for use in geological maps. Sections and subsurface exploratory logs (relevant parts)	
IS : 8009 (Part-1)	Code of practice for calculation of settlements of foundations (shallow foundations subjected to Symmetrical vertical loads).	
IS : 8764	Method for determination of point load strength index of rocks	
IS : 9143	Method for determination of unconfined compressive strength of rock materials	ASTM D 2938
IS : 9179	Method of Preparation of rock Specimen for laboratory Testing	ASTM D 4543
IS : 9259	Specification for Liquid Limit Apparatus	ASTM D 4318
IS : 9640	Specification for Spilt Spoon Sampler	ASTM D 1586
IS : 10050	Method of Determination of Slake Durability Index of Rocks	ASTM D 4644

IS : 11315	Description of Discontinuities in Rock Mass – Core recovery and Rock Quality.	
	CBI&P Manual on Transmission Line Towers – Chapter 10: Foundation	

3.4.1 Soil Investigation at Normal Locations: One bore hole of 150 mm dia shall be drilled at the center point of the tower. Standard penetration Test (S.P.T) shall be carried out at 1.50 m interval or change of strata up to the required depth of 2 1/2 times below the depth of foundation below existing surface elevation or refusal whichever occurs earlier (By refusal it shall be mean that a standard penetration blow count 'N' of 100 is recorded for 30 cm penetration). Bore details and water table up to required depth below existing surface elevation or refusal whichever occurs earlier shall be furnished in the report.

3.4.2 Soil Investigation at Special Locations: At certain locations such as river banks, river beds or midstream of river and at other places, special soil investigation shall be carried out by drilling two holes each of 150 mm diameter at each tower location on the diagonally opposite legs of the tower, considering the base width of tower as 20m.

Standard penetration tests shall be carried out at every 3.0 m intervals or change of strata till refusal is met subject to maximum of 50 m below the existing surface elevation.

Undisturbed samples of soil shall be collected at every 5m intervals up to 15 mts and 3mts beyond 15 mts. or change of strata whichever occurs earlier.

In the hard rock the bore drilling shall be continued at least 5m to ascertain its sufficient thickness.

Samples collected through any of the above methods are tested for sieve analysis, liquid, plastic and shrinkage limits, specific gravity, chemical analysis, free swell index etc to establish bearing capacity and density of soil.

3.4.3 Preparation of Test Reports

The investigation report shall contain the following test results:

1. Grain size analysis
2. Nomenclature of soil
3. Atterbergs limit (Liquid and plastic limit only)
4. Tri-axial shear test results containing information about angle of internal friction and cohesion.
5. S.P.T results containing information about natural moisture content, Specific gravity and Bulk unit weight.
6. Consolidation test.
7. Unconfined compression test
8. Unconsolidated un-drained test.

9. Presence of carbonates, sulphates, nitrates and organic matters and any other chemicals harmful to the concrete foundation –obtained from chemical test on soil sample.
10. For rocky, soil core recovery and crushing strength of the rock shall be furnished.
11. The bearing capacities of soil at 3.5 m below the existing surface elevation for normal investigation and at a depth fixed considering the bore log data as mentioned in clause 11.13.3 below the existing surface elevation for special soil investigation shall be furnished considering approximate base width of foundation.

In addition to the above the following data also shall be furnished in the report of special soil investigation.

1. Scouring depth in case the locations area at the bank of river or at midstream duly collecting the Hydraulic particulars of the river from CWC or State authorities corresponding to the nearby station. However, the hydraulic data may be corrected / modified with respect to the topography / cross section of the river at that particular location.
2. Silting factor in case of midstream and river bank locations where submergence is envisaged.
3. Depth of fill, if any
4. Details of water table, water struck etc.
5. Compressibility of sub-soil stratification.
6. Settlement characteristics of the shallow foundations.

The above test results shall be summarized strata-wise as well as in a combined tabular form with all relevant graphs, charts, tables, diagrams and photographs, if any, shall be furnished in the test reports.

The test report shall include bore logs. Bore logs of each bore hole clearly identify the stratification and type of soil stratum with depth up to the refusal. The locations of water table shall be identified on the bore log. The value of SPT at depth where conducted and various laboratory tests conducted from samples collected at various depths shall be clearly shown against the particular stratum.

The report should contain specific recommendation for the type of foundation. In case the soil parameters obtained from the soil investigation report for a particular tower location differ from the ones considered during design, the Purchaser will develop a fresh design.

The type of foundations to be constructed at each tower site shall be based on the soil characteristics indicated on the route profile sheets and as determined by the contractor and approved by the Purchaser during the progress of the work. The Purchaser reserves the right to change the type of foundation at any location where conditions during the progress of work indicated the use of a different type of foundation.

The Purchaser will furnish the foundations designed for the soil conditions encountered in the excavations. If the soil conditions vary significantly between different excavations on one tower then foundations of different classes may be installed. The foundations for each

tower in a straight section of the line shall be placed so that the longitudinal axis of the tower cross arm will be in a plane perpendicular to the transverse of the line. Unless otherwise directed by the purchaser, the foundations for each angle tower shall be placed in a manner so that the tower cross arms lie in a plane bisecting the interior angle formed by the intersection of the transverses of adjacent sections of the line.

When determining the classification of the foundation at site the following procedure shall be followed.

- i) The initial excavation shall be done to the dimensions of the immediate smaller foundation classification to that determined by the soil investigation.
- ii) The base of the excavation shall be examined to determine the bearing capacity of the soil and the minimum foundation classification ascertained.
- iii) The walls of the excavation shall be examined to determine the soil classification, angle of repose, and a suitable foundation classification selected to meet the soils encountered.
- iv) The level of ground water or the expected level of ground water during the rainy season or standing water over the site shall also be considered when determining the foundation classification.

Characteristic values of different soils are as given below.

Type of Soil	Bearing strength Kg/Sq.Mtr	Weight of soil Kg/Cu.Mtr	Angle of Repose Degrees
Normal Dry soil	27350	1440	30
Soil in Wet Location	13675	940	15
Soft Rock (Dry Black cotton soil)	62500	1440	20
Hard Rock	125000		

Lateral Bearing Strength of Earth:

$$\text{Side Thrust Force (F)} = \frac{1}{2} \times W \times h^2 \times B \times \frac{(1 + \sin \Phi)}{(1 - \sin \Phi)}$$

where W= Weight of soil, B= 0.65, Φ = Angle of earth frustum.

3.4.4 Classification of Foundations: Similar but separate foundations are to be laid for the four legs of a lattice tower. For each type of tower different types of foundations are to be designed suitable for different soils.

Following types of foundations are adopted under normal conditions.

- 1) Inverted frustum with chimney and bottom concrete pad with or without steel reinforcement
- 2) Stepped pads with chimney, with or without steel reinforcement
- 3) Mass concreting of excavated pits of designed dimensions for rocky locations
- 4) Well foundations with anchor bolts laid in river bed locations
- 5) Pile foundations in locations where soils of poor bearing capacity are met with.

The foundation designs for various types of Foundations as given below shall be adopted in the construction of Transmission Lines and shall be based on the following instruction.

Sl. No.	Soil at the location of tower	Classification of foundation to be adopted.
1.	When water table is below foundation level and where normal dry cohesive and homogeneous soils are met up to full depth having clay content of 10-15%.	Dry
2(a).	Where sub-soil water is met at 1.50 meters or more below the ground level in normal soil	Wet
(b)	Where surface water could stand for long period with water penetration not exceeding 1.0 m below ground level (e.g. Paddy fields, Sugarcane fields)	
3(a).	Where sub-soil water is encountered between 0.75 meter and 1.50 meters depth below ground level.	Partially Submerged / Partially Black Cotton
(b)	Where top layer of Black Cotton soil extends up to 50% of the depth with normal soil thereafter	
Note – 1	Where soil is clayey type, not necessarily black in color, which shrinks when dry, swells when wet.	
4(a)	Where sub-soil water Table is within 0.75 m depth from ground level.	Fully Submerged – Black Cotton
(b)	Where top layer of Black Cotton soil exceeds 50% and extends up to full depth or is followed by normal soil.	
(c)	Where top layer is normal soil up to 50% of the depth but the lower layer is a Black Cotton soil	
Note – 2	In case of items 4(a), (b) & (c) above, the concerned Superintending Engineer (Civil) shall personally inspect and certify on soil classification and shall not delegate this responsibility to any sub-ordinate officers.	
5(a)	Where decomposed or fissured rock, hard gravel, kanker, limestone, laterite or any other soil of similar nature is met.	Fissured / soft rock
(b)	Where top layer of normal dry soil extends up to 85% of the depth followed by fissured rock without presence of water.	

6(a)	Where Hard rock is encountered at 1.5 m or less below ground level.	Hard Rock
(b)	Where Hard rock is encountered form 1.5 m to 2.5 m below Ground Level though Top layer is of normal soil	
(c)	Where chiseling, drilling and blasting is required for excavation.	
Note – 3	While classifying foundation of Wet, Partially Submerged / Partially Black Cotton, Fully Submerged / Black Cotton foundations mentioned above, the worst conditions may be considered and not necessarily the conditions prevailing at the time of inspection. For instance, there are areas where sub-soil water rises when canal water is let-out in the field raising sub-soil water to a considerable degree. Similarly the effect of monsoon or when the nearby reservoirs are full should be considered and not the conditions prevailing in open season or summer when work is carried out normally. In all such cases, the Chief Engineer (Civil) shall personally inspect and certify the requirement of higher classification on case to case basis.	
Note – 4	For critical locations of cut-point / Angle Towers, the classification of Tower Foundations may be at next higher type for ensuring safety of the transmission line that is likely to be subjected to variable forces from time to time on account of change in season and climatic conditions. This shall be decided by the concerned Superintending Engineer (Civil) on case to case basis on personal inspection.	
Note – 5	In case of highly collapsible & loose soils and river crossings, special design for foundations is to be made by Civil Engineering Wing for adoption on case to case basis.	
Note –6	At locations subjected to water logging, particularly in paddy fields, ponds, marshy areas, etc., the chimney of all stubs to be raised to 600 mm over the normal chimney being adopted in other cases. This shall be done after complete erection of towers as a separate item for identified locations.	

In addition to the above, depending on the site conditions more varieties of foundations may be introduced suitable for intermediate conditions under the above classifications to effect more economy.

In case of any deviation in classification of any foundation found necessary at the time of execution of the works in the earlier finalized classification, such deviation shall be permissible only with prior approval of the Chief Engineer of the respective TL & SS Zone based on Justification for such deviation up to 10% of the total number of locations / concrete volume of the line. Above such limit, the approval is to be accorded by the Committee of Technical Directors.

Vigilance wing shall test check the soil classification finalized by the detailed survey other than dry.

3.4.5 Design of Foundations:

Factor of safety to be adopted: 132kV, 220kV and 400kV lines – 1.1 for normal conditions and 1.1 for broken wire condition based on limit load concept.

Nature of loads considered in designing foundations: Down thrust or compression for normal and broken wire condition, Uplift for normal and broken wire condition and Side thrust – Transverse / longitudinal for normal and broken wire condition.

The following characteristic values of concrete of 1:2:4 mix are adopted in the design of tower foundations.

1) Weight of dry concrete	=	2400 kg / Cu.Mtr
2) Weight of concrete in wet and Submersible location.	=	1400 kg / Cu.Mtr
3) Bond strength between stub Angle and concrete	=	10 kg / sq. cm.
4) Maximum stress in concrete	=	153 kg / sq. cm.
5) Limit bond stress between concrete and reinforcement steel deformed bars in Tension	=	16 kg / sq. cm.
6) The modular ratio m	=	19

3.5 Construction of Transmission Lines

Works below Ground level:

3.5.1 Setting of Stubs:

The stubs shall be set correctly at the exact locations and alignment and precisely at correct levels. Stubs shall be set in the presence of authorized representative of the purchaser available at site, for which adequate advance intimation shall be given to the purchaser by the contractor.

The concrete level shall be set with their tops 225 mm (minimum) above ground level and coping shall be of 75mm above the chimney.

The embedded end of the stub angle shall have a 150mm thick clear concrete cover over the top of lean concrete sub-base in case of dry foundations and a 200mm thick clear cover in case of wet, PS, and FS foundations.

The minimum length of stub encased in concrete below the ground level shall not be less than 1.5 m. However the stub shall extend up to the bottom of foundation having a clear concrete cover as specified above.

The depth of foundation below ground level shall be 3.5m. Except in hard rock foundation, the cutting of stub length is not allowed in any circumstances.

In any case the foundation should be 3.0m for each leg in original soil irrespective of the level difference between any two legs. The level difference up to 1.5m should be covered with extended stub along with chimney in addition to the standard length. The extended stub and chimney details will be furnished by Purchaser at the time of execution.

3.5.2 Excavation:

Earth excavation has to be done in all types of soils which can be excavated with pick axe & crow bars in all conditions such as dry, wet, slushy etc., and in hard rock requiring blasting including shoring, shuttering and dewatering wherever necessary covering initial lead and one extra lift. The contractor must satisfy himself about general conditions of transmission line route and ascertain the existing and future obstructions likely to come up during the execution of the contract to carry out the work. Excavation shall be as per approved drawing.

The grading near all excavations shall be controlled so that the surface of the ground will be properly sloped or diked to prevent surface water from running into the excavated areas during construction.

Excavation shall include blasting if required and the removal of all materials required to execute the work properly and shall be made with sufficient clearance to permit the placing, inspection and setting of forms and completion of all works for which the excavation was made.

Sides and bottoms of excavations shall be cut sharp and true. When machines are used for excavation, the last 300 mm before reaching the required level shall be excavated by hand or by such equipment that will leave the strata at the required final level, in its natural condition. The bottom of excavation shall be trimmed to the required level. Any extra excavation when carried below the prescribed level shall be brought to the prescribed level by filling with the lean concrete as specified at the contractor's cost.

All excavations for installation of underground facilities, such as piping, trenches, ducts, etc. shall be open cut.

Excavations for foundations shall be carried to an adequate depth below the bottom of structural concrete and then be brought to the required level by sand filling and/or placing lean concrete of 1:4:8/1:3:6 mix with aggregate of 20 mm nominal size.

Where the excavation is to be carried out below the foundation level of an adjacent structure, precautions such as under pinning, shoring and skirting etc. shall be taken. No excavation shall be done unless such precautionary measures are carried out as per direction of Engineer-in-charge.

Loose, soft, in sand or in loose strata encountered in excavation at the required depth shall on Engineer-in-charge's instructions be excavated to a firm bed and the difference made up to the required level by filling with lean concrete PCC (1:4:8) conforming to IS: 456-2000. No foundation shall rest on filled up soil. In case filled up soil is encountered

below the foundation, excavation shall be carried up to 500mm in virgin soil and space between level of foundation and 500mm in natural soil shall be back filled with sand (if the space is up to 500mm) or PCC 1:4:8 (if the space is more than 500mm).

Foundation pits shall not be excavated to the full depth unless construction is imminent. The last fifteen (15) cm depth of the excavation shall not be removed until concreting work is imminent.

3.5.3 Shoring and Shuttering: Shoring and shuttering shall be done keeping in view the requirements given in IS: 3764 (latest). For excavations to be made in sandy soils or water bearing strata or in any other type of soil where there is every likelihood of pits collapsing, shoring and shuttering made out of timber planks or steel frames of adequate strength as per requirements shall necessarily be provided.

Where excavation required bracing, sheeting or shoring etc. the contractor shall submit to the purchaser the design and drawings showing arrangement and details of proposed installation for examination and approval, and shall not proceed until approved by the purchaser.

3.5.4 Excavation in Hard Rock: In case of excavation in hard rock requiring blasting, extreme care shall be taken with regard to storing, handling and use of explosives. Materials used for blasting such as explosives, detonators, fuses, tamping materials etc. shall be of approved make and of good quality. Proper storage of these materials shall be ensured.

The contractor shall familiarize himself with all applicable laws and regulations. Also reference to S.S.no.203 of APDSS shall be made.

Blasting operations shall be carried out under the supervision of competent and licensed person and trained workmen. Proper precautions for safety of persons and property shall be taken.

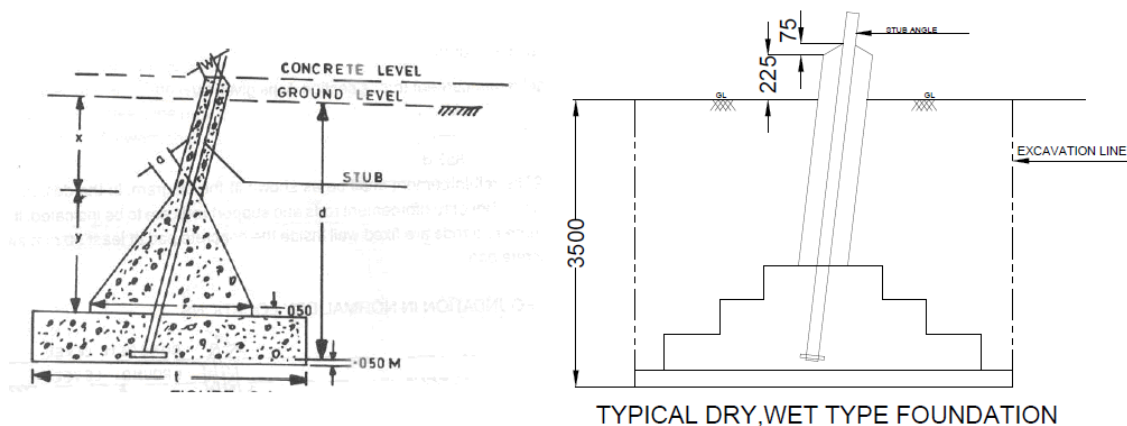
Where blasting is prohibited or not practicable, excavation shall be carried out by chiseling at no extra cost to the owner. The decision of the Engineer-in-Charge in this regard shall be final.

3.5.5 Excavation below Water Table: Wherever water table is met with during the excavation, the Contractor shall dewater and maintain the water table below the bottom of the excavation level during excavation, concreting and backfilling. The guidelines for de-watering during construction specified in IS: 9759 (latest) shall be followed. Dewatering shall be carried out either manually or by mechanical pumps or power driven pumps to facilitate excavation and casting of foundation. The pumps shall be suitable for handling muddy water. The pits shall be kept dewatered until 24 hours after concreting the foundations.

All excavated materials such as hard rock, boulders, bricks, dismantled concrete blocks, etc. shall be stacked separately as directed by the Engineer and shall be the property of the Purchaser.

Excavated material shall be placed beyond 1.5 meters from the edge of the pit or trench or half the depth of the pit or trench whichever is more or further away if directed by the Engineer. Excavation shall not be carried out below the foundation level of structure close by until required precautions have been taken.

3.5.6 Foundation in Normal Dry Location:



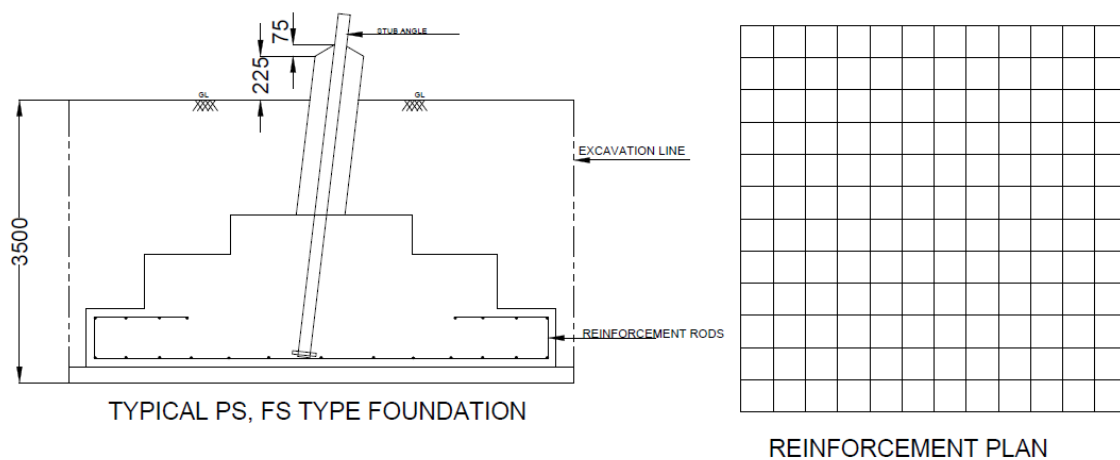
The maximum compression is obtained by applying the factor of safety to the value of compression due to Bending Moment Forces acting on the tower, dead weight of tower and power conductors and ground wire and weight of concrete. The bearing strength of the ground of area 'b' Sq. Mtr. should be more than the above maximum compression. The total uplift force is calculated based on the transverse and longitudinal forces. The minimum vertical loads due to conductors and ground wire and the dead weight of tower and weight of concrete are calculated per leg and deducted from the total uplift force to arrive at the net uplift. Counter weight for this uplift is provided by the weight of earth pyramid and concrete frustum. It is to be checked whether maximum uplift after applying factor of safety is fully compensated by the counter weight. The proposed foundation has to be checked for side thrust also. Based on the horizontal component of the stress in the stub, the maximum side thrust is calculated after applying the necessary factor of safety. The lateral bearing capacity of the soil is obtained by calculations based on the soil characteristics. This lateral bearing capacity of the soil should be equal to or more than the above maximum side thrust. The depth of the stub below ground level indicated as 'd' is decided by the design of tower and hence cannot be altered. While choosing dimensions 'a' and 'w', care must be taken to ensure that the thickness of concrete all around the stub is not less than 100 mm.

3.5.7 Foundation in Wet Locations:

In case of wet foundation, the bearing strength of the soil is half of dry soil and the angle of internal resistance. In view of this an additional concrete slab with or without steel reinforcement as shown in fig, underneath the inverted frustum may be provided. However, the dimension 'x', 'y' and 'z' have to be chosen, keeping in view the fixed dimension d (depth of stub below ground level).

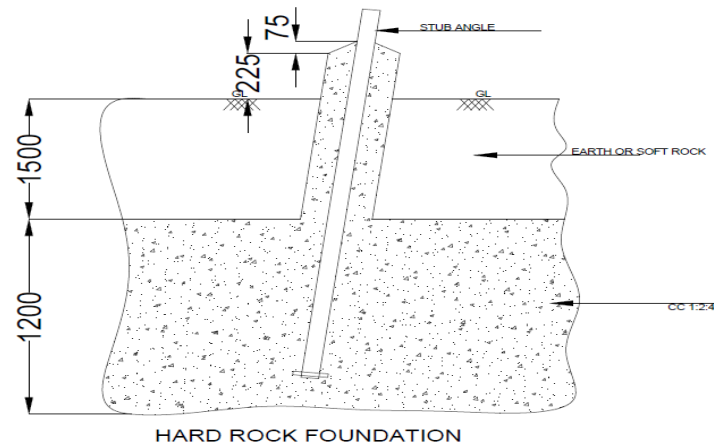
3.5.8 Foundation in Submersible Locations:

In case of fully submersible location steel reinforcement has to be provided in view of a large bottom concrete pad and as the over-hang of bottom concrete pad is too long to be contained under compression. The dimensions t and z are determined based on the soil characteristics and the design values of compression and uplift.



3.5.9 Foundation in Rocky Locations

In view of tremendous bearing strength of rock and bond strength between stub angle and concrete, special type of foundation is to be designed providing for preparing a much smaller pit and mass concreting after stub setting. The base width and depth in the hard rock have to be decided based on the design values of compression and uplift. The excavation in the hard rock is to be done by drilling, blasting and chiseling. Dimensions of the pit shall be limited to base width and depth within hard rock portion. After stub setting the pit in the hard rock and chimney shall be filled with concrete of 1:2:4 Mix as shown in the figure. Depending upon how deep below ground level, the rock is met with; the stub angle may have to be cut to limit the depth of stub below ground level to (C-0.050) mtrs. It may be noted that necessary holes have to be provided at the bottom of the stub angle to fix the cleat. The remaining portion of the pit above the hard rock level shall be backfilled with the excavated rock bits and earth properly rammed to form a homogeneous earth pyramid. The dimension of the surface width at the hard rock portion may be kept slightly less than the designed base width at the bottom of hard rock to ensure rigidity of concrete block. The dimension of chimney portion may normally be taken the same as those of wet foundations.



3.5.10 Backfilling:

After completion of foundation work and prior to backfilling, all forms, temporary shoring, timber etc. shall be removed and the excavation cleaned of all trash, debris and perishable materials. Backfilling shall begin only with the approval of the purchaser.

Backfilling of excavation in trenches around foundations and elsewhere shall be with one of following materials, as directed by the Engineer-in-charge in each location.

- Ordinary soil
- Selected earth from soil heap or from borrowed area.
- Hard core.
- Sand filling
- Lean concrete. The material shall be free from fobbing roots, hard lumps and any other foreign organic materials

Excavation shall be cleaned of all trash, debris and perishable materials before backfilling.

Backfill shall not be dropped directly upon or against structure or facility where there is danger of displacement or damage. Backfill shall be placed in horizontal layers not exceeding 150 mm in thickness. Each layer shall be compacted with proper moisture content and with such equipment as may be required to obtain a density equal to or greater than 94% of maximum as determined by the IS:2720 and IS:4701. For cohesive soils each layer shall be wetted, or dried by aeration, to a moisture content of 3 to 5 per cent above optimum. Trucks or heavy equipment for depositing or compacting backfill shall not be used within 1.5 meters of building walls, or other facilities which may be damaged by their weight or operation. Pushing of earth for back filling shall not be adopted under any circumstances. Backfill adjacent to pipes shall be hand placed, free of stones, concrete etc. compact uniformly on both sides of the pipe and where practicable, to a depth of 300 mm over the top of pipes.

Black cotton soil shall not be used for backfilling around the structure. Cushion of sand be laid. Over this 75 mm thick layer of stone aggregate, with stone size uniformly. This shall then be compacted by light roller (by 2 ton roller and 4 to 5 passes) or any other means. After compacting, sand shall be uniformly spread and water shall be sprayed over it to ensure that the voids are filled with sand. Water shall be spread in such a manner that bulking in sand does not take place. This process will be repeated till the filling reaches the desired level. When it reaches the finished level, surface shall be flooded with water for 24 hrs, allowed to dry and then rammed and consolidated to avoid any settlement at a later stage.

3.5.11 Formwork:

Formwork shall be as per IS: 456-2000 and shall be composed of steel and/or best quality shuttering wood of non-absorbent type timber. The timber shall be free from knots and shall be of medium grain as far as possible.

Formwork shall be composed of steel and/or best quality shuttering wood of non-absorbent type. Timber shall be free from significant knots and shall be of medium grain as far as possible and hard woods shall be used as caps and wedges under or over posts. Plywood or equivalent shall be used where specified to obtain smooth surfaces, for exposed, concrete work. Struts shall generally be mild steel tubes, and strong Sal wood is 150 mm in diameter or above. Materials used for the form work inclusive of the supports and centering shall be capable of withstanding the working load and remain undistorted throughout the period it is left in service.

The centering shall be true and rigid and thoroughly braced both horizontally and diagonally. The form work shall be strong enough to withstand the effects of vibration, without appreciable deflection, bulging, distortion or loosening of its components. The joints in the formwork shall be sufficiently tight to prevent any leakage or mortar. The formwork shall have a smooth uniform surface free from honeycombs, air bubbles, bulges, fins and other blemishes. To achieve the desired rigidity, the bolts, space blocks, the wires and clamps shall be used but they must in no way impair the strength of concrete or leave stains or marks on the finished surface.

For exposed interior and exterior concrete surfaces of beams, columns and walls, plywood or other approved forms, thoroughly cleaned and tied together with approved corrosion-resistant devices shall be used. The temporary openings shall be so formed that they can be conveniently closed when required and must not leave any mark on the concrete.

Cleaning & Treatment of Forms: All parts of the forms shall be thoroughly cleaned of old concrete, wood shavings, saw dust, dirt and dust sticking to them before they are fixed in position. All rubbish, loose concrete, chippings, shavings, sawdust etc. shall be scrupulously removed from the interior of the forms before concrete is poured. Compressed air jet and/or water jet along with wire brushes, brooms etc. shall be used for cleaning.

The inside surface of the formwork shall be treated with approved non-staining oil or other compound before it is placed in position. Care shall be taken that oil or other compound does not come in contact with reinforcing steel or construction joint surfaces

and shall be non-staining and non-injurious to concrete. They shall not be allowed to accumulate at the bottom of the formwork. The oiling of the formwork will be inspected just prior to placement of concrete and redone wherever necessary.

Reuse of Forms: Formwork may be reused, provided that it is true, un-warped, thoroughly clean and without broken or damaged edges and equal in use in every respect to a new lumber. All form lumber shall have the contact surfaces re-oiled or recoated with an approved composition prior to usage.

Classification: Generally, the 'ordinary' class formwork shall be used unless otherwise directed by the Engineer.

a) Ordinary: These shall be used in places where ordinary surface finish is required and shall be composed of steel and/or approved good quality partially seasoned timber.

b) Plywood: These shall be used in exposed surfaces, where a specially good finish is required and shall be made of approved brand of heavy quality plywood to produce a perfectly uniform and smooth surface conforming to the shape described in the drawing with required grain texture on the concrete.

c) Ornamental: These shall be used where ornamental and curved surface are required and shall be made of selected best quality well seasoned timbers or of plywood, which can be shaped correctly.

3.5.12 Reinforcement:

The steel bars used for reinforcement may be of 6mm to 32 mm dia as per the design requirement. Mild steel round bars, cold twisted and deformed bars as medium tensile or high yield strength steel conforming to IS:432 and IS:1786-1979, plain hard drawn steel wire fabric etc will be used as reinforcement.

Requirements for a concrete cover over steel reinforcement, projection of bars for bending with future extensions, mesh reinforcement and other items to connection with proper placing shall be strictly adhered to. All steel for reinforcement shall be free from loose scales, oil, grease, paint or other harmful matters immediately before placing the concrete.

Reinforcing steel shall be bent in accordance with the procedure specified in IS: 2502 or as approved by the Engineer. Bends and shapes shall comply strictly with the dimensions corresponding to the approved Bar Bending Schedules. No reinforcement shall be bent when already in position in the work. Bars shall not be straightened in a manner that will injure the material. Re-bending bars shall be bent by machine or other approved means producing a gradual and even motion. All the bars shall be cold bent unless otherwise approved.

The radius of the bend shall not be less than 4x bar diameter for plain mild steel or 6 x bar diameter for deformed bars.

Welding: Normal bond laps in reinforcement may be placed by lap or butt-welding reinforcement bars, if asked by the Engineer, under certain conditions. The work should be done with suitable safeguards in accordance with relevant Indian Standards & IS: 2751 for welding of mild steel bars used in reinforced concrete construction as per IS:

2751 and IS: 456. Welded mesh fabrics conforming to IS: 1566 may also be used if specified in the Schedule of items and drawings.

Laps and anchorage lengths of reinforcing bars shall be in accordance with IS: 456, unless otherwise specified. If the bars in a lap are not of the same diameter, the smaller will guide the lap length. The laps shall be staggered as far as practicable and as directed by the Engineer and not more than 50% of the bars shall be lapped at a particular section. Arrangements for placing concrete shall be such that reinforcement in position does not have to bear extra load and get disturbed.

Covers for Reinforcement: Care should be taken to ensure that projecting ends of ties and other embedded metal do not encroach into the concrete cover. Where concrete blocks are used for ensuring the cover and positioning reinforcement with suitable binding wire, they shall be made of mortar not leaner than 1 (one) part cement to 2 (two) parts sand by volume and cured in a pond for at least 14 (fourteen) days. Their strength shall correspond to the strength of concrete proposed for the structure. Where such cover blocks are used, all cover, spacers shall be secured firmly so that they are not disturbed during vibration.

Tolerances: Reinforcement shall be placed within the following tolerances as specified in Clause 11.3 of IS: 456-2000:

- (a) For effective depth 200 mm or less + 10mm
- (b) For effective depth more than 200 mm + 15 mm

The cover shall in no case be reduced by more than one third of specified cover or 5 mm whichever is less.

3.5.13 Foundation Concrete:

Cement, Coarse and Fine Aggregates, Water, Admixture used if any and reinforcement steel etc. used in forming, mixing, placing, finishing, curing and testing of plain and reinforced concrete for foundation work for transmission line towers shall meet the requirements stipulated in relevant standards mentioned under specifications for works. The contractor shall furnish all labour, equipment and materials required for complete performance of the work in accordance with the drawings and as described herein

i) Preliminary Tests

A test conducted in laboratory on the trial mix of concrete produced in a laboratory with the objective of:

Designing of a concrete mix before the actual concreting operation starts;

Determining the adjustments required in the design mix when there is a change in the materials used during the execution of work;

Verifying the strength of the concrete mix.

ii) Work Tests

A test conducted in the field or in a laboratory on the specimen made on the works, out of the concrete being used on the works.

Design mix concrete shall be used on all concrete works, except where specified otherwise. Work shall not commence until the Purchaser has approved the control/design concrete mix. The contractor shall allow sufficient time for all the obligations and tests etc. to be carried out prior to approval.

NOTE: Mix design shall take account of any chemicals harmful to concrete found to be present during soil investigation.

Concrete Mix Review:

The source and quality of concrete materials and concrete proportions proposed for the work shall be submitted to the Engineer for review before the concrete work is started. Complete certified reports prepared by an independent testing laboratory and covering the materials and proportions shall be submitted. Review of these reports will be for general acceptability only and continued compliance with all contract provisions only will be required. The Engineer shall have the option to witness the preparation of the trial mixes, testing etc.

Reports on admixture shall include the classification, brand, manufacturer and active chemical ingredient. All admixtures, conforming to relevant IS Codes, shall be the products of one manufacturer approved by the Engineer.

Reports on the fine aggregates shall include the sources, type, gradation, deleterious substance, soundness and the results of all tests required to verify compliance IS: 383.

Reports on the coarse aggregates shall include the source, type, gradation, deleterious substances, soundness, abrasion loss and the results of all tests required to comply with IS:383.

Using concrete materials acceptable to the purchaser: A concrete mix shall be designed and tested for each size and gradation of aggregates and for consistency intended for use on the work. Design quantities and test results of each mix shall be submitted for review. Acceptable mixes shall be subjected to field adjustments as necessary to meet the requirements of these specifications. Should the contractor wish to use alternative sources for sand and aggregate the additional design mixes must be supplied.

The report for each concrete mix submitted for review shall include the following information:

- (a) Slump on which the design is based.
- (b) Total litres of water per cubic meter.
- (c) Water-cement ratio.
- (d) Ratio of fine to coarse aggregates.
- (e) Weight (surface dry) of each aggregate per cubic meter.
- (f) Quantity of each admixture.
- (g) Air content, if any.
- (h) Compressive strength based on 7 days and 28 day's compression test.
- (i) Time of initial set.
- (j) Time of final set.

(k) Weight of cement used in the mix.

Concrete test specimens shall be made cured and tested in conformity with IS: 516. These tests shall be conducted at approved laboratory. Calibration certificates for the test equipment shall be available on demand. The mould and materials for cubes and cylinders shall be supplied by the contractor who shall also arrange to transport the cubes/ cylinders to laboratory at his own cost. The cost of the testing shall also be borne by the contractor.

Concrete Mixing:

Concrete mixing shall conform to IS: 456-1992. Concrete shall only be mixed in a mechanical mixer. Mixing by hand is strictly prohibited. On sites where access is very difficult then “one bag” mixers capable of being dismantled and carried in shall be employed.

The proportion of fine and coarse aggregates, cement and water shall be as determined by the mix design in case of controlled concrete. The quantities of fine and coarse aggregates shall be determined by weight. The engineer may allow the quantity of aggregates to be determined by equivalent volume basis after the relationship between the weight and volume is well established by trial and the same will be verified frequently. The quantity of cement shall always be determined by weight. The water shall be measured accurately after giving proper allowance for surface water present in the aggregates for which regular check shall be made for bulking in the case of volume batching in accordance with IS:2386 (Part-III).

Detailed procedure and precautions to be observed in mixing, conveyance of concrete, depositing, temperature at the time of placing and compaction of concrete is available in pages 97 to 100 (substation construction concreting)

Contractor shall keep an accurate record of the date on which the concrete is cast for each part of work and date on which the forms are removed.

To secure maximum density and eliminate formation of air pockets, the concrete shall be thoroughly vibrated and worked around all reinforcements, embedded facilities and into corners of forms during and immediately after placing. Unless other methods are authorized by the Purchaser, mechanical vibrators conforming to IS: 2505, IS: 2506, IS: 2514 and IS: 4656 shall be used for this purpose, the type and operation of which is subject to the approval of the purchaser.

The placing of concrete shall be in a continuous operation with no interruption in each location. Concrete shall be handled from the place of mixing to the place of final deposit as rapidly as practicable by methods, which will prevent segregation.

Concrete shall normally be placed in continuous horizontal layers. Construction joints in foundations shall not be permitted. Concrete shall be compacted to the maximum practicable density during the placement and thoroughly worked around the reinforcement if any and around the embedded stubs and into the corners of the formwork, with vibrators or any other means approved by the purchaser.

Repairs of imperfection in concrete shall be completed within 24 hours after the removal of forms. Repair of concrete shall be performed only in the presence of the purchaser or his

representative. All exposed corners shall be slightly rounded or chamfered. Concrete in the top of foundations shall be sloped to provide drainage away from stub angles.

3.5.14 Curing: The concrete after setting for 24 hours shall be cured by keeping the concrete wet continuously for a period of 14 days after laying. The pit may be backfilled with selected earth sprinkled with necessary amount of water and well consolidated in layers not exceeding 200mm after a minimum period of 24 hours and there after both the back filled earth and exposed chimney top shall be kept wet for the remainder of the prescribed time of 14 days. The uncovered concrete chimney above the back filled earth shall be kept wet by providing empty gunny bags dipped in water fully wrapped around the concrete chimney for curing and ensuring that the bags kept wet by the frequent pouring of water on them.

For curing the foundations below ground level, after backfilling, 150mm high earthen embankment along the sides of excavation pits shall be made and sufficient water shall be poured in the backfilled pits so that standing water may remain above the backfilled earth.

In high temperature and low humidity areas, more frequent sprinkling shall be done.

In cold weather at or below freezing temperature, concrete shall be insulated with layer of straw or similar material covered with a waterproof sheet material to help retention of the original heat of concrete plus heat of hydration. Curing shall be carried out for longer periods to the satisfaction of purchaser, to ensure that the concrete attains the strength and quality.

The stubs of foundations constructed in fully submerged soil shall be painted after installation with black bituminous paint overlapping the steel / concrete interface from 150 mm below the top of concrete to 500 mm above.

3.5.15 Sampling and Testing: Samples of concrete shall be taken at the direction of the Engineer in the field in accordance with IS: 1199 'Methods of Sampling & Analysis of concrete'. The testing shall be carried out as per IS: 456 and other relevant codes.

The samples shall be tested for strength and consistency at any approved laboratory in accordance with IS: 516. These tests shall be conducted at approved laboratory or at the contractor's premises under the supervision of the Purchaser's representative. Calibration certificates for the test equipment shall be available on demand. The mould and materials for cubes and cylinders shall be supplied by the contractor who shall also arrange to transport the cubes/ cylinders to laboratory at his own cost. The cost of the testing shall also be borne by the contractor.

The number of samples to be taken for testing and verifying concrete strength shall be in accordance with IS: 456 but shall be a minimum of four (4) cubes per foundation and as per the directions of purchaser.

Samples shall be cured under laboratory conditions except when in the opinion of the purchaser extreme weather conditions may prevail at which time the purchaser may require additional cubes cured under job conditions.

If the strength of the cubes for any portion of the concrete work falls below the specified compressive strength, the criteria for acceptance of the portion of the work shall be as stipulated in IS: 456.

If the concrete falls below the specified compressive strength then the contractor shall:

- i) Analyze the actual loads on the foundation to determine its adequate strength. If acceptable, this shall require a payment to the purchaser for the reduced quality.
- ii) Propose modifications to bring the strength of the foundation to a level acceptable to the purchaser. All modifications shall be at the contractor's expense.
- iii) Break out and replace the foundation as per the Purchasers instruction at the contractor's expense.

The purchaser shall also reserve the right to reject whole or any part of the work. In case of acceptance of such works, the standard deviations shall be worked out, and examined by the purchaser and if he is satisfied only then such works can be accepted at the reduced rates. Furthermore, the purchaser shall have the right to order a change in the mix or the water cement ratio for the remaining portion of the foundations at no extra cost to the purchaser.

3.5.16 Concreting of Foundation:

The contractor shall inform the purchaser or his authorized representative sufficiently in advance about the programme of concreting the location.

3.5.17 Protection of Tower Foundation: The work shall include all necessary stone revetment, concreting and earth filling above ground level. Special measures for protection of foundations shall be taken in respect of locations close to/in nallah, river-beds, etc. by providing suitable crate of galvanized wire netting and meshing packed with boulders. The top seal cover of the revetment work shall be done with PCC 1:3:6 nominal mix. The contractor shall furnish recommendations for providing protection at such locations.

Where the ground surface is irregular the foundation shall be finished off in a substantial and permanent way by forming a plinth by side cutting and building a suitable random stone revetment or in case of rock foundation by building up with concrete as desired by the purchaser. The number of retaining walls and breast walls en-route transmission line shall be intimated by the contractor for obtaining the decision of the purchaser before taking up erection.

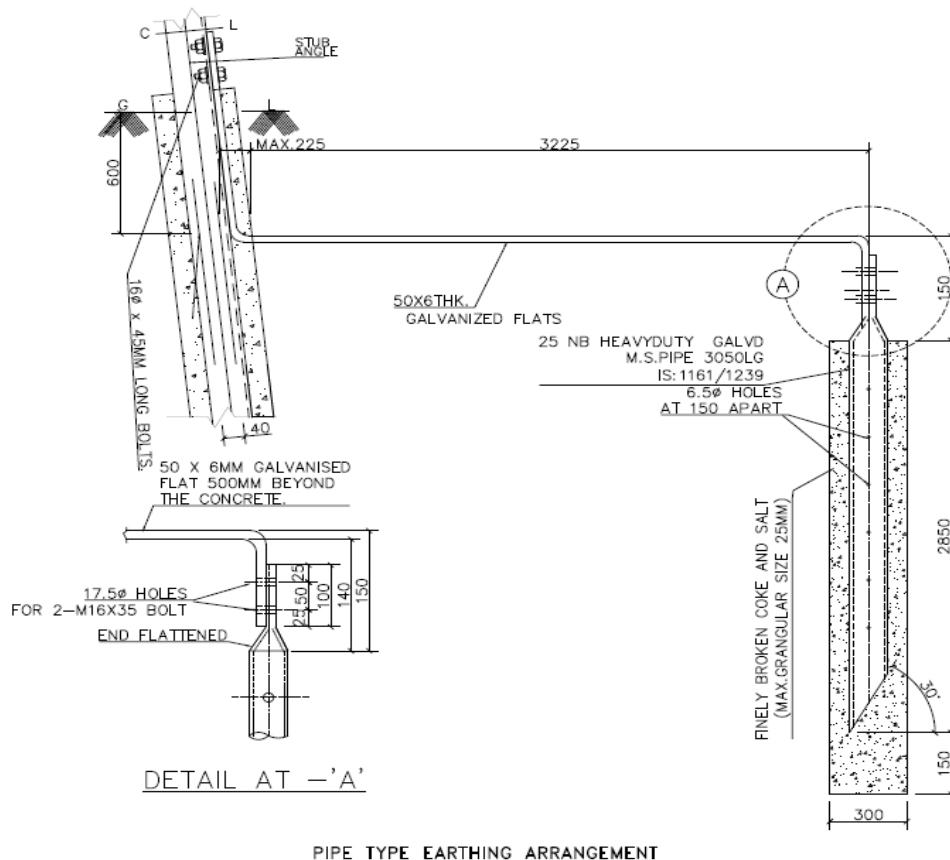
3.5.18 T & P Required:

i)	Concrete mixers	2 Nos.
ii)	Needle vibrators	4 Nos.
iii)	Cube moulds	8 Nos.
iv)	Water tankers	2 Nos.
v)	Compaction rammers	2 Nos.
vi)	Template supporting jacks	20 Nos.
vii)	IS Sieves (all sizes)	1 set.

viii)	Vernier calipers & screw gauge	1 set.
ix)	Steel ladders	2 Nos.
x)	Dewatering pumps	3 Nos.

3.5.19 Earthing:

Each tower shall be earthed after the foundation has been cast. The installation of earthing sets shall be in accordance with relevant standard specifications. The galvanized steel pipe sets shall be installed in the ground near the towers and connected to the tower legs by means of galvanized steel flat as shown in Drawing. The grounding shall be effected by making about 350mm dia and 3600mm deep pit at a distance of not less than 3650mm diagonally away from the stubs and filling in the pits with finely broken coke having grain sizes not more than 25mm thick. Coke shall be maintained up to a distance of 150mm from the pipe on all sides. The top edge of the pipe shall be at least 600mm below the ground level. The steel strip shall be buried not less than 600mm depth from the ground level.

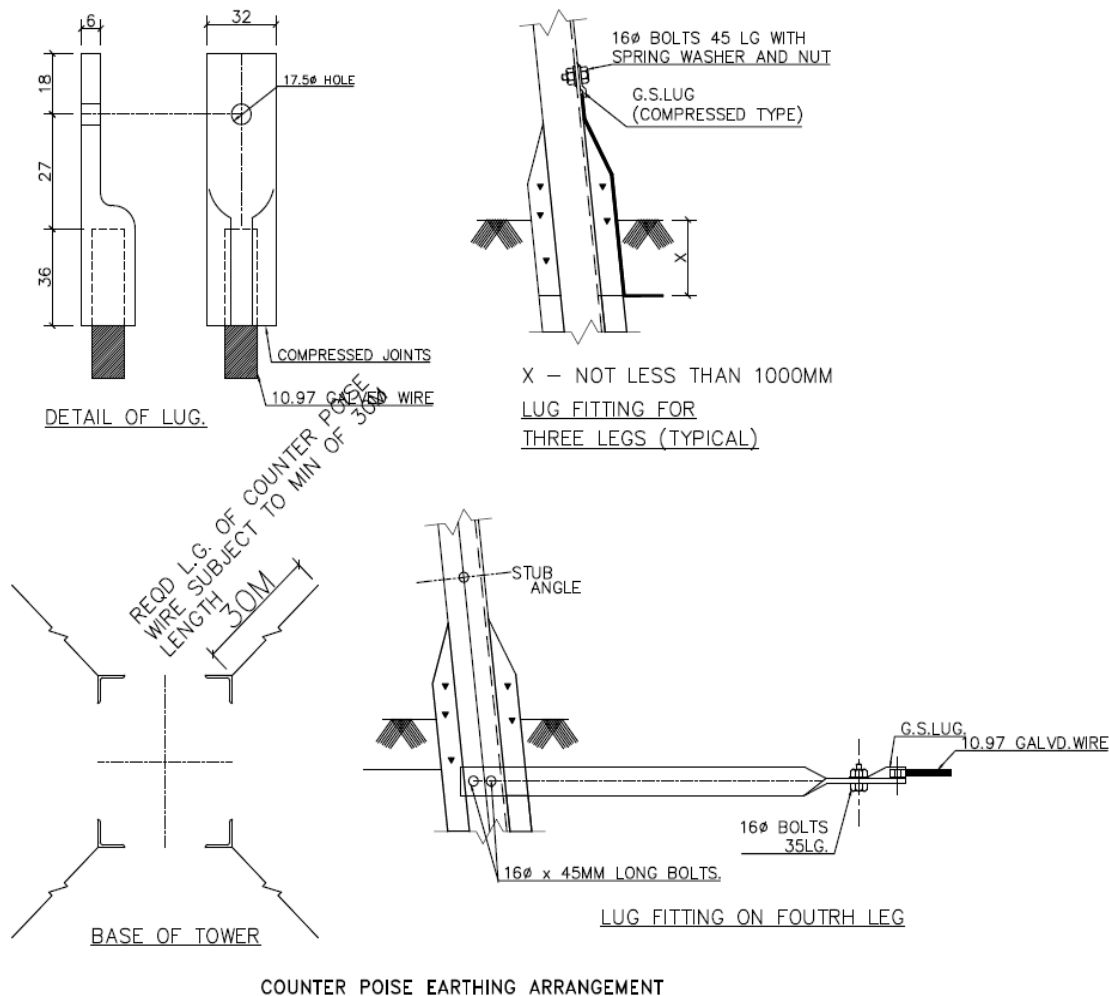


Tower Footing Resistance: The tower footing resistance of all towers shall be measured in dry weather after their erection and before the stringing of earth wire. Tower footing resistance shall not exceed 10 ohms. In case the resistance exceeds the specified values, multiple pipe earthing or counterpoise earthing shall be adopted in accordance with the following procedure, but without interfering with the foundation concrete even though the earth strip/counterpoise lead remains exposed at the tower end.

The connections in such case shall be made with the existing lattice member holes on the leg just above the chimney top.

Multiple Pipe Earthing: Where tower foundation resistance exceeds 10 ohms, the desired earthing resistance shall be obtained by installing additional pipe earthing sets. The distance between the electrodes in such cases shall preferably be not less than twice the length of electrode.

Counterpoise Earth: Counterpoise earth consists of four lengths of galvanized steel stranded wires, each fitted with a lug for connection to the tower leg at one end. The wires are connected to each of the legs and taken radially away from the tower and embedded horizontally 600mm below ground level. The length of each wire is normally limited to 30m but may be increased if the resistance requirements are not met. Galvanized steel stranded wire preferably of the same size of the overhead ground wire may be used for this purpose. A typical example of counterpoise type earthing to tower is given in the drawing below.



Where a tower stands on rock, efforts shall be made to obtain a good ground by carrying a length of galvanized steel flat from the tower legs to earthing pipe driven in damp soil at the

shortest possible distance from the tower. The connecting flat shall be buried in a groove cut in the rock surface and adequately protected from damage.

The contractor shall measure and record the resistance of each tower to earth after erection and before installing the earth wire and submit the same to the purchaser. He shall provide adequate notice to the Purchaser so the Purchaser can witness the measurements if he so wishes. The measurements shall be made during the dry season.

All towers are to be earthed properly before stringing operation is taken up.

3.5.20 Tree/Crop Compensation Right-of-way, Cutting of trees etc:

Payment of compensation for damaged crops or fruit bearing trees shall be initially made by the contractor, which will be reimbursed by APTRANSCO later on. The compensation so payable in respect of damaged crops shall be based on the assessment of MRO. In respect of the trees, compensation so payable is the lowest of the rates fixed by the Horticulture/NABARD/MRO. The contractor shall take up the payment of compensation amount only after written approval by the Project Manager (Executive Engineer). The payment shall be made in the presence of representatives of SE (TLC), Accounts and Vigilance wings of APTRANSCO. The Superintending Engineer/ TLC shall finalize the compensation claims.

The contractor shall take all possible steps to see that standing crops etc. are not damaged during execution of works. When such damage is inevitable, the compensation will be borne by the APTRANSCO to the extent of land required for laying of foundation, provided the damage is with prior concurrence of the Executive Engineer. The contractor shall bear the compensation for damages caused without prior concurrence of the Executive Engineer concerned. Any extra land required by the contractor temporarily for dumping of the construction material and consequent damage to the crops etc. shall be the responsibility of the contractor.

In the event of any obstruction being encountered from the local villagers /authorities, the contractor shall immediately notify the Executive Engineer who shall take such steps as may be necessary to clear the obstruction. The contractor or his representative or gangs shall not adopt antagonistic attitude towards the village authorities with whom they may come into contact, but shall immediately report to the Executive Engineer any case of obstruction which cannot be settled amicably. No trees shall be cut until the APTRANSCO has made necessary arrangement with the authorities concerned and permission is given to the contractor to fell such trees. APTRANSCO shall arrange to remove the obstacles as soon as possible. At times however, it may not be possible for the APTRANSCO to arrange right-of-way for laying foundations or erecting the towers or stringing the line. At all such times, the contractor shall shift his gangs to other locations, to maintain continuity of work.

APTRANSCO will arrange the right-of-way along the transmission line route. Any avoidable or deliberate damage done to standing crop or private property by the erection

contractor's persons shall be compensated by the erection contractor without affecting the work.

APTRANSCO will acquire only such piece of land as is actually required for each tower foundation. Any extra land required by the erection contractor temporarily for dumping of the construction material and consequent damage to crops etc. shall be arranged by the erection contractor at his expenses. Arranging access roads / right-of-way for transport of material from road side to work sites also shall be done by the erection contractor with the consent of the property owners and any compensation in that respect will be his responsibility. The erection contractor shall take all reasonable steps for preventing damage to crops during execution of the contract work.

Clearing of obstructions falling in the right-of-way as per IS: 5613 (part-2, section2)-1985 and lopping or trimming of the portion of the trees falling within the minimum electrical clearance zone shall be the responsibility of the purchaser. However, any lopping or trimming of tree branches obstructing the line of sight during check survey shall be the responsibility of the erection contractor.

3.5.21 Tower Erection :

The towers shall be erected on the foundations not less than 14 days after concreting or till such time the concrete has acquired sufficient strength. The towers are erected as per the erection drawings furnished by the manufacturers to facilitate erection. For the convenience of assembling the tower parts during erection operations, each member is marked in the factory to correspond with a number shown in the erection drawing. Any damage to the steel and injuring of galvanizing shall be avoided. No member shall be subjected to any undue over stress, during erection

Method of Erection: There are four main methods of erection of steel transmission towers

- (i) Build-up method or piecemeal method.
- (ii) Section method
- (iii) Ground assembly method
- (iv) Helicopter method.

Build up Method: This method is normally adopted for erection of 66 kV, 132 kV, 220

kV and 400 kV transmission line towers due to the following advantages:

- Tower materials can be supplied to site in knocked down condition, which facilitates easier and cheaper transportation.
- It does not require any heavy machinery such as cranes etc. Tower erection activity can be done in any kind of terrain and mostly throughout the year.
- Availability of workmen at cheap rates.

This method consists of erecting the towers, member by member. The tower members are kept on ground serially according to erection sequence to avoid search or time loss. The erection progresses from the bottom upwards. The four main corner leg members of the first sections of each corner leg are bolted together at the ground and erected.

The cross braces of the first section which are already assembled on the ground are raised one by one as a unit and bolted to the already erected corner leg angles. First section of the tower thus built and horizontal stunts (belt members) if any, are bolted in position. For assembling the second section of the tower, two gin poles are placed one each on the top of diagonally opposite corner legs. These two poles are used, for raising parts of second section. The leg members and braces of this section are then hoisted and assembled. The gin poles are then shifted to the corner leg members on the top of second section to raise the parts of third section of the tower in position for assembly. Gin poles are thus moved up as the tower is assembled. This process is continued till the complete tower is erected. Cross-arm members are assembled on the ground and raised up and fixed to the main body of the tower. For heavier towers, a small boom is rigged on one of the tower legs for hoisting purposes. The members/sections are hoisted either manually or by winch machines operated from the ground. For smaller base towers/vertical configuration towers one gin pole is used instead of two gin poles. In order to maintain speed and efficiency, a small assembly party goes ahead of the main erection gang and its purpose is to sort out the tower members, keeping the members in correct position on the ground and assembling the panels on the ground, which can be erected as a complete unit.

Section Method: In the section method, major sections of the tower are assembled on the ground and the same are erected as units. Either a mobile crane or a gin pole is used. The gin pole used is approximately 10m long and is held in place by means of guys by the side of the tower to be erected. The two opposite sides of the tower section of the tower are assembled on the ground. Each assembled side is then lifted clear of the ground with the gin or derrick and is lowered into position on bolts to stubs or anchor bolts.

One side is held in place with props while the other side is being erected. The two opposite sides are then laced together with cross members and diagonals: and the assembled section is lined up, made square to the line. After completing the first section, gin pole is set on the top of the first section. The gin rests on a strut of the tower immediately below the leg joint. The gin pole then has to be properly guyed into position.

The first face of the second section is raised. To raise the second face of this section it is necessary to slide the foot of the gin on the strut of the opposite face of the tower. After the two opposite faces are raised, the lacing on the other two sides is bolted up. The last lift raises the top of the towers. After the tower top is placed and all side lacings have been bolted up all the guys are thrown off except one, which is used to lower the gin pole. Sometimes whole one face of the tower is assembled on the ground, hoisted and supported in position. The opposite face is similarly assembled and hoisted and then the bracing angles connecting these two faces are fitted.

Ground Assembly Method: This method consists of assembling the tower on ground, and erecting it as a complete unit. The complete tower is assembled in horizontal position on even ground. The tower is assembled along the direction of the line to allow the cross

arms to be fitted. On sloping ground, however, elaborate packing of the low side is essential before assembly commences. After the assembly is complete, the tower is picked up from the ground with the help of a crane and carried to its location, and set on its foundations. For this method of erection, a level piece of ground close to footing is chosen from the tower assembly. This method is not useful when the towers are large and heavy and the foundations are located in arable land where building and erecting complete towers would cause damage to large areas or in hilly terrain where the assembly of complete tower on sloping ground may not be possible and it may be difficult to get crane into position to raise the complete tower.

This method may not be feasible at many locations, because of prohibitive cost of mobile crane, and non-availability of good approach roads to tower locations.

Helicopter Method: In the helicopter method, the transmission tower is erected in section. For example bottom section is first lifted on to the stubs and then the upper section is lifted and bolted to the first section and the process is repeated till the complete tower is erected. Sometimes a completely assembled tower is raised with the help of helicopter. Helicopters are also used for lifting completely assembled towers with guys from the marshalling yards where these are fabricated and then transported one by one to line locations. Helicopter hovers over the line location while the tower is securely guyed. The ground crew men connect and tighten the tower guys. As soon as the guy wires are adequately tensioned the helicopter disengages and moves away. This method is adopted where approach is very difficult or to speed up the construction of the transmission line.

The contractor shall be entirely responsible for correct erection for all towers as per the approved drawings and their correct setting on the alignment finally approved by the purchaser. The towers must be truly vertical after erection, the permitted tolerance in verticality being 1 in 360 of the tower height. No straining will be permitted to make the towers vertical.

A reasonable amount of drifting as permissible in IS:5613 (Part 3, section-2)-1989 shall be allowed in assembling, but reaming for correction of mismatched holes due to shop errors will not be permitted. If any shop errors are discovered, the contractor shall notify the purchaser, who will decide whether the errors may be corrected in the field or members returned to tower fabricator for correction or replacement. All galvanized surfaces damaged as a result of correction shall be made good to the satisfaction of the department.

The contractor shall give complete details of the erection procedures. Before starting erection of an upper section, the lower section shall be completely braced and all bolts provided in accordance with approved drawings.

Tower shall be fitted with number plate, danger plate, phase plates, circuit plates and anti-climbing device as described. After complete erection of tower, all blank holes, if any, are to be filled by Bolts and nuts of correct size. Suspension towers shall be fitted with Bird guards

Tightening and Punching of Bolts and Nuts: The number of bolts required for joining two or more members of a tower are worked out based on the maximum values of compression and tension i.e. after applying factors of safety obtaining in the member to

be joined to the main member. Normally for E.H.T transmission line towers, the bolts of 16 mm dia are used. The bolts of different lengths will be required depending upon the thickness of the members to be joined. The dia of the bolt holes to be provided to the tower members shall be 17.5 mm. The centre of the bolt hole shall be away by not less than 20 mm from the rolled edge and 23 mm from the sheared edge. The bolts and nuts shall be hot dip galvanized and shall conform to IS 12427 of 1988. The bolts and nuts are to be used with electro galvanized spring washers of 3mm thickness. For design purpose, the maximum bearing strength of the bolts of property class 5.6 quality is taken as 6320 Kg/cm^2 and shear strength $3160/\text{Kg/cm}^2$

All nuts shall be tightened properly using correct size torque wrenches. Before tightening, it will be ensured that filler washers and plates are placed in relevant gaps between members, bolts of proper size and length are inserted and one spring washer used under each nut, and in case of step bolts, spring washers have been placed under the outer nuts. The tightening shall progressively be carried out from the top downwards, care being taken that all bolts at every level are tightened simultaneously. The threads of bolts projecting outside of the nuts shall be punched at three positions on the diameter to ensure that the nuts are not loosened in course of time. If during tightening a nut is found to be slipping or running over the bolt threads, the bolt together with the nut shall be replaced.

All the bolts projected outside the nuts shall be welded with the nuts at two diametrically opposite places. The length of each welding shall be at least 10mm. The welding shall be provided from ground level up to bottom cross arm level. After welding cold galvanized paint (zinc rich paint) having at least 90% (per cent) zinc content shall be applied to the welded portion. At least two coats of the paint shall be applied.

Alternately use of epoxy resin adhesive which can serve the purpose of locking the nuts permanently with the bolts and nuts to prevent pilferage of the tower members may be considered.

All the inter contact surfaces especially in coastal and highly polluted areas at the joint shall be painted with zinc rich paint to avoid rust formation, before assembling the tower.

3.5.22 Stringing of Conductors and Earth Wire

Insulator Hoisting: Suspension insulator strings shall be used on suspension towers and tension insulator strings on angle and dead end towers, the strings shall be fixed generally on the tower just prior to the stringing of conductors. Damaged insulators and fittings shall not be used on the assemblies. Before hoisting, all insulators shall be cleaned in a manner that will not spoil, injure or scratch the surface of the insulator, but in no case shall any oil be used for the purpose. Security clips shall be in position for the insulators before hoisting. Corona control rings in case of 400kV lines only shall be fitted. Arcing horns or guard rings, if required, shall be placed along the line on suspension, and facing upwards on tension insulator string assemblies.

Insulation resistance value of each insulator shall be measured with a suitable Megger and those insulators with a value of 50Mega ohms only shall be used.

The installation of string assemblies shall also include the installation of armor rod sets at suspension locations.

Handling of Conductor and Ground Wire:

Running out the Conductors: Before commencement of stringing, the contractor shall submit stringing charts for the conductor and earth wire for various temperatures corresponding to ruling spans on the basis of the data given and also on the data obtained from the detailed survey. The contractor shall provide a drum schedule, based upon the tower schedule and line profile, to show efficient use of the conductor for the Purchasers approval.

While paving out the conductors, care shall be taken to see that the conductors do not touch and rub against the ground or objects that could cause scratches or damage to the strands. The conductor shall be run, out of the drums from the top in order to avoid damage due to chafing. Immediately after paving out, the conductor shall be raised at the supports to the levels of the clamp and placed into the running blocks.

The conductor shall be continuously observed for loose or broken strands or any other damage. When approaching the end of a drum length, at least three coils shall be left when the stringing operations are to be stopped. These coils are to be removed carefully, and if another length is required to be run, a joint shall be made as per the recommendations of the conductor accessory manufacturers. The contractor shall use running out blocks suitable for joint protectors to ensure that the joints remain straight during tension stringing.

Adequate steps shall be taken to prevent clashing of sub-conductors from the process of paving out to the installations of the spacers/spacer dampers. Care shall be taken that both sub-conductor of a bundle are from the same conductor supplier and preferably from the same batch so that creep behavior of the sub-conductor remains identical. During sagging, care shall be taken to eliminate differential sag in the sub-conductor as far as possible. However, in no case sag mismatch shall be more than 25mm. Conductor splices shall be so made that they do not crack or get damaged in the stringing operation.

The sequence of paving out shall be from top downwards, i.e., the ground wire shall be run first, followed by the conductors in succession alternating across the tower between phases. Unbalance of loads on towers shall be avoided as far as possible.

The proposed transmission line may run parallel for certain distance with the existing 400kV, 220kV or 132kV lines which may remain energized during the stringing period. As a result there is a possibility of dangerous voltage build-up due to electromagnetic and electrostatic coupling in the pulling wire conductors and ground wires. It shall be the contractor's responsibility to take adequate safety precautions to protect his employees and others from this potential danger. Running grounds and earthing of running blocks at each tower shall be installed as a minimum requirement.

Wherever towers are not designed for one side stringing, proper guying arrangement shall be made by the contractor during stringing to avoid unbalanced loads on towers. The

sagging and landing of the phase conductors and ground wires shall be done in pairs i.e. both top phases or both middle phases etc.

Traveler/Running Blocks: Installation of travelers, including finger lines where used, requires consideration of traveler attachment methods and the need for and location of traveler grounds and uplift rollers. For single conductor vertical insulator assemblies, the travelers are normally connected directly to the insulator, and with 'vee' string insulator assemblies, to the yoke plate. For most bundled conductor lines, the travelers are connected to the yoke plate. With post type insulators, the travelers are connected to the end of the insulators. Where travelers are installed to string through tension towers, the travelers are normally connected directly to the tower. If substantial line angles are involved, two travelers in tandem may be required to reduce the bending radius of the conductor the load on each traveler, or both.

Where bundled conductor travelers are used at line angle locations of over 5 degrees, it is advisable to change to individual single conductor travelers after the passage of the running board to facilitate accurate sagging.

The groove of the running blocks shall be of such a design that the seat is semicircular and larger than the diameter of the conductor, ground wire and it does not slip over or rub against the sides. The grooves shall be lined with hard rubber or neoprene to avoid damage to conductor and shall be mounted on properly lubricated bearings.

The running blocks shall be suspended in a manner to suit the design of the cross-arm. All running blocks, especially those at the tensioning end shall be fitted on the cross arms with jute cloth wrapped over the steel work and under the slings to avoid damage to the slings as well as to the protective surface finish of the steel work. **Normally, suspension towers shall not be used even for temporary termination. In case small or medium angle towers are used even for temporary terminations, these shall be well guyed and steps be taken by the contractor to avoid damage.** Guying proposals along with necessary calculations shall be submitted, for approval, by the contractor to the Purchaser.

Use of traveling grounds and choice of locations must be based on the degree of exposure to electrical hazards. When such hazards exist, as a minimum, traveler grounds should be installed at the first and last tower between tensioner and puller. When stringing in proximity to energized lines, additional grounds shall be installed as required, but at a maximum distance not exceeding 3 km. Additionally, grounds shall be installed within a reasonable distance on each side of an energized crossing, preferably on the adjacent structure.

Travelers with grounds are usually sensitive to direction and care must be exercised in hanging the travelers. Usually the grounds are connected to the pulling end. Each traveler with grounds must be connected with temporary grounding sets to provide an electrical connection between the traveler and earth, or to some conducting medium that is at earth potential. Personnel should never be in series, with a ground lead. Traveler grounds should have a suitable grounding stub located in an accessible position to enable placing and removing the ground clamps, with hot sticks when necessary. Traveler grounds also help protect the sheave linings.

Repairs to Conductors: Repairs to conductors, if necessary, shall be carried out during the paving out operations, with repair sleeves. Repairing of conductor surface shall be done only in case of minor damage, scratch marks or not more than 2 broken strands in the outer layer etc. keeping in view both electrical and mechanical safe requirements. The final conductor surface shall be clean, smooth and shall be without any projections, sharp points, cuts, abrasions etc. If the damage is greater than above or extends to the successive layers then a mid-span joint shall be used.

Crossings: Derricks and scaffolding shall be used where roads, rivers, channels, telecommunication or overhead power lines, railways lines, fences or walls have to be crossed during stringing operations. It shall be seen that normal services are not interrupted or damage caused to property. Shutdown shall be obtained when working at crossing of overhead power lines. The contractor shall be entirely responsible for the proper handling of the conductor, ground wire and accessories in the field.

Paving out Earth wire: Normally earth wire drums are mounted on a turn-table. Pulling machine/tractor is employed to pull the earth wire. Earth wire running blocks are hoisted on the towers prior to taking up of this operation. The earth wire while paving out passes through the earth wire running blocks. Earth wire splices shall be made in such a way that they do not crack or get damaged in the stringing operations. It should be noted that no earth wire joints are allowed within 30 m from the tension or suspension clamp fittings.

Paving out Conductor: Slack Layout or Direct Installation Method: Using this method, the conductor is paved out over the ground rollers by means of a pulling vehicle or the reel carried along the line on a vehicle. The conductor reels are positioned on reel stands or jack either placed on the ground or mounted on a transporting vehicle. These stands are designed to support reel on a shaft permitting it to rotate as the conductor is pulled out. Usually a braking device is provided to prevent over-running and backlash.

When the conductor is paved out past a tower pulling is stopped and the conductor is placed in travelers attached to the structure before proceeding to the next structure.

This method is generally applicable to the construction of new lines in cases where maintenance of conductor surface condition is not critical and where terrain is easily accessible to a pulling vehicle. The method is not usually economically applicable in urban locations where hazards exist from traffic or where there is danger of contact with energized circuits, nor it is practical in mountainous regions inaccessible to pulling vehicles.

Major equipment required to perform slack stringing includes reels stands, pulling vehicles and a splicing cart.

Tension Stringing Method: Multi-conductor lines shall generally be strung with the help of tension stringing equipment. Using this method, the conductor is kept under tension during the stringing process. Normally, this method is used to keep the conductor clear of the ground and obstacles which might cause conductor surface damage and clear of energized circuits. It requires pulling of a light pilot line through the travelers, which in turn is used to pull in a heavier pulling line. The pulling line is then used to pull in the conductors from the reel stands using specially designed tensioners and pullers. For

lighter conductors, a lightweight pulling line may be used in place of pilot line to directly pull in the conductor. A helicopter or ground vehicle can be used to pull or lay out a pilot line or pulling line. Where a helicopter is used to pull out a line, synthetic rope is normally used to attach the line to the helicopter and prevent the pulling or pilot line from flipping into the rotor blades upon release. The tension method of stringing is applicable where it is desired to keep the conductor off the ground to minimize surface damage or in areas where frequent crossings are encountered. The amount of right of way travel by heavy equipment is also reduced. Usually, this method provides the most economical means of stringing conductor. The helicopter use is particularly advantageous in rugged or poorly accessible terrain.

Major equipment required for tension stringing includes reel stands, tensioners, puller, reel winder, pilot line winder, splicing cart and helicopter or pulling vehicle.

While running out the conductors, care shall be taken such that the conductors do not touch and rub against the ground or objects, which could cause scratches or damage to the strands. The conductor shall not be over-strained during erection. The conductor shall be run out of the drums from the top in order to avoid damage due to chafing.

Wherever required, jointing of conductor during paving out will be carried out.

Jointing: All the joints on the conductor and ground wire shall be of compression type, in accordance with the recommendations of the manufacturer for which all necessary tools and equipment like compressors dies, etc. shall have to be arranged by the contractor. Each part of the joint shall be cleaned by wire brush to make it rust or dirt free and shall properly be greased with anti-corrosive compound, if required and as recommended by the supplier before the final compression is done with the compressors.

All joints or splices shall be made at least 15 metres away from the structures. No joints or splices shall be made in the span crossing over main roads, railways and rivers or in the span adjacent to a tension tower. No joints in the conductor or earth wire shall be permitted without the approval of the Purchaser. Not more than one joint per sub-conductor shall be allowed in a span. The compression type fitting used shall be self-centering type or care shall be taken to mark the conductor to indicate when the fitting is sitting on the conductor properly. During compression or splicing operations the conductor shall be handled in such a manner as to prevent lateral or vertical bearing against the dies. After pressing the joint, the aluminum sleeve shall have all corners rounded; burrs and sharp edges removed and smoothened. The compression of the joints shall be as per manufacturer's instructions.

During stringing of conductor, to avoid any damage to the joint, the contractor shall use a suitable protector with mid span compression joints in case joints are to be passed over pulley blocks/aerial rollers. The size of the groove of the pulley shall be such that the joint along with protector can be passed over it smoothly. The arrangement to be adopted shall be explained in the bid.

3.5.22.1 Stringing Procedure:

Site Selection: The selection of pull, tension, anchor and splicing sites must consider accessibility, location of deadmen, length of conductor to be strung, available conductor and line lengths, puller capacity, including placement of pullers, tensioners and conductor anchor locations, placement of reel stands, pilot line winders, reel winders and the ability to provide an adequate grounding system.

Equipment Locations: The locations of the puller, tensioners and intermediate anchor sites must be selected so that the structures are not overloaded. A pulling line slope of three horizontal to one vertical from the traveler to the site is considered good practice. It is also necessary that the puller be so positioned that the pulling line enters the machine at the smallest horizontal angle thereby minimizing the possibility of damaging the line. When a bull wheel type puller is employed, the reel winder to recover the pulling line is located at the pulling site. The pilot line winder is located at the tensioner site.

The arrangement of the tensioner and reel stands should be such that the lateral angle between the conductor as it approaches the bull wheel and the plane of rotation of the wheel is not large enough to cause the conductor to rub on the sides of the groove. For example, bird caging problems were eliminated in large conductor by using a maximum fleet angle of 1.5 degree from the plane normal to the conductor reel axis and a back tension of approximately 4500 N. problems of bird caging are normally more acute in the case of large conductors having three or more aluminum layers.

Anchors: Anchors are normally required for holding equipment in place and snubbing conductors against tensions imposed. The type of anchor is dependent upon the soil conditions and stringing and sagging tensions. Portable equipment as well as ground type anchors are often used for this purpose. Slack should be removed from all anchor lines prior to loading to minimize the possibility of equipment movement or impact loads to the anchors.

Equipment Grounding: Adequate grounding must be established at all sites. The methods required and equipment used will be determined by the degree of exposure to electrical hazards and the soil conditions at the site. All equipment, conductors, anchors and structures within the work area must be bonded together and to the ground source.

Installation of conductor: Once the rope pulling lines have been installed prior to pulling in any conductor or conductive type pulling lines, a running ground must be installed between the reel stand or tensioner for conductor, or puller for pulling line, and the first tower. This ground must be bonded to the ground previously established at the site.

Pulling lines are usually pulled in under tension. The pulling line is then connected to a single conductor through swivel link, or to bundle conductors through swivel links and a running board.

Swivel links should not be used on a three strand synthetic pulling line. Pulling lines may be synthetic fibre or wire rope. When wire rope is used, it is recommended that swaged type or braided type be used since it has fewer tendencies to rotate under load, which minimizes spinning problems.

A ball bearing swivel link is usually used for the connections between conductors, pulling lines and running boards. Swivel links must have sufficient rated working load to withstand loads placed on them during tension stringing. They should also be compatible with the travelers being used so that they can pass through without spreading or damaging the sheaves. These special line stringing swivel links are clevis type and compatible with woven wire grips and swaged steel pulling lines. It is recommended that swivel links not be passed over bull wheels under significant tension since they may be weakened or damaged due to bending.

When reeving the bull wheels of a tensioner with the conductor entering and leaving the wheel from the top facing in the direction of pull, the conductor should enter from the left and leave from the right for right hand lay (standard for aluminum conductor) and enter from the right and leave from the left for left-hand lay (standard for ground wire). The procedure eliminates the tendency of loosening of outer layer strands while conductor passes around the bull wheel.

It is recommended that conductor of only one manufacturer is used in a given pull, and preferably in any given ruling span. This precaution helps in minimizing the possibility of difference in sag characteristics of conductor significantly.

Attachment of the conductor to the pulling line, running board or to another reel of conductor to be pulled successively is accomplished by the use of woven wire grips. These grips should be compatible strength wise and sized as close as possible for the conductor or pulling line on which they are used. Overall diameter of the grip over the conductor or rope should be small enough to pass over the sheaves without damage to the sheave or its lining and the grip must also be capable of mating with a proper size swivel link.

Metal bands should be installed over the grip to prevent it from accidentally coming off and dropping the conductor. The open end of the grip should be secured with two bands. This should then be wrapped with tape to prevent accidentally stripping the grip of the conductor if the end were to snag or catch. This is particularly important when these grips are used on pulling lines or between lengths of conductor when more than one reel is strung. The grips will then pass through the travelers backwards and if the ends are not banded and taped, they may slip off.

Pulling speed is an important factor in achieving a smooth stringing operation. Speeds of 3-4 km/hour usually provide a smooth passage of the running board or connecting hardware, or both, over the travelers, whereas slower speeds may cause significant swinging of the traveler and insulator hardware assemblies. Higher speeds create a potential hazard of greater damage in case of a malfunction.

The maximum tension imposed on a conductor during stringing operations should not exceed than necessary to clear obstructions on the ground. The clearance should be confirmed by observation. In general, stringing tension about one-half of the sagging tension is a good criterion. If greater tensions are required, consideration must be given to any possible pre-stressing of conductors that may result, based on the tension and time involved. Consideration must also be given to the fact that when long lengths of conductor are strung, the tension at the pulling end may exceed the tension at the tensioner by a significant amount. Difference in tension is caused by the length of

conductor strung, number and performance of travelers, differences in elevation of supporting structures, etc.

Light and steady back tension should be maintained on the conductor reels at all times sufficient to prevent over run in case of sudden stop. It must also be sufficient to cause the conductor to lie snugly in the first groove of the bull wheel and to prevent slack in the conductor between bull wheels. It may be necessary periodically to loosen the brake on the reel stand, as the conductor is paved off. As the reel empties, the moment arm available to overcome the brake drag is reduced, and the tension therefore rises. This may cause the conductor to wedge into the underlying layers on the reel.

The reel should be positioned so that it will rotate in the same direction as the bull wheels. Loosening of the stranding that often occurs between the reel and the bull wheels of the tensioner is caused to a great extent by coil memory in the conductor. As the conductor is unwound from the reel and straightens out, the outer strands become loose, a condition that is particularly noticeable in a large diameter conductor and can be best observed at the point at which it leaves the reel. As the conductor enters the bull wheel groove, the pressure of contact tends to push the loose outer strands back towards the reel where the looseness accumulates, leading to the condition commonly known as bird caging. If this condition is not controlled, the strands can get damaged to the extent that the damaged area of conductor must be removed. This problem can be remedied by allowing enough distance between the reel and tensioner to permit the strand looseness to distribute along the intervening length of conductor and simultaneously maintaining enough back tension on the reel. Stretch the core and inner strands to sufficiently tighten the outer strands.

The maximum time conductors may safely remain in the travelers depends on wind induced vibration or other motion of the conductors. Wind blown sand can severely damage conductors in a few hours if clearance is less than about 3 m over loose sand with little vegetation. Damage from vibration at sagging tensions is quite possible and, when required, dampers should be installed promptly. However, at lower tensions generally used for initial stringing, damage to conductors or sheave bearings, or both, is not likely to occur from vibration. Even for travelers having lined sheaves with root diameters 20 times the conductor diameter, it is important to complete conductor stringing, sagging, plumb marking, clipping, spacing and damping operations as soon as possible to prevent conductor damage from weather, particularly wind. Conductor should not be strung if adverse weather is predicted before the entire sequence can be completed.

Sub-conductor oscillation may occur in bundled conductor lines and tie-down methods involving temporary spacers, or other means may be required to prevent conductor surface damage prior to installation of spacers. Temporarily positioning of one sub-conductor above another to prevent conductor clashing is undesirable since different tension history will produce sub-conductor mismatch unless the tensions are low and duration short enough so that creep is not a factor. Conductor clashing can mar the strands and produce silvers, which can result in radio noise generation.

If a bull wheel type puller is utilized, the pulling line must be recovered during the pulling operation on a separate piece of equipment. This function is usually performed by a reel winder, which is placed behind the puller in an arrangement similar to the reel

stand at the tension site. These coils shall be removed carefully and if another length is required to be run out, a joint shall be made according to the recommendation of the manufacturers. Drum battens shall be removed just prior to moving drums on drum stands.

The conductors, joints and clamp shall be erected in such a manner that no bird caging, over-tensioning of individual wires of layers or other deformation or damage to the conductors shall occur. Clamps for hauling devices shall, under erection conditions, allow no relative movement of strands or layers of the conductors.

Scaffolding shall be used where roads, rivers, channel telecommunication or overhead power lines, railway lines, fences or walls have to be crossed during stringing operations. It shall be seen that normal services are not interrupted or damage caused to property. Shut-down shall be obtained when working at crossing of overhead power lines.

The sequence of running out shall be from top to downwards i.e. the earth wire shall be run out first, followed by the conductors in succession. In case of horizontal configuration tower, middle conductor shall be strung before stringing of outer conductors is taken-up.

3.5.22.2 Sagging Operation: The conductors shall be pulled up to the desired sag as per sag board fixed with reference to initial stringing chart on tower and left in running block for at least one hour after which the sag shall be re-checked and adjusted, if necessary, before transferring the conductors from the running blocks to the suspension clamps. The conductors shall be clamped within 36 hours of sagging in. Thermometer should be used at site for identifying tension and sag, accordingly fixing the sag boards on tower.

The sag will be checked in the first and the last span of the section in case of sections up to eight spans and in one intermediate span also for sections with more than eight spans. The sag shall also be checked when the conductors have been drawn up and transferred from running blocks to the insulator clamps.

The running blocks attached to the suspension string, when suspended from the tower shall be so adjusted that the conductors on running blocks will be at the same height as the suspension clamp to which it is to be secured.

At sharp vertical downward angles, the sags and tensions shall be checked on both sides of the angles, the conductor and earth wire shall be checked on the running block for equality of tension on both sides. The suspension insulator assemblies shall normally assume vertical positions when the conductor is clamped.

Tensioning and sagging operations shall be carried out in calm weather when rapid changes in temperatures are not likely to occur. In areas where calm weather is not prevalent during working season, the contractor shall recommend the precautions to be taken during final tensioning and sagging of conductor.

3.5.22.3 Final Sagging of Conductor and Earth wire:

The tensioning and sagging shall be done in accordance with the approved initial stringing charts before the conductors and ground wire are finally attached to the towers through the ground wire clamps for the ground wire and insulator strings for the conductor.

Provision for ground undulations, errors in stringing and compensation for creep in conductors shall be considered at the time of stringing of conductors and as per approved stringing charts developed by the Contractor.

No pre-stressing/over-tensioning of the ground wire shall be done.

The adjustment of sub-conductor sag by means of sag adjustment devices provided in the insulator string shall not be permitted at the time of stringing of the conductors. The sag adjustment plates shall be kept in fully open position at the time of stringing of the conductor.

The final sagging of the Conductor shall be done by sagging winches.

After being rough sagged, the conductor/earth wire shall not be allowed to hang in the stringing blocks for more than 96 hours before being pulled to the specified sag.

The sag will be checked in the first and last span of the Section in case of Sections up to eight spans and in one intermediate span also for sections with more than eight spans. The sag shall also be checked when the conductors have been drawn up and transported from running blocks to the insulator clamps.

The running blocks, which are suspended from the transmission structure for sagging, shall be so adjusted that the conductors on running blocks will be at the same height as the suspension clamp to which it is to be secured.

At sharp vertical angles, the sags and tensions shall be checked on both sides of the angle, the conductor and earth wire shall be checked on the running blocks for quality of tension on both sides. The suspension insulator assembly will normally assume vertical positions when the conductor is clamped.

Tensioning and sagging operations shall be carried out in normal weather when rapid changes in temperatures are not likely to occur. Sag board and dynamometers shall be employed for measuring sag and tension respectively.

The dynamometers employed shall be periodically checked and calibrated with a standard dynamometer.

Attempts to sag conductor on excessively windy day should be avoided since serious error can result due to conductor uplift caused by wind pressure on the conductor.

Once a section has been sagged, the sub-conductors of the bundle should be checked for evenness. Unevenness, if any, shall be rectified as far as possible with the help of sag adjuster.

The travelers which are used to string conductor are not frictionless and therefore, can cause problems during a sagging operation. If one or more of the travelers becomes jammed, sagging can become very difficult. A traveler which swings in the directions of the pull may be an indication of a defective traveler. Should unexplainable sagging difficulties occur, the traveler should be checked. Tensions applied to the conductor to overcome sticky or jammed travelers can cause sudden abrupt movement of the

conductor in the sagging spans and quickly cause change of sag, particularly, if the conductor is already tensioned to the required value.

During sagging care shall be taken to eliminate differential sags in the sub-conductor as far as possible. However, in no case sag mismatch of more than 25 mm shall be allowed.

----- INITIAL STRINGING CHARTS FOR CONDUCTOR -----								
LINE : 400 KV DC line								
SECTION DETAILS :								
SECTION FROM : LOC9		SECTION TO : LOC 15			EQUIVALENT SPAN : 346.9			
LIMITING CONDITION : 32 DEG. C WITH NIL WIND								
TEMPERATURE : 32.0 DEG.C WIND PRESSURE : 0.0 KG/M2 ICE THICKNESS : 0.00 CM TENSION : 3652.1 KG								

TEMPERATURE	TENSION	360.0	360.0	360.0	340.0	330.0	326.0	

LOCATION NO.		LOC9	LOC10	LOC11	LOC12	LOC13	LOC14	LOC15

0.0(-26.0)	5172.8	6.276	6.276	6.276	5.598	5.274	5.147	
2.0(-24.0)	5100.7	6.365	6.365	6.365	5.677	5.348	5.219	
4.0(-22.0)	5030.3	6.454	6.454	6.454	5.757	5.423	5.292	
6.0(-20.0)	4961.5	6.543	6.543	6.543	5.836	5.498	5.366	
8.0(-18.0)	4894.4	6.633	6.633	6.633	5.917	5.574	5.439	
10.0(-16.0)	4828.8	6.723	6.723	6.723	5.997	5.649	5.513	
12.0(-14.0)	4764.8	6.813	6.813	6.813	6.077	5.725	5.587	
14.0(-12.0)	4702.3	6.904	6.904	6.904	6.158	5.801	5.661	
16.0(-10.0)	4641.4	6.995	6.995	6.995	6.239	5.877	5.736	
18.0(-8.0)	4581.9	7.085	7.085	7.085	6.320	5.954	5.810	
20.0(-6.0)	4523.8	7.176	7.176	7.176	6.401	6.030	5.885	
22.0(-4.0)	4467.2	7.267	7.267	7.267	6.482	6.107	5.959	
24.0(-2.0)	4411.9	7.358	7.358	7.358	6.564	6.183	6.034	
26.0(0.0)	4358.0	7.449	7.449	7.449	6.645	6.260	6.109	
28.0(2.0)	4305.4	7.540	7.540	7.540	6.726	6.336	6.183	
30.0(4.0)	4254.1	7.631	7.631	7.631	6.807	6.413	6.258	
32.0(6.0)	4204.0	7.722	7.722	7.722	6.888	6.489	6.333	
34.0(8.0)	4155.1	7.813	7.813	7.813	6.969	6.565	6.407	
36.0(10.0)	4107.4	7.904	7.904	7.904	7.050	6.641	6.481	
38.0(12.0)	4060.9	7.995	7.995	7.995	7.131	6.718	6.556	
40.0(14.0)	4015.5	8.085	8.085	8.085	7.212	6.794	6.630	
42.0(16.0)	3971.1	8.175	8.175	8.175	7.292	6.869	6.704	
44.0(18.0)	3927.9	8.265	8.265	8.265	7.372	6.945	6.778	
46.0(20.0)	3885.6	8.355	8.355	8.355	7.453	7.021	6.851	
48.0(22.0)	3844.4	8.445	8.445	8.445	7.533	7.096	6.925	
50.0(24.0)	3804.1	8.534	8.534	8.534	7.612	7.171	6.998	
52.0(26.0)	3764.8	8.623	8.623	8.623	7.692	7.246	7.071	
54.0(28.0)	3726.3	8.712	8.712	8.712	7.771	7.321	7.144	
56.0(30.0)	3688.8	8.801	8.801	8.801	7.850	7.395	7.217	

58.0(32.0)	3652.1	8.889	8.889	8.889	7.929	7.469	7.289	
60.0(34.0)	3616.3	8.977	8.977	8.977	8.008	7.543	7.362	
62.0(36.0)	3581.3	9.065	9.065	9.065	8.086	7.617	7.434	
64.0(38.0)	3547.1	9.153	9.153	9.153	8.164	7.691	7.505	
66.0(40.0)	3513.6	9.240	9.240	9.240	8.242	7.764	7.577	
68.0(42.0)	3480.9	9.327	9.327	9.327	8.319	7.837	7.648	
70.0(44.0)	3448.9	9.413	9.413	9.413	8.396	7.910	7.719	
72.0(46.0)	3417.6	9.499	9.499	9.499	8.473	7.982	7.790	
74.0(48.0)	3387.0	9.585	9.585	9.585	8.550	8.054	7.860	
75.0(49.0)	3371.9	9.628	9.628	9.628	8.588	8.090	7.895	
77.0(51.0)	3342.3	9.713	9.713	9.713	8.664	8.162	7.965	
79.0(53.0)	3313.3	9.798	9.798	9.798	8.740	8.233	8.035	
81.0(55.0)	3284.9	9.883	9.883	9.883	8.815	8.304	8.104	
83.0(57.0)	3257.1	9.967	9.967	9.967	8.891	8.375	8.173	
85.0(59.0)	3229.9	10.051	10.051	10.051	8.965	8.446	8.242	

NOTES : 1. ALL LOADS ARE IN KG AND SAG IN METRES.
2. BRACKETED TEMPERATURES ARE VALUES AFTER CONSIDERING CREEP.

FINAL STRINGING CHARTS FOR CONDUCTOR

TEMPARATURE	TENSION	360.0	360.0	360.0	340.0	330.0	326.0
LOCATION NO.	LOC9	LOC10	LOC11	LOC12	LOC13	LOC14	LOC15
0.0	4358.0	7.449	7.449	7.449	6.645	6.260	6.109
2.0	4305.4	7.540	7.540	7.540	6.726	6.336	6.183
4.0	4254.1	7.631	7.631	7.631	6.807	6.413	6.258
6.0	4204.0	7.722	7.722	7.722	6.888	6.489	6.333
8.0	4155.1	7.813	7.813	7.813	6.969	6.565	6.407
10.0	4107.4	7.904	7.904	7.904	7.050	6.641	6.481
12.0	4060.9	7.995	7.995	7.995	7.131	6.718	6.556
14.0	4015.5	8.085	8.085	8.085	7.212	6.794	6.630
16.0	3971.1	8.175	8.175	8.175	7.292	6.869	6.704
18.0	3927.9	8.265	8.265	8.265	7.372	6.945	6.778
20.0	3885.6	8.355	8.355	8.355	7.453	7.021	6.851
22.0	3844.4	8.445	8.445	8.445	7.533	7.096	6.925
24.0	3804.1	8.534	8.534	8.534	7.612	7.171	6.998
26.0	3764.8	8.623	8.623	8.623	7.692	7.246	7.071
28.0	3726.3	8.712	8.712	8.712	7.771	7.321	7.144
30.0	3688.8	8.801	8.801	8.801	7.850	7.395	7.217
32.0	3652.1	8.889	8.889	8.889	7.929	7.469	7.289
34.0	3616.3	8.977	8.977	8.977	8.008	7.543	7.362
36.0	3581.3	9.065	9.065	9.065	8.086	7.617	7.434
38.0	3547.1	9.153	9.153	9.153	8.164	7.691	7.505
40.0	3513.6	9.240	9.240	9.240	8.242	7.764	7.577
42.0	3480.9	9.327	9.327	9.327	8.319	7.837	7.648
44.0	3448.9	9.413	9.413	9.413	8.396	7.910	7.719
46.0	3417.6	9.499	9.499	9.499	8.473	7.982	7.790
48.0	3387.0	9.585	9.585	9.585	8.550	8.054	7.860
50.0	3357.0	9.671	9.671	9.671	8.626	8.126	7.930
52.0	3327.7	9.756	9.756	9.756	8.702	8.198	8.000
54.0	3299.0	9.841	9.841	9.841	8.778	8.269	8.070
56.0	3271.0	9.925	9.925	9.925	8.853	8.340	8.139
58.0	3243.5	10.009	10.009	10.009	8.928	8.411	8.208
60.0	3216.5	10.093	10.093	10.093	9.003	8.481	8.277
62.0	3190.2	10.177	10.177	10.177	9.077	8.551	8.345
64.0	3164.3	10.260	10.260	10.260	9.151	8.621	8.413
66.0	3139.0	10.342	10.342	10.342	9.225	8.690	8.481
68.0	3114.2	10.425	10.425	10.425	9.299	8.760	8.549
70.0	3089.9	10.507	10.507	10.507	9.372	8.829	8.616
72.0	3066.0	10.588	10.588	10.588	9.445	8.897	8.683
74.0	3042.7	10.670	10.670	10.670	9.517	8.966	8.750
75.0	3031.2	10.710	10.710	10.710	9.553	9.000	8.783
77.0	3008.5	10.791	10.791	10.791	9.625	9.068	8.849
79.0	2986.2	10.872	10.872	10.872	9.697	9.135	8.915
81.0	2964.4	10.952	10.952	10.952	9.769	9.202	8.981
83.0	2942.9	11.031	11.031	11.031	9.840	9.269	9.046
85.0	2921.9	11.111	11.111	11.111	9.911	9.336	9.111

3.5.22.4 Clipping in/clamping in of conductors

Conductor shall be fitted with the armor rods at suspension point and with vibration dampers at suspension and tension points.

The jumpers at the section and angle towers shall be formed to parabolic shape to ensure maximum clearance requirements. Pilot suspension insulator string shall be used, where required by the existing tower design.

Fasteners in all fittings and accessories shall be secured in position. The security clip shall be properly opened and strung into position.

The clipping portion of the conductor stringing operation involves the work following sagging and plumb marking of the conductors. This entails removing the conductors from the travelers and placing them in their permanent suspension clamps attached to the insulator assemblies.

When clipping is being done, care must be exercised to ascertain that the conductors are grounded prior to clipping despite the fact that the lines being clipped are not attached to any electrical source. This involves placing a local ground upon the conductor at the location of work.

After the conductors have been marked, the erection crew will lift the weight of the conductors, allowing the travelers to be removed and the suspension clamps, and armour rod, if any used, to be placed on the conductors. Lifting is normally done by use of a hoist suspended from the structure and a conductor-lifting hook, which is designed so as not to notch or severely bend the conductors. After placing the suspension clamps on the conductor, the hooks are lowered thereby placing the weight of the conductor on the suspension clamp and completing the assembly. Where bundle conductors are used, the multiple conductors may be lifted simultaneously by using a yoke arrangement supporting the hooks and a single hoist or other lifting means.

3.5.22.5 Installation of Spacers

Following the clipping operations for bundled conductor line, spacers must be installed. This is done by pacing the erection crew on the conductors in the 'conductor car' normally known as spacer cycle to ride from structure. Depending on the length of line and the equipment available, cars may be hand powered, towed by persons on the ground or in adjacent structures with ropes, or powered by a small engine on the car itself. Care must be exercised to ensure that the concentrated load of the man, car and equipment does not increase the sag appreciably to cause a hazard from obstructions over which the car will pass. The installation of the spacers on the conductor varies with the type and manufacturer of the spacer and is normally done as per the manufacture's recommendations.

The load of the man, car and equipment should be equally distributed to all sub-conductors of the phase. This is particularly important at the time each spacer is attached. Number of spacers per span and the spacing are provided as per the approved spacer placement chart.

3.5.22.6 Installation of Vibration Dampers/Spacer Dampers: Vibration Dampers/Spacer Dampers are normally placed on the conductors immediately following clipping to prevent any possible wind vibration damage to the conductors, which at critical tensions and wind conditions can occur in a matter of a few hours.

The number of dampers/ spacer dampers and spacing are provided as per the design requirement and instructions of the manufactures.

3.5.22.7 Jumpering: The jumpers at the section and angle towers shall be formed to parabolic shape to ensure maximum clearance requirement. Pilot suspension insulator string shall be used, if found necessary, to restrict the jumper swings to the design values. Clearance between conductors and ground and between jumpers and the tower steel work shall be checked during erection and before handing over the line.

Ground undulation: A provision of 150 mm shall be made to account for any undulations in the ground in final still air sag at maximum

3.5.22.8 HOT-LINE STRINGING OF E.H.V. LINES

General: Hot line stringing means stringing of second circuit on the same tower with first circuit electrically & mechanically loaded.

Hot-line stringing is done in this country only up to 220 kV. The advantage of stringing second circuit at a later date (with hot-line method) is saving initial capital investment in the form of conductors, insulators hardware etc. besides, with provision of Double circuit towers from the beginning saves way leave problems as a separate corridor is not required for second circuit.

Precautions: Being a specialized job hot-line works call for special precautions. All the crewmembers shall be provided with rubber shoes and hand-gloves for use during stringing without fail.

All the drums of conductor and pilot wires shall be solidly earthed. All the tension locations, where the conductor ends are terminated, shall be solidly earthed.

In addition to above, during final sagging and clipping operation, standard earthing rods are used for connecting each conductor to the tower body.

Operations: Arrangement for earthing the conductor drums and pilot wire drums is made at both the ends of the section under stringing. The hoisting of insulators, clamping of pilot wire and the conductor and rough sagging of conductor is done as per normal stringing method.

Before marking and clipping the dead ends, each phase conductor is solidly earthed in two separated sets: - one set is earthed by means of droppers and earthing rods and second set is by earthing of conductor end to tower body.

While removing the second set of earthing, the conductor end is removed first and the tower end later. Similarly in case of the first set the cable is disconnected from conductor end first and the rod end later.

Similarly, before clipping the conductor on the suspension towers, each conductor on both the sides of the clamp is earthed to tower body. After the clipping is over, the earthing cable is first removed from the conductor end later from the tower end.

In order to limit the parallelism and induced voltages, it is advisable to do the jumpering work at the end. While doing the jumpering work also the earthing cables are required to be provided.

Earthing: Solid earthings are provided by driving one or more G.I. SPIKES in the soil as done in pipe type of earthing. If required, more pipes are driven at the same place. In any case the soil resistance should not be more than 5 ohms.

In case of rocky soils, counterpoise type earthing system is used. The length of the wires is decided by trial & error till the earth resistance is lowered to 5 ohms or less.

For earthing a flexible copper cable having 10 sq.mm area (20 Ampere capacity) is used. The cable is generally armoured type for rough use. Proper clamps/connectors are used to connect the cable to the conductor and to the earth.

3.5.23 TOWER ACCESSORIES:

Bird Guards: These are fixed to the cross-arms of tangent towers to prevent birds from perching over the insulator strings. If such provision is not made, the droplets may foul continuously with the insulator string resulting in breakdown of insulation. The bird guard is made of 18 gauge M.S sheet.

Anti-Climbing Devices: These devices are provided to towers at a height of about 3.00 Mtrs. from ground at vulnerable places such as road crossings, near villages and other inhabited places. These anti climbing devices prevent persons from reaching the live power conductors or their vicinity. The anti climbing devices are made of M.S angle and barbed steel wire.

Danger Plates: 16 gauge M.S. sheet of size 200 x 325 Mtr. is used as Danger Plate. The word 'DANGER' in English and Local Language shall be inscribed on the Plate. Danger sign depicting of a skull above two bones is painted on the Danger Plate. The voltage at which the EHV line is charged is also indicated on the plate. Provision is made in the danger plate to fix it on the tower leg with 16mm bolts.

Number Plates: Each tower in any transmission line is allotted a number in a serial order commencing from one terminal tower and ending with the terminal tower on the other end. The number plate is made of 16 gauge sheet of 100 x 150 Mtr. Size. The number is enameled in Red on white enameled background. The number plate is fixed to the tower body at about 4 Mtrs ground level.

Phase Plates: Each angle tower is provided with a set of three circular discs of 0.100 mtr. dia each enameled in Red, Yellow and Blue. These phase plates are fixed to the towers at a height of about 4 mtr, above ground.

3.6 Field quality Plan

1. Check Survey

- i) Verification of line deviation angle and bisection for proper location of towers.
- ii) Verification of meeting statutory clearances.
- iii) Check spans on either side of the tower location.
- iv) Mark distances and angles from angle point at 3 conspicuous places to identify the angle point location in case of displacement of angle point peg.
- v) At peg marks GPS marking should be done. This ensures correct position of peg even if it is removed, as the longitudes and latitudes are recorded.

2. Soil Investigation

- i) Soil Penetration Test (SPT) to be performed at all angle points, at locations where soil strata changes, railway and national/state road crossings, power line crossings and special locations.
- ii) Perform soil investigation for every KM of soil. Investigation is done by way of ERM method, time is saved and soil investigation can be done without disturbing standing crops.

3. Pit Marking

- i) Mark position of all the four pits on the ground as per pit marking drawing for standard type of foundation and note levels of the center of each leg pit w.r.t center peg of the tower.
- ii) Assess volume of bench cutting or use of hill side extension revetment if required and take approval of the Superintending Engineer /Chief Engineer.

4. Foundation Classification

- i) One of the foundation pits to be used as a trial pit and excavated as per normal soil dry type foundation.
- ii) Observe following for classification
 - Type of cultivation surrounding tower and whether encasement of stub required due to surface water.
 - Type of strata and depth of each layer.
 - Water table/level.
 - Maximum water table in the near by village well.
- iii) Check and record soil classification and foundation classification as per relevant clauses of the agreement and excavate pit as per approved drawing for the type of foundation classification.

5. Form Work

Verify form work dimensions, rigidity, adequacy of tightness to prevent loss of cement water from concrete, ensure form surfaces in contact with concrete wetted and sprayed with fine sand/treated with black oil or waste oil/mould releasing agent every time before use.

6. Stub setting and Stub setting template

- i) Recheck the depth of the pits w.r.t center peg level and pit dimensions as per approved foundation classification.
- ii) Check under cutting as per approved drawing.
- iii) Position fully assembled and bolt tightened stub setting template with supporting jacks placed on firm ground and level the template.
- iv) Check placing a green concrete block of thickness equal to the clearance between the stub end and concrete to mitigate settling of template.
- v) Check height of template above the center peg level.

7. Reinforcement

- i) Check reinforcement dimensions as per bar bending schedule. Tie reinforcement at alternative crossing points with suitable binding wire.
- ii) Verify using chair and gitties to ensure proper spacing in two layers reinforcement and minimum cover of 50 mm on the bars respectively.
- iii) Before commencement of concreting ensure sufficient quantity of chairs and gitties are fabricated and made available at stores for use at locations.

8. Concrete Mixing

- i) Ensure using coarse aggregate (metal) and fine aggregate (sand) as per IS-383.
- ii) Check coarse aggregate for flakiness, soft stone and laminar shape.
- iii) Check cement for approved brand.
- iv) Ensure proper mixing of concrete as per the guide lines.
- v) After mixing and before placing the concrete in the foundation pit, take samples for checking compressive strength and slump test of concrete.
- vi) Engage ready mix where ever possible to enable execute fast work.

9. Placing of Concrete

- i) Check providing lean concrete (M 10) base 100 mm thick at bottom of the excavated pit before placing reinforcement.
- ii) Use pointing/poking rod and vibrator for compaction of concrete ensuring vibrator head does not come in contact with steel, hardened concrete etc.,

10. Stripping of Form Work

Ensure stripping formwork after about 24 hrs and check for any damage, honey combing and do necessary rectification.

11. Back Filling

- i) Ensure back filling on foundation in layers and ensure proper consolidation.
- ii) Ensure all top soils to be placed at the surface in case of towers located on cultivated land.
- iii) Excess earth available over and above ground level (after consolidation) should be transported away from the site.

12. Curing

Ensure proper curing by keeping adequate quantity of water and storing arrangement available at site.

13. Earthing of Tower

- i) Ensure tower footing resistance not to exceed 10 Ohms.
- ii) Use pipe earthing or counter poise earthing as per approved drawings to ensure minimum tower footing resistance.

3.6.1 A Field Quality Assurance plan indicating the components to be checked, sampling basis, standards and testing agency is furnished below.

Sl. No	Component operation and description of test	Sampling plan with basis	Reference
1. Detailed Survey and Alignment			
a)	Field survey/Walk over survey	100%	Technical specification Geographical Map, Route alignment, Route Plan & Measurement Schedules
(b)	Plotting of Route	100%	Technical specification, Field book, Geographical Map, Route alignment, Route plan
(c)	Profiling	100%	Technical specification, Field book, Graph sheets, approved route alignment.
(d)	Tower Spotting	100%	Technical specification, Approved Tower spotting data & Sag Template, Field Book, approved route alignment
(e)	Tower Schedule	100%	Technical specification, Approved Route alignment & route profile tower schedule, sag template, tower spotting data
Note: Testing/checking is to be done by contractor. Counter checking is to be done by AEE/EE/SE, construction. Tower schedule should be counter checked by EE/SE and approved.			

2.	Check Survey Bisection of Angle/Accuracy of Alignment	100%	Technical specification IS: 5613, and other relevant standards. Approved Route Map & Route Profiles, Tower/line Schedule and Sag Template etc.
(a)			
(b)	Check for profile levels and electrical clearances	100%	- do -
(c)	Check for span marking and lengths	100%	Technical specs IS: 5613 and other relevant standards, Apprd. Profile drgs. Tower schedule, tower spotting data.
(d)	Check for tower type& position as per site condition	100%	- do -
(e)	Estimation of benching &Revetment volumes (as per site conditions)	100% (To be done by contractor)	Technical specification IS: 5613 and other relevant standards Apprd. Tower leg location counters, approved profile
(f)	Final Profile & tower schedule	100%	Modified profile drawing and amended tower schedule
Note: Testing/checking is to be done by contractor. Counter checking is to be done by AEE/EE/SE, construction. Span marking, tower type as per the site condition and final profile & tower schedule should be counter checked by EE/SE and approved. Benching should be checked by EE, Construction and Revetment by SE, Construction.			
3. Soil Investigation			
A	At Normal location Bore log/Trial Pit for obtaining details/types of soil encountered. Including gradation of samples at specified levels, ground water levels etc. (at center of tower)	At locations as indicated by APTRANSCO	Technical specification IS:1498, 1892, 2720, 4464, 6935, SP-36 & and other relevant standards
B	Soil Resistivity	One Location in a stretch of 2 to 3 Km or at locations approved by APTransco	IS:2131, IS 2720 and Technical Specifications
C	Tests on soil samples Visual and Engineering classifications	- do -	Technical specification IS:5613, IS:1498 and other relevant specifications
D	Tests on Rock Visual classifications	At locations as indicated by APTRANSCO	Technical specification IS:2131, 2720, 4078, 4474, 1498, 5613and other relevant standards
Note: To be done by contractor on his own or through APTRANSCO's approved agency, and to be cross checked by AEE/EE/SE, construction and approved.			
4	Selection of Site for Material Storage	100% (To be done by contractor and to be counter checked by AEE/EE/SE, construction)	Technical specification, utility/industry storage document Wooden sleepers, wooden planks, tarpaulin, steel sheets, bricks, Barbed wire for fencing etc site

			shall be free from termites
5. Checking of foundation materials			
A <u>Cement</u>		Supply source to be approved by AP Transco	
(i)	Fineness	For each source MTC shall be furnished for every lot of 200 MTs and part thereof	APTRANSCO Technical specification IS:269, 456, 1489, 4031, 8112, 12269 and other relevant standards
(ii)	Compressive Strength	- do -	- do -
(iii)	Initial & Final setting time	- do -	- do -
iv)	Soundness	- do -	- do -
(v)	Chemical composition of Cement	- do -	APTRANSCO Technical specification IS:269, 456, 1489, 4031, 8112, 12269 and other relevant standards
B. <u>Coarse Aggregates</u> One sample per lot of 200Cum or part per each source for each size			
(i)	Determination of Particle size (sieve analysis)	One sample per lot of 200Cum or part per each source	Technical specification IS :383, IS:2386 and other relevant standards
(ii)	Flakiness Index	- do -	Technical specification IS :383, IS:2386 and other relevant standards
(iii)	Crushing Value	- do -	Technical specn, IS :383, IS:2386 and other relevant standards
(iv)	Specific gravity	- do -	- do -
v)	Bulk Density	- do -	- do -
vi)	Absorption Value	- do -	- do -
vii)	Moisture Content	- do -	- do -
viii)	Presence of deleterious materials	- do -	- do -
C. <u>Fine Aggregates</u> One sample per lot of 200Cum or part per each source			
(i)	Gradation/ Determination of Particle Size (Sieve analysis)	- do -	Technical specification IS :236, 383, 456, 2386, 2430, 4031 and other relevant standards
(ii)	Specific gravity and density	- do -	Technical specification IS :236, 383, 456, 2386, 2430, 4031 and other relevant standards
iii)	Moisture Content	- do -	- do -
iv)	Absorption Value	- do -	-do -
v)	Bulk Density	- do -	- do -
vi)	Presence of deleterious materials	- do -	- do -
D. <u>Water</u>			
(i)	Suitability (Potable water is	One sample for source	Technical specification IS 456,

	considered suitable for concreting)		IS:3025 and other relevant standards
(ii)	Cleanliness (Visual Check)	100%	- do -
iii)	P.H. Value	One sample per source	- do - Min-6 and Max-8
E. Reinforcement Steel			
(i)	Identification & Size	Random	Technical specification and approved drawings & IS 432, 1139 & 1786 and other relevant standards
(ii)	(a) Strength (Tensile test, Yield stress/proof stress) (b) percentage elongation	For steel as per IS 1786 under 10mm one sample per each 25 MT or part thereof 10mm-16mm one sample per each 35 MT or part thereof. Over 16 mm 1 sample per each 45 MT or part thereof.	- do -
iv)	(a) Bend Rebend Test (b) Reverse bend test for HDS wires		Technical specification IS: 432, 1139, 1786 2502 and other relevant standards
v)	Chemical analysis test	One sample per source	IS:432, IS:1139, IS:1786 and specification
F. Earthing Materials			
(i)	Visual identification	100% (to be done by contractor and counter checked by CE, Construction)	Technical specification IS: 5613 and other relevant standards
(ii)	Bill of material & installation	100% (by contractor and counter checked by EE/SE, Construction)	Technical specification approved drawings & IS 5613
Note: Cement, coarse and fine aggregates, reinforcement steel and water are to be tested as above by contractor at manufacturer's works or an approved test lab by APTRANSCO. To be reviewed by AEE/EE/SE, Construction and approved.			
6. (A) Before Excavation			
(i)	(a) Checking of pegs condition as per line Alignment (b) Checking of pit marking as per drawing (c) Trial pit (d) Classification of soil (e) Pit marking (f) Pit levels w.r.t. centre peg levels (g) Depth of pits as per centre peg level (estimate)	100% Every Location	Approved line alignment/profiles Tech. Specification. IS 4091, 5613, CBI & P Publication No.268 and other relevant standards Excavation and foundation drawings
(ii)	Benching	Where required	Technical specification IS 5613, approved Foundation leg contour

			Profiles and other relevant standards
(B) Excavation			
(i)	a)Dimensional conformity b)verticality and squareness of each pit c)Verification of classification of soil type and type of foundation	Each Location	Technical specifications IS:3764, 408, 4091 &5613, SP:16 and other relevant standards Approved excavation Drgs./ Specification
(ii)	a)Shoring and Strutting (Check durability strength & soundness of staging, fonts adequacy and specific levels) b)Dewatering (where required)	As required	Technical specification applicable state/ local body safety regulations. IS:456 and other relevant standards
C) Stub and Template			
(i)	a)Identification & Assembly b)Stub setting c)Template level width&Diagonal d)ground clearance e)Stub clearance f)Tightening of bolts nuts for template, stubs and cleats	100% Every Location	Technical specification IS: 5613. Approved drawings of stub template and foundation drawing
D)	Shuttering (Form work) Fixing of form boxes check for identification dimensions parallelization and squareness and equidistance from stubs	100% in all collapsible location	Technical specification IS 456 and other relevant standards approved drawings
Note: To be checked by contractor and counter checked by AE/AEE, construction and approved. Soil classification, shuttering works to be jointly inspected by contractor and AE/AEE.			
E)	Concreting		
(i)	Control Concrete mix design	100%	Technical specification IS 456 and other relevant standards & approved drawings
(ii)	Identification of material and water supply sources	100%	Technical specification IS 383,456 IS:3025, 3550 and other relevant standards
(iii)	Determination of characteristics of aggregates, cement, water etc.	100%	Technical specification IS 269,383,456, 3125, 3550 and other relevant standards
(iv)	Preparation of mix and taking of samples for strength (7days, 14 days & 28 days) and slump report	100%	Technical specification IS 456 and other relevant standards
(v)	Review of controlled		

	concrete mix report a) Mixing of concrete b) padding/lean concrete base	100% 100%	Technical specification IS 456 and other relevant standards
	c) Reinforcement placing fixing as per bar bending schedule 2. Check for proper cover spacers and chairs. 3. Check whether lapping of bars is tied properly.	100%	Technical specification IS:2502 and other relevant standards and approved drawing
	d) Fixing of form boxes check for identification, dimensions parallelization and squareness and equidistance from stubs e) Placing of concrete and ramming f) Fixing of chimney column width, length, check square and parallelism and equidistance from stub g) Placing concrete, poking & ramming	100%	Technical specification IS 456, IS:5613 and other relevant standards approved drawings
Note: Control concrete mix design& identification of material and water supply source s to be jointly inspected by contractor and AE/AEE. Tests shall be conducted by contractor at APTRANSCO's approved test laboratory. Test results to be checked and approved by AE/AEE/EE, Construction. All other checks to be done by contractor and counter checked by AE/AEE and approved.			
F)	Box removal check for dimensional conformity and workmanship	100%	Technical specification IS 456, and other relevant standards approved Drawings.
Note: To be jointly checked by contractor and AE/AEE and approved. Reinforcement rods should not be exposed. Boxes should not be opened after 24 hours.			
G)	Backfilling	100% all Locations	Technical Specification, IS: 5613, and other relevant standards Boulder size 80 mm (Max)
Note: To be done by contractor and counter checked by AE/AEE/EE. Boulders of size more than 80mm should not be allowed for backfilling. Sufficient water should be poured and rammed for every 200mm layer of earth. 100mm height earthen bund along with the side of excavation for filling water			
H)	Coping and Curing	100%	Technical Specification, IS:5613, and other relevant standards and approved drawing
Note: To be done by contractor and counter checked by AE/AEE and approved. At locations in the paddy fields or in the low lying areas, the chimney is to be extended as per AP			

Transco Approved drawing. The corner reinforcement rods 200 mm below the final chimney level to be left un concerted and the extensions of chimney for this portion and coping shall be done after tower erection. Curing should be continued for minimum 15 days.			
I)	Laying of Earthing (Pipe or Counterpoise type). (Based on measurement of soil resistivity/ tower footing resistance)	100% all Locations	Technical specification IS 3403
Note: Earthing type to be decided by APTRANSCO. Work to be jointly inspected by contractor and AE/AEE and approved.			
J)	<u>Concrete Cubes Testing</u> i) Strength under compression ii) Slump test iii) Unit weight of concrete	100% one sample for each location (One sample consists of min 4 test cubes for 28 days strength)	Technical specification. IS 456, 516, 1199 and other relevant standards
Note: Testing to be done by contractor at approved laboratory by APTRANSCO standard cube moulds, to be checked by AE/AEE/EE. Cubes must be tested within a week of 20 days curing period and test results should be approved by APTRANSCO before tower erection.			
K)	<u>Bricks</u> a) Absorption strength b) Compressive strength c) Efflorescence	After 24 hours immersion immersion in cold water - do - - do -	IS:3495-1966 Not more than 20% by weight Not less than 40Kg/cm ² Not more than “Moderate”
Note: Testing to be done at APTRANSCO's approved laboratory, to be checked by AEE/EE/SE.			
L)	<u>Earth work and Compaction control:</u> Degree of compaction	1 test per 2000sq.mm. area	IS:2720 (Part-28)
M)	<u>Roads</u>		
1.	<u>Water Bound Macadam</u> a) Aggregate impact value	1 test per 250 Cum	IS: 2386 (Part-4)
	b) Grading of aggregate and screening	2 tests per 250 Cum	IS: 2386 (Part-1)
	c) Flakiness index and elongation index	1 test per 250 Cum	IS: 2386 (Part-1)
	d) Atterberg limits of blinding material	1 test per 50 Cum	IS: 2720 (Part-5)
	e) Water absorption	1 test per source	IS: 2386 (Part-30)
	f) Thickness	Regularly	.....
2.	<u>Bituminous Macadam/ Fix Seal Surfacing</u> a) Quality of binder b) Temperature of binder c) Aggregate impact value d) Flakiness index e) Stripping of aggregate f) Water absorption	1 test per lot or per 10 tonnes. Regularly 1 test per 250 Cum 2 tests per 250 Cum 1 test per source 1 test per source	IS:73/217/8887 Appendix – 10.6 IS:2386 (Part-4) IS:2386 (Part-1) IS:6241 – 1971 IS:2386 (Part-3)

	g)Grading of aggregates h)Binder content i)Density of compacted layer (for Bituminous Macadam) j)Soundness(Magnesium and Sodium Sulphate) (for Fix Seal Surfacing) k)Thickness(Fix Seal Surfacing)	1 test per 100Cum 2 tests per day 1 testper1000Sqmare 1 test per source Regularly	IS:2386 (Part-1) IRC Specification, Appendix-10.8 IRC Specification IS:2386 (Part-5) --
3	<u>Granular and Sub-Base</u> a)Gradation/Determination of particle size (Sieve analysis) b)Atterburg limits c)Density of compacted layer	2 tests per 500 Cum 2 tests per 500 Cum 1 set of test per 2000Sq.m	IS:2720 (Part-4) IS:2720 (Part-5) IS:2720 (Part-28)
Note: To be tested by contractor at APTRANSCO approved testing laboratory, to be checked by EE/SE. Test results to be reviewed and approved by APTRANSCO. Item M (f) to be checked by AE/AEE.			
7)	Tower Erection		
A)	<u>Materials checking</u> i)Checking of tower members for damage, cleanliness, galvanizing and stacking ii)Checking of GI bolts nuts, step bolts, D-shackles, U-bolts, spring washers& accessories iii)Dimensional check	100% 100% Random	Technical specifications, IS:5613& other relevant standards and approved drawings
Note: To be done by contractor and counter checked by AE/AEE/EE and approved.			
B)	<u>Erection of Super structure</u> i)Checking of leg members/ bracing/redundant size&proper placement ii)Tightness of bolts, identification, cleanliness galvanizing iii)Punching of tightened bolts iv)Checking of assembly and verticality v)Tack welding vi)Tower footing resistance measurement before & after earthing vii)Fixing of Danger plates, Number plates&Phase plates, Circuit plates	Random 100% each location - do - - do - 100% each location -do- -do-	Technical specifications,IS:5613 & other relevant standards and approved drawings. (Tightening of bolts nuts with torque wrenches)

	&earth wire iv)Jumpering (pre-formed) v)Tension stringing(if any). Installation of pilot string on D/DD tower	-do- -do- -do-	
Note: To be jointly inspected by contractor and AE/AEE/EE and approved. Use of TSE, Sagging winch, Hydraulic Dynamometer, Metal enclosed thermometer and other tools etc. shall be ensured. Item (iii) shall be considering creep and no bend curve in the joint. Minimum clearance to be maintained at 2.1 mtrs. for 220kV and 1.54 mtrs. for 132kV.			
9	Final Checking		
(a)	i) Check for Backfilling ii) Removing any stored material near to the tower iii) Store extra back fill within the base of the tower iv) Checking of prospective revetment with weep holes and store packing of weep holes.	100%	Specifications, IS:5613 and other relevant standards and approved Drgs.
(b)	Check for ACD & all tower accessories	Entire Route	- do -
(c)	Check for Tightening, punching and tack welding of bolts	- do -	- do-
(d)	Check for Final ground and electrical clearances	- do -	- do-
(e)	Check for effectiveness of Earthing	- do -	- do-
(f)	Meggering of the Line	100%	- do-
(g)	Conductor continuity Test	- do -	- do-
(h)	Measurement of line resistance	- do -	- do-
(i)	Phase sequence	- do -	- do-
Note: To be jointly checked by contractor and EE/SE and approved. All excess material should be cleared away as indicated in the specification			

Testing and Commissioning of the line should be done by TRANSCO testing agency as per the procedure given in chapter-IV.

Post Commissioning checks such as check for visual corona at insulator, hardware, conductor accessories etc. at identified locations shall be done by APTRANSCO.

Note:

Route Plan, approved profiles, approved tower schedule sag template etc will be made available by the purchaser if the detailed survey is already carried out by the Purchaser

Contractor must ascertain TRANSCO's clearance before receipt of material i.e., Tower parts, Conductors, Hardware fitting accessories, insulators earthwire etc. at site.

APTRANSCO site office Engineers/Field quality Engineers should witness/review specified tests.

T & P of the erection contractor shall be inspected at site by the APTRANSCO before their use.

3.6.2 Check list of works at various stages:

Note: Checks made at each stage by both the contractor and the Transco engineer should be recorded in prescribed forms. Both contractor's authorized representative and Transco's representative shall sign the format after examining the checks and ensuring correctness of results. Next stage works shall be taken up only after clearance of previous stage works.

Sample format:

Name of line: Name of contractor:
Location No.: Type of tower:
Approved Drawing No.:

Details of checks	<u>Ok. /NotOk.</u>	<u>Yes/No</u>	<u>Values of results (qty/ unit)</u>
i)			
ii)			
iii)			

Certificate: - Cleared for -----

For contractor	For APTRANSCO
Signature:	Signature:
(Name, Designation, Date)	(Name, Designation, Date)

3.6.3 Checks to be conducted at each stage:

1. CHECK SURVEY

Approved detailed survey profile drg.Nos.: ---- Reference level: -----

Peg Marked Suspension Locations w.r.t Detailed Survey Profile :

Alignment of Location w.r.t previous and next location :

Whether Location of center peg/position of various landmarks are matching as per profile

Whether there are any new features on ground, w.r.t. profiles necessitating realignment / shifting :

Span on both sides of location	As per profile (Metres)	Actual (Metres)

Preceding span/Succeeding span (Loc.No):

Angle of deviation and bisection at tower loc:	As per profile	Actual

a) Angle of deviation

b) Bisection

After ensuring correct results clearance for pit marking should be given.

2. PIT MARKING

Approved Pit Marking Drg. Nos: ----- Angle of Bisection:
Position of pegs in line/longitudinal and transverse direction:
Position of leg pegs w.r.t center peg of tower:
Position of all four pits is on leveled ground and safe:
Dimensions of pit marking are per drgs. :
Whether Benching/Revetment required : Yes/No. If yes, then whether contour maps/Revetment drgs.prepared; Calculated volume (cu.m); whether approved by designated authority.
To be cleared for excavation, after satisfactory checks.

3. FOUNDATION CLASSIFICATION

Strata wise pit details:

I) Strata depth and predominant soil at each pit : pit A/1, pit B/2, pit C/3, pit D/4
(Note: Classification may also be given on one pit excavation basis for normal dry soil foundation dimension.)

ii) Sub-soil water table details as on date pit wise: pits A/1, B/2, C/3, and D/4.

iii) Water table in near by well as on date: mtrs.

iv) Maximum sub-soil water table during monsoon after local enquiry: ...mtrs

v) Surface water table on ground in monsoon and its duration: mtrs for days

vi) Type of cultivation: Paddy fields / Cultivated land/ Barren land

Whether encasement of stubs required due to surface water: Yes/No

If yes, height of encasement above ground level: mtrs.

vii) Whether soil investigation (SPT) carried out at this loc. or nearby loc.

viii) If this loc. strata details are comparable with above soil investigation report or any other loc. of this line. Loc. No.....

ix) Details of soil investigation report:-

a) Strata depth b) Subsoil water table: mtrs.

c) Ultimate Bearing capacity: mtrs. d) Angle of Repose (Φ): degrees

x) Foundation classification proposed by contractor:

As per SPT/Trial pit - As per Actual

Contractor shall furnish Remarks/ Reason for the proposed classification in writing to the project designated authority (EE/SE/CE, Civil) who shall visit the site and verify the details and approve suitable classification and communicate in writing

4. STUB SETTING

i) Approved drg.Nos: a) Stub setting template
b) Pit dimension

- c) Stub assembly
- ii) Pit Dimensions.
- Depth of pits From Ref. Level Ground Level
Pit A Pit B Pit C Pit D
 - Whether Pit dimensions are as per approved foundation classification
 - Whether excavated soil is kept 2m away from pit edge
 - Whether under cutting done in case of partially dry, dry Fissured rocks & mixed dry
- iii) Alignment of template.
- Tangent Tower
 - In the direction of line Yes/No
 - Angle Tower
 - Angle of deviation (Φ) degrees
 - Alignment of template on bisection Yes/No
- iv) Diagonals of template
AC.....m BD.....m

STUB SETTING ON BISECTION

- Check level of template by dumpy/water level
 - Height of template above ground level: Cms.
 - Clearance between lowest part of stub and P.C.C. (to be not less than 15cms in dry and 20cms in wet foundation or as specified in the drawing)
LegA - cm. LegB - cm. LegC - cm. LegD - cm
 - Whether Jacks placed on firmground:
 - Whether Template supports/jacks positioning causing any danger to collapse of pit:
 - Whether green concrete blocks placed below stubs to avoid displacement of stub. (only for Prop setting):
 - Whether all members of template are fixed as per drg. and fully tightened:
 - Checking of stubs
 - Stub dimensions are as per type of tower: Yes /No
 - All plates/cleats fixed with required no. of Nut/bolts and are fully tightened: Yes /No
 - Is earth flat fixed (for tower earthing): Yes /No
- Stub setting to be cleared after conducting above checks.

5. CONSTRUCTION MATERIALS

(A) CEMENT

- Manufacturer's name (Whether approved brand): (Ramco/Pennar/Raasi etc.):
- Quantity required - Quantity available at location -
- Quality – Stacking, Organic/foreign material, Lumps:
- Protective covering found :
 - Condition of cement bags :
- No. of cement bags leaking: -----

(B) COARSE & FINE AGGREGATE

- Proper Stacking of aggregates:

- ii) Size of Coarse aggregate 20 mm (80 to 85%) 10 mm (15 to 20%)
- iii) Fine aggregate /sand 4.75 mm conforming to Grade Zone – I sand.
- iv) Quantity required - Quantity available at location -
- v) Source of receipt : (whether approved)
- vi) Presence of Organic material and foreign material- if yes, ensure cleaning
- vii) Coarse aggregate- check for Flakiness, soft slice and laminar shape:
- viii) Fine aggregate/Sand- Check for Lumps and silt and if yes, sieve available for cleaning:

(C) Dimensions of measuring box (30cm x 30cm x 39cms height): Ok/Not Ok

(D) Proportion of concrete mix by volume derived from controlled design mix by weight:

Grade of cement	Quantity of Coarse aggregate	Quantity of Fine aggregate	Quantity of cement	Quantity of water
M - 15	6 boxes	3 boxes	1 bag	34.1 litres
M - 20	4 boxes	2 boxes	1 bag	28 litres

Volume proportioning of material by boxes to be verified and conformed after finalization of controlled design mix by weight.

(E) Quality and quantity of water as per specifications: Ok/ Not Ok

(F) Reinforcement Steel: Quality and quantity as per approved drawings/Specifications:

Diameter	Qty.required	Qty.available	Approved source	Quality o.k./not o.k.
6mm				
8mm				
12mm				
16mm				
22mm				
32mm				
....mm				

- i) Approved reinforcement bending schedule Drawing No.....
- ii) Cleanliness of reinforcement bars from rust, mill deposit etc.:
- iv) Binding wire availability:
- v) Adequate fabricated chairs and gitties for supporting of reinforcement bars availability:

(G) Form boxes: a) Whether dimensions are as per approved designs
b) Whether oiling of inner wall of form boxes done or not

Check for availability of tools such as Level instruments, Theodolites, Sieves of different sizes, Screw gauge, Slump cone, Cubes casting etc. and their proper working.

After the checks, the materials and T&P may be cleared for lean concreting.

(H) Lean Concreting:

- a) Are Pits free from all Foreign Materials
- b) Are Pits free from standing water (Dewatering continued in advance by Pumps / Buckets)

- c) Mix ratio 1:3:6 with 40 mm metal
- d) Concrete mixing by mixer as per specification
- e) Mixer running time (mixing Time 2 ½ minutes)
- f) De-watering to be done
- g) Lean concreting to be done up to specified level and in all the four pits
- h) No. of cement bags consumed - As per design/ Actual

(I) In case of excess excavation/filling done by lean concrete and no loose soil is permitted for filling, Volume of excess lean concrete - ...

After checking lean concreting work as above pits shall be cleared for installation of reinforcement and form boxes.

6. INSTALLATION OF REINFORCEMENT STEEL & FORM BOXES

- i) Apprd.Drg.Nos. -----
 - ii) a) Quality/Qty. of reinforcement steel as per specification:
 - b) Bending /Placing as per approved drg:
 - c) Required no. of chairs approved (Min dia-12mm, Max spacing-500mm):
 - d) Binding done as per specifications:
 - e) Any undue stress or bending of steel bars:
 - f) Whether Steel is clean and free from loose rust or any other foreign materials.
 - g) Position of bars with respect to stub as per drawing:
 - iii) Form Boxes:-
 - a) Dimensions as per approved drawing:
 - b) Placing with respect to stub as per approved drawing:
 - iv) Clear cover of 50 mm (or as per specification)
- After the checks clearance may be given for foundation casting.

7. MIXING, PLACING AND COMPACTION OF CONCRETE

- i) Approved Drawing Nos. -----
- ii) Mix Ratio
- a) For Pyramid/base with 20 mm metal with specified ratio:
- b) For chimney with 20 mm metal with specified ratio:
- c) Water to cement ratio as per specification:
- iii) Mixing done by Mixer (Running time 2 ½ minutes)
- iv) Use of poking rod for compacting:
- v) Use of vibrator for compacting:
- vi) Whether checking of template levels & its diagonals at regular intervals
- vii) Casting of legs done in continuity:
- viii) No. of cement bags consumed: As per drg: Actual:
- ix) Removal of stub template, shoring & shuttering and stripping of form work after 24 hours of concreting, observe for any damage and attend rectification:
- x) Back filling and compaction of backfilled as per specn:
- xi) Curing of backfilled earth & chimney carried out for a minimum period of 14 days after concreting as per specn:
- a) Availability of water pump with storing arrangement for curing purpose -----

- b) Date of start of curing -----
 c) Date of completion of curing -----
 xiii) Cubes, last sent for testing as per approved FQP :
 xiv) All the surplus materials removed from site:

After conducting these checks, foundation may be cleared for tower erection subject to fulfillment of Part (I) before tower erection and Part (II) in due course as follows.

Part-I: Setting period (28 days) is allowed as per specification

Part-II: (i) Revetment benching proposal status
 (ii) Revetment benching likely execution date

CONCRETE CUBE TEST REPORT

Name of work : Agreement No. :
 Sample No. : Identification Mark :
 Portion of Work or Qty. representing sample:
 Date & Time of casting : Proportion of Mix :
 Duration of Curing at site and
 Site temperature before transportation to test Lab and Temperature at
 7 days 28 days :
 1. Due date of test
 2. Actual date of testing
 3. Delay in testing
 4. Actual Average compressive strength
 5. Is average compressive strength equal to or
 more than specified compressive strength : Yes/No

(Signature of Executing Agency)

Date.....

(Signature of APTransco official)

Date.....

WATER TEST REPORT

Name of line..... Source of water supply.....
 Sample Indent Mark.....
 Name of Executing Agency..... Date.....
 Name & address of Test Lab
 Test Report Reference No.

Sl. No.	Description	Requirement/ Tested as per	Permissible limits
1	Water	potable	----
2	Naturalization 100ml H2O	IS:3025	
3	PH value	IS:456	Not less than 6
4	Solids a) organic b) Inorganic c) Sulphate SO3 d) Chlorides	IS:3025	200 mg/litre 3000 mg/litre 4000 mg/litre 2000 mg/l for non-

	e) Suspended matter		reinforced concrete 500 mg/l for reinforced concrete
5	Compressive strength (20 days) for three 150mm concrete cubes made with proposed water vis-à-vis similar cubes made with distilled water	IS:516	90%
6	(a)Initial setting time for test cube made with proposed water (b)variation in initial setting time for test cube made with proposed water and distilled water	IS:4031	Not less than 30 months 30 months

Note: Values from the latest revisions/amendments of relevant IS codes may be considered.

Signature of Local Official
Date:

Signature of Erection Agency
Date:

Sample is approved for concreting.

Signature of APTRANSCO Official
Date:

Registers for Construction materials such as cement, coarse and fine aggregates and reinforcement steel and concrete cube test reports shall be maintained, for recording the details of samples collected and tests conducted as per field quality assurance plan, joint reports for collection of samples in case of site testing.

Particulars of quantity of materials received, batch no./lot no, manufacturer's test reports and results of tests conducted etc. shall also be entered and authenticated.

3.6.4 List of items to be checked:

TOWER ERECTION :

- 1.Setting period of foundation is allowed for at least 14 days (preferably 28 days) as per specification
2. All tested tools and plants and safety equipments in working conditions are available at site
3. All tower members, Nuts, bolts are available at site without any damage, bent or rusting
and kept on ground serially according to erection sequence
4. Benching /revetment, if any, completed. If not, then program of completion
5. Whether shutdown of power line, if required, is arranged
6. Whether required no. of safety helmets, safety belts & safety shoes are being used.
7. First section is completely braced and all plane diagonals are placed in proper position
8. Guying of tower provided as per approved drawings and norms. Guying to be terminated
on firm ground.
9. All nuts/bolts, flat/spring washers are provided as per approved drawings

10. All bolts to have the nuts facing outside for horizontal or near horizontal bolt connections and downwards for vertical bolt connections
11. All the inner contact surfaces at joints painted with zinc rich paint (as per Technical Specification)
12. Subsequent section are erected only after complete erection and bracing of previous section
13. Any undue stress, bending or damage of member during erection noticed
14. Filling of holes or cutting of members during erection observed
15. Any heavy hammering of bolt causing damage of threads noticed
16. Any substitute of tower member erected, if, yes, member nos.
17. Tightening is done progressively from top to bottom
18. All bolts at same level on all the four faces tightened simultaneously starting from leg to face on right side by four individuals
19. Slipping/running over nuts/bolts are replaced by new ones
20. Threaded portion of bolts projected outside of nut is not less than 3 mm and not more than 8 mm
21. Punching of threads projected outside is done at three positions on dia
22. Half round Tack welding of bolts nuts at two diametrically opposite places upto the bottom cross arm and each weld length at least 10mm
- 22 Zinc rich (at least 90% zinc content) on the tack welds on the nuts
23. Verticality of tower (1 in 360) is checked with help of Theodolite for both longitudinal & transverse direction. This is within specified limits
24. Details of missing member, nut, bolts, etc.
25. Mention the tower footing resistance value:

After satisfactory completion of above checks, a certificate to the effect that Tower erection is complete in all respects and footing resistance is within permissible limit is to be given duly signed by both Contractor and Transco's representatives.

TOWER ACCESSORIES

1. GI bolts and nuts fully tightened and placed as per approved drawing.
 - a) Number Plate
 - b) Phase Plates (set of 3 per circuit)
 - c) Danger Plates
 - d) Circuit Plate (2 Nos.)
 - e) Name plate
 - f) Bird guards (Suspension tower only)
 - g) Earthing bond (One on suspension tower and two on tension towers)
(37/7/0.417 mm Stranded Tinned Copper)
 - h) Step bolts with spring washers 450 mm spaced on diagonally opposite leg provided 3.5m above the ground level to top of the tower
 - i) Step bolt holes available up to 3.5m above ground level.
2. Anti-climbing device including barbed wire, cleats, Barbed wire fixing galvanized MS member with fully tightened bolts.
3. Aviation signals/Paints as per requirement/specification provided where required.

After satisfactory completion of above checks, a certificate to the effect of satisfactory completion to be given by both contractor and Transco's representatives.

PIPE TYPE EARTHING

- 1) Earthing on leg A/1
- 2) GI Pipe (25mm dia, 3m long) Flat (50x6 mm, 5m Long) with nuts and bolts fully tightened and placed as per approved drawing.
- 3) Placement of Flat along with stub and bending of flat inside the form box as per approved drawing.
- 4) Burying of Flat 650mm below ground
- 5) Bore hole (300 mm dia) and depth (3000 mm)
- 6) Gap (150 mm) between the GI pipe bottom end and bottom of the bore hole
- 7) Finely broken coke (grain size not more than 25 mm) and salt (proportion 10:1) filled in bore hole around the pipe.
- 8) Mix of Bentonite powder in 1:6 ratio
- 9) Back filling done
- 10) Earthing resistance measurement (less than 10 Ohms) and if higher value is observed, then whether additional earthing pipe installed.
- 12) Repeat earthing resistance measurement (to be less than 10 ohms)

COUNTERPOISE EARTHING

- 1) Earthing provided on all the four legs
- 2) GSS earth wire 7/3.15, 25m long, MS rod (20 mm dia, 6mtrs long) with nuts and bolts fully tightened and placed as per approved drawing.
- 3) Burying of GSS earthwire 1000 mm below ground
- 4) MS rod (20mm dia, 600 mm length) at the end of earthwire.
- 5) Back filling done
- 6) Earthing resistance measurement (not less than 10 ohms). If higher value is observed then whether additional counter poise installed
- 7) Repeat earthing resistance measurement (should be less than 10 ohms)

After conducting above checks a certificate on Footing resistance should be furnished by Contractor and Transco's representatives.

STRINGING

A) General:

Approved Tension Stringing Chart:- Approved Drum Schedule:-

- 1) Back filling of soil and revetment/ benching wherever required is done.
- 2) Towers are tightened properly and all the members, nut/bolts are provided.
- 3) Tress in the ROW removed to facilitate smooth stringing
- 4) Are all line materials, tested and calibrated T &P safety equipments and relevant drawings available for stringing.

- 5) Whether Shutdown of Power line/Railway block if required, is arranged.
- 6) Necessary Protection/scaffolding / warning signals provided for Railway/Power line/P&T line/Road crossing.
- 7) Towers vulnerable for one side load are guyed properly.

B) Paving out Earth wire:

- 1) Whether all safety measures are ensured in carrying out the Work.
- 2) All pulleys fixed on towers for paving out are moving freely.
- 3) Effective communication exists through walkie-talkie and through persons with red flags on towers.
- 4) Earthwire is being constantly checked as it is unwound, Damaged portion, if any, is removed.
- 5) Necessary arrangement have been provided to avoid rubbing of earthwire against hard ground.

C) Paving out Conductor:

- 1) Check for ensuring all safety measures.
- 2) Conductor drums are placed properly to avoid bird caging.
- 3) Sequence of paving out is such that unbalancing of load on tower is avoided
- 4) Travelers fixed on towers are moving freely
- 5) Effective communication exists through Walkie-Talkie and through persons with red flags on towers.
- 6) Conductor is checked continuously as it is unwound from drum. Damaged portion if any, is removed/repaired.
- 7) Proper arrangements made to avoid rubbing of conductor on ground/hard surfaces.

D) Final Sagging & Tensioning of Earth wire & Conductor

- 1) Sag Board is fixed correctly after taking into account length of suspension clamp/ Record on the details such as Make, type/ batch No, date of manufacture of fittings in case of Earthwire and Suspension insulator string in case of conductor.
- 2) Sag/Tension is measured correctly at prevailing temperature and details recorded.
- 3) Minimum Ground Clearance, clearance over Power line/Railway Line/River crossing/Telecom/Road are as per specification.

E) Dead Ending

- 1) Subsequent to final sagging, dead end work is done marking the length of conductor corresponding to single/double tension string for conductor and dead end clamp for ground wire.
- 2) Corresponding to dead end clamp drawing, the aluminum strands over the steel core are cut and steel portion and aluminum portion of dead end clamp is compressed as applicable to conductor and only steel clamps for ground wire.
- 3) Clipping offsets marked with felt tip marker and not with sharp instruments that may cause dent in conductor strands.
- 4) For power line crossing section precautions taken before clipping:-
 - i) The existing power line conductors are grounded.
 - ii) No person in series with the potential electric circuit.

- 5) Prior to installation/removing dead end jumper on structure, earthing is done on both sides of the work and connected to structure.
- 6) Suspension clamps and dampers installed within 36 hours after final connection to structure
- 7) Center of the body (cushion) and clamp body of AGS clamp coincide with the armor rods, marked point on the conductor.
- 8) Difference in length between the longest and shortest rod when applied not to exceed 13 mm.

F) Conductor Fittings and Attachments

- 1) Spacers and dampers fixed within 24 hours of conductor clamping as per Manufacturer's recommendations.
- 2) a) Whether spacer cars/cycles are fixed with meter counters for measuring intra spacing of spacers/ spacer dampers during placement and if no,
b) How the distance between spacers/spacer dampers is measured.
- 3) Vibration dampers for ground wire installed as per manufacturer's recommendations within 24 hours of clipping.
- 4) Span marker on ground wire, if required, installed on ground wire after clamping and fixing of vibration dampers on the ground wire

G) Tower Hardware

- 1) Tower Hardware viz. phase plates, number plates, circuit plates, copper earthing bond, phase plates and danger plate fixed as per approved drawing.
- 2) Anti-climbing devices fixed as per approved drawing.
- 3) Step bolts with 2 Nos. nuts and one spring washer fixed as per approved drawing.

After satisfactory checks from A to G indicated above a certificate on satisfactory completion of stringing in all respects should be furnished duly signed by both Contractor and Transco's representatives.

Record on the details such as Make, type/ batch No, date of manufacture, quantity required and utilized at each location circuit wise, phase wise and wire wise and those checks mentioned against each, for the following materials should be maintained duly signed by both Contractor and Transco's representatives. Record for each of the materials may be maintained separately.

(A)

1. Earth wire/Conductor: Drum No, length, length paved out and paved between location Nos. may also be furnished.

2. Compression type Mid-span joint for earth wire/Conductor and repair sleeve for conductor:

- a) Mid-span joint has been provided at least 50 feet away from tower.
- b) There is no mid-span joint over Railway/River/Main Road crossing.
- c) Not more than one mid-span joint provided in one span for each earth wire/conductor
- d) Repair sleeve shall be used if number of damaged strands is not more than 2

strands in outer layer of the conductor. No repair sleeve shall be used in case of ground wire. If damage is in more than the permissible strands, the damaged portion shall be removed and mid span joint provided.

e) Dimensions are recorded.

3. Insulators:

- a) Quantity required as per specification, quantity used at each location phase wise and conductor and jumper wise should be recorded.
- b) I.R.values of each insulator measured to be recorded (use 5kV megger)
Insulators are cleaned with soft cloth. Check for proper glazing, no crack, scratch or white spots on surface and proper fitting of “R” clips
- c) Insulators are hoisted without causing any damage

4. Hardware Fitting:

- a) Type of fitting - I/V Single/Double, Suspension/Tension.
- b) No. of fittings used at each location circuit wise, phase wise for conductor and jumper to be recorded
- c) All nuts/bolts properly tightened.
- d) All Components of fittings have been provided as per approved drawings.
Dimensions and galvanizing are OK. Fitting is cleaned and there is no damage to any component.
- e) All spilt pins properly provided.
- f) In case of Tension fittings, dimensions before and after compression recorded

5. Suspension/Tension Clamps for Earth Wire:

- a) All components of clamps have been provided as per approved drawings.
Dimensions and galvanizing are OK. Clamp is cleaned and there is not damage to any component.
- b) All Nuts & bolts have been properly tightened, to 5 Kg m torque.
- c) Split pins have been properly fixed.
- d) In case of tension clamp, dimensions before and after compression recorded

6. Vibration Dampers (V.D.) for Earth wire and Conductor:

- a) All components of V.D. have been provided as per approved drawings. Dimensions and galvanizing are OK. Clamp is cleaned and there is no damage to any component including messenger wire.
- b) All Nuts & bolts have been properly tightened, to 4 Kg m torque.
- c) V.D. Fixed as per approved placement chart.

7. Line Spacer/Spacer Damper/Jumper Spacer:

- a) Spacer/Spacer damper fixed as per approved placement chart.

(B) Check for Sag Measurement for Conductor :

- 1) Sag Board/dynamometer fixed between Loc No- & Temperature- °C
- 2) Measurement of Sag/Tension.

Item	Phase/ Wire No.	Sag/tension as per chart		Sag/Tension as per actual	
		Initial sagging	Final sagging	Initial sagging	Final sagging
Sag Tension					

- 3) During paving out/rough sagging, tension in conductor was as per technical specifications (50% of sagging tension).
- 4) Calibration certification for dynamometer to be checked.
- 5) Vertical clearance between top conductor and earth wire at minimum clearance point along the span to be indicated -----

(C) Location wise Dimensional details of the following materials i.e., length and outer diameter before compression, after compression as per drawing and as observed, for steel and aluminum portions may be recorded.

1. Tension clamps for conductor
2. Tension clamps for GSS Earth wire
3. Mid-span joints for conductor
4. Repair Sleeves for conductor
5. Mid-span joints for GSS Earth wire

- a) The following may be checked as per approved drawing.
- a) Marking and cutting
 - b) Correct sizes of Dies
 - c) Centering & fixing of Sleeves
 - d) Fixing of all the components i.e., Aluminium end pipes, hole plugs etc.
 - e) Compression of sleeves at specified pressure.
- b) All the sharp edges have been filled after compression.
- c) There is no crack, bend or any damage to joint after compression.
- d) Bores in the sleeves are perfectly clean

(D) Drum schedule record covering the following should be maintained:

Name of the line: Name of the Contractor:

Section: From To Sectional length:

Sl. No.	Drum No.	Make	Length (metres)	Phase	Paving out between locations	Quantity consumed	Balance Bit length	Bit to be used at	Remarks

3.7 Statutory Inspection:

After completion of the works, final checking of the line shall be done by the contractor to ensure that all the foundation works, tower erection, and stringing have been done strictly according to the specifications and as approved by the purchaser.

- a) Wherever required, it should be ensured that revetment is provided.
- b) The line insulation is tested by the contractor by providing his own equipment, labour etc. to the satisfaction of the purchaser.
- c) The right-of-way all along the route of line is clear of all obstructions and meets requirements of clause 5.3 of IS: 5613 (Part-3, Section-2)-1989.
- d) In addition to the tests stipulated in IS: 5613 (Part-3, Section-2)-1989 the tower foundation resistance at the locations decided by the purchaser, shall be measured.
- e) Two copies of the profile, route alignment and tower design, structural drawings, bill of material, shop drawings of all towers are to be modified “AS BUILT” and submitted to the purchaser for reference and record.

The SE in charge of construction of the line shall then request the concerned SE (TL&SS) to conduct final inspection of complete line, duly furnishing all records of the line pertaining to design and execution. The SE (O&M) shall arrange for thorough inspection of the line keeping in mind the following main points:

- a) Sufficient backfilled earth is lying over each foundation pit and it is adequately compacted.
- b) Concreted chimneys and their copings are in good shape.
- c) All the tower members are correctly used, strictly according to final approved drawings and are free from any defect or damage whatsoever.
- d) All bolts are properly tightened and punched/and half round welded (as specified).
- e) The stringing of the conductors and ground wire has been done as per the approved stringing charts and desired clearances are clearly available.
- f) All conductor and ground wire accessories are properly installed.
- g) All other requirements to complete the work like fixing of danger plates, phase plates, number plate, circuit plates, anti-climbing device, bird guards etc. are properly installed.
- h) Ground clearance, mid-span clearances, proper fixing of hardware and insulators shall be checked.

Any defects found as a result of inspection and testing shall be got rectified through the contractor immediately to the satisfaction of the purchaser without any extra charges.

Protection system for the line in the connected substation has to be tested for correct operation with the adopted relay settings communicated by the Power system group.

Proper communication between the stations connecting the line and the load dispatch shall be checked and ensured before charging the line.

Necessary charging instructions communicated by Grid operation wing shall be followed and the line shall be idle charged (No load) to check the condition of the line and then the line can be taken into commercial operation. All these operations shall be done with due intimation to the load dispatch centre and under their directions.

Final inspection details for each tower should be furnished by the contractor in the PROFORMA given below.

3.7.1 TRANSMISSION LINES FINAL INSPECTION

LINE NAME:

Inspected by:	<u>Structure</u>	
Date :	Type Ht.	Tower Sl. No.

A. CONDUCTOR: Suspension Structures

Type of Hardware Assembly	Correct?
Insulators - Clean ? Broken ?	Count

	<u>Properly Installed?</u>					
	<u>Yes</u>			<u>No</u>		
	<u>R</u>	<u>Y</u>	<u>B</u>	<u>R</u>	<u>Y</u>	<u>B</u>

Suspension clamp ?	.....
Grading Rings/ Corona Control Rings ?	.....
Armour Rod?	.....
Dampers?	.....
Over Head Groundwire (OHGW)	.....
OHGW Dampers ?	.....

B. CONDUCTOR: Angle Structure

Type of Hardware Assembly	Correct?
Insulators - Clean? Broken?	Count

		<u>Properly Installed ?</u>					
		<u>Yes</u>			<u>No</u>		
		<u>R</u>	<u>Y</u>	<u>B</u>	<u>R</u>	<u>Y</u>	<u>B</u>
Dead End Bodies ?							
Hardware Components, Cotter Pins							
Dampers ?							
Grading Rings/ Corona Control Rings ?							
Dampers ?							
Groundwire (OHGW)							
Dampers ?							

C. OTHER OBSERVATIONS: Where Applicable

		<u>Properly Installed ?</u>					
		<u>Yes</u>			<u>No</u>		
		<u>R</u>	<u>Y</u>	<u>B</u>	<u>R</u>	<u>Y</u>	<u>B</u>
Span ahead – Correct number of Spacers ?							
Spacers properly installed ?							
Adequate ground clearance obvious ?							
Obvious danger trees ?							
Broken strands or debris on conductor ?							
Span ahead – sag mismatch ?							

D. STRUCTURES: Steel

		<u>Properly Installed ?</u>	
		<u>Yes</u>	<u>No</u>
Towers	: Is there any loose, missing or damaged numbers ?	.....	
	: Are there any missing or loose bolts ?	.....	
Signs	: Number Plate ?	.....	
	: Danger Plate ?	.....	
	: Phase Plate ?	.....	
	: Bird Guards ?	.....	
	: Aerial Warning Required ?	.....	
Backfill	: Is all backfill at proper level	.....	

	: Are there rocks in cultivated area ?	.....
Counter poise	: Required ?	.....
	: Does route differ from drawing ?	.....
	: Is site restoration satisfactory ?	.....

E. BOLT TORQUE AND COMPRESSION JOINTS (based on site records)

Yes No

-
1. Bolts and nuts of suspension clamps, spacers, Dampers, etc., tightened properly ?	.....
2. Compression joints made properly ?	.....

F. REMARKS:

3.8 EHV SUBSTATIONS:

Substations are the points for controlling supply of power on different routes by means of various equipment such as transformers, compensating equipment, circuit breakers, isolators etc. The various circuits are joined together through these components to bus-bar systems at the substations. One of the prime requirements of a good substation layout is that it should be as economical as possible. The layout should ensure desired degree of flexibility, reliability, ease of operation and maintenance and safety of the operation and maintenance personnel. The layouts should not lead to breakdowns due to faults within the substation. While planning the layout and orientation of a substation, adequate provision may be made for installation of towers for the incoming/outgoing lines, in order to avoid right of way problems in future. Also provision may be made accordingly in the construction of emanating transmission lines.

Steps in construction of EHV Substation (132kV and above voltages) are

- 1) Acquiring suitable land
- 2) Civil works in switch yard viz. leveling, foundations for equipment, retaining walls, compound wall with security fencing, cable ducts, storm water drains, construction of roads and culverts,
- 3) Construction of control room,
- 4) Erection of all electrical equipment including power transformers,
- 5) auxiliary works such as Battery and battery charger installation and commissioning and DC distribution, Earthing, switch yard lighting, arrangements for water supply, Fire protection system, Diesel generator set for standby supply etc. and testing and commissioning of the substation.

3.8.1 Land:

Substation layout is influenced to a greater extent by the dimensions of various equipment and their accessories and on the type of Bus-bar arrangement. Suitable land to the extent required for the voltage class of the substation shall be identified taking into consideration, features such as no. of feeders, no. of transformers, type of bus-bar system proposed and future extensions required if any.

Pre requisites of land for substation: Close proximity to loads, proper approach to the site, free from habitations in the surroundings, easy take off arrangements for lines present and future.

Suitable Govt. land with fairly a level surface with a normal soil shall be identified for alienation to APTRANSCO with the help of Revenue Authorities. Govt. of A.P. vide G.O.No 342 dt.20-4-10 issued an order that all the District Collectors / Quasi Government Bodies / Local Government bodies etc., under their control in the State shall take necessary action for giving advance possession of the vacant Government lands for construction of Sub-stations by APTRANSCO / DISCOMs pending finalization of alienation and procedural formalities in order to expedite the construction work, and that the APTRANSCO / DISCOMs will follow all the necessary procedural formalities subsequently and payment of land cost will be made as determined by Government.

In case of non availability of suitable govt. land, efforts to procure private land at reasonable value shall be made. The land shall be free from litigations in addition to meeting the requirements as indicated in the pre-requisites.

3.8.2 Land acquisition procedure for Private lands through Revenue Authorities:

- i. In case of non-availability of suitable Government lands in the area, to get the confirmation of the same from the concerned Mandal Revenue Officer (Tahasildar) for confirming the non-availability of Government Land in and around the village where the new Sub-Station is proposed to be constructed.
- ii. After receipt of confirmation from MRO suitable private lands in the same area has to be identified by APTRANSCO duly conducting joint inspection with revenue authorities.
- iii. After identification of private land, concerned RDO shall be requested through a letter for giving proceedings on acquisition of the above said land.
- iv. In response to the APTRANSCO's (EE/TLC) request, Concerned RDO will request APTRANSCO to submit the L.P. Schedules in Form I as per LA Manual and also combined sketch in quadruplicate. The APTRANSCO officials (EE/TLC) with the help of revenue authorities have to prepare the L.P. Schedule in prescribed proforma along with field sketch and submit to concerned Dist Collector, who will forward the same to concerned RDO with instructions to collect the approximate land cost from APTRANSCO. Simultaneously, RDO will instruct the concerned Tahsildar to inspect the alignment on ground and submit Draft Notification (D.N.) and Draft Declaration (D.D.) proposals immediately.
- v. The DN, DD proposals will be prepared by the Tahasildar and sent to District Collector through RDO for approval.

- vi. The Dist Collector will approve the Draft notification and 5-A after enquiry and also send for publication in official Gazette to be printed locally.
- vii. Upon receipt of the intimation from RDO / Dist Collector, EE/TLC will prepare the estimate for payment of the land cost and submit the proposals to Head Quarter through SE/TLC.
- viii. Upon receipt of the above proposals the construction wing at HQ will circulate a file to the Board through estate officer for approval of Board for authorizing SE/TLC for arranging the payment.
- ix. After receipt of authorization, the SE/TLC will arrange the payment of proposed land cost to RDO
- x. After getting preliminary valuation proposal from Tahsildar and after payment of estimated land value by APTRANSCO, award enquiry will be conducted by the concerned RDO and the enquiry report submitted to District Collector.
- xi. The District level Negotiation Committee consisting of the Dist Collector along with RDO, Tahsildar, and Executive Engineer/TLC then conduct negotiations with the concerned land owners. After consideration of all the relevant factors, the negotiation committee will decide and approve the Market value of the land inclusive of statutory benefits under Sec 11(2) of the L.A. Act.
- xii. Based on the minutes of the negotiation committee meeting, the RDO will prepare the Draft award and submit to District collector for approval.
- xiii. After draft award approval, notice will be given to land owners by Tahasildar to collect cheques issued by RDO. After issue of cheques to the land owners the site will be taken over by revenue Authorities and issued to APTRANSCO

A substation requires land for switch yard, control and administrative building, stores, security barrack, colony etc. Keeping provision for future expansion and considering increasing cost of land approximate size of land required for different substations are as follows.

132 /33 kV SS	--	5 - 8 acres
220 /132 kV SS	--	8 - 15 acres
400 /220 kV SS	--	45 - 60 acres

The size of the control room building depends on the number of rooms and equipments in the room. A typical control room building of a 400kV substation having one and half breaker bus scheme with 8 nos. diameters, and a 220kV system with double main and transfer bus for 12 nos. breakers on an average requires about 1000sq. metres which includes control room, relay and PLCC room, MCC room, Battery room, office room, conference room, maintenance room, record room, Test laboratory, etc.

In an automated station, relays and communication equipment may be accommodated in an outdoor bay controller unit located in the switch yard. Only computer peripherals and communication equipment need to be accommodated in the control room. The size of the control room gets substantially reduced.

3.9 Important Technical Specifications for Substation Works:

a) **Switchyard Civil works:** include the following

- Foundations for switchyard gantry structures, equipment supporting structures & their control cubicles, bus post insulator, bay marshalling kiosks and lightning mast etc.
- Foundations for power transformers(No. and capacity to be specified) including soak pit underneath transformers & their cooling banks, R.C.C central oil collecting pit and oil & rain / emulsifier, drainage arrangement from transformer soak pits to central oil collecting pit and oil water separator including laying of all necessary R.C.C pipes of class NP-3 and construction of manholes, providing submersible type sump pumps with auto start arrangements for pumping out discharge from central oil collecting pit to oil-water separator etc. as required & approved by the purchaser. This specification normally applies to 400kV class transformers. The specification may be suitably modified for 220kV and below class transformers as required. It is desirable that this specification is adopted for transformers of capacity 100MVA and above in 220kV class. The scope shall also include the construction of R.C.C baffle/fire protection walls between transformers as per statutory requirements. (Whether erection of transformer is included or excluded from the scope of the contract shall be specified)
- Pile foundations where required.
- R.C.C cable trenches of various sizes with removable type of R.C.C pre-cast covers including edge protection angles in cable trenches, inserts for cable tray supports etc. The scope shall also include designing and providing suitable arrangements for cable trenches at the crossing of roads, road-cum-rail track etc. using NP-3 class R.C.C pipes or G.I conduits embedded in R.C.C for bearing safely the loads likely to be imposed on them as per applicable I.S/I.R.C codes.
- Suitable water drainage arrangement from cable trenches shall be provided by providing slope along the length of cable trenches and by providing sumps of suitable capacities at required locations for collecting water from cable trenches and disposing of water so collected into nearest storm water drains by providing submersible type sump pumps with auto start and with all necessary electrical/mechanical arrangements as per specification and as required and approved by the purchaser.
- Construction of all CC roads within the switchyard area, R.C.C road-cum-rail track, jacking platforms at the crossings of railway tracks, anchor blocks for facilitating the pulling of the transformers during erection/maintenance etc.
- The final grading & metal spreading of the switchyard including anti-weed treatment. This work shall be carried out after all foundations and underground works like cable trenches, drains etc. have been completed. The final grading shall include spreading of metal layer after giving anti-weed treatment to the soil underneath these layers.

- The complete storm water drainage for the switchyard including all siphons, R.C.C pipe culverts, R.C.C box culverts etc. required for drainage at cable/pipe trench crossings, road/rail track crossings etc. The scope shall also include the connection of the switchyard drainage with the natural drainage.

b) Substation Construction Works:

- Soil investigation.
- Leveling of the site.
- Anti weed treatment and anti Termite treatment
- Construction of Security Fencing in the switch yard
- Construction of Service Roads and Drainage System.
- Construction of Control House (single/double storeyed) including supply of doors and windows
- Construction of Fire fighting cum DG set building.
- Stores cum Office building.
- Construction of Platforms
- Construction of 33kV Substation(for auxiliary supply in case of a 400kV substation and 220kV switching stations)
- Water Supply and Sanitary System
- Any other Auxiliary buildings and works as required.

c) Erection Works:

- Erection of main and auxiliary structures including supply of raw steel, fabrication and galvanization of structures.
- Erection of all substation/bay equipment including Panels, Power Transformers, Battery and Charger etc.
- Stringing of bus bars, ground wire, jumpering, connections between equipment, buses, etc. including supply of hardware fittings and clamps and connectors.
- Earthing system including laying of C.I.pipes and B.H. coke for earth pits / alternate method of earthing.
- Cable laying and terminations including erection of marshalling kiosk/boxes.
- Yard illumination, fire fighting etc.

Type of Construction: The sub-station structures shall be lattice type galvanized structures. The foundations of main structures are stub type and other structures are

foundation bolt type. The 220KV and 132 kV buses are normally strung with single/ double MOOSE ACSR conductor and 400kV buses are strung with double/quadruple MOOSE ACSR conductor depending on the maximum power flow along the bus. Control&Relay panels, LT AC panels, battery, battery charger and D.C distribution board are to be erected in Control house.

In an Automated station control&relay panels and communication equipment form part of bay controller units to be mounted in the outdoor switch yard near the bays.

Drawings: The following drawings shall be provided along with the specification to give an idea about the work involved

- Control house plan, foundation details, Reinforcement details of columns, beams, roof etc., electrification of control house, cable duct in control house.
- Compound wall, Retaining wall
- Cable duct in switchyard, cable duct at road crossing points.
- Earth mat details
- Main gate and wicket gate
- Foundation and structural drawings

3.9.1 CODES AND STANDARDS: All equipment materials fabrication galvanizing and tests shall conform to the latest applicable standards, codes etc. mentioned here in or to equivalent applicable international standards

Sl. No.	STANDARD	TITLE
	IS 8112/1989	43 grade ordinary Portland cement
	IS 1786/1985	High strength deformed steel bars and wires for concrete reinforcement
	IS 456/1978	Code of practice for plain and reinforced concrete
	IS: 1199	Methods of sampling and analysis of concrete.
	IS: 1838	Preformed fillers for expansion joints in concrete non-extruding and resilient type(Bitumen impregnated filler
	IS: 2386 Part III:	Specific gravity, density, voids, absorption and buckling.
	IS: 2505	General requirements for concrete vibrators, immersion type.
	IS: 2506	Screed board concrete vibrators:

IS: 2514	Concrete vibrating tables.
IS: 3025	Methods of sampling and test (physical and chemical) for water used in industry
IS: 3370	Code of practice for concrete structure for the storage of liquids
IS: 3350	Methods of tests for routine control for water used in industry.
IS: 4656	Form vibrators for concrete.
IS: 516	Methods of test for strength of concrete.
IS 383/1970	Course and fine aggregates from natural sources for concrete
IS 2062/1992	Steel for general structural purposes
IS 432(Part-1& / Part-2)/1982	Mild steel and medium tensile steel bars and hard drawn steel wire for concrete reinforcement.
IS 12427/1988	Transmission Tower Bolts
IS 1367 (part II)	Technical supply conditions for threaded steel fasteners - Product grade and tolerances
IS 1363 (partIII)	Hexagon Nuts (size range M5 to M64)
IS3063/1994	Fasteners - single coil rectangular section spring washers
IS2629/1985	Recommended practice for hot dip galvanizing on Iron & Steel
IS4759/1984	Hot dip Zinc coatings on structural steel and allied products
IS7181/1986	Horizontally C.I double flanged pipes for water, gas and sewage valve fittings for compressed gas
IS3224/1979	Cylinders excluding liquefied petroleum gas cylinders
IS2026	Station Transformer
IS5039/1983	Distribution pillars for voltages not exceeding 1000 volts
IS4072/1975	Steel for spring washers
IS1573/1986	Electroplated Coatings of Zinc on Iron & Steel
IS 2202(Part-I)/1991	Wooden flush door shutters
IS4351/1976	Specification for steel Door frames
IS513/1994	Cold rolled low carbon steel sheets and strips

IS617/1975	Aluminum and aluminum alloy ingots and castings for general engineering purposes
IS5561/1970	Electric power connectors
IS 486(Part-I)/1993	Metal fittings of Insulators for overhead power lines with normal voltage greater than 1000 V – general requirements&tests
IS 2486 (part-2)/1989	Insulator fittings for overhead power lines with a nominal voltage greater than 1000V-Dimensional requirements
IS2108/1977	Blackheart malleable iron castings.
IS2486/	Hardware fittings, clamps and connectors
IS4984	P.V.C. Pipes
APSS	Andhra Pradesh Standard Specification.

Climatic & Isoceraunic Conditions: Please refer general terms and conditions for material specifications (Chapter-2)

3.9.2 Compliance with Regulations: Unless otherwise specified, works shall be carried out in accordance with the Indian Electricity Act. 1910, Indian Electricity Rules 1956 , Electricity Act2003 or any other revisions thereof which may be issued during the currency of the contract and the requirements of any other regulations and Acts in India to which the utility may be subjected to.

3.9.3 The following general terms form part of the specification:

- a) APTRANSCO shall provide approved Site-cum-Electrical layouts, Control House drawings, Structural & foundation drawings, Bill of materials, other civil & electrical drawings and list of manufacturers/ suppliers for procurement of equipment & materials.
- b) The contractor shall execute the works as per the approved drawings mentioned above and shall procure equipment & materials as per specification from approved list of manufacturers.
- c) Contractor shall complete the works in full shape and handover in fully operational condition within time specified in the Contract.

3.10 Construction of Substations:

Leveling: Substation switch yard should be leveled as directed, with the surplus earth left over after back filling structure foundations. If surplus earth is not adequate for leveling, the leveling should be done by excavating earth in any portion of substation site and filling

should be done with such earth for leveling switchyard. If this is not sufficient, the switchyard is to be leveled by gravel from the approved borrowed areas. Clearing of the entire site by removing bushes, hedges, unwanted plant growth and other things shall form part of leveling work. The work shall be carried out as per IS 301,302 and 138.

While fixing levels for the control room, switch yard and internal roads, factors like flooding of the substation from the adjoining areas, approach roads and canals around the land during rainy season, shall be borne in mind. The levels shall be so fixed that quantity of cutting and filling of earth and filling with borrowed earth is kept at minimum. If need be, the switch yard levels can be fixed in two or three steps without affecting statutory ground clearances prescribed for various voltages.

After award of work, site cum electrical layout drawing with levels fixed shall be issued to the contractor. Contractor shall arrange for leveling the land as per the levels fixed by the department, by cutting and filling the earth to the extent required and filling by borrowed earth wherever required. The soil shall be consolidated after leveling by compacting layers not exceeding 150mm.thickness.

3.10.1 Information to be furnished after award: The following information and data including samples where necessary shall be submitted by the Contractor progressively during the execution of the contract.

- Programme of Execution: As per the time schedule of contract, the Contractor has to submit a Master Programme for completion of the work. This Master Programme may have to be reviewed and updated by the Contractor, quarterly or at more frequent intervals as may be directed by the Engineer depending on the exigencies of the work. Detailed day-to-day programme of every month is submitted by the contractor before the end of the preceding month.
- Samples: Samples of the following materials and any other materials proposed to be used shall be submitted, in sufficient quantities free of cost, for approval. Approved samples will be preserved by the Engineer for future reference. The approval of the Engineer shall not, in any way, relieve the contractor of his responsibility of supplying materials of specified qualities:
 1. Coarse and fine aggregates, Bricks, Road metal. Admixtures.
 2. Plywood for formwork.
 3. Embedded and anchorage materials as requested by the Engineer.
 4. Joint sealing strips and other waterproofing materials, Joint filling compounds.
- Design Mix: Design mix as specified giving proportions of the ingredients, sources of aggregates and cement, along with accompanying test results of trial mixes as per relevant I.S., is to be submitted to the Engineer for his approval before it can be used on the works.
- Detailed working drawings and Bar Bending Schedules in accordance with the specification.

- Detailed Drawings and Designs of Formworks to be used
- Detailed Drawings for Templates & Temporary Supports for Embedment
- Mill Test Reports for Reinforcing Steel to be supplied by the Contractor.
- Inspection Reports in respect of formwork and reinforcement and any other item of work as may be desired by the Engineer.
- Test Reports of various materials and concrete as required under the clause “sampling&testing” of the specification.

Compaction: Compaction shall be achieved by the use of smooth wheeled rollers, pneumatic type rollers, sheep’s foot rollers; vibrating plates, frog rammers; power rammers and such other equipment as shall be specified. Compaction shall be carried out on each layer of thickness not more than 150mm thickness. Density tests shall be made on each compacted layer and the density attained shall not be less than 98% of maximum dry density (standard proctor for the type of material used). A record of the density tests conducted on each layer shall be recorded in a register maintained by field staff.

Anti weed treatment and anti termite treatment for excavated site shall be done

3.10.2 EXCAVATION & FOUNDATIONS FOR STRUCTURES:

a) **Excavation:** Specification shall cover excavation for structures, buildings, foundations, trenches, drain channels, and underground facilities and retaining walls as shown in the approved drawings and as specified. Earth excavation has to be done in all types of soils which can be excavated with pick axe & crow bars in all conditions such as dry, wet, slushy etc., and in hard rock requiring blasting including shoring, shuttering and dewatering wherever necessary covering initial lead and one extra lift. Detailed procedure is already covered under transmission lines.

b) **Backfill:** For details refer back filling under construction of transmission lines.

c) Foundation Concrete:

General Requirements: All materials, tests, mixing, placing, formwork, reinforcing and workmanship shall conform to IS: 456-2000 “Code of practice for Plain and Reinforced Concrete for general building construction” and other relevant Indian Standard codes.

Nominal Mix and Design mix: 1:2.5:5, 1:3:6 and 1:4:8 shall be of Nominal Mix. M20 and above shall be of Design Mix. The mix proportions for all grades of concrete shall be designed to obtain strengths for respective grades of concrete.

Preliminary tests as specified in the IS: 456 and required by the purchaser, shall be carried out sufficiently ahead of the actual commencement of the work with different grades of concrete made from representative samples of aggregates and cement expected to be used

on the job to ascertain the ratios by weight of cement to total quantities of fine and coarse aggregate and the water cement ratio required to produce a concrete of specified strength and desired workability.

Concrete shall be either ordinary or controlled and in grades designated M-10, M-15, and M-20 as specified in IS: 456 (latest edition). In addition, nominal mixes of 1:3:6 and 1:4:8 of nominal size aggregate of 20 mm maximum or as indicated in drawings, by volume or any other mix as per requirement shall be used where specified.

Ordinary Concrete: Ordinary concrete is recommended only when accurate control is impracticable and not necessary. However, ordinary concrete shall be used only in the lean concrete wherever allowed.

If ordinary concrete made in accordance with the proportions given in IS: 456 for a particular grade does not yield the specified strength and fails to satisfy the requirements of 'Acceptance Criteria' as specified in IS: 456, the cement content shall be increased as directed by the purchaser to obtain a specified strength at no extra cost. This shall not however be classified as a higher grade on the ground that the test strengths were found higher than the minimum specified.

Controlled Concrete: Controlled concrete shall be used on all concrete works, except where specified otherwise. Controlled concrete for use in plain and reinforced concrete structures shall be in grade M-20.

Mixes Design Criteria: Concrete mixes will be designed keeping the following considerations in view.

- Consistent with the various other requirements of the mix, the quantity of water should be kept at the lowest possible level.
- The nominal maximum size of coarse aggregate shall be as large as possible within the limits specified.
- The various fractions of coarse and fine aggregates should be mixed in such a proportion as to produce the best possible combined internal grading giving the densest and most workable mix.
- The finished concrete should have adequate durability in all condition, to withstand satisfactorily the weather and other destruction agencies that it is expected to be subjected to in actual service.
- Concrete shall be thoroughly mixed to a uniform consistency in the mixing machines of approved types. Mixing shall continue until the cement is thoroughly distributed throughout the mass, and shall last at least two minutes or for 80 turns of the mixer after the whole of the water has been added. Any concrete showing signs of initial setting before being deposited shall not be used in the works and shall be removed from the site.
- The concrete shall be discharged from the mixer on to a level watertight platform or floor or into a water tight receptacle. Normally hand mixing of concrete will not be allowed but where the total quantity of concrete is considerably small,

the mixing may be done by hand subject to the approval and entirely at the discretion and satisfaction of the Engineer.

Minimum cement content and maximum water-cement ratio for concrete exposed to sulphate attack and for concrete to ensure durability under different condition of exposure, strength requirement for different grades of concrete, proportion for nominal mix concrete, are given in the following tables. For identical condition, if values given in the tables shown below are different from those mentioned in IS: 456, the values as indicated in the table shown herein below shall prevail.

TABLE - I

Grade of concrete	Specific Characteristic Compressive Grade of concrete strength of 15 cm Cubes at 28 days conducted in accordance with IS: 516 (All values in N/Sq.mm)
M - 15	15
M - 20	20
M - 25	25

TABLE – II

Mix proportions (by weight) expected to give different degree of workability with different values of water cement ratio Cement/ Total aggregate ratios.

Workability	Water Cement ratio	Ratio by weight of cement to gravel aggregate		Ratio by weight of cement to crushed stone aggregate	
		20mm size	40mm size	20mm size	40mm size
1	2	3	4	5	6
Very low	0.4	1:4.8	1:5.3	1:4.5	1:5.4
Slump	0.5	1:7.2	1:7.7	1:6.6	1:7.4
0-25mm	0.6	1:9.4	1:10.0	1:7.8	1:9.6
	0.7	1:10.0	1:12.0	1:8.7	1:10.0

Low	0.4	1:3.9	1:4.5	1:3.5	1:4.0
Slump	0.5	1:5.5	1:6.7	1:5.0	1:5.5
25-60 mm	0.6	1:6.8	1:7.4	1:6.3	1:7.0
	0.7	1:6.0	1:8.5	1:7.4	1:8.0

Medium	0.4	1:3.5	1:3.8	1:3.1	1:3.6
Slump	0.5	1:4.8	1:5.7	1:4.2	1:5.0
50-100 mm	0.6	1:6.0	1:7.3	1:5.2	1:6.2

High	0.4	1:3.2	1:3.5	1:2.9	1:3.3
Slump	0.5	1:4.4	1:5.2	1:3.9	1:4.6
100 -	0.6	1:5.4	1:6.4	1:4.7	1:5.7
175 mm	0.7	1:6.2	1:7.4	1:5.5	1:6.5

Note: The above figures are for guidance only. The actual cement aggregate ratios are to be worked out from the specific gravities of Coarse Aggregates and sand being used and from trial mixes.

Reinforcement: Mild steel round bars, cold twisted and deformed bars as medium tensile or high yield strength steel conforming to IS:432 and IS:1786-1979, plain hard drawn steel wire fabric etc will be used as reinforcement. Detailed procedure and precautions already covered under transmission lines construction.

Form work: For details see form work under transmission lines.

Conveyance of Concrete: The concrete shall be conveyed from the mixer to its place in the works as rapidly as possible and in such a manner that there shall be no separation or loss of the ingredients. In no circumstances shall more than half an hour lapse between the time when water is added to the mix and the time when the concrete is finally consolidated in position. Concrete distributing chutes shall not have inclination of more than 45degrees from the horizontal. In no case shall concrete be dropped from barrows or otherwise from a height of more than one and half meters.

Depositing Concrete: Before any concrete is put in, any filling of pockets or trimming the sides where found necessary to suit the level and line of the concrete to be laid shall be carried out. Unless otherwise approved, concrete shall be placed in one operation to the full thickness of members.

Consolidating Concrete: After concrete has been placed, it shall be spread, if necessary and thoroughly compacted by approved mechanical vibration to maximum subsidence without segregation and thoroughly worked around shape. To secure maximum density and eliminate formation of air pockets, the concrete shall be thoroughly vibrated and

worked around all reinforcement, embedded facilities and into corners or forms during and immediately after placing. Mechanical vibrators conforming to IS: 2505, IS: 2506, IS: 2514 and IS: 4656 (all latest edition) shall be used for this purpose. The extent of vibration shall be through the entire depth and width of each new layer. Duration of vibration shall be sufficient to accomplish thorough compaction and complete embedment of reinforcement. Excess cement paste thus formed at the top of each layer shall be removed before the succeeding layer is deposited. Vibrators shall not be used for pushing concrete into adjoining areas. In thin members with heavy congestion of reinforcement or other embedment, where effective use of internal vibrator is doubtful, in addition to immersion vibrators, form vibrators conforming to IS: 4656 may be used. For slabs and other similar structures, screed vibrator as per IS: 2506 shall be used. Hand tamping may be allowed in rare cases, subject to the approval of the Engineer. Care must be taken to ensure that the inserts, fixtures, reinforcement and formwork are not displaced or distorted during placing and consolidation of concrete.

Immersion type vibration shall be provided at the rate of at least one 65 mm unit per cu.m. per hour together with at least one stand by vibrator of the appropriate size. Vibrators shall be inserted in the concrete at a sufficient number of places so that their fields of influence overlap and shall not be used to work the concrete along with forms or screeds. Where electrically operated vibrators are used, diesel or petrol driven stand by vibrators shall be available for carrying on uninterrupted vibration in case of a power failure.

Concrete to be vibrated shall be placed in level layers of suitable thickness not greater than the effective length of the vibrator needle. The internal vibrator shall not be used to spread the concrete for filling. It is advisable to deposit concrete well in advance of the point of vibration. When the concrete is being continuously deposited to a uniform depth along a member, vibrator shall not be operated too near to the free end of the advancing concrete, usually not within 1.20 meters of it. Every effort shall be made to keep the surface of the previously placed layer of concrete alive so that the succeeding layer can be amalgamated with it by vibration process. Following points shall be kept in mind while vibrating concrete.

- The concrete shall be placed in shallow layers consistent with the method being used to place and vibrate the concrete. Usually concrete shall be placed in thickness not more than 300 mm and on initial placing in thickness not more than 150 mm.
- The vibrator head shall be dipped through filling which is to be consolidated to further depth of 10 to 20 mm in the lowest layer which has already been consolidated.
- Vibration shall be carefully controlled, the internal vibrator being systematically inserted at points minimum 450 mm and maintained in position for a fixed time. Immersion for periods of 5 to 15 seconds should normally be sufficient. The limit of action is judged by surface appearance. The surface shall neither be honey combed nor shall it contain excess mortar.

- The vibrator shall be inserted vertically. With inclined or haphazard insertion it will be impossible to regulate the degree of compaction in all portions of the concrete. Care shall be taken to prevent contact of immersion vibrators with form work, reinforcement steel and finished surfaces. Immersion vibrators shall not come in contact with reinforcement steel if initial set of concrete around it has started.
- The vibrator shall be allowed to penetrate on its own accord and should be withdrawn quite slowly, at the rate of about 75 mm per second, whilst still running, so as to allow the redistribution of the concrete in its wake.

The rate of placement of concrete shall be such that no cold joint is formed and fresh concrete is placed always against green concrete that is still plastic and workable. Sufficient tarpaulins or other similar protective arrangement for completely covering the still green concrete from rain may be kept at the site of placement. If there has been any sign of washing of cement and sand, the entire affected concrete shall be removed immediately. Suitable precautions shall be taken in advance to guard against rains before leaving the fresh concrete unattended. No accumulation of water shall be permitted on or around freshly laid concrete.

Slabs, beams and similar members shall be poured in one operation. In special circumstances with the approval of the Engineer-in charge, these can be poured in horizontal layers not exceeding fifty (50) cm. in depth. When poured in layers, it must be ensured that the under layer, is not already hardened. Bleeding of under layer if any, shall be effectively removed. Moulding, throating, drip course, etc. shall be poured as shown on the drawings or as directed by the Engineer. Holes shall be provided, and bolts, sleeves, anchors, fastenings or other fixtures shall be embedded in concrete as shown on the drawings or as directed by the Engineer.

In case the forms or supports get displaced during or immediately after the placement and bring the concrete surface out of alignment beyond tolerance limits, the Engineer may direct to remove the portion and reconstruct or repair the same at the Contractor's expense.

The Engineer shall decide upon the time interval between two placements of concrete of different ages coming in contact with each other, taking in consideration the degree of maturity of the older concrete, shrinkage, heat dissipation and the ability of the older concrete to withstand the load imposed upon it by the fresh placement.

Concrete shall not ordinarily be placed under water. In unavoidable cases, such concreting shall be done only with the specific approval of procedure and application by the Engineer-in-charge. The concrete shall contain at least 10 percent more cement than that required for the same mix placed in the dry, the quality of extra cement varying with condition of placing. The relevant clauses of IS: 456 (latest edition) should be adhered to 11.12(D) (w). Retamping of concrete or mortar which has partially hardened shall not be permitted.

All excavations prepared for concrete construction shall be maintained free of water until such concrete work is completed. Water used for flushing concrete placing equipment shall be discharged clear of the concrete and forms.

Contractor shall keep an accurate record of the date on which the concrete is cast for each part of work and date on which the forms are removed.

Finish of Concrete Surfaces: Floor surfaces shall be worked to a smooth even finish to correct levels of falls as indicated in the drawings or as directed.

Curing: Curing shall be as per IS: 456. Unless otherwise specified all concrete shall be moist cured by keeping all exposed surfaces, edges and corners continuously moist for at least twenty one days after being placed, by spraying, ponding or covering with waterproof paper or moisture retaining fabric.

Newly placed concrete shall be protected by approved means from rain, sun and wind. Concrete placed below the ground level shall be protected against contamination from falling earth during and after placing. Concrete placed in ground containing deleterious substances, shall be protected from contact with such ground, or with water draining from such ground, during placing of concrete and for a period of at least three days. The ground water around newly poured concrete shall be kept to an approved level by pumping out or other adequate means of drainage to prevent floatation or flooding.

As soon as the concrete has hardened sufficiently, it shall be covered either with sand, Hessian, canvas burlap or similar materials which will hold moisture for long period and prevent loss of moisture from concrete and kept continuously wet for at least 18 (eighteen) days after final setting. Curing by continuous sprinkling of water will be allowed if the Engineer is satisfied with the adequacy of the arrangements made by the Contractor.

Curing of concrete shall start after 8 hours of placement and in hot weather within 4 hours of placement of exposed faces. During the first 24 hours, the concrete shall be cured by use of wet burlap or such other means to cover the concrete surfaces. In very hot weather, precaution shall be taken to see that the temperature of wet concrete does not exceed 38 deg. C while placing.

Concrete slabs and floors shall be cured by flooding with water of minimum 25 mm depth for the period mentioned above. Approved curing compounds may be used in lieu of moist curing with the permission of the Engineer-in-charge. Such compounds shall be applied to all exposed surfaces of the concrete as soon as possible after the concrete has set.

Wash water: Wash water shall be removed in a manner to prevent running down and staining of concrete surfaces which will be exposed at the completion of the work. Should unsightly wash water streak develop on the exposed surfaces, they shall be removed and water has to be lead to a suitable place as directed by Engineer- in charge.

Grouting: The blockouts and bolt holes which have to be grouted shall be cleaned thoroughly by use of compressed air immediately before taking up the grouting operations. Cement sand mix in 1:1 proportion and aluminum powder or anti-shrinkage admixture of approved quality shall be first blended thoroughly in the required proportion as per manufacturer's specification. Grout shall then be prepared by mixing this admixture with water in the proportion of 2 parts by weight of cement to one part by weight of water. The quantity of aluminum powder shall usually be of the order of

0.005% by weight of cement. Any grout which has been mixed for a period longer than half an hour shall not be used on the work.

Concrete surfaces receiving the grout shall be properly roughened removing laitance and exposing good concrete. The steel surfaces coming in contact with the grout should be cleaned of rust, mill scales, paints, oil or grease and be wet before setting into place for grouting.

Immediately after preparation, the grout shall be poured into the block outs, pockets and bolts holes either from the sides or through the holes provided for this purpose in the base plate by using special equipment for pressure grouting. It shall be ensured by poking with rod and by tapping of bolts, that the block out is completely filled without leaving any voids. The pouring shall stop as soon as each hole is filled and any excess grout found on the surface on the concrete foundation shall be completely removed and the surface dried.

Under-Pinning/Grouting: It shall be resorted to for filling the space between the underside of base plate and the top of foundation concrete. After grouting has been completed, space between the top surface of the foundation concrete and the underside of the base plate shall be filled with mortar or concrete depending upon thickness to be filled as follows:-

Less than 40 mm	Dry packed mortar
Over 40 mm	Dry packed fine concrete

Use of dry pack concrete: The widely used method of obtaining satisfactory grout is based on principle of using lowest water cement ratio reducing the shrinkage to a minimum. Pozzolana cement having less shrinkage than ordinary Portland cement is preferred for this grouting. Only enough water shall be added to produce a grout. The proper amount of mixing water and proper consistency are those which will produce a grout which is at the point of becoming rubbery when the material is solidly packed. Any mortar which has been mixed for a period longer than an hour shall not be used.

Use of special admixtures: To reduce the shrinkage, anti-shrinkage materials as specified earlier to be added.

Plastering: Plastering foundation plinths 12mm thick in 1:3 cement mortar and white washing (two coats) with janatacem cement paint. All projections of plinths and masonry above ground level shall also be provided with janatacem cement paint.

3.10.3 CABLE DUCT:

Cable & Pipe Trenches (400kV SS Switch yard):

- Cable and pipe trenches shall be of reinforced concrete type with removable type reinforcement cement concrete covers. These trenches shall not be used as storm water drains. The bed of the cable/pipe trenches along their length shall be provided a slope of 1:750 to 1:1000 to drain any rain/seepage water that may enter them. The overall depth of various type of cable/pipe trenches shall be so decided as to take care of above provision of longitudinal slope along their length without compromising the clearance required between bottom most tray of cable trench

and bed of the cable trench.

- Suitable expansion joints shall be provided in cable/pipe trenches as per IS specification with PVC water stoppers, bitumen impregnated filler boards, bitumen sealing compound as per specifications or as directed by the purchaser. The water proofing cement additive shall be used for the construction of cable trenches to ensure water tight construction.
- The water from cable trenches shall be collected in suitably located sumps from where this water shall be disposed off by pumping into nearest storm water drains. The sump pits shall be of R.C.C construction covered at top with provision of manhole, rungs and installing 2 Nos. of 100% capacity submersible type sump pumps for pumping out the water from the sump pit with auto start and auto shutdown depending upon the level of water in the sump pit. All accessories like suction and discharge pipes for transferring water from sump pits to nearest storm water drains shall be provided. The grade of concrete for the construction of sump pits is M-20 conforming to IS: 456-2000.
- All cable trenches shall be provided with edge protection angles of size not less than 45x45x5 mm and suitable length as decided at the time of engineering. Suitable lugs of reinforcement steel (10 mm dia minimum) shall be welded to edge protection angles for ensuring their rigidity in the concrete. The weight of a single pre-cast R.C.C cover shall not be more than 75 Kg. Suitable lifting hooks of size 10mm MS rod minimum shall be provided for easy handling of these covers.
- The covers of cable trenches shall be of such designs that do not allow any rainwater to enter into them. Necessary embedded steel plates shall be provided for supporting the cable trays.
- The top of cable trenches shall be kept 150 mm above finished ground level. The backfilling shall be with excavated soils.
- In cable/pipe trenches, construction joints shall be provided between the base slab and sidewall with PVC water stoppers.

3.10.3.1 Cable Trench in 220&132kV Substations:

Switch yard: The cable duct in the switchyard shall be constructed as per drawing. It shall comprise of 230mm thick brick work in cement mortar 1:6 on either sides. The depth and width of the duct shall be 500mm and 960mm respectively. Cables are to be buried in sand in this duct over 1:4:8 CC with 40mm HBG metal bed of 100mm thick. The cable duct shall be covered with a RCC slab of 50mm thick of proportion 1:2:4 with 10 to 12mm HBG metal with 8mm tor steel placed at 150mm in either direction. The cable duct covering slab shall be in flush with the top of the brick work.

Road Crossing: Cable duct of width 750 mm and 400 mm depth having 8 Nos. 100 mm dia AC pipes in two horizontal rows duly embedded in cement concrete 1:4:8 with 20 mm HBG metal shall, be constructed as per drawing. Rate shall include cost of cement, AC pipes and other materials and labor. Length of duct shall be 8 meters and shall be constructed as directed by Engineer.

Control Room: In the control room cable duct is to be constructed as per the approved drawing at lintel levels as per instructions of Engineer-in-charge at site. G.I. Weld mesh cable trays of 300mm width and 3 meters long with 25 x 25 x 4 mm angle frames to be placed in the duct. These cable trays are to be supported on Galvanized M.S. Angles of 45 x 45 x 5mm, and fixed in the cable duct as per the drawing. Cable duct will be covered with 7 mm Galvanized chequered plate. The main cable trenches entering at control room should be sealed to avoid entry of any creatures.

3.10.4 TRANSFORMER FOUNDATIONS: It shall consist of a R.C.C. soak pit having pedestal for supporting the transformer/reactor and its cooling bank etc. The size of the soak pit shall be 1.0 M bigger all round than the plan size of transformer. The depth of soak pit shall be adequate to accommodate the full quantity of oil contained in the transformer plus 50% of emulsifier water in voids of metal filling inside the soak pit.

The metal size to be filled in the soak pit shall be of 60 mm to 40 mm nominal size and it shall be ensured that 40% of voids are available in the metal filling after its packing in soak pit. The top of the metal filling inside the soak pit shall be 200 mm below the top of the rail.

Central Oil collecting Pit: A common R.C.C central oil-collecting pit shall be provided for all the transformers. This pit shall be closed type and waterproof construction with necessary manholes and rungs etc. for maintenance purposes. The soak pits of transformers shall be connected to this central oil-collecting pit through underground R.C.C pipes and manholes. The size of the oil collecting pit shall be adequate to accommodate the full quantity of oil contained in the largest transformer including rain water and emulsifier water required for the biggest transformer and to ensure that no oil/emulsifier water remains in the transformer soak pit/drain pipes and the level of soak pit shall be accordingly decided. The size of R.C.C pipes to be used for connecting the soak pit of the transformers to the central oil collecting pit shall not be less than 300 mm diameter and shall be of class NP4 conforming to IS: 458(latest) as per recommendations of tariff Advisory Committee. The central oil collecting pit shall have provision for installing 2 Nos. of 100% capacity sump pumps with all accessories like suction and discharge pipes for transferring discharge to oil-water separator such that each pump can pump oil/rain water/emulsifier discharge of auto-transformer of biggest transformer in the switchyard. The suitable size oil-water separator shall be designed and provided by the contractor in a manner that oil would be separated from water and same shall be retained in oil water separator while water shall be disposed off to the nearest storm water drain. The oil water separator shall also be of R.C.C construction. Design of transformer foundations shall be carried out based on the relevant drawings, loading data etc. to be furnished by the purchaser.

3.10.5 Drainage of Switchyard Area: Suitable drainage arrangement shall be designed and provided by to drain off the rainwater quickly and efficiently from switchyard area. For this purpose, the yard shall be sloped away from control building and also from cable trenches, so as to prevent ingress of rainwater into them. The arrangements of drainage provided shall be connected at suitable points to drainage system for rest of the switchyard (or the water shall be drained off to suitable outlet as approved by the purchaser).

All surface drains shall be constructed with brick masonry in cement-sand mortar 1:5 (1 cement: 5 Coarse sand) and these shall be plastered inside with cement-sand mortar 1:5 (1 cement: 5 fine sand). The thickness of plaster shall be not less than 20 mm. The bricks to be used for the construction of drains shall be of 2nd class conforming to relevant IS code. The longitudinal slope of drains shall be so decided that there is no accumulation of silt in the drains and rain water is disposed off as quickly as possible without causing any flooding in the switchyard area. However, the slope of drains shall not be lesser than 1:1000.

The minimum width of any drain shall not be less than 400 mm and depth of drain shall not be less than 300 mm.

3.10.6 EARTHING SYSTEM: Details

Item	Size	Material
i) Main Earthing Conductor	40 mm dia rod	Mild Steel
ii) Conductor above ground level and earthing leads for equipment structures, columns and other auxiliary structures buildings.	75x12 mm flat	Galvanized Steel
iii) Earthing leads for cable trenches.	50 x 8mm	G. S Flat
iv) Rod Electrode	40 mm dia	MildSteel3000mm long rod
v) Riser below ground connecting Earth Mat to above ground level Earthing GS flat	40mm dia	M.S.Rod
vi) Earthing of Indoor LT panels and outdoor Marshalling boxes, MOM Boxes, Junction Boxes & Lighting Panels, cable trays & cables.	50 x 8 mm	G.S.Flat

vii) CI pipe electrode Pipe back filled treated with BH coke mixed with salt (in treated earth pit)	2.75 mtrs. 125 mm dia.	CI pipe electrode
viii) Earthing for Motors	25 x 3 mm flat	Galvanized Steel

Connections from mat to the switchyard and transformer yard equipment; framework and other earthing points shall be made.

3.10.6.1 DESIGN CONSIDERATION: The design of the earthing mat shall be based on the following:

Average soil resistivity: (Ohm-metre)	As per soil test results to be determined prior to preparation of designs

Magnitude of design fault current:

Duration of fault (Second):	40KA/ One (1)

Duration of shock (Second):	Half (0.5)

Material of earthing mat:	Mild Steel conductor

Type of joints

a) Permanent:	Welded
b) Suitable for testing operations:	Bolted

Values of maximum allowable

Temperature in

a) Welded joints (deg.C) :	620
b) Bolted joints (deg.C) :	310

Value of design ambient temperature:	As per project site data

Type of surface layer:	Crushed rock of size 15-20 mm

Average resistivity of surface layer (Ohm-meter):	3000

Thickness of surface layer:	150 mm

Minimum size and type of earthing mat conductor	MS Rod 40mm dia

Allowance for corrosiveness:	To be considered in design according to type of soil

The design of the earthing mat shall be such that the safe values of touch, step and transfer potential are not exceeded under any condition. The combined resistance of earth grid including rods in the station shall not exceed 1.0 Ω (maximum). Earth electrodes shall be provided as required and connected to earth mat to achieve the desired value.

All conductors buried in earth and concrete shall be mild steel. All conductors above ground level and earthing leads shall be galvanized steel.

After completion of earth mat, the earth resistivity may be measured. In case the earth resistance is more than one ohm, earth mat may be extended /extra electrodes installed or other appropriate steps taken so that the earth resistance is less than one ohm.

3.10.6.2 EARTH MAT: M.S.Flat of sizes 100x16mm and 50x8mm confirming to IS 2062 shall be used for earthing. The earth mat shall be as per the drawing and extend over the entire switchyard. The earth mat shall be formed with the steel flats buried in the ground at a depth of 600 mm on edge. Wherever necessary, these shall have to be buried at larger depths to restrict potentials within permissible values. G.I. wire shall be used to connect the overhead ground wires to the ground mat, along the structures at all the locations.

All the junctions of the steel flats while forming the earth mat and taking risers from the earth mat for giving earth connections to equipment, steel structures, conduits cable sheaths shall be properly welded. All joints shall be provided with suitable angle pieces for proper contact between two flats.

The earth mat shall be formed by welding 50 x 8 mm steel flat to the 100 x 16 mm peripheral earth conductor. The grounding grid shall be spaced about 5 meters, in longitude and about 5 meters in the transverse directions. After completion of earth mat, the earth resistivity may be measured. In case the earth resistance is more than one ohm, earth mat may be extended / extra electrodes installed so that the earth resistance is brought below one ohm.

Wherever earthing conductors cross cable trenches, underground service ducts, pipes, tunnels, railway tracks etc., it shall be laid minimum 300 mm below them and shall be re-routed in case it fouls with equipment/structure foundations.

Earthing conductors along their run in cable trench, cable ladders, walls, etc. shall be supported by suitable welding/cleating at intervals of 750 mm. Earthing conductors along cable trenches shall be on the wall nearer to the equipment. Wherever it passes through walls, floors, etc., galvanized iron sleeves shall be provided for the passage of the conductor. Both ends of sleeve shall be sealed to prevent the passage of water through the sleeves.

Earthing conductor around the building in addition to earthmat below the building shall be buried in earth at a minimum distance of 1500 mm from the outer boundary of the building. In case high temperature is encountered at some location, the earthing

conductor shall be laid minimum 1500 mm away from such location. Reinforcement provided in the building shall also be connected to earthmat. The area of reinforcements shall not be considered contributing to the earthmat design requirement.

In outdoor areas, tap connections shall be brought 450 mm above ground level for making connections in future, if equipment is not available at the time of installations.

Earthing conductors embedded in the concrete shall have approximately 50 mm concrete cover.

If the earthing mat extends right up to fencing and the design calculations reveal that the values of touch potentials both from within and outside the fenced-in area are within safe limits, fencing shall be connected with the earthing mat at frequent intervals. If the earthing mat extends right up to the fencing, but the calculations reveal that touch potential at the fence is beyond tolerable limits, the earthing mat shall be terminated about 1.5 meter within the boundary line of the fence and the fence shall be electrically isolated and independently earthed by running earthing conductor underneath the fence and bounded with the fence at frequent intervals or by means of adequate number of earthing electrodes.

3.10.6.3 Installation: Back-fill material to be placed over buried earth conductor shall be free from stones and other harmful mixtures. Back-fill material shall be placed in layers of 150 mm, uniformly spread along the ditch, and tempered. Planks or other protections shall be placed over conductors in hazardous areas after layer of earth has been placed over the conductor, but before placement of balance of back fill. If the excavated soil is found unsuitable for back filling, suitable soil brought from outside shall be used.

Earthing wires shall be installed before the commencement of concrete work.

3.10.6.4 Equipment & Structural Earthing:

Earthing pads/terminals shall be provided by the Supplier of the apparatus/equipment at accessible position. The connection between earthing pads and the earthing grid shall be made by short and direct earthing leads free from kinks and splices. Neutral connection shall never be used for the equipment earthing.

Steel/RCC columns, metallic stairs etc. shall be connected to the nearby earthing grid conductor by two earthing leads. Electrical continuity shall be ensured by bonding different sections of hand-rails and metallic stairs.

Metallic pipes; conduits and cable tray sections for cable installation shall be bonded to ensure electrical continuity and connected to earthing conductors at regular interval. Apart from intermediate connections, beginning and end points shall also be connected to earthing system. Metallic conduits shall not be used as earth continuity conductor.

A separate earthing conductor shall be provided for earthing lighting fixtures, receptacles, switches, junction boxes, lighting conduits etc.

Wherever earthing conductor crosses or runs along metallic structures such as gas, water, steam conduits, etc. and steel reinforcement in concrete it shall be bonded to the same.

Light poles, junction boxes on the poles, cable and cable boxes/glands, lockout switches etc. shall be connected to the earthing conductor running along with the supply cable which in turn shall be connected to earthing grid conductor at a minimum two points whether specifically shown or not.

Railway tracks within switchyard area shall be bonded across fishplates and connected to earthing grid at several locations. At the point where track leaves the plant substation area, the rail section shall be provided with insulated joint at both ends.

Every alternate post of the fence and gates shall be connected to earthing loop by one lead.

Flexible earthing connectors shall be provided where flexible conduits are connected to rigid conduits to ensure continuity.

Metallic frames of all electrical equipments shall be earthed by two separate and distinct connections with earthing system. Shield wire in substations shall be connected to the earthing grid at every alternate switchyard gantry tower

A separate earth electrode (rod of 3.0m) shall be provided adjacent to structures supporting lightning arrester and coupling capacitors. Earth connections shall be as short and as straight as practicable. Lightning arresters and lightning down conductors and CVT are connected to main mat at least at two points at a depth of 600mm below ground. The risers taken along the main switchyard structures and equipment structures (up to their top) shall be clamped to the structures at an interval of not more than one meter.

3.10.6.5 Jointing:

Earthing connections with equipment earthing pads and at treated / untreated pits shall be bolted type. Contact surfaces shall be free from scale, paint, enamel, grease, rust or dirt. Two bolts shall be provided for making each connection. Equipment bolted connection, after being checked and tested, shall be painted with anti corrosive paint/compound.

The design of earthing mat shall provide for welded joints between the earthing mat conductors, except where the mat may have to be isolated from equipment, cable sheath, test pits, etc. for testing. The joints intended to be isolated for testing shall be bolted. Connection between equipment earthing lead and main earthing conductors and between main earthing conductors shall be welded/brazed type.

The welds shall be treated with Barium Chromate to protect them from rusting. The exposed steel conductors/risers shall be protected with bituminous paint. The Barium Chromate treated surfaces shall thereafter be painted with red lead and aluminum paint and coated with bituminous paint.

Steel to copper connections shall be brazed type and shall be treated to prevent moisture ingress.

Resistance of the joint shall not be more than the resistance of the equivalent length of the conductor.

3.10.6.6 Power Cable Earthing:

Metallic sheaths and armor of all multi core power cables shall be earthed at both equipment and switchgear ends as per IS: 1255. Sheath and armor of single core power cables shall be earthed at switchgear end only.

3.10.6.7 Specific Requirement for Earthing Systems:

Each earthing lead from the neutral of the power transformer shall be directly connected to pipe electrodes of treated earth pits which, in turn, shall be connected to station earthing grid. All pipe electrodes shall have cement concrete pit with a Cast Iron cover hinged to a cast iron frame to have an access to the joints.

Auxiliary earth mat of size 900 x 900 mm comprising of closely spaced (300x300mm) conductors shall be provided at 300 mm below ground under the operating handles of the isolators further, and connected to the main mat at least at two points. Operating handle of isolator shall be bonded together by a flexible connection. MOM boxes both for main and earth switch shall be directly connected to the earthing mat.

Galvanized Steel: Steel conductors above ground level shall be galvanized according to IS: 2629. The minimum weight of the zinc coating shall be 650 gm/sq.m.

Each transformer shall be provided with 3 nos treated earth pits near to them for earthing (as per the standard practice). Cast iron pipes 125 mm in dia and 2.75 meters long and 12.7 mm/ 9.5mm thick shall be buried vertically to a depth of 2.75 metres in the pits. Finely broken coke and salt shall be filled at least 150 mm around the pipe for the entire depth. These earth pits in turn shall be connected to the earth mat. Circular R.C.C. Collar with diameter of 1 meter/0.75metres and height of 65cm, 50mm thickness shall also be provided for each treated pit. Where it is not possible to go to a depth of 2.75 metres, 1.3M x1.3M MS plate of 25mm thickness shall be buried vertically in a pit of 2metres depth, surrounded by finely broken coke or Bentonite powder. Earth pit with MS plate shall be located at least 2 metres away from any building or structural foundation. Plates shall be at least 15 metres apart.

All fence corner posts and gate posts shall be connected to the ground by providing 32 mm dia M.S. rods of 3 meter length near the posts and connected to the main grounding mat.

All paint, enamel and scale shall be removed from surface of contact in metal surface before making ground connection.

50 x 8 mm (flat) ground conductor shall be run in cable routes and shall be connected to the ground mat at an interval of 10 metres.

Earth pits shall be provided near the Lightning arrestors pits for earthing (as per the standard practice).

3.10.7 CABLES:

LT Power Cable: XLPE insulated 1100 V grade power cables shall be FR LS type of category C1 conforming to IS: 7098 Part-I (as amended up to date). The conductor shall be stranded aluminum, circular/shaped and compacted. In multi-core cables, the core shall be identified by red, yellow, blue and black colored strips or coloring of insulation. For multi-core cables the inner sheath and outer sheath shall be of extruded PVC of Type ST-2 of IS: 5831. The outer sheath shall have FRLS properties. Armoring for single core cables shall be aluminum strips/wires and for multi-core cables galvanized steel strips/wires.

PVC insulated 1100V grade power cables shall be FR type of category C1 conforming to IS: 1554 (Part-I) (as amended up to date) and shall be suitable for a steady conductor temperature of 70 deg. C. The conductor shall be stranded aluminum. The insulation shall be extruded PVC of Type-A of IS: 5831. The inner and outer sheath shall be of extruded PVC of Type ST-1 of IS: 5831. The outer sheath shall have FRLS properties. The armor shall be galvanized steel wire or strip for multi-core cables and aluminum wire or strip for single core cables conforming to IS: 3975.

Control Cables: The 1100V grade control cables shall be FR type category C1 conforming to IS: 1554(Part-I) (as amended up to date). The conductor shall be stranded copper. The insulation shall be extruded PVC of Type-A of IS: 5831. The inner and outer sheath shall be extruded PVC of type ST-1 of IS: 5831, and shall be gray in color except where specifically advised by the Purchaser to be black. The armor shall be of galvanized steel wire / strip for control cables. The outer sheath shall have FRLS properties.

Cores shall be identified as per IS: 1554 (Part-I) for cables up to five (5) cores. For cables with more than five (5) cores, the identification shall be done by printing legible alphabets on all cores. The alphabets shall be white, and shall be printed at about 100 mm interval all along the cable length.

CABLING: Cabling shall be on cable racks, in built up trenches, vertical channels, excavated trenches for direct burial, pulled through pipes, and conduits laid in concrete ducts, run clamped on wall/ceiling/steel structures etc.

Cables in outdoor switchyard shall be laid on angles embedded in trenches, excavated trenches for direct burial, and pulled through pipes and conduits. In cable vault below control room building / bay kiosk, cables shall be laid on ladder type cable trays clamped on wall / ceiling / steel structures etc. as approved.

Cables inside the Switchyard shall be laid on angle supports at 600 mm spacing with separate tiers for control and power cables.

Cables shall be generally located adjoining the electrical equipment through the pipe insert embedded in the floor. In the case of equipments located away from cable trench either pipe inserts shall be embedded in the floor connecting the cable trench and the equipment or in case the distance is small, notch/opening on the floor shall be provided.

In all these cases necessary bending radii as recommended by the cable supplier shall be maintained.

Cable supporting angles shall be welded to the continuous vertical supporting structure embedded in the wall to the suitable anchor inserts welded to the reinforcement of the wall (wherever applicable).

All metal parts inside the trench shall be bonded to earthing systems.

All steel structures/plates would be painted with non-corrosive paint and earthing conductor in cable trench shall be painted red.

Trench wall shall be clear of the equipment by minimum 100 mm.

Necessary opening and G.I. pipes shall be provided for taking out cables for lighting fixtures.

Necessary HDPE pipes shall be supplied and provided to run optical fibre wire wherever required.

Cables entering the control room from outdoor areas shall be sealed. Spare glands shall be sealed for control panels and marshalling boxes. Cables shall cross control room basement wall in 4" R.C.C. Hume Pipe embedded in cement concrete in basement wall.

In each cable run some extra length shall be kept at a suitable point to enable one or two straight through joints to be made, should the cable develop fault at a later date.

Metal sheath and armor of the cable shall be bound to the earthing system of the station by a steel strip wire. Bending the metal sheaths of single core cables in close **trefoil** formation shall be as stipulated in the relevant codes of practices.

3.10.8 LIGHTNING PROTECTION SYSTEM: Direct Stroke Lightning Protection system covers lightning masts and overhead shield wires wherever necessary to protect the entire 400/220 KV switchyard including bus-bars, equipment buildings transformer yards, feeder yards, auxiliaries etc. from the direct stroke of lightning.

The following Indian Standards can be followed to the extent these are relevant:

- Protection of buildings and allied structures against lightning.	IS: 2309:196
- Code of Practice for Earthing.	IS: 3043-19, Indian Electricity Rules with latest amendments
- National Electricity Safety Code	IEEE-80.

3.10.8.1 DESIGN REQUIREMENTS: The direct stroke lightning protection system shall be based on adequate number of lightning masts of appropriate height installed in the switchyard in such a manner that they provide adequate shielding cover to all the

400/220 KV bus-bars, their connections to the bay equipment and other equipment from direct lightning strokes.

The lightning masts shall consist of latticed steel structures on the top of which pipes of adequate dimensions and height shall be rigidly fixed suitably.

Conductors of the lightning protection system shall not be connected with the conductors of the safety earthing system above ground level.

Down conductors shall be cleated on the structures at 750 mm interval.

A 40 mm dia, 3000 mm long MS Earth Electrode shall be provided with lightning masts. Connection between each down conductor and rod electrodes shall be made via test joint located approximately 1500 mm above ground level.

Lightning conductors shall not pass through or run inside G.I. conduits.

All metallic structures within a vicinity of 2000 mm in air and 5000 mm below ground shall be bounded to the conductors of lightning protection system.

Lightning protection system installation shall be in strict accordance with the latest editions of Indian Electricity Rules, Indian Standards and Codes of Practice and Regulations existing in the locality where the system is installed.

Ground down leads shall be used to connect lightning receiver pipe on the lightning mast to the grounding mat.

Lightning protection system down conductors shall not be connected to other conductors above ground level. Also no intermediate earthing connection shall be made to lightning arrester, transformer and voltage transformer earthing leads, which shall be directly connected to rod electrode.

The lightning protection system shall not be in direct contact with underground metallic service ducts and cables.

3.10.9 Lighting System: The equipment such as distribution boards, lighting panels for normal and emergency lighting, lighting fixtures, luminaries, lamps, wiring accessories, junction boxes conduits, conduit accessories, fittings etc. and materials as would be found necessary for illuminating the switchyard with S.V lamps, rechargeable fitting shall be provided by the contractor as per the specification here under.

The high pressure sodium vapor lamps with fittings conforming to relevant IS where applicable with latest revisions of M/s.Crompton Greaves make of Model SSS 251H 250 Watts capacity or equivalent of Phillips or GEC or Bajaj make for yard lighting of EHT sub stations. The luminary shall have deep drawn anodized single piece aluminum body with circular/oval lamp compartment with suitable control gear consisting of low loss heavy duty electronic ballast like OPAL make, power factor improved capacitor, external electronic igniter and also provided with detachable parabolic reflectors. These fittings shall be provided for A.C lighting as per lighting arrangement specified in the drawing. The locations of the light fittings in the switchyard will be indicated by the Engineer. The twin tube rechargeable emergency light fittings shall be portable and of approved quality.

Alternately energy efficient lamps such as CFLs / LEDs with wattage sufficient to provide adequate illumination in the switch yard may be considered.

The lighting system shall consist of normal AC lighting from 3 phase 415 volts supply.

YARD LIGHTING PILLAR BOX: Whether proof out-door type, 'Yard lighting Pillar Box for AC lighting having the following specifications for EHT sub-stations is to be provided.

The box should be made of 2 mm thick Galvanized M.S.Sheet of size 700 x 500 x 150mm (as per drawing). The box should have hinged type door vermin proof, weather proof. Rubber beading has to be provided around the door. Door of the box should be provided with panel type lock. The top portion of the box shall be slanting, so that the rain water will fall away easily.

The box should be provided with 1 No. 60 Amps 3-Pole MCBs, 6 Nos. 20 Amps and 6 Nos. 10 Amps, Single pole MCBs and required copper Bus bars (20 mm x 5 mm) duly mounted Insulators fixed to Fibre glass sheet (neatly fixed in the box) with sufficient access for giving the cable connections. 20 Nos. cable glands should be supplied and the required holes are to be provided in the box duly half punched for taking cables into the box as per convenience. One hole should be of 35 mm dia for three phase cable and rest of 16 mm dia for lighting cables.

4 Nos. Galvanized M.S.Flats 50 x 6 mm should be welded to the box with one No. hole suitable for 5/8" dia bolts to facilitate easy mounting.

SUPPORTS FOR FIXTURES:

- i) The lights shall be mounted on structures with necessary cantilever arrangement
- ii) The steel mounting arrangements shall be as per the drawing and same shall be galvanized. The mounting arrangement shall be earthed at two locations with 8 SWG GI Wire.
- iii) All lighting fixtures shall be mounted in accordance with the standard installation practice. Splices in lighting circuits shall be avoided. Required size of fuses shall be provided for each light junction box.

3.10.10 Marshalling Boxes for C.Ts, P.Ts, and C.V.Ts.

The box should be made of 2 mm thick Galvanized M.S.Sheet of size 750x400x150 mm with hinged type door, vermin proof and weather proof. Rubber beading has to be provided around the door. Necessary brackets on the back side of the box should be provided for mounting on the structures. Doors of the box should be provided with panel type look. The roof portion of the box shall be slanting so that rain water will not stagnate. Two rows having 20 Nos. terminals in one and 14 Nos. in other should be provided in the box. The terminals should be of disconnecting and testing type (Type CDTTS). Three Nos. holes (Half punched) suitable for 6x2.5 sq.mm copper cable and 3

Nos. holes (half punched) suitable for 4x2.5 Sq.mm copper cable should be provided at the bottom to take the cables into the box. Suitable cable glands should be provided. Terminals in the Marshalling box should have facility for easy earthing, shorting, isolating and testing. 2 Sets of Earthing stud of 1/2" dia with suitable nuts, flat and spring washers are to be provided.

For Marshalling boxes for PTs: Ten Nos. (10 Nos.) HRC fuses of 2 amps rating of reputed make, with neutral link (with Bolts and Nuts) and one No. 3 pole MCB (10 amps) shall be provided.

For Marshalling boxes for CVTs: 6 Nos. HRC Fuses of 2 Amps rating of reputed make, with neutral link with bolts and nuts shall be provided.

MARSHALLING KIOSKS: The marshalling kiosk shall be of out door type suitable for operation in humid, dusty and tropical atmosphere with seasonal wet, dry and dusty condition as per clause-6.1 of I.S 5039/1969. The kiosk should be made of 3mm Galvanized M.S Sheet of size 1200x800x450mm. Each kiosk shall consist of

- a) Detachable blank gland plate at the bottom
- b) 200 Nos Heavy duty terminals stud type (5mm Sq) of rating 15 Amps to take 2.5 Sq mm copper / 4 Sq.mm Aluminum conductors.
- c) 2 Amps HRC fuses (Reputed make)
- d) Provision for three Numbers test terminal blocks.
- e) Local illumination lamps - 2 Nos.
- f) 2 /3- Pin 5/15 Amps. Multi point Plug with Switch - 3 Nos.
- g) The terminal blocks shall be provided in vertical formation. They shall be fully enclosed with removable covers made of barrier moulded integrally. Such block shall have washer and binding screw for external connection and white marking strip for ex-circuit identification and moulded plastic cover. All terminals shall be clearly marked with identification markers.
- h) Arrangement of terminals shall be as to safely connect or disconnect terminals on live circuits and replace the fuse links.
- i) Adequate space heaters shall be provided in the Marshalling kiosk as required.
- j) The box shall be provided with self supporting Galvanized M.S.Channel 100x50mm., welded to the bottom side of the Box and 4 Nos. holes are to be provided (suitable for 3/4" dia bolts) for fixing to the plinth with galvanized bolts.

- (k) The Kiosk shall be provided with a set of double hinged doors at the front and back. The doors shall be provided with 2Nos panel locks and 1No.pad lock. It shall have a door switch operated AC illuminating lamps which gets switched on when door is opened and gets switched off when closed. Two No. studs shall be provided on the body for giving earth connection to Marshalling Boxes.

3.10.11 Erection of Structures:

The Structures shall be erected by piece-meal method on the foundations, after allowing the required curing time for the foundations. The members shall not be strained or bent during the course of erection. Care shall be taken to see that the jointing surfaces are clean and free from dirt or grit and fit properly. The structures shall be erected strictly in accordance with the approved drawings. After erection of structures the bolts shall be checked to ascertain that all nuts are fully tight. The structures must be truly vertical after erection and no straining shall be permitted to bring them to vertical position. The tolerance allowed for verticality is 1 in 360 structure height.

3.10.12 Stringing of Busbar & Ground Wire:

The bus will be formed with single/Twin/ Quadruple Moose/ ACSR conductor and shall be strung to required tension as per switchyard layout drawing. The stringing of bus conductors covers installation of tension insulator strings, suspension insulator strings, post type insulator stacks and other accessories along with tensioning of conductor and clamps. The jumpering to various equipment and the ground wire stringing shall also be done. The G.I. Ground wire shall be strung as detailed in the layout drawing.

The sag of bus conductor shall not be more than 1%. Damaged conductors shall not be used. No joints are to be made. The conductor surface shall be clean and smooth without any projections, sharp points, cuts or abrasions, etc., and the conductor shall be continuous in span.

3.10.13 Erection of Equipment:

Erection of equipment shall be in accordance with the manufacturer's installation drawings / instructions and recommendations

For erection of control , relay and LTAC panels and DC distribution Board in control room MS channels are required to be embedded in floor and grouting of foundations bolts in these channels is also to be done by the contractor. Control and Relay panels, AC and DC distribution boards, Battery and charger, communication equipment (PLCC panels/ OLTE, exchanges, battery and charger etc.) are to be erected as per the layout.

Rubber mat of approved quantity is to be provided in the control room in front of the panels of 137 cm width and 15 mm thickness throughout the panel length.

Power transformers, Circuit breakers, Instrument transformers (CTs,CVTs,IVTs), LAs, Isolators with/without earth switch, wave traps and Bus bars shall be erected in the switch yard as shown in the substation layout. Marshalling boxes are to be mounted underneath the instrument transformers on their support structures.

Marshalling kiosks are to be erected on the foundations laid at different locations as shown in the drawing for interconnection between equipment groups as per the drawing.

3.10.14 Supply of CO2 Fire Extinguishers :

Carbon-di-oxide (CO2) gas filled cylinders fitted with appropriate valves conforming to IS 3224 are to be provided in the substation. The test certificates issued by the Chief Controller of Explosives Department and cylinder manufacturer's certificates for the supplies already made should be made available.

The following codes and standards shall be applicable for conducting test unless otherwise modified or supplemented by the enclosed procedure and mutually agreed to between the Purchaser and the contractor.

1.	NFPA – 13	: Standard for the installation of sprinkler system
2.	NFPA – 15	: Standard for water spray fixed system for the fire protection
3.	NFPA – 12A	: Standard for Halon 1301 Fire Extinguishing System
4.	NFPA – 72E	: Standard on Automatic Fire Detectors.
5.	Fire Protection Manual by TAC (Latest Edition).	
6.	NFPA – 12	: Standard on Carbon dioxide extinguisher systems.
7.	IS: 3034	:Fire safety of industrial building: Electrical generating and distributing stations code of practice

3.10.15 Construction of Fire Protection Wall:

Fire protection walls are to be constructed as per the approved drawing between the Power Transformers (Normally provided for power transformers of 220kV class and above and for 132kV 50 MVA capacity and above).

3.10.16 Spreading of HBG Metal:

20 mm HBG metal of 100 mm thickness shall be spread in switch yard. Kerb stones of size 200 x200 mm shall be provided in the switchyard to retain the metal all along the periphery of the metal spreading where ever it is required. The Kerb stones shall be buried in the ground up to 100mm deep. The joints between the Kerb stones shall be done in CM (1:6) and plastering the Kerb stones shall be done in CM (1:2) .Before spreading the HBG metal care shall be taken to remove all the vegetation and roots of the plant. The trimming of the earth surface for perfect level ground should be carried out and the surface should be watered and rammed for consolidation with suitable means and the earth surface should be given chemical treatment for anti-vegetation growth.

The crushed metal dust or quarry dust should not be used. The HBG metal shall be brought from the approved Quarry as directed by engineer

3.10.17 Construction of Control House (Single storeyed)

FOUNDATION EXCAVATION: This work shall be done as per drawing for control House and as per the technical specification. In case hard rock is met with, anchor rods shall be provided with 1000mm length of 16mm dia tor after drilling 20mm dia hole for a depth of 500mm inside hard rock and 500mm above hard rock for fixing in position with foundation mat. The anchor rod shall be fixed in the hole with C.M. (1:2) as directed by the Engineer.

FOUNDATION CONCRETE: Cement concrete 1:4:8 with 40 mm well graded hard broken metal for foundations 100mm thick including cost and conveyance of all materials, all leads and lifts and curing etc. complete for finished item of work as base concrete for the walls and columns of the structures.

FOUNDATION BASEMENT:

MASONRY:

Random rubble or uncoarsed rubble masonry with hard stone in cement mortar 1:6 for foundations up to ground level including cost and conveyance of all materials all leads and lifts and curing etc., complete for finished work and including cost of cement.

Coarsed rubble stone masonry 2nd sort with hard stone in cement mortar 1:6 for basement and wall above G.L., masonry work above G L including cost and conveyance of all materials ,all leads and lifts and curing etc., complete for finished item of work. The relevant APSS clauses 601,602 &615 are applicable to this work.

Pile foundations for BC soils: This should be done as per the drawing for pile foundation and as per the Technical Specification. The C.R. Masonry shall be executed over grade beam from ground level to finished floor level.

PLINTH BEAM: As specified in drawing for control house, plinth beam is to be provided.

SUPERSTRUCTURE:

Brick work in cement mortar 1:6 for walls in superstructure at ground floor and first floor and parapet with well burnt 2nd class country bricks including scaffolding, cost and conveyance of all materials all leads and lifts and curing etc., complete and including cost of cement. The relevant APSS clauses 501&504 are applicable to this work.

FILLING FOUNDATION AND BASEMENT: Back filling of foundations shall be done with excavated soils including watering and consolidating in 150mm layers for normal soils. Sand cushion for foundations and flooring area including, watering and consolidation shall be provided for BC soils. Anti-termite and Anti-weed treatment for foundations basement and flooring shall be provided. Compaction shall be obtained up to 98% proctor density.

FLOORING:

- Providing of C.C.1: 6:10, 100mm thick for flooring using 50% of 20mm and 50% of 40mm HBG Metal. The work shall be carried out as per APSS clause No.402.
- Providing flooring with ceramic tiles of approved quality of size and thickness with suitable colour border over cement mortar bed of CM (1:3) 25 to 40 mm thick inclusive of cost and conveyance of all materials, all leads and lifts curing etc. complete for finished item of work for rooms other than battery room & PLCC room. Skirting for height of 200mm shall be provided around the periphery. The work shall be carried out complying with APSS clauses 701 & 703.
- Plastering in cement mortar 1:3, 12 mm thick and finishing smooth to the required slope and thread lined for battery room flooring including curing, shall be done. The Battery room flooring, sides, shall be provided with superior quality Acid resistant paint of approved colour two coats, over one coat of primer. The acid resistant painting shall be carried out complying to APSS clauses 1201 & 1214.
- Vinyl flooring shall be provided for PLCC room with vinyl PVC rickvin tiles 8-10mm thick with adhesive of good quality over CM (1:3) 20 mm thick finished surfaced. The samples of the materials shall be got approved by the Engineer-in-charge of work before commitment of the work.

FALSE FLOORING: MS Pedestals shall be with 20mm dia stud, top 15 mm machine threaded along with nut and check nut with necessary washers for level adjustment. The stud shall be fixed to 100x100x6 mm MS plate on top and bottom. The top plate will be welded with restraining angle 25x25x3 mm, 38mm long as per drawings, the pedestal shall be placed at all junctions of the panels 600x600mm and at such other locations as specified by the Engineer-in-charges. The pedestal shall be securely fixed to the floor with suitable adhesive.

Cold rolled steel channel stringers shall be of size 40x40x3.15mm placed over top head of pedestals in both directions true to level and alignment.

The floor panels of size 600x600mm, 35mm thick phenol formaldehyde resin bonded three layered teak wood particle board (Nova Teak super or equivalent) with 2mm high pressure decorative laminated, super shade finish of fire resistant quality or equivalent, fixed to the board surface with adhesive of approved quality.

The floor panels shall have holes and openings of size indicated in the drawings and as per directions of the Engineer-in-charge. The edges of panels shall have a hard PVC beading of approved shape and size. The beading shall be flush fitted with suitable size groove cut along the edges of the panels and fixed with adhesive.

All the MS sections shall be galvanized. The floor panels shall be numbered.

SUPPLY AND FIXING OF DOORS AND WINDOWS:

- A) Supply & fixing in position M.S.hollow frames of size 105x60mm, 1.25 mm thick for doors along with accessories such as M.S. hinges 100mm long etc., as per the technical specification.
- B) Supply & fixing 30mm block board solid core, flush type door shutters of commercial quality in single/double leaf conforming to IS 2202 (part-1) - 1973 suitable for the door frames of size 1.220 m x 2.135 m, 0.915 m x 2.135 m, 0.750 m x 2.135 m .
- C) Supply, fabrication and erection of Aluminium anodized sliding 62.0x31.6x1.5 mm for two track windows using outer frame box type 92.2x31.6x1.5mm with three tracks on all four sides window plain section 40X18X1.6 window top & bottom 40x18x1.6 window inter lock section 40x18x1.6 with 5 mm clear glass and glazing clips 19.05X 17.27 with all necessary accessories and fittings such as rubber gaskets special rollers and stoppers etc, as per the sizes given below 2.0 mx1.35 m (with three equal sections of sliding type) Aluminium safety grills shall be provided as directed by Engineer In charge.
- D) Supply, fabrication and erection of aluminium anodized 12mm clear glass door with 44.45x101.60x1.90mm thickness (1.64 Kg/m) box section for the outer frame with special door top and door bottom with special double action floor spring of ISI for inner and outer rotation with 12mm clear glass and all necessary accessories and fittings such as rubber gasket 8" lock and handle etc., complete fitting as per the sizes given below. 1.81 m x 2.135 m
- E) Supply, fabrication and erection of aluminium anodized doors using outer frame box 38.10x63.50x1.75 mm thickness (1.06Kg/m) door vertical

44.45x47.62x1.90 mm thickness (0.976Kg/m) door top 44.50x48x2mm thick (1.533 Kg/m) door bottom 44.50x101.60x1.90 thick (1.640Kg/m) door centre 49.91x44.45x1.60 thick (0.897 Kgs/m) glazing clip 19.05x17.27(0.75kgs/m) with 5 mm clear glass with all necessary accessories and fittings such as rubber gasket 4 Nos. butterfly type handles 8" lock with handle with special action floor spring of ISI for inner and outer rotation 0.9 m X 2.135 m

BED BLOCKS UNDER LINTELS:

Bed blocks in CC 1:3:6 proportion using 20mm size HBG metal under lintels with necessary form work shall be provided.

LINTELS:

RCC 1:2:4 Proportion nominal mix for lintels using 12 mm to 20 mm size hard broken including scaffolding, centering machine-mixing, vibrating curing, finishing, cost and conveyance of all materials, all leads and lifts in all position of the building at all heights including cost of cement and steel for finished item of work.

COLUMNS & BEAMS:

RCC 1:2:4 Proportion nominal mix for footings, plinth beams, columns and beams with 12 mm to 20 mm size hard broken metal including cost of cement centering scaffolding, shuttering machine-mixing, vibrating, curing and finishing to the required tolerances.

SUN SHADES:

RCC 1:2:4 proportion nominal mix for sunshade of 100mm thick wide using 12mm to 20 mm size hard broken metal including scaffolding centering, machine mixing, vibrating, curing and finishing to the required slopes and providing lip at the bottom ends including cement plastering 12mm thick with CM 1:5 proportion dubara sponge finish to the exposed faces of sun shades, including the cost and conveyance of all materials including the cost of cement and steel.

RCC ROOF SLAB:

RCC 1:2:4 nominal mix using 12mm to 20 mm size hard broken metal for required thickness including cost of cement , centering, machine mixing concrete, laying concrete, vibrating curing etc. PVC rain water pipes of 100 mm dia with 2mm thick shall be provided from roof level to ground level. Opening shall be left over for providing 100mm dia PVC Pipes while casting the slab.

SAMPLING AND STRENGTH TEST OF CONCRETE MIX: Samples from each fresh concrete shall be taken as per ISI1199 and cubes shall be made, cured and tested at 28 days in accordance with IS 516. In order to get a relatively quicker idea of the quality of concrete,

optional tests at 7 days may be carried out. The sampling should be spread over the entire period of concreting and cover all mixing units.

Frequency:

<u>Quantity of concrete in work cum.</u>	<u>Number of samples</u>
1 to 5 cum	1
6 to 15 cum	2
16 to 30 cum	3
31 to 50 cum	4
51 and above	4 + one additional sample for each additional 50 cum or part there of.

Three test specimens shall be made for each sample for testing at 28 days. Additional samples may be required for various purposes such as to determine strength of concrete at 7 days etc.

PLASTERING ITEMS:

Walls in superstructure shall be plastered with cement mortar (1:5) proportions 12mm thick on even surface side and 20 mm thick on uneven surface side with 16mm thick in CM (1:4) for 1st coat & 4mm thick in CM (1:3) for second coat, including cement Plastering roof slab with cement mortar (1:3) 20mm thick and with Acco proof cement compound of 1 Kg per bag of cement duly making necessary slopes to drain the rain water. Roof ceiling shall be plastered with C.M. (1:4) 12mm thick for 1st coat & 4mm thick CM(1:3) for 2nd coat. Pointing to CRS masonry in basement shall be in cement mortar with CM (1:3) including curing etc.

PAINTING ITEMS:

Painting to wood work: 2 coats with synthetic enamel paint first grade of approved make and colour over a primary coat (total 3 coats)

Painting to steel work (grills): 2 coats with synthetic enamel paint first grade of approved make and colour over a primary coat (total 3 coats)

Painting 2 coats with rubber based acid resisting enamel paint over one coat of primer to the walls, flooring and ceiling of the battery room.

Painting outside of walls with two coats of exterior type Acrylic emulsion paints of approved colour and make over a primary coat (total 3 coats in all heights) including curing. Internal walls shall be painted with 2 coats of Acrylic emulsion of approved quality, over one coat of cement primer paint.

3.10.17.1 AIR CONDITIONING SYSTEM:

Air conditioning units for control room and bay kiosks shall be set to maintain the following inside conditions.

DBT $24.4^{\circ}\text{C} \pm 2^{\circ}\text{C}$

Air conditioning requirement in Control room building and bay kiosks shall be met using split AC units. Design (heat load) calculation has to be made to estimate the required no. of split AC units for erection in control room. The AC units of high wall type split AC units of 2TR capacity each complete with air cooled outdoor condensing unit having hermetically sealed compressor and high wall type indoor evaporator unit with cordless remote controller shall be provided.

2Nos. AC units of 2 TR capacity shall be installed in each bay kiosk (1 working + 1 stand by). In case of failure of one unit the other unit shall come into service to restore normalcy. Provision shall be made to monitor/control all the AC units through Sub-Station automation system (SAS)

The split AC units will be complete with indoor evaporator unit, outdoor condensing units and cordless remote control units.

Outdoor unit shall comprise of hermetically sealed reciprocating/ rotary compressors mounted on vibration isolators, propeller type axial flow fans and copper tube aluminum finned coils all assembled in a sheet metal casing. The casing and the total unit shall be properly treated and shall be weatherproof type. They shall be compact in size and shall have horizontal discharge of air.

The indoor units shall be high wall type. The indoor unit shall be compact and shall have elegant appearance. They shall have low noise centrifugal blowers driven by special motors and copper tube aluminum finned cooling coils. Removable and washable polypropylene filters shall be provided. They shall be complete with multi function cordless remote control unit with special features like programmable timer, sleep mode and soft dry mode etc.

Ventilation System:

Exhaust fans of propeller type/axial type shall be provided for the rooms which are not air conditioned, complete with suitable drive motors, DOL starters, rain protection cowl with screen, grouting bolts etc. These shall be fed from a local distribution board. The schedule of wall mounted ventilation/exhaust fans are as mentioned below.

Sl. No	Location	Capacity (each)	Static Pr. (mm Hg)
1.	Cable vault	3000	15
2.	MCC room	2000	10
3.	Office room, Aux buildings	1500	5

4.	Store room	1500	5
5.	Toilets	1000	5
6.	Pantry / guest house	500	5

ENVIRONMENT ASPECTS FOR SUBSTATION:

Ground cleaning operations during starting of the construction of substation shall be carried out by manual or mechanical methods only. No chemical method shall be used that may lead to chemical contamination of the site.

CONSTRUCTION OF SEPTIC TANK:

Septic tank of size 2 x 0.9 x 2.3 meters (Inner dimension) is to be constructed with C.C 1:3:6 with 20 mm HBG metal 230 mm thick at the bottom, RR walls in all four sides in CM 1:6 providing baffle wall as required from the inlet pipe level towards floor of the septic tank in RCC 1:2:4, 75 mm thick and with roof slab of 100mm thick in RCC 1:2:4 with 12 to 20 mm metal with an opening of 0.6 x 0.6 meters for manhole. The septic tank is to be provided with 4.5meters long 100 mm dia A.C. ventilating pipe with cowl. The outlet from the septic tank should be standard 'T' fitting of glazed earthenware pipe. The centre of the outlet pipe should be about 150mm below the center of the inlet. The floor and sides of the septic tank should be plastered in cement mortar (1:3), 20 mm thick.

The thickness of the wall should be 450 mm. The floor of the tank should slope at 1 in 30 towards one end to facilitate cleaning of deposits and the manhole should be above this. The reinforcement for the roof slab and baffle wall should be with 12 mm and 6 mm dia M.S rounds at 150 C/C. The tank should be provided with 0.6 x 0.6 meters size C.I. frame and cover for manhole. The inlet and outlet pipes shall be S.W.G. 150 mm dia. S.W.G. pipe of 150mm dia shall be laid from water closets, wash basin, bath, and urinal to septic tank inclusive of all specials and accessories.

CONSTRUCTION OF MANHOLES:

Manholes of 450 x 450 x 450mm size are to be constructed over bed concrete of 1:4:8 with 40 mm HBG metal 150 mm thick, with brick/stone masonry in CM 1:6, 230 mm thick and plastered inside with CM (1:3) 12 mm thick. The channels in the manhole should be semicircular in the bottom half and of diameter equal to seven. Above the horizontal diameter, the sides should be extended vertically to the same level as the crown of the outgoing pipes and the top edge suitably rounded off. The manhole is to be provided with 0.45 x 0.45 meter C.I. frame and cover.

3.10.18 Formation of Roads:

WBM road formation shall be with WBM surface using 65mm size IRC metal to a thickness of 75mm (100mm thick loose metal compacted to 75mm thick) including hand packing the metal, sectioning to proper camber ,spreading gravel at the rate of 25% of metal for blindage and watering and consolidating by rolling with 8 to 10T power roller for 15

days and over this metal surface forming 75mm thick compacted metal surface by spreading 40mm size IRC hard broken metal(100mm thick loose metal compacted to 75mm thick) sectioning to proper camber, spreading gravel at the rate of 25% of the metal for blindage, watering and consolidating the surface for 15 days with 8 to 10T power roller and forming 500mm width gravel berms on both sides of the road.

20 mm thick bituminous surface dressing with 0.27 cum. of nominal size of 12 mm HBG machine crushed chips premixed with bitumen at the rate of 52 kgs. of 80/100 grade per cum of chips shall be laid over a teak coat of bitumen laid at the rate of 9kgs. of 80/100 grade bitumen per ten Sq.m (total qty. of 23Kgs. bitumen per 10Sq.m) over the WBM surface including stacking the metal for pre-measurement, dusting, mixing the bitumen and chips, spreading to proper camber, rolling with 8 to 10 tonne capacity power roller, flushing coarse sand on the surface at the rate of 0.015 cum / 10 Sq.mt including of all materials etc., complete.

CC Road:

Preparation of surface: The WBM surface over which CC road is to be laid shall be thoroughly cleaned with wire brushes and brooms etc. as directed. The bays for laying of concrete road shall be free of soft spots and shall be properly drained. The prepared bays shall conform to the lines, grades at cross sections as directed. 100mm thick cement concrete (1:2:4) using 12 to 20mm HBG metal shall be laid for forming road and for kerbs.

Laying: The use of forms, locations of joints, concrete mixing, transporting, placing compaction, curing etc. shall be as per clause 15 of APSS. The joints shall be placed in with ½” thick Mastic pads at the intervals as per the directions of Engineer-in-charge.

3.10.19 Erection of Gates: Main gates shall be supported on RCC pillars. These shall include necessary anchors, rollers, guides etc. in complete shape. Main gate pillars shall be constructed as per the approved drawing. No. Wicket gate shall be grouted into pillars constructed in brick masonry. After erection of gates they shall be painted with two coats of superior quality enamel paint over a coat of primer

3.10.20 Construction of Compound Wall:

The compound wall shall be constructed as per the approved drawing. 10 rows of barbed wire 150 mm apart over the compound wall as indicated in the drawing is to be strung. Galvanized M.S.Angles are to be grouted in compound wall and fixed at 4.5 metres intervals. During construction of compound wall due to different levels obtained along the boundary, the basement portion of wall may need to be raised as directed by Engineer. The G.I. barbed wire shall conform to IS: 278 latest of glidden type (type-B) with line wire and point wire of 2.5 mm dia.

3.10.21 Electrification of Control House:

Electrification of the Control House is to be done with flexible copper unsheathed PVC cable with No. 14 SWG GI wire for earth continuity in surface PVC box type casing run over the walls of the Control House.

3.10.22 COMMON BUILDING MATERIALS Requirements:

The aggregates such as sand, metal shall be obtained from the source as indicated in lead statements. The aggregates both fine and coarse shall comply with the requirements of I.S.456 for concrete and I.S.383 for sand for use in rendering, plastering and mortar except as hereinafter stated and shall be clean, washed and free from dirt. Samples shall be submitted to the Engineer and all aggregates used in the work shall be at least equal to the approved samples.

FINE AGGREGATE: The fine aggregate for concrete, shall consist of naturally occurring and graded in accordance with the requirements of IS.383 for grading Zone-2 or grading Zone-3 except that no particle shall exceed 3/16 inch. It shall be free from excessive sharpness. Fine aggregate cement mortar and lime mortar and rendering plastering shall comply with IS 383.

COARSE AGGREGATE: Coarse aggregate shall be graded to produce sound concrete and for reinforced concrete shall be such that at least 5% by weight will pass a mesh of a size 1/4 per inch less than the minimum lateral distance between the reinforcing bars or 1/4 inch less than the minimum cover, whichever is smaller.

WATER FOR CONCRETE:

Clean fresh water shall be used for mixing concrete grout and mortar and curing. The water used for mixing and curing shall be free from deleterious matter and acids and alkaline substances in a solution or suspension. Potable water shall generally be used for mixing and curing concrete.

In respect of drinking water, filtration and chlorination by approved means shall be installed as necessary to obtain the required standard. Storage and distribution of potable water shall be such as to prevent contamination.

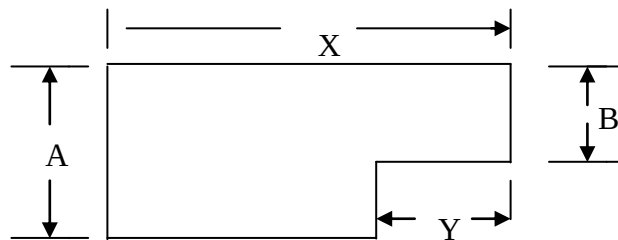
PROCUREMENT OF STEEL, FABRICATION & GALVANISATION:

Steel such as MS angles, plates, Channels and M.S Rounds required for fabrication of structures shall be procured by the contractor. The structures shall be fabricated as per the structural drawings and galvanized. Proto type structure shall be fabricated and shop drawings for all the structures, stub setting templates etc. shall be furnished. Mass fabrication of the structures shall be done after their approval.

DOORS AND WINDOWS

Cold formed M.S. Hollow Door Frames: The Cold formed pressed steel frames shall be manufactured from cold rolled sheet metal of 1.25 mm thickness and of size 105 x 60 mm. The frames shall be thoroughly cleaned. Free of rust, mill scale, dirt, oil etc., by mechanical and chemical means before giving an anticorrosive red oxide primer. The selection of raw material and construction of frame shall be as per the recommendations of Indian Specification I.S.513-1963 and I.S. 4351-1976. The door frame shall be provided with 100mm M.S hinges and along with accessories

- **Material Finish:** The door and frames shall be supplied in red oxide primer painted finish.
- **Tolerances:** Tolerances on thickness and other dimensions of the materials shall be as per I.S. 513 and I.S.4351 latest issued.
- **Packing:** Door frames shall be packed in knockdown conditions ready to be erected at site. Each frame shall be packed separately along with corresponding accessories in a gunny wrapping.
- Section dimensions of the M.S cold formed Hollow door frames X=105mm, Y=30mm, A=60mm, B=45mm Thickness of MS steel used shall be 1.25 mm as per I.S.4351-1976.



ACCESSORIES:

The following accessories shall be supplied along with each door frame.

- i) Built in (welded) hinges of 100 mm size--3Nos. for single shutter door and 6 Nos. for double shutter door.
- ii) Hold fasts -- 6 (six) Nos.
- i) Bottom tie of 10 mm square rod -- 1 (one) No.
- iv) Fastening bolts and nuts -- 8(eight) Nos.
- v) Stiffeners -- 4 Nos on either side and 3 Nos on top at suitable intervals.

Shutters: Shutter shall be of block board solid core flush type commercial make conforming to I.S. 2202(part - 1) 1973 Thickness shall be 30 mm. Acceptance tests will be done on the doors as per above ISS.

Sizes of Shutters for Doors: The over all sizes for doors shall be mentioned in the schedule. The actual sizes of doors shutters shall be manufactured duly deducting 2 x 75 mm width wise and 1 x 75 mm length wise towards provision of MS door frames (No MS frame for the bottom threshold)

Accessories: The following accessories shall be supplied along with each Door.

- i) Tower Bolt: 3 Nos. for double as per the note.
- ii) Tower bolts : 2 Nos. for single leaf in specification.
- iii) Al drops : 1 No.
- iv) Stopper : 2 Nos. for double leaf.
- v) Stopper : 1 No. for single
- vi) Handle : 1 No.

Aluminum Windows, Ventilators and Fittings:

The aluminum windows, ventilators shall conform to relevant IS specifications. All windows, ventilators, louvres etc., shall be of sizes as specified and conform to the description in the respective item of work. For centre hung and top hinge ventilators suitable spring catch/pulley and chord arrangement shall be provided for facility of opening. Whenever fly meshes over windows have been called for, they shall be fixed on the window and suitable lever type or roto type arrangement shall be provided for opening or closing of the glazed panels from inside. Aluminum safety grills shall be provided as directed by Engineer-in-charge.

Glazed windows, louvres and ventilators shall be provided with either clear or pin headed glass 5.5 mm thick which shall be free from all blemishes and shall conform to IS: 1761. Glass should have uniform refractive index.

Aluminum Doors: The door shall be built from anodized aluminum sections. The finished work shall be plumb, in line and free from corrugation, depression or wavy appearance. Field connections of all works may be made with concealed screws or approved type of fasteners or may be welded as approved by the engineer. All glazing shall be of high approved quality.

Partitions: The partition shall be hollow aluminium section of 63x38 mm.16 gauge (with in filled timber of silver oak) frame work, fully glazed or as per drawing Glazing shall be fixed to the frame work with anodized aluminium sections and performed rubber beading all around.

SANITARY FITTINGS:

Sanitary fittings shall be of porcelain type in the toilets of the control room and ceramic tiles flooring in toilets.

Sanitary fittings to be provided are of standard make conforming to ISI specification and of approved colour. Following is the list of fittings to be provided in the toilets.

1.	Water closet with flushing tank}	
2.	Wash Hand Basin	} as per schedule
3.	Shower point in bath room	}
4.	Flat back urinal	}

All the above fittings are properly fixed in the flooring and walls with suitable means and neatly finished. Plumbing work for water line for toilets and bath rooms and wash hand basin shall be done with 1/2" dia. G.I.Pipe. Main line from Syntex tank shall be with 3/4" dia. G.I.Pipe line. W.C. line shall be laid with C.I. waste pipe line and connected to the main line in the man holes.

Bath room water and waste water from wash hand basin are taken separately and connected into a man hole located out side and later on connected to the pipe line to the septic tank. All the pipe joints are neatly finished with cement paste and buried in the flooring, with necessary accessories like 'O'traps, gully traps and necessary CI/SWG bends. Care shall be taken to see that joints before covering with earth / concrete are tested for leakage and rectification carried out, if any and closed.

The ceramic tiles of approved colour and make should be neatly fixed in toilets up to 5feet level on the walls and also on flooring over a bed cement paste on the concrete. Care shall be taken while laying the ceramic tiles on flooring that proper slopes are maintained to avoid stagnation of water. The adequate down ward slope shall be maintained while laying flooring tiles to drain out water to the gully traps. It is desirable to lay flooring tiles with mat finish k type to avoid slippery surface.

Anti-weed Treatment:

For safeguarding the switch yard against the growth of weeds, weedicides (such as Biodex-C, Grammaxene, Fernoxene or equivalent products) should be mixed with water in accordance with the manufacturer's instruction (3 liters of weedicide mixed with 200 liters of water is a standard practice) and this solution should be spread over the earth with a chemical spraying pump on the ground.

The anti weed treatment should be given only after moisture content of the soil is brought below 29%. After completion of spraying of the anti-weed chemicals and before taking up the next activity, a period of 24 hours should be allowed for penetration of the chemical in to the soil.

Anti-Termite treatment: Required to set up a chemical barrier against attack by subterranean termites in the areas like cable trenches etc. This work shall in general, be executed as specified in IS: 6313 part -II and as per approved specification of the agency having special know-how for the job. All necessary work to ensure uniform distribution and proper penetration of treating solution shall be done. Soil treatment shall not be done

when it is raining or when the soil is wet with rain or sub soil water. Once formed, the treated soil barrier shall not be distributed.

Chemicals and rate of application: Any of the following chemicals (conforming to relevant Indian standards) in water emulsion shall be applied by pressure pumps uniformly over the area treated.

Chemicals	Concentration / weight percent
Dieldrin (IS: 1052-1962)	0.5
Aldrin (IS: 1306-1958)	0.5
Chlordane (IS: 2863-1964)	1.0
Heptachlor	0.5

Treatment of Cable Trenches: Cable trenches may be fully enveloped by the chemical barrier by treating with chemicals at the rate of 15 liters /sqm. on vertical surfaces of excavated trench walls and bottom surfaces at the rate of 5 liters /sqm. Chemical treatment shall be done in stages following the compaction of earth in layers. The treatment shall be carried out after the ramming operation is done by padding the earth at 150mm. Centres close to the wall surface and spraying the chemicals in the specified dose.

Permanent Storm Water Drainage System: Rain water PVC pipes shall be adequately provided to drain out the rain water without over flow. Minimum 100mm dia pipe, 2mm thickness shall be provided to drain out 40 sqm of roof surface area. All vertical down spout pipes and pipe fittings shall run inside the walls. All vertical down spout pipes shall be connected to water proof roofing by means of lead funnels, protected at the out side by a cover net of brass wire or by 90 deg. Bends (elbow).

PVC Pipes: PVC Pipes where called for shall be either unplasticised PVC pipes or high density polyethylene pipes supplied with appropriate fittings.

Pipes and Fittings: The pipes and fittings shall be of 10 kgs per Sq.m. pressure class. The plastic pipes are to be handled with care and stored in a place protected from sun. Plastic pipes and fittings shall confirm to ISI: 4984.

3.11 PILE FOUNDATIONS

Bored Piles: RCC cast in SITU:

Installation depth shall be related to the 'top of rock. Identification of the top of rock shall be on the basis of visual assessment of the pile spoil and on boring conditions. The horizon depth shall be confirmed, when encountered, by visual examination of a standard penetration test sample in accordance with IS-2131, 198, taken from each pile bore.

The piles shall be socketted into hard rock strata up to a depth of 1000 mm. The length of socketting shall be adjusted after test pile is cast and tested and /or pile spoil.

Setting out: Setting out shall be carried out from the main grid lines of the proposed structures. Immediately before installation of the pile, the pile position shall be marked with suitable identification of pins or markers.

Position: For a pile head cut off, at or above ground level, the maximum permitted deviation of the pile head cut off center from the center point, shown on the setting out drawing, shall be 50 mm in any direction. For a pile head cut off below ground level an additional tolerance will be permitted on the assumption that the pile head has been within tolerance, if the cut off had been at ground level.

Verticality: The maximum permitted deviation of the finished pile from the vertical shall be 1 in 100.

The following records concerning pile foundations shall be prepared and made available.

- a) Contract reference, pile location type and reference
- b) Specified cut off level, Ground level at commencement of pile installation/Working level (if difference from ground level)
- c) Diameter of pile. Date and time of boring, Date and time of concreting
- d) Levels at which seepages encountered
- e) Bottom level and diameter of temporary casing
- f) Level of top of rock together with details of sampling (level, length, type, description)
- g) Pile toe level, Top of finished concrete level
- h) Level of water or drilling fluid at commencement of placing concrete
- i) Details of drilling fluid including specific gravity measurement as directed
- j) Details of pile base cleaning operations
- k) Full details of permanent casing, Length and details of reinforcement placed
- l) Volume of concrete installed in pile; Method of placing concrete; Concrete mix and control test results

Construction of Piles: Sequence shall be selected to avoid piles being bored close to other recently constructed piles.

Drilling fluid (Bentonite) shall be in accordance with clause A 3.1 of IS 2911 Part-I, Section-II. The equipment and accessories required for construction of bored piles shall be of a standard type.

Boring: While boring in cohesion less deposits below the water table, care shall be taken to avoid the inflow of water and soil into the bore hole by adding water and maintaining a level potentially above the standing water level. If the hole is unstable during boring either temporary casing or substitution of drilling fluid for the water shall be used to ensure stability. In cohesive soils, water shall not be added for boring purposes.

Temporary casing shall be advanced with the boring tools, and excavation shall not be carried out below the toe of the casing.

Temporary casings shall be free from significant distortion. They shall be of uniform cross section throughout each continuous length. They shall be free from internal projections and encrusted concrete which might prevent the formation of piles.

Stability of Pile excavation using Bentonite Slurry or equivalent: The level of the fluid in the excavation shall be maintained so that the fluid pressure always exceeds the pressures exerted by the soils and external ground water, and an adequate temporary casing shall be used in conjunction with the method to ensure stability of the strata near ground level in the base and shall be maintained at a level not less than 1 mtr. above the equilibrium level of the ground water. During boring the consistency of the drilling fluid shall be controlled in accordance with IS-2911 part-I, section-II.

Spillage and disposal of Drilling Fluid: All reasonable steps shall be taken to prevent the spillage of bentonite suspension on the site in areas outside the immediate vicinity of boring. Discarded bentonite shall be removed from the site immediately. Any disposal of bentonite shall comply with the regulation of the local controlling authority.

Pumping from Bore holes: Pumping from bore hole shall not generally be done. However small quantities of accumulated water may be pumped from dry bore for cleaning out purposes prior to concreting.

Continuity of Construction: Boring of any pile once commenced shall be completed and concreted on the same working day.

Cleanliness of Base Piles: On completion of boring, loose, disturbed or remoulded soil and rock shall be removed from the base of the pile.

Reinforcement of Pile: The main longitudinal reinforcing bars in piles shall be in one continuous length unless otherwise approved. In long piles, joints will be permitted in main longitudinal bars but these shall be kept to a minimum. Joints in adjacent bars shall be staggered at least 1m apart along the length of the pile. Lapped joints shall be staggered by at least 1.3 times the lap length. Joints in reinforcement shall be such that

the full strength of the bar is effective across the joint and the reinforcement cage is of sound construction for installation in the pile bore.

Longitudinal reinforcement shall be provided for the full length of the pile and shall extend above pile cut-off level as shown in drawings. Longitudinal reinforcement shall be formed into a rigid cage to resist deformation during handling and installation if necessary by the use of additional reinforcement subject to the approval of the Engineer.

Lap or splice joints shall be provided with sufficient link bars to resist eccentric forces. Minimum cover to main reinforcement in the pile shaft shall be 75 mm and should be subject to approval of Engineer.

General Concreting: The method of placing and the workability of the concrete shall be such that a continuous monolithic concrete shaft of the full cross section is formed. Mechanical vibrators shall not be used to compact concrete.

Concrete Mix Parameters: Concrete in piles shall be of grade M15 except that its consistency shall be compatible with the particular method of pile installation proposed. The slump of the concrete shall range between 100 and 180 mm depending on the manner of concreting in accordance with clause 6.34 of IS 2911 Part I

The concrete shall be placed in such a manner that segregation does not occur. Concrete to be placed below water or drilling fluid shall be placed by tremie or other approved method and shall not be discharged freely into water for drilling mud. Where tremie placing is to be used it shall be in accordance with clause 7.5 of IS 2911 Part I. Section 2. Where concrete is placed through drilling mud, the specific gravity of the mud at the bottom of the boring shall not exceed 1.2 immediate prior to placing concrete. The amount of mud to be sampled should be adequate to suit the test apparatus (generally ½ to 1 litre is adequate.)

Concrete shall be cast to a minimum of 500 mm above the cut off level or local ground water level whichever is the higher.

Extraction of Casing: The method of extracting the temporary casing shall be such that the concrete in the casing does not lift and maintains its workability so that it flows freely against the pile bore. Utmost care shall be exercised in maintaining an adequate head of concrete above the bottom of the casing until concreting is completed so as to prevent the inflow of soil and/or water into the bore.

Temporary Backfilling: Sections of empty hole remaining above the head of the pile shall be temporarily backfilled with sand of a distinctive colour prior to excavation for pile cap construction.

Load Tests on Pile: The load tests shall be carried out on the pile after 28 days after the installation of the pile in position. The load tests shall be carried out on single pile.

Method of testing: The test shall be conducted as per ISS 2911 (Part I – Para D4 Cyclic – loading tests) except as described herein.

The test load to be applied on the loading platform supported on pile shall be twice the proposed safe designed load of the pile. The test load shall be applied in 7 increments equal to $\frac{1}{4}$, $\frac{1}{2}$, $\frac{3}{4}$, 1, $1\frac{1}{4}$, $1\frac{3}{4}$, and 2 times the proposed working load. Readings of the settlement and rebounds shall be reckoned against a constant elevation bench mark and shall be recorded to $\frac{1}{30}^{\text{th}}$ of a cm. for each increment or decrement of load. After the proposed work load has been applied and for each increment thereafter the test load shall remain in place until there is no settlement in a two hour period. The final test load shall remain in place until the settlement does not exceed $\frac{1}{30}^{\text{th}}$ of a cm. in 48 hours. The final test loading shall be removed in decrements not exceeding $\frac{1}{4}^{\text{th}}$ of the total test load with intervals of not less than 1 hour rebound shall be recorded after each decrement is removed and the final rebound shall be recorded 24 hours after the entire test load has been removed.

Number of Tests: Not less than 2 (two) piles should be subjected to load tests for 100 Nos. of piles installed. The piles to be tested shall be selected from separate groups or as indicated by the Engineer. Further tests, if necessary shall be made on the basis of the results of load tests. The test piles shall be used for foundation of the structure. Net settlement of the top of pile after the conduct of cyclic tests with the maximum load of twice the design load shall not be greater than 12 mm

Pull out Test: A trial pile shall be installed in such a location as directed by the Engineer, where it does not interfere with working piles. The specification and details of the trial pile shall be same as for working pile. An outer casing shall be provided such that the trial pile has a clearance of at least 20mm allround. The object of the test is to determine the strength of socketting provided for in the drawing and adjustments, if any required. The test shall be carried out to failure point.

Method of Measurement: Forming pile shaft shall be measured in running metres from the approved toe level to cut-off level for each diameter of pile.

Empty boring shall be measured in running metres from working ground level to cut-off level for each diameter of pile.

Concrete pile shaft shall be measured in running metres from the approved toe level to cut-off level for each diameter of pile.

Reinforcement including projection above cut-off level is measured by weight in tonnes. The weight shall be arrived at by multiplying the length, shown on the drawings or otherwise directed by the Engineer – in charge by the sectional weights.

Trial piles, reactions piles, rock chiseling if any shall be measured and ‘clubbed together’ with works piles, although tests are enumerated separately.

IS CODES (LATEST EDITIONS): Important relevant IS in this section.

IS 2911 – Part I Section : Concrete piles section bored cast in situ piles.

IS 2911 – Part IV : Load test on piles.

UNDER REAMED PILES.

The execution of under reamed pile foundation shall conform to IS code 2911 (Part III) 1978 and specification given in building Digest No. 56 of Central Building Research Institute Roorkee.

The depths of piles are tentatively assessed with double bulb. The depths are likely to be increased or decreased based on site conditions.

3.12 Field Quality Plan:

3.12.1 Civil works: In respect of foundations, foundation materials, earth work, roads etc, field quality plan for transmission lines explained earlier, may be referred.

Field quality plan for structures, electrical equipment and other related materials& works in the substations is given here under.

Contractor and Transco's project supervisor should ensure that all materials received at site are inspected and cleared by the purchase unit.

On receipt of the materials at site, packing cases of all the materials should be checked for any damages, by the contractor. Quantity of materials received as per the approved drawings to be checked and shortages if any to be reported. After opening the package, check for internal damages, cracks, deformations/ deep scratches etc. to the materials, damage to any porcelain parts, cementing, sealing gaskets, terminal blocks, space heaters etc, should be done. All oil filled equipment should be checked for oil leakages. Ensure proper handling and storage of the packages as per the directions given on the package or as given in the drawings/bill of materials/packing list.

All the checks are to be made by the contractor and random check done by AE/AEE/EE

Storage of materials: Check that all assemblies/components are properly packed in their original or similar packing with suitable clamps, brace and polythene covers as required. All the packages are stored in a ventilated and covered storage. All small fragile items are stored in proper containers at safe locations to avoid any damage. These shall be stored as per the directions given in the Instruction Manual. Necessary identification marks or tags should be kept intact for easy identification. Items shall be stored in an orderly manner to facilitate easy removal from storage site as and when required without causing any damage. Heavy packages shall not be stacked one above the other. There should not be any sudden jerks or impact on the packages while handling. Packages should not be dropped on the ground.

Following specific checks on the materials noted against each, in addition to the general checks mentioned above shall be carried out.

3.12.2 Main and Auxiliary Structure:

Receipt of required quantity of hardware (bolts&nuts, washers, foundation bolts) and their dimensions and suitability as per drawings.

Structures are clean, free from sharp kinks, bends etc. galvanizing of steel structures and any kind of defects on galvanized surfaces.

Necessary identification marks on each of the structure members for matching as per the approved drawings.

Structures are stacked to avoid direct contact with soil or water and to avoid white rust cover.

To be stored section wise, size wise for identification and easy removal.

Check for centre to centre distance of foundation bolts, finished ground level setting, grouting works.

Check for proper lifting arrangement, verticality, leveling and alignment, tightness of bolts and structure earthing.

3.12.3 Current and Voltage Transformers:

Name plate for required rating and design as per the approved drawings.

Marking of proper terminals, identification marks for primary and secondary terminals, neutral terminal in case of CVT.

Nitrogen and oil leakage.

To be stored in a place protected from dirt, dust, ingress of moisture and stored vertically as per the manufacturer's instructions.

Ensure lifting of CT/VT using lifting lugs only. Check for orientation of incoming and outgoing.

Erection as per instruction Manual. Check for tightening of all bolts& nuts, and level with respect to Aluminum tube.

Check earthing terminal for connection to earth at correct location. In case of CVT ensure earthing of HF connection if it is not utilized.

Check for oil levels up to the mark.

3.12.4 Isolators:

Any damage to galvanized parts and galvanization defects.

All current carrying parts, insulators and operating mechanism are to be stored to protect from dirt and moisture as per manufacturer's instructions.

Structures are erected as per approved drawing. Foundation bolts are tightened properly.

Base shall be installed over the two structure columns.

Installation of rotary assembly on the base.

Support insulators shall be installed properly.

Lever plates to be installed as per manufacturer's instruction Manual.

Cross tandem pipes are coupled correctly.

Operating mechanism should be correctly assembled and erected at required height and fixed at correct location as shown in the drawing.

Adequate tightening of nuts with torque wrench, to be ensured.

Check connections to the isolator.

3.12.5 Lightning Arrester:

Ensure ratings as per the order.

Surge counters, corona rings and supports are stored indoors in a safe manner.

Arrester should be erected by/handled with chain pulley and Nylon rope round the porcelain .

For arresters provided with insulating base, the base must be bolted to the structure.

Surge monitor should be mounted as per drawing at a convenient height and should be connected in parallel to the insulating base.

Care shall be taken to avoid corona rings striking the porcelain.

3.12.6 Bay Marshalling Box:

Terminal blocks/terminals are not damaged

Necessary cable glands have been received/fitted as per the approved drawings and the box is vermin proof.

Doors are operating and are properly lockable and keys are available.

Any glass (fragile) items are broken/missing. Relays, instruments, gauges, meters etc. are in their position.

3.12.7.Clamps and connectors: General checks as indicated above.

3.12.8 Insulators&Insulator Hardware including bus Post Type Insulator:

Receipt of necessary items like hardware, corona ring etc. as per the drawing.

Properly repacked to avoid any damage before sending for storage.

Install the insulator stacks over the columns and secure the bolts properly.

Check for clearances of insulators before and after erection

3.12.9 Earth wire, Conductor and Cables:

Rolling of drums in proper direction as per the mark indicated on the drums at the time of storage or erection.

3.12.10 IPS Aluminum Tubes:

Measure ID&OD of the Aluminum tube to check the thickness as per specification

Properly stacked to avoid direct contact with soil or water (Follow manufacturer's instructions if any).

3.12.11 Circuit Breakers:

All components of CB received as per packing list/bill of materials

Check for any gas leakage/oil leakage/smell.

Shall be stored as per manufacturer's instructions and away from inflammable material.

Control cubicle should be stored duly covering with dry and covered plates.
Ensure completeness of erection of CB as per drawing and Manual in correct phase sequence and location with proper tools.
Check for all wire and bus connection and tightness of bellow connections.
Check for all cable terminations and electrical continuity
After filling with SF6 gas and air at required pressures, check for leakages thoroughly.
Check for connection between individual pole unit and control unit.

3.12.12 Control& Relay Panels and LT Switch gear:

Proper mounting of all required mountings (Ref: approved drawing, specification, bill of materials, packing list)
Proper operation of doors and availability of keys.
All indicating lamps, fuses/MCBs, alarms, terminals including spare terminals, panel wiring as per the approved drawings, bill of materials.
Shall be stored above ground in vertical position under cover shed, protecting from rain, dust and fire.
Ensure foundation/ground is level. Panels should be in one level and line. Should be bolted to the seating channels properly.
Check for the arrangement for cable entry and vermin proof arrangement.

3.12.13 Checks before erection (Pre-erection checks)

Before taking up erection of structures/equipment, all relevant drawings, instruction/erection manuals should be made available at site.
After assembly of sub-components of an equipment ensure that all insulators and conductors are thoroughly cleaned, all terminals are smooth and free from dirt, dents and paints etc.
Ensure that ends of aluminum tubes, earth conductors etc. which are to be welded are properly cleaned and are free from paints.
All welding materials/equipments, electrodes, filler wire, welding machine are made available at site. Electrodes used shall bear ISI mark. All protective and safety measures shall be ensured while welding. (Reference to Specification, approved welding procedure may be made). Qualified welder should be employed for all welding works.
All tools and tackles and instruments required for erection shall be available and in working condition.

3.12.14 Civil works: Reference (Datum) levels and co-ordinates should be checked. Referred centre lines of complete switchyard installation are permanently and clearly marked to the given dimensions.

Check that various openings/pockets, embedments and foundation blocks have been provided at required locations to the given dimensions in the lay out/ foundation drawing.
Check that various foundation bolts that are to be grouted are done so at proper location to the given dimensions as per the drawing and as per the design. Correctness of

foundation bolt size and its projection above ground level should be checked. Wherever possible foundation bolts are to be welded to main reinforcement steel. Any deviations noticed in the civil works are to be recorded in writing and reported to competent authority (EE/SE/CE Civil) and remedial measures taken before commencement of erection.

All equipment are placed/erected in position, matching with the dimensions and level given in the lay out.

Check the earthing scheme and ensure that necessary points have been brought to necessary working level from station earth for equipment earthing purpose at required locations.

(Reference to approved switchyard layout drawing, foundation drawing station earthing layout and equipment earthing details may be made).

3.12.15 Checks during erection:

Check that pre-layout survey has been carried out and necessary modification done, to verify and achieve the position of various equipments to the connected levels and position of foundation bolts, pockets and cut-outs.

Check that structures are erected with proper alignment and specified levels are maintained. Structures shall be properly tightened /grouted only after alignment.

Check that associate equipments are placed in their proper position during erection.

Check that clearances between phases, phase to earth are conforming to design/standard values.

Check that CTs are erected strictly as per the layout drawing and in correct order to see that polarity is correct. Secondary of CTs shall remain shorted until they are connected to the instruments/relays. Oil levels shall be checked for level marked in the gauge.

Check that earthing of various equipments, structures etc. are done as per approved earthing drawing.

(Reference to approved layout and foundation drawings, general arrangement drawing, manufacturers' instruction manuals)

3.12.16 Stringing of Main Bus-bars:

Ensure providing correct insulator stringing with hardware mounted.

Check for tension for sag of strung busbar.

Check for torque values while tightening clamps of conductors.

Check for electrical clearances.

3.12.17 Illumination System:

Check the conduit fixing, tightness of bolts, glanding, dressing, electrical wiring continuity, and proper earthing .

Check for correct rating of lamps and sockets and their correct location as per drawing and their proper fixing.

Conduct all operational tests on lighting fixtures with supply voltage and check the correctness and working of the protective devices (fuses, MCBs, no fuse breakers etc).

3.12.18 Earthing System:

Check for the routing, bending of MS/GI earth flats, MS rods, for quality in welding at joints, equipment, Steel structures etc. Check for the tightness of all bolts.

Check the depth of earth pits and dimensions as per drawing. Check for the addition of salt and coke/ bentonite powder or any other chemicals as per specification in case of a treated pit. Check the Masonry work, treatment of welded joints etc.

Check the continuity of earth, between individual equipment earth to main earthing system. Measure earth resistance values of individual electrodes.

3.12.19 Aluminum Tube:

Remove the scratches on the Al.tube by polishing.

Ensure proper alignment of Aluminum tube, and correct length of Al.tube.

Conduct Dye penetration test ,visual MV drop test and radiography tests on welded joints to check the quality.

3.12.20 Cables, Cable support/tray and route:

Check the cable support/tray and route and ensure that no sharp objects are available in the cable route.

Check for bend radius, for cable tags, proper earthing of cable trench/tray.

Make sure that proper gradient is maintained in the cable trench.

Wherever cable trenches are not provided, ensure proper burial of cables in ground, duly providing markers at regular intervals.

All the checks indicated above right from receipt of materials to storage, handling, pre erection and erection stages should be done by the contractor on 100% materials and to be counter checked and reviewed by the officers of APTransco at random.

Damages or shortages are to be rectified/replaced by the contractor as instructed by Transco as per provisions of contract.

After erection, required pre-commissioning tests on various equipment shall be got done by the contractor/manufacturer or by Transco as per the contract provisions. Various pre-commissioning tests to be done are explained in the chapter on Testing& Commissioning of Transmission Projects. A record of test results of all tests together with reference values (factory test results) shall be prepared by the construction unit in charge of the project, which should be reviewed and approved by the Project Manager (EE/SE, construction) before commissioning.

3.13 Quality Control:

Contractor shall establish and maintain quality control for different items of work and materials as may be directed by the Engineer to assure compliance with contract requirements and maintain and submit to the Engineer records of the same. Field Quality

Assurance Plan for ensuring the quality at various stages during execution of works shall be prepared and shall be binding on both the contractor and project executing unit.

Copies of records and tests for the items noted in the quality plan, as well as, records of corrective action taken shall be submitted to the Engineer for approval as may be desired.

Field officers in charge of execution of project (both electrical and civil engineers) are responsible for quality control at various stages of project execution, as they oversee the works on a regular basis.

The Quality Control wing at Headquarters under the Joint Managing Director (Vigilance and Security) will conduct quality control checks at random while carrying out inspections of construction of all new EHV substations and lines. Field construction units should prepare in advance, weekly programme for execution of project works in consultation with the contractor and intimate the same to the quality control wing, who in turn would arrange for inspection of various works as directed by JMD (V&S).

Observations of Quality Control wing, made with reference to specifications and Quality Assurance Plan/Field Quality Plan during the inspections will be recorded in the Prescribed Form. This form shall be signed by the field officers, contractor or his representative, and by the Engineer from QC unit and a copy of the same shall be issued to the field Engineer and the contractor at site for taking action on the observations made and to send a report on action taken on the remarks.

The detailed inspection reports of QC wing will be sent to concerned Executive Engineer, Chief Engineer, with copies to JMD (Vigilance & Security) and Technical Directors concerned.

Action taken reports received from the field construction units will be consolidated by QC unit and put up for review by JMD (V&S).

QC remarks and the field reports will also be periodically reviewed by the CMD, JMD (V&S) and the technical Directors once in a quarter.

3.13.1 Penalties to be imposed for deficiencies in quality of works:

During execution of works, if any deficiency in quality of works is found in deviation to the specification / Agreement, penalty shall be levied for different nature of deficiencies as mentioned below under different categories.

Category I: Not using (i) prescribed shoring, shuttering and dewatering equipment, (ii) measurement boxes, (iii) Form boxes for different types of foundations and steel measuring boxes, (iv) not providing adequate number of chairs to the steel reinforcements, (v) not carrying out back filling and compaction of the foundation pits in layers and leveling the tower footings properly, (vi) not ensuring that the excavated earth is dumped at least 2 meters away from the pit etc., and (vii) not providing copings to the tower legs / stubs,(viii) not providing water tanker, Earth rammers/Earth vibrators.

Category II: Use of reinforcement steel without ISI mark, not using vibrators for effective consolidation of the concrete during foundation works, not using proper templates for firmly keeping the stubs in position when templates are supplied by the contractor & improper fixing of stubs, non ensuring of tower verticality, use of rusted stubs and tower parts if supply is by the contractor, non painting of butt joints and rusted stubs with zinc rich paint immediately after erection of the towers & stringing, non fixing of earth flat to the stub, non deployment of technical personnel for supervision of works by the contractor. Also not fixing of vibration dampers firmly, repair sleeves wherever necessary, not properly fixing of arcing horns both tower side and line side and bird guards etc., as per specification.

Category III: Use of improper grade / quality of raw material like H.B.G. metal, water and sand for concreting, using clogged and / or lump / clotted cement for concreting, not ensuring proper curing for foundation concrete, not ensuring that all the members of the tower are placed in position and firmly fixed with bolts and nuts immediately after erection of tower, not ensuring that Half round seam welding of the nuts before stringing of the line.

For the deficiencies in the quality of works noticed by the engineer, penalties should be levied at the rates indicated below for each category and for repetition of deficiency.

Category type	First instance(Rs)	Second instance (Rs)	Third instance (Rs)
Category I	5,000 /-	10,000/-	15,000 /-
Category II	7,500 /-	15,000/-	22,500 /-
Category III	10,000 /-	20,000/-	30,000 /-

Penalty for quality lapses on various aspects, as indicated above, will be levied accordingly as directed by CMD in the review meeting.

Repeated violations of quality will entail in Blacklist/Debar of the default contracting Agency.

It is mandatory to test the construction materials before commencement of work. The QC wing also shall collect samples of construction materials at random for testing the same at Standard Laboratories. If the samples fail to fulfill the test results as per Standards, action shall be taken to make good the loss sustained.

The Quality Assurance Plans (QAP) and Field Quality Plans (FQP) shall be reviewed periodically and updated taking into consideration any amendments/modifications to National and International Standards and Codes and Standard practices in TRANSCO.

3.13.2 Accountability of Field Officers in charge of Works:

Site Order Book shall be maintained at all Work Sites to record the instructions of field officers to the contractors in respect of works. This Book shall be signed by both the Field Officers and the Contractor or his representative in token of

acknowledgement for compliance. This shall be reviewed by all Senior Officers visiting the work spots during their inspection.

The material / work shall be in conformity with the specification.

Marking of date of concreting, type of tower, classification of foundation on the stub after completion of foundation casting shall be mandatory.

3.13.3 Statutory Inspection:

After completion of the substation works, the contractor shall carryout final checking of all the works done as per the contract to make sure the works are completed duly maintaining the quality as per the specification. All the required tests on civil and electrical installations in the scope of contractor shall be conducted and test reports furnished to the SE Construction for approval.

The EE, Construction shall get all the equipment tested for proper installation and operation in accordance with the manufacturer's recommendations.

All the equipment particulars as per the nameplate and the particulars of lines to be energized from the newly constructed substation such as voltage and length of the line, configuration, size and no. of conductors employed, details of equipment connected at the other end of the line etc. shall be furnished to the CE/Power Systems to conduct necessary studies and issue the relay settings including the CT and VT ratios to be adopted. The EE in charge shall arrange to ensure installation of communication facility (PLCC/Optic Fibre etc) through the telecommunication wing before completing the substation works. The relays shall be got tested by MRT wing with the approved settings to ensure proper operation of protection. Services of the manufacturers shall be utilized wherever stipulated in the tenders depending on the need.

The EE/SE Construction shall arrange to furnish the following documents to the SE O&M (TL&SS):

- Structural and layout drawings of the substation
- All drawings and details related to control room, other buildings, fire protection systems, Diesel Generator systems, AC and DC distributions, water supply arrangement etc
- All drawings, details and instruction manuals supplied by the manufacturers for all the equipment installed in the substation
- Details about the earthing provided in the station together with the earthing layout drawings.
- Cable schedules giving full details of the inter connections made between the equipment in the switch yard and the control room
- Approved relay settings communicated by the CE Power systems

The SE (O&M) will arrange for inspection of all the civil works and all electrical and miscellaneous works done by the contractor in line with the specification to ensure no omissions at any stage. Observations made by the SE and the remarks if any communicated shall be complied with by the Construction unit and the contractor before energizing the substation.

The SE (O&M) shall arrange for testing the relays with the approved settings to ensure correct operation and arrange for conducting pre-commissioning tests on all the equipment. Communication facilities available both departmental and P&T shall be checked for normal operation.

After ensuring that every thing has been checked and found correct, the substation shall be idle charged duly informing SE Grid Operation(Load Despatch Centre) and under his directions.

3.14 Safety Requirements in construction of Transmission Lines & Substations

Safety shall form an integral part of work processes to ensure safety for employees including employees of contractors and sub-contractors as well as visitors.

Provisions relating to Transco:- A sound and scientific safety management system should be set up which shall include:

- a) Formulation of a written statement of policy in respect of safety and health of employees.
- b) Defining and documenting responsibilities for all levels of functionaries to carry out safety related activities including responsibilities of the contractors.
- c) Preparing detailed Safety Manual complying with statutory requirements, manufacturers' recommendations, BIS and any other relevant standards and codes.
- d) Establishing procedures to identify hazards that could give rise to the potential of injury health impairment or death and measures to control impact of such hazards.
- e) Providing adequate human, physical and financial resources to implement the safety management system.
- f) Providing safe working environment and evolving framework for occupational safety and health.
- g) Providing and maintaining medical facilities.
- h) Providing adequate training to all employees to make them aware of safety related issues.
- i) Establishing system for accident reporting, analysis, investigation and implementation of recommendations.
- j) Establishing system for proper communication, documentation and record management in relation to occupational safety and health.
- k) Filing periodic and other returns to the statutory bodies as required under various Acts and Rules within stipulated time.
- l) Formulating emergency management plan for quickly and effectively dealing with

- probable emergencies that may arise on site as well as off-site.
- m) Establishing methodology for internal and external audit of safety management system.
 - n) Establishing system for periodic monitoring and review of safety system by Management.
 - o) Overseeing the safety performance of the contractors.

Detailed site specific safety manuals should be prepared. However common safety manuals may be prepared for similar installations. Safety Manuals shall be prepared for construction of Transmission Lines and Substations and for Operation& Maintenance of Lines & Substations.

3.14.1 Provisions relating to Contractor:

Transco shall incorporate requisite safety provisions in the contract document which are required to be complied by the contractor's personnel during execution of contract to facilitate safe working during execution of works.

Contractor shall observe safety requirements as laid down in the contract as well as comply with statutory requirements as provided in the existing Acts/Rules. In case of sub-contracts, it shall be the responsibility of main contractor that all safety requirements are followed by the employees/staff of the sub-contractors.

One of the employees of the contractor shall act as safety coordinator, who will liaison with safety officer on matters relating to safety.

Contractor shall be responsible for non-compliance of any of the safety measures, implications, injuries, fatalities and compensation arising out of such situations or incidents.

In case of any accident, contractor shall immediately submit a statement of such accidents to the department and the safety officer concerned for the project showing the details of accident, any injury /casualties, extent of property damage and remedial action taken to prevent recurrence. The contractor shall submit a statement of various accidents to the department at the end of each month within a week.

3.14.2 Reporting of accidents:

- i) Notice of any accident, resulting in death of any person or in such bodily injury which is likely to cause death or prevents the injured person from working for a period of 48 hours or more, shall be sent to the statutory authorities within the prescribed time as per the Factories Act and Rules or the Building and other Construction workers (Regulation of Employment and Conditions of Service) Act and Rules as applicable.
- ii) Cases of outage of a substation or a transmission line 132kV and above due to any accident related to any equipment (e.g. fire, explosion, emission of hazardous chemicals, collapse of transmission tower, flooding of sub-station

area) shall be reported to the Authority within 24 hours, whether or not any death or disablement is caused to any person.

3.14.3 Emergency Management Plan:

- i) An on site emergency management plan shall be formulated for a) each substation and b) group of transmission lines for quickly and effectively dealing with probable emergencies like fire, explosion, gas leakages, landslides, floods etc. and reducing response time.
- ii) Provisions to be made for the onsite emergency management plans shall conform to the following:
 - (a) Major fire in cable gallery
 - (b) Major fire in transformer yard
- iii) Onsite emergency management plan shall include the following:-
 - (a) Name and address of Chief incident controller
 - (b) Alarm system and method of reporting/declaring emergency
 - (c) Emergency response procedure including response to Off-site emergency management plan and Crisis & Disaster management plan.
 - (d) Details of the key personnel of the emergency team and their responsibilities
 - (e) Addresses and contact numbers of outside organizations (including local administration, police, hospitals, organizations located nearby) involved in assisting during emergency with their role
 - (f) Risk assessment information giving possible nature of incidents/events giving rise to emergency conditions, risk analysis and impact assessment.
 - (g) Details about the site:
 - i) Locations where emergency can arise
 - ii) Emergency control room/Alternate emergency control room
 - iii) Demarcation of safe assembly zone relevant to each type emergency condition
 - (h) Internal and external communication plan during emergency

- (i) Details of fire fighting and other facilities and their operating procedures available to deal with emergency conditions
- (j) Details of first aid and hospital services available and their adequacy.
- (k) Post emergency activities:
 - (i) Collection of records
 - (ii) Conducting enquiries and concluding preventive measures
 - (iii) Making insurance claims
 - (iv) Preparation of enquiry report and suggestion scheme
 - (v) Implementation of enquiry report recommendations
 - (vi) Rehabilitation of affected persons
 - (vii) To restart the plant
- iv) Onsite emergency management plan for the substations and lines should be prepared by the department before commissioning. In case of existing substations and lines the plan may be prepared within 90 days.
However in case of construction of Substations and lines, emergency action plan shall be prepared, before commencement of construction activity, to handle emergencies like fire, explosion, collapse of lifting appliances and transport equipment, collapse of building or structures, gas leakages, landslides, floods etc.
- v) Department should ensure that a mock drill of the onsite emergency management plan is conducted at least once every six months.

3.14.4 Medical facilities:

Medical facilities shall be provided to arrange immediate relief to accident victims. A fully equipped first-aid box shall be made available at the plant or at the site. A few persons (say 5) should be trained in first-aid procedures amongst whom at least one shall always be available during the working period.

Arrangements for procuring ambulance van for transportation of persons involved in serious accident or sickness to the hospital; shall be made at short notice.

3.14.5 Safety Training and Awareness:

Regular training programmes should be conducted for all employees covering general safety awareness, first-aid, emergency procedures including shock treatment, use of personal protective equipment, safety pre-cautions while handling electro-mechanical equipment, use of different types of fire fighting equipment, response in the event of emergencies including fire, floods, landslides, earthquakes etc., site specific hazards and relevant safety acts, rules and regulations.

Project implementing officer shall ensure that adequate safety training is provided by the contractor to his personnel.

3.14.6 Safety Manual for construction of Substations and lines:

A Safety Manual shall be prepared with the following contents:

Safety policy, Safety organization, Responsibilities of contractor, responsibilities of employees, Reporting of accidents, Enquiry of accident/dangerous occurrence, occupational health and medical facilities, emergency management plan, location of safety equipment and emergency facilities in the substation, safety inspections/audits, Safety training, awareness and promotion, Personal protection equipment, communication facilities, Fire prevention and protection, emergency escape routes.

Tools for working at height: Scaffolds, Ladders, Working platform, Fall arresting equipment, Temporary stairs, Suspended jhoolas, Floor openings.

Safe working environment: Illumination and emergency lighting, Noise pollution, Harmful gases and dust pollution, Thermal radiation, Ventilation, Confined spaces.

Safety in handling oils, Safety in painting works, Safety in transportation, earth moving equipment and other construction equipment/machinery, Safety in use of electricity

Safety in handling electrical equipment such as: Earthing of equipment, working on bus-bars, transformers, circuit breakers, insulators etc, Working on lines during installation of insulators, stringing of conductors, jumpering and fixing of spacers/vibration dampers, EHV/HV static capacitor banks, opening or splicing de-energized conductors or overhead ground wires, storage batteries, testing of MV/HV/EHV equipment, SF6 gas filled equipment.

House keeping, Safety in material handling, safety in use of lifting machines and tackles, Safety while lifting heavy equipment, fencing of rotating machinery, Safety during demolition and excavations, Safety while working in any rainy and foggy environment, safety during blasting, Safety in trenches works, Handling and use of explosives, handling of flammable gases, safety in piling, safety in structural steel works, Safety in concreting work, Safety in welding and cutting operations, Safety in grinding and machining, safety in use of hand tools and power operated tools, Safety in waste disposal, safety in road cutting works, working adjacent to rail tracks& roads .

VOLUME - IV

MANUAL ON TESTING&COMMISSIONING OF EHVSUBSTATIONS AND LINES

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4.1 SUBSTATION

TESTING OF EQUIPMENT

4.1.1 POWER TRANSFORMERS

After installation of transformer on the plinth, accessories viz. Radiators, Headers, Bushings, Air Blowers, Oil pumps with connecting pipes, OLTC Drive mechanism and the connecting pipes to diverter switch compartments, Marshalling box, etc. have to be mounted on the transformer as per the manufacturers' drawings.

Oil should be admitted into the transformer from its bottom valve and suction side to be connected to the top valve to evacuate nitrogen/dry air inside the transformer as the oil fills from the bottom. It is preferable to fill the oil received from the works (in barrels) into an oil tanker of sufficient capacity and filter this oil separately. This helps in removing moisture absorbed in the oil during transport and storage. Fairly moisture free filtered oil now can be admitted from the oil tanker to the transformer.

The following check list provides various checks to be conducted for transformer assembly.

1	Availability of erection drawings and literature at site	Yes/No
2	Whether all components available at site in good condition	Yes/No
3	Rinsed all the piping, radiators, conservator etc. with 60kV tested oil and blocked with dummy plates	Yes/No
4	Filtered the oil for 60kV BDV and recorded in the erection register	Yes/No
5	Measured the IR values of HV, MV condenser type bushings(with a 5kV megger) and observed more than 5000 MΩ after removing coverings, wrappers etc and cleaning	Yes/No
6	Washed with hot oil (in case of other bushings of plain porcelain type)	Yes/No
7	Assembled the bushing after fixing corona shield and removing links and bends in pull through leads, on the turret at proper incline	Yes/No
8	Complete assembly of HV, LV, Ter. & Neutral bushings done correctly	Yes/No
9	Completed all piping work, conservator, explosion vent, equalizer pipes etc. as per the drawing and filled with oil , Bucholz relay checked	Yes/No
10	Filled radiator after washing individually and ensuring removal of blanking plates and free movement of butterfly valves both top and bottom	Yes/No
11	Measured IR values with temperature after filling of oil and compared with factory test value and recorded in the register.	Yes/No
12	For drying out of Transformer	
	(a) Applied proper lagging around the transformer. Fire fighting equipment kept at site	Yes/No
	(b) Filter machine cleaned and filled with transformer oil	Yes/No
	(c) Filter connected with outlet into the conservator and inlet from the bottom tank	Yes/No

	(d) Filter heaters switched on and the filter temperature maintained less than 60°C and filter vacuum maintained at 755mm of mercury	Yes/No
	(e) Dehydration process for 7 days maintained oil temperature 60°C in the transformer (thermometer pockets filled with oil)	Yes/No
13	Filled the radiators with 60kV BDV tested oil. Opened the bottom butterfly valve provided between main tank and radiators after opening top air release valve to communicate with main tank	Yes/No
14	All gases released from different release points in the order of ascending heights	Yes/No
15	HV, LV, Tertiary Neutral earthing provided	Yes/No
16	Petroleum jelly applied in clamps and connectors in the transformer bushing studs and checked the tightness	Yes/No
17	Blue silica gel crystals of 2.5 to 4mm size filled in the breather. Breather filled with oil after removing bottom cup, transit protection cover, cork packing etc.	Yes/No
18	Removed blanking plates on explosion vent pipe and fixed diaphragm	Yes/No
19	In case of transformers provided with thermo-siphon filter and air-cell (pronol bag) breathing arrangement checked up as per manufacturers recommendations	Yes/No
20	All air release points and other points thoroughly checked to ensure that there is no oil leakage	Yes/No

4.1.1.1 Testing of Transformer

After installation and assembly at site, the following pre-commissioning tests on transformer should be conducted. These are basically low voltage tests.

- Ratio
- Polarity and vector group
- Measurement of Magnetizing current and No Load losses (3-phase 415V to be supplied on low voltage side of the transformer)
- Measurement of Short circuit current, Load losses and Impedance [at all taps] (3-phase 415volts supply to be given on the high voltage side and the other side shorted)
- Magnetic Balance Test
- Measurement of winding resistance at all taps
- Insulation Resistance and polarization index

4.1.1.2 Testing of Auxiliary Protective devices

Checking of operation of alarms and trips of following auxiliary relays

- i) High temperature settings for oil and winding temperatures
- ii) Bucholz relay and OLTC oil surge relay
- iii) Pressure relief device

Checking for running /stopping of cooler fans and/or oil circulating pumps in groups at the set pressures Conduct all checks and tests on turret mounted CTs as indicated under CTs

4.1.1.3 OLTC

- Checking for manual and electrical operation (both local & remote and lower & raise) of On Load Tap Changer and for continuity between the operations
- Check for operation of limit switches at the extreme tap positions and mechanical interlock between manual and electrical operation
- Check for Master/Follower and out of step relay operation of transformers if parallel operation is intended

4.1.1.4 Tests for reference (Signature): The following tests should be done before commissioning and the results compared with the factory test results. These results should be kept as reference values for comparison with the future test results of these tests while conducting, as a part of O&M later.

- Measurement of Capacitance and $\tan\delta$ of windings, Condenser Bushings
- Dissolved Gas analysis
- Furan Analysis (to measure degree of polymerization)
- Frequency Response Analysis
- Recovery Voltage Measurement
- Oil sample test for Dielectric strength, acidity, specific resistance, moisture content and $\tan\delta$

4.1.1.5 Tests on main protective relays:

The following protective relays connected to the transformer HV/IV/Tertiary sides shall be tested for proper operation duly adopting the settings communicated by the Power systems

- Over current / Earth fault relays (directional/non-directional)
- Operation of the instantaneous elements for the set current value
- Differential relays with bias and restraint features including through current stability
- Restricted Earth fault relays
- Local Breaker Backup (LBB) relays
- Over flux relay
- Under and Over voltage relays

Testing procedures for the above protective relays are described under the topic “Testing of Relays”.

4.1.2 CIRCUIT BREAKERS

Physical checks for any damages to components of the circuit breaker should be made. Tightness of connections at all jumpers, flanges, joints in pipes, valves etc. should be checked. Check for oil/ gas/ air leakages at concerned valves/pipes and all oil seals, gaskets should be made. Checking and tightening of all foundation bolts should be done.

The following pre-commissioning tests/checks shall be conducted.

- Measurement of Insulation Resistance – Phase to earth, Between phases, across contacts with breaker open
- Measurement of Capacitance and $\tan\delta$ of Voltage Grading capacitors. The grading capacitors are oil filled paper capacitor type
- Purity and Dew point measurement of SF6 gas at rated pressure of the breaker and at atmospheric pressure
- In ABCBs Dew point of air to be measured. Air serves as insulation as well as arc quenching medium
- Measurement of CB close, open, close-open, timings with CB Operation analyzer
- Measurement of Dynamic contact Resistance and contact travel
- Operation of Pole Discrepancy relay: To measure the difference in closing and opening times of different poles of CB where the poles are individually operated (220kV and above). Simultaneous closing of all the three poles in case of a three pole/ gang operated breaker (132kV and below)
- Check for proper working of carrier inter trip and auto-reclose features (for feeder breakers)
- Check for capacitor tripping device where provided
- Measurement of resistance and current drawn by close coil and trip coils I&II
- Checking of interconnecting cables to bay marshalling box
- Checking of operating mechanism
- Checking of operation counter and all mechanical indications
- Checking of all Non-return valves/ Safety valves
- Checking of local/remote breaker operations

Check for correct operation of following operational lockouts at set pressures

- SF6 gas pressure- alarm and lockout at different set pressures
- Pneumatic operating system – Automatic start/stop of air compressor at set pressures
- CB closing lockout
- CB operational lockout
- CB auto-reclose lockout

4.1.3 CURRENT TRANSFORMERS

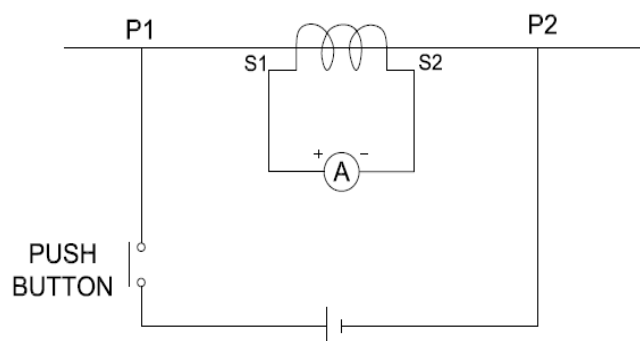
Physical observation of the CTs for proper installation with respect to the drawings and SS layout should be made. Tightness of bolts of support structures to the foundation and CT base mounting to the support structure shall be ensured. Oil leakages in case of oil filled CTs and SF6

gas leakages/rated pressure of gas in case of SF6 gas filled CTs to be observed. Bellows provided for taking care of oil expansion shall be checked for proper functioning.

The following checks and electrical tests shall be conducted.

- Checking of tightness of all electrical connections including connections made in the marshalling box.
- Checking for tightness of CT secondary terminals and checking healthiness of secondary terminal bushings.
- Checking for short circuiting the secondary terminals of such CT secondary windings which are not required. Shorting should be done at secondary terminals in the CT secondary terminal box.
- Checking for earthing of common point of three phases of each secondary winding at one point only, preferably at the marshalling box.
- Measurement of IR values including Di-electric absorption ratio and Polarization index of primary to body and primary to secondary with a 5 kV megger
- Measurement of IR values between secondary winding of each core to body and between different secondary windings of the CT with a 0.5 kV megger
- Measurement of capacitance and $\tan\delta$ of the CT.
- Measurement of secondary winding resistance of each secondary winding
- Testing for Magnetization characteristics (knee point voltage) of CT cores.
- Ratio test for approved CT ratios in all the cores including complete wiring in the secondary side (up to the C&R panels) to ensure correct ratio and continuity of the wiring.
- Check for polarity of CTs, to ensure correct directional sensitivity of metering and protection system.

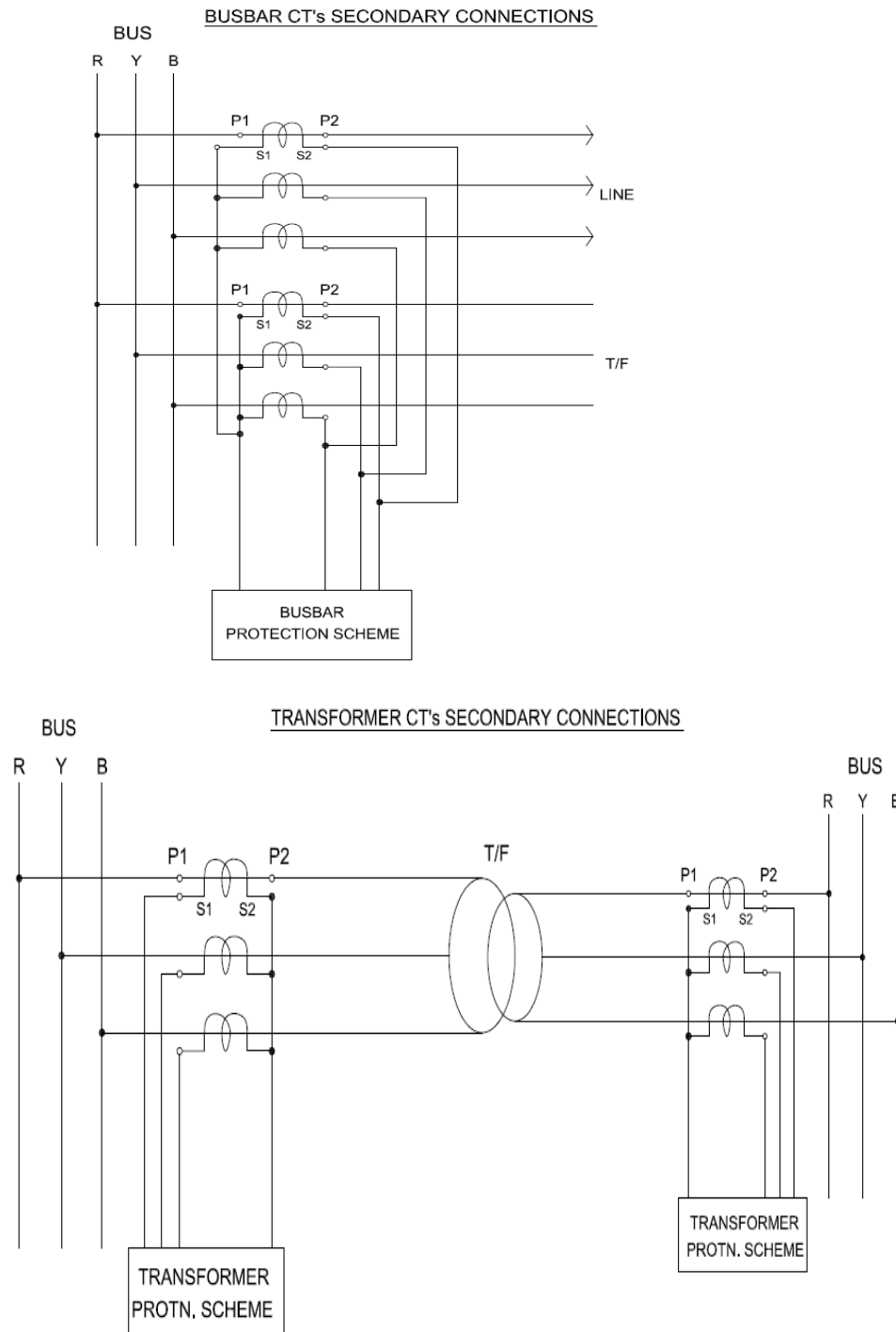
Each CT should be individually tested to verify the polarity markings on primary and secondary windings. Test circuit is given below.



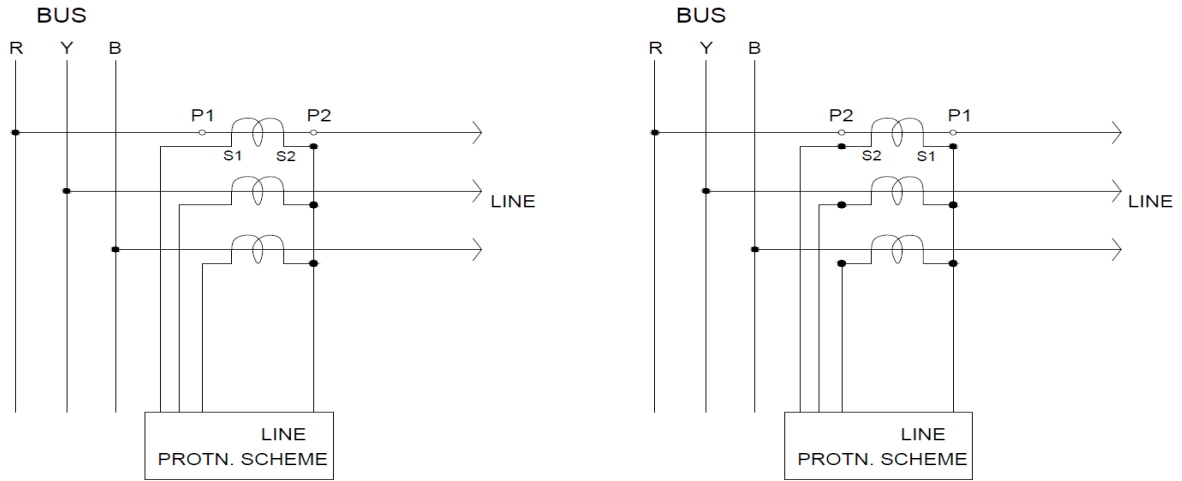
CT Polarity test

Ammeter “A” is a robust moving coil permanent magnet center zero type instrument. Primary winding is given DC supply momentarily from a low voltage battery through a push button. When push button is pressed with the above markings on CT and ammeter, the ammeter should give a +ve flick, indicating correct polarity. Multi meters and Digital ammeters can also be used.

CT secondary connections to transformers, bus bars, and feeders:



LINE CT's SECONDARY CONNECTIONS



Where CT secondary connections are to be made in star, the star point should be made as follows.

Irrespective of the polarity on the primary side, star point on secondary side shall be on line side for feeders and on the equipment side for the bus bars, and transformers as shown in the figures in the previous page.

Eg. In case of a feeder protection, if P1 is towards the bus, then S2s' are to be shorted and if P2 is towards bus then S1s' are to be shorted.

4.1.4 VOLTAGE TRANSFORMERS (CVTs / IVTs)

Visual observation for any cracks/breakages should be made. Mounting of capacitor stacks, electro magnetic units, and terminal box shall be checked for correctness as per the drawing. Tightness of foundation bolts connecting the support structures to the foundation and the bolts connecting base of the VTs/CVTs to the supporting structures should be ensured. The following checks shall be made.

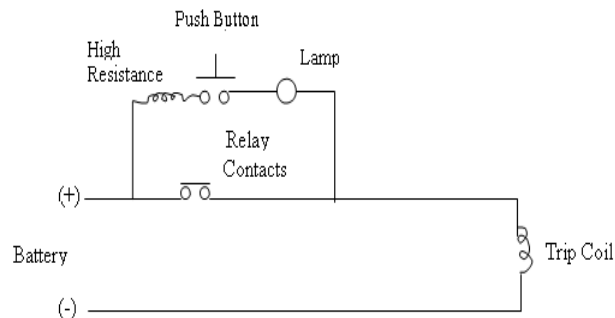
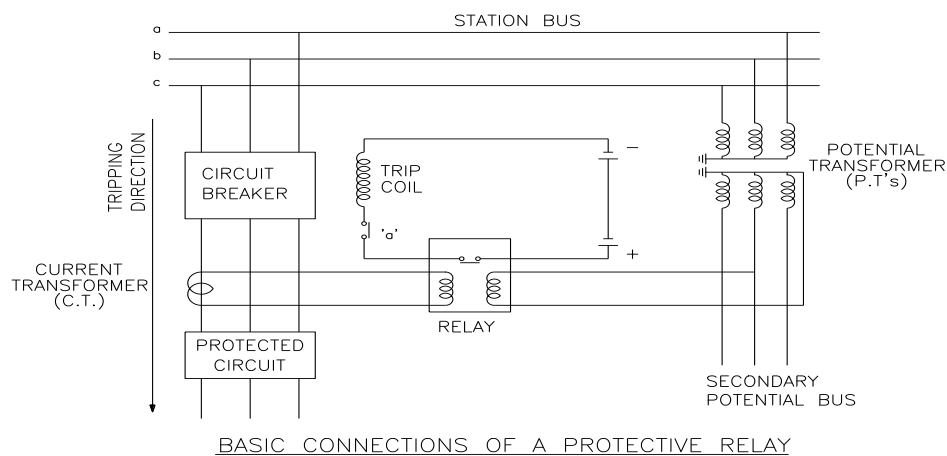
- Check for tightness of all electrical connections on primary and secondary sides of CVTs/VTs including connections in the marshalling box.
- Check for oil leakages and oil level
- Ratio test –voltage in all the secondary windings should be measured
- Insulation resistance of primary to body and primary to secondary windings to be measured by a 5 kV megger
- Insulation resistance of secondary to body and between secondary windings to be measure by a0.5 kV megger
- Measurement of capacitance and $\tan \delta$ of CVTs
- Checking of HF point in case of CVTs. Caution given on the name plate by the manufacturer should be followed
- Check for adopting the approved ratios and connections for different secondary windings

4.1.5 PROTECTIVE RELAYS

Function of Protective Relaying

It is to cause a prompt removal from service of any element of a power system when it suffers a short circuit or when it starts to operate in any abnormal manner that might cause damage or otherwise interfere with the effective operation of the rest of the system. The relaying equipment is aided in this task by circuit breakers that are capable of disconnecting the faulty element when they are called upon to do by the relaying equipment.

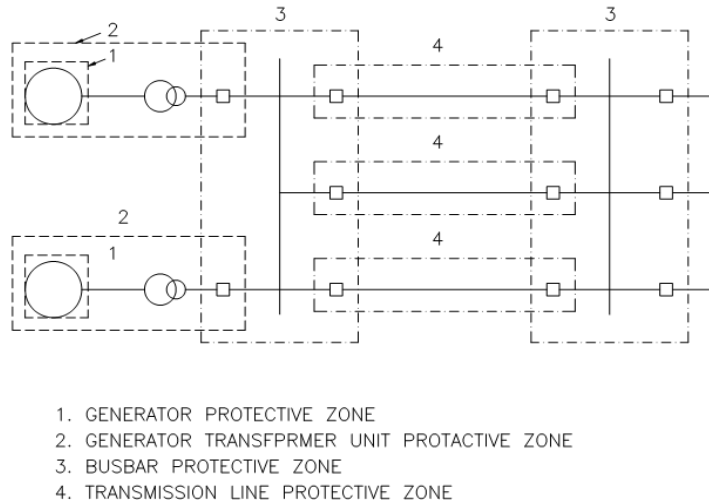
The basic connections of a protective relay and healthy trip circuit are indicated below.



4.1.5.1 Functional requirement of relay:

- i) **Reliability:** The most important requisite of protective relay is reliability since they supervise the circuit for a long time before a fault occurs; if a fault then occurs, the relays must respond instantly and correctly.
- ii) **Selectivity:** The relay must be able to discriminate (select) between those conditions for which prompt operation is required and those for which no operation, or time delayed operation is required.

- iii) **Sensitivity:** The relaying equipment must be sufficiently sensitive so that it operates reliably when required under the actual conditions that produces least operating tendency.
- iv) **Speed:** The relay must operate at the required speed. It should neither be too slow which may result in damage to the equipment nor should it be too fast which may result in undesired operation.



PROTECTIVE ZONES

4.1.5.2 Norms of Protection being followed in APTRANSCO Lines

Sl.No.	Voltage	Protection Scheme
1.	400 KV Line	Main-I: Non switched or Numerical Distance Scheme Main-II: Non switched or Numerical Distance Scheme
2.	220 KV Line	Main-I: Non switched distance scheme (Fed from Bus PTs) Main-II: Non switched distance scheme (Fed from line CVTs) With a changeover facility from bus PT to line CVT and vice-versa.
3.	132 KV lines	Main Protection: Switched or numerical distance scheme (fed from bus From Bus PT) Back up Protection: 3 Nos. directional IDMT O/L Relays and 1 No. directional IDMT E/L relay.
4.	33 KV lines	Non-directional IDMT 3 OIL and 1 E/L relays.
5.	11 KV lines	Non-directional IDMT 2 OIL and 1 E/L relays.

Note: 33kV and 11kV lines are provided with instantaneous elements

Bus bars: All 220 KV and 400kV bus bars will have busbar protection scheme with main and check zone

Breaker failure protection: The LBB protection scheme will be provided for all 220KV and 400kV stations (along with busbar protection scheme)

Transformers:

Voltage ratio & capacity	HV Side	LV Side	Common relays
i. 132/33or11KV above 8 MV A and below 31.5 MV A	3 O/L relays + 1 dir. E/L relay	3 O/L relays + 1 E/L relay	Differential, Buchholz, OL TC Buchholz, OT, WT
ii. 132/33 or 11KV, 31.5 MVA & above	3 O/L relays + 1 dir. E/L relay	3 O/L relays + 1 E/L relay	Differential, Over flux, Buchholz, OL TC PRV,OT, WT
lii. 220/33 or 11KV, 31.5MVA& 50MVA 220/132KV, 100 MVA	3 O/L relays + 1 dir. E/L relay	3 O/L relays + 1 dir. relay	Differential, Over flux, Buchholz, OL TC PRV,OT, WT
iv. 400/220KV 315MVA	3 directional O/L relays (with dir.highset) + 1 directional E/L relays. Restricted E/F relay + 3 Directional OIL relays for action	3 directional O/L relays (with dir.highset)+ 1 directional E/L relay. Restricted E/F relay	Differential, Over flux, Buchholz, OL TC PRV, OT, WT and overload (alarm) relay

4.1.5.3 DEVICE NUMBERS AND THEIR UNIVERSAL NOMENCLATURE

2	Time delay relay
3	Interlocking relay
21	Distance relay
25	Check synchronizing relay
27	Under voltage relay
30	Annunciator relay
32	Directional power (Reverse power) relay
37	Low forward power relay
40	Field failure (loss of excitation) relay
46	Negative phase sequence relay
49	Machine or Transformer Thermal relay

50	Instantaneous Over current relay
51	A.C IDMT over current relay
52	Circuit breaker
52a	Circuit breaker Auxiliary switch “Normally open” (‘a’ contact)
52b	Circuit breaker Auxiliary switch “Normally closed” (‘b’ contact)
55	Power Factor relay
56	Field Application relay
59	Over voltage relay
60	Voltage or current balance relay
64	Earth fault relay
67	Directional relay
68	Locking relay
74	Alarm relay
76	D.C Over current relay
78	Phase angle measuring or out of step relay
79	AC Auto reclose relay
81	Frequency relay
81U	Under frequency relay
81O	Over frequency relay
83	Automatic selective control or transfer relay
86	Tripping Relay
87	Differential relay
87G	Generator differential relay
87GT	Overall differential relay
87U	UAT differential relay
87NT	Restricted earth fault relay
95	Trip circuit supervision relay
99	Over flux relay
186A	Auto reclose lockout relay
186B	Auto reclose lockout relay

4.1.5.4 Data to be furnished to Power Systems Unit for computing Relay Settings:

(a)Power Transformers:

Voltage ratio, No. of windings, Rated capacity, Short circuit withstand capacity, % Impedance, Tapping range, Method of neutral grounding

Current transformer on HV and IV/LV sides: No. of cores, Ratios of each core and its accuracy class, Rated burden in VA, Short circuit withstand capacity, Knee point voltage of protection class cores

Bus PT on HV and IV/LV sides: Ratio, No. of windings and their accuracy class, Capacitors and intermediate transformer details and compensating reactor details in case of CVTs.

Circuit breakers on HV and IV/LV sides: Rated current, breaking capacity and peak making capacity, Breaker open and close timings, Individual pole operated/ gang operated, pole discrepancy features

Control & Relay Panels: Make and type of relays

(b) Capacitors:

Rated Voltage, Current, KVAR rating and capacitance of individual capacitor, Total No. of capacitors and no. of parallel / series groups per phase, Single or double star formation, Inrush current capability,

Series reactor: Rating, inductance, rated current, inrush withstand current

Current transformers: No. of cores, ratio of each core and accuracy class, Rated burden in VA, Short circuit withstand capacity

Neutral Displacement protection: Method of neutral unbalance protection i.e. by Neutral CT or by RVT, ratios/ voltage ratings

Circuit breaker: rated current, breaking capacity and peak making capacity, breaker open and close timings

Control & Relay Panels: Make and types of relays provided, particulars of automatic power-factor correction relays provided and switching steps/ sequence, if any

(c) Transmission Lines:

Line length in Km, Size of conductor and no. of sub conductors per phase, configuration of the line, No. of locations

Current Transformers: No. of cores, Ratio of each core and accuracy class, rated burden in VA, short circuit withstand capability, Knee point voltage of protection class cores

Voltage Transformers (Both line CVT and Bus VT): Ratio, No. of windings and their accuracy class, Capacitors and intermediate transformer details and compensating reactor details in case of CVTs.

Circuit breakers: Rated current, breaking capacity and peak making capacity, Breaker open and close timings, Individual pole operated/ gang operated, pole discrepancy features

Control & Relay Panels: Make and Type of Relays

After receipt of the information as mentioned above; in respect of new substation/ line, new bay in a substation, new line, or augmentation, Power system wing works out the type of protection and the relay settings to be adopted for various relays duly taking into consideration impedance to the source and fault (both remote and dead faults), fault levels at the buses of the substations under consideration, maximum continuous operating voltages and currents etc.

Approved settings for various relays installed in the substation as communicated by Power system unit should be adopted .Testing of relays shall be done adopting the approved settings.

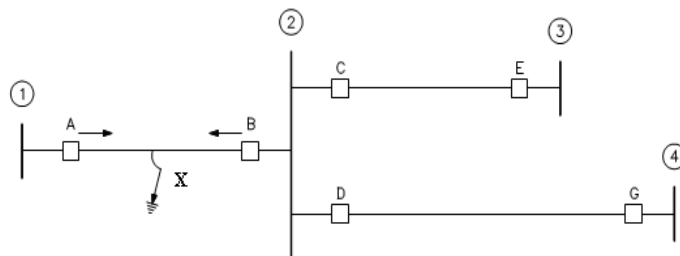
4.1.5.4 TRANSMISSION LINE PROTECTION

Distance Relays Principles

Introduction: In a Power Transmission system, it is impossible to co-ordinate over current or directional over current relays to provide protection for the transmission lines, since for a given fault location, the current seen by the relay varies over a wide range depending upon the system operating conditions.

Impedance relays offer protection of transmission lines connected in a network. Though “Unit” protection is ideal for feeders, it is found that “Unit” protection for feeders is not economical when long lines are involved. A Non-Unit form of protection like distance relay, offers considerable economic and technical advantage. They are comparatively simple to apply, operate with extremely high speed, and both primary and backup protection features are inherent in them. Moreover, they can be easily modified to work as unit schemes by coordinating them with power line carrier facilities and are suitable for high speed reclosing. The impedance relay is made to respond to the impedance between the relay location and the fault point. The impedance is proportional to the distance to the fault, (hence the name ‘distance relay’) and is therefore independent of the fault current levels.

Ex: Consider the following system to be a section of a larger system:



For the fault at X, the relays at A & B will operate in the forward direction (i.e. for currents flowing from the bus onto the line)

A distance relay compares the currents and voltages at the relaying point with current providing the operating torque and the voltage provides the restraining torque. In other words an impedance relay is a voltage restrained overcurrent relay.

The equation at the balance point in a simple impedance relay is $K_1 V^2 = K_2 I^2$ or $V/I = K_3$ where K_1 , K_2 and K_3 are constants. In other words, the relay is on the verge of operation at a constant value of V/I ratio, which may be expressed as an impedance.

For a fault at the far end of the line, the local voltage is the IZ drop in the line and therefore the

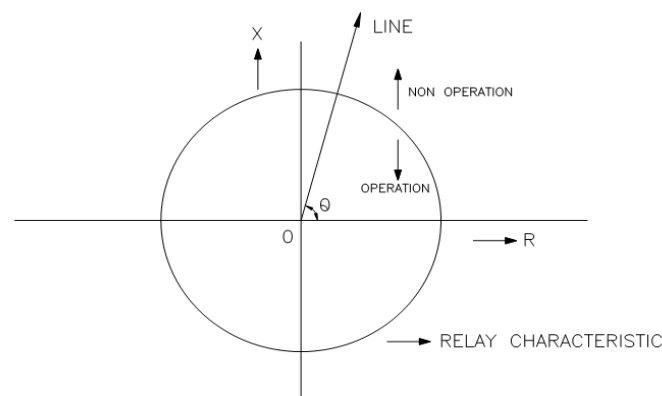
voltage to current ratio for such a fault will be ' Z ', where Z is the impedance of the line. For a fault internal to the protected section, $V/I < Z$ and for a fault beyond the protection section, V/I is $> Z$. The V/I ratio at the relay can be termed as the "impedance" seen by the relay. The relay will operate if the impedance seen by the relay is less than ' Z '. Since the impedance seen is directly proportional to the length of the line between the relay and the fault, it is also a measure of distance to the fault from the relay and hence such relays which compare the voltage and currents are called "distance relays".

Since the operating characteristics of the relay depend upon the ratio of voltage and current and the phase angle between them, their characteristics can be best represented on an R-X diagram where both V/I ratio and the phase angle can be plotted in terms of an impedance $R+jX$. Further, the power system impedance like fault impedance, power swings, loads etc. can also be plotted on the same R-X diagram. Therefore response of a particular relay during power swing, faults and other system disturbances can easily be assessed.

Types of Distance Relays:

- (1) Impedance relay
- (2) Reactance relay
- (3) Mho relay
- (4) Modified Impedance relay

Impedance relay: Characteristics of an impedance relay on R-X diagram is shown in fig

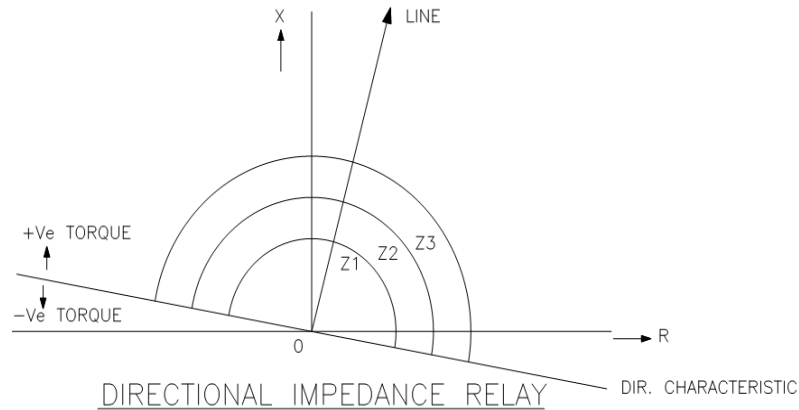


IMPEDANCE RELAY

The numerical value of the ratio of V to I is shown as the length of the radius vector, such as Z and the phase angle between V and I determines the position of the vector, as shown.

Operation of the impedance relay is practically independent of the phase angle between V and I . The operating characteristic is a circle with its center at the origin, and hence the relay is non-directional.

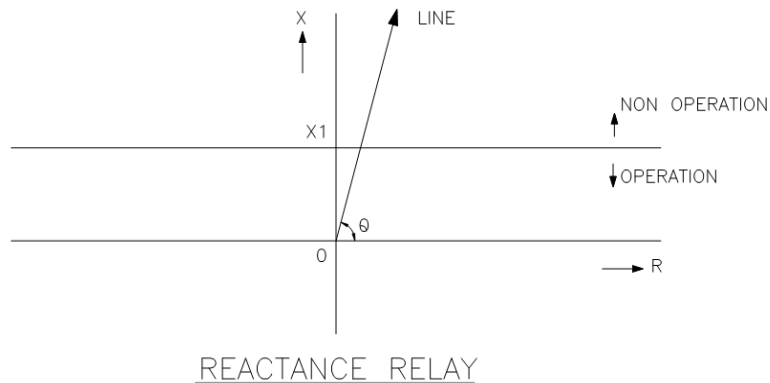
Characteristic of a directional impedance relay in the complex R-X phase is shown below



Along the line impedance locus line, the positive sequence impedance of the protected line as seen by the relay between its location and different points along the protected line can be plotted. The directional unit of the relay causes separation of the regions of the relay characteristic shown in the figure by a line drawn perpendicular to the line impedance locus. The net result is that tripping will occur only for points that are both within the circles and above the directional unit characteristic.

Reactance type Distance Relay

Reactance relay measures $V/I \sin \theta$ (i.e. $Z \sin \theta$). Whenever the reactance measured by the relay is less than the set value, the relay operates. The operating characteristic on R-X diagram is indicated below:



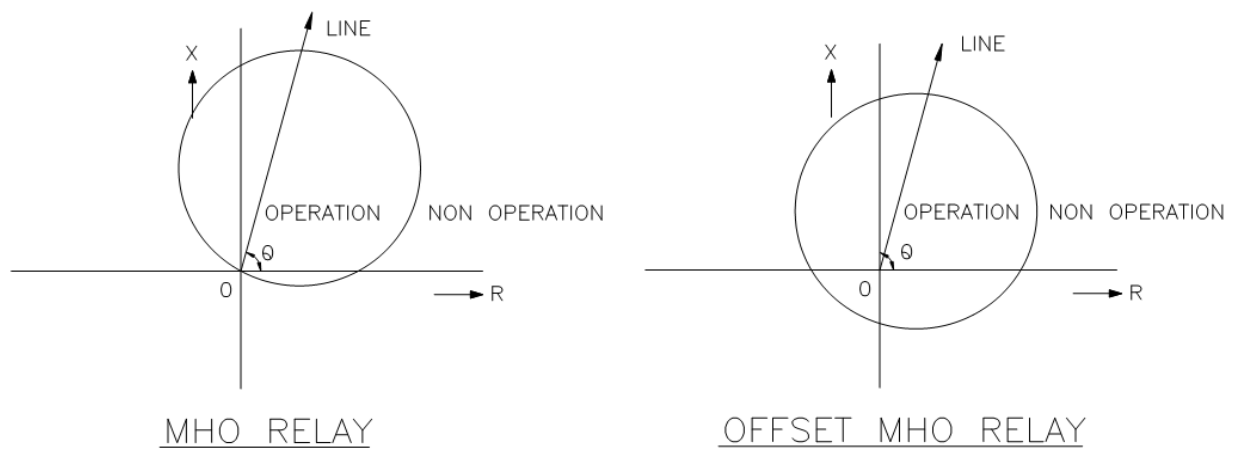
The resistance component of impedance has no effect on the operation of reactance relay. The relay responds solely to reactance component of impedance. This relay is inherently non-directional. The relay is most suitable to detect earth faults where the effect of arc resistance may render other types of relays to detect faults with difficulty.

Mho relay:

This is a directional impedance relay, also known as admittance relay. Its characteristic on R-X diagram is a circle whose circumference passes through the origin as illustrated in Figure below showing that the relay is inherently directional and it only operates for faults in the forward direction.

Modified impedance relay:

Also known as offset Mho relay whose characteristic encloses the origin on R-X diagram as indicated in the figure below



This offset mho relay has three main applications: -

- i) Busbar zone backup
- ii) Carrier starting unit in distance/carrier blocking schemes.
- iii) Power Swing blocking.

Other Operating characteristics

During the days of electromagnetic relays, the characteristics involving straight lines and / or circles on R-X diagram were only possible. With the advent of static relays, microprocessor based relays and presently of numerical relays, desired / required operating characteristic is possible giving wider choice for selection of relays.

DISTANCE RELAYS APPLICATION

Relay Setting

Since the distance relays are fed from the secondaries of line CTs and bus PTs/line CVTs, the line parameters are to be converted into secondary values to set the relay as per requirements.

$$Z_{\text{secy}} = Z_{\text{pri}} / \text{Impedance ratio}$$

(where Impedance ratio = P.T.Ratio/C.T.Ratio)

It is to be noted that C.T Ratios (and P.T Ratios) and relay settings are inter-related. Hence any change in C.T .ratio has to be effected along with revision of relay settings only.

For the lines, the impedance in Ohms per KM is approximately as under:

KV	Z1 (=Z2)	Line Angle
132 KV	0.4	60 to 70 Deg
220 KV	0.4	70 to 80 Deg
400 KV	0.3	80 to 85 Deg

A distance relay is either of 3 zones or 4 zones to provide protection.

To ensure proper coordination between distance relays in power system, it is customary to choose relay ohmic setting as follows: -

Sino.	Zones	Reactance	Time
1.	Zone-1	80% of ZL	Instantaneous o intentional time delay)
2.	Zone-2	100% of ZL + 40-50% of ZSL	0.3 to 0.4 seconds
3.	Zone-3	100% of ZL + 120% of ZSL	0.6 to 0.8 seconds
4.	Zone-4	100% of ZL + 120% of ZLL	0.9 to 1.5 seconds

Where ZL = Positive sequence impedance of line to be protected.

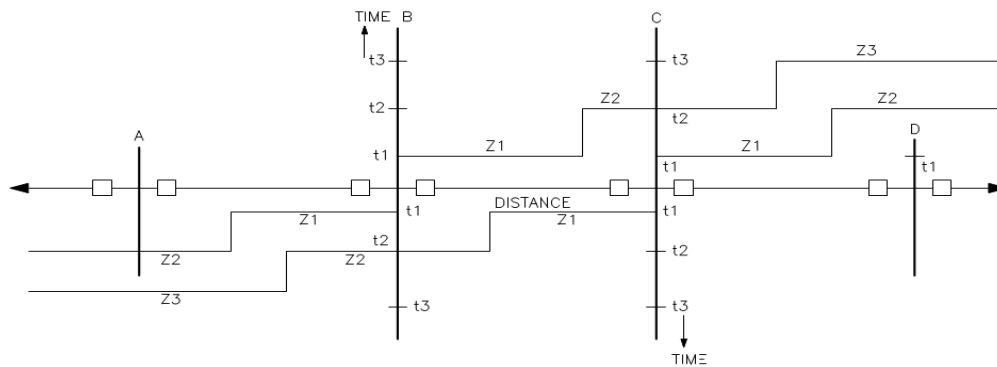
ZSL = Positive sequence impedance of adjacent shortest line.

ZLL = Positive sequence impedance of adjacent longest line.

Note:

- i) Where a three zone relay only is available, the zone 3 will be set to cover the adjacent longest line
- ii) The zonal timings will be carefully selected to properly grade with the relays on adjoining sections.

Typical 3 zone time distance characteristic of distance relay is shown in sketch below:



THREE ZONE TIME-DISTANCE CHARACTERISTICS

The zone-1 reach is limited to 80% of ZL to provide a reasonable margin against a possible overreach due to errors in CTs, PTs, relay measurement, line parameters, etc.

The zone-2 reach is set to cover up to 40-50% of adjoining line so that this will definitely cover the balance 20% of main line (after zone-1 reach) and provides backup to adjoining line relay. Zone-2 setting shall be not less than 120% of ZL in order to ensure definite coverage of 100% of main line.

The zone-3 & zone-4 reaches will be suitably set to provide backup for relays on adjacent lines with proper time gradation.

Distance Scheme consists of the following major components

- i) Starters.**
- ii) Measuring units.**
- iii) Timers**
- iv) Auxiliary relays**
- i) Starters:**

The starting relay (or starter) initiates the distance scheme in the event of a fault within the required reach (more than zone-3).

Other functions of the starter are:

- a) Starting of timer relays for second and third zones.
- b) Switching of the respective faulty phase currents and voltage to the measuring unit in a switched scheme.

The starters are generally of Mho or impedance type.

With Mho type starters: Measuring units for phase and earth faults can be either directional or non-directional as Mho starters are inherently directional

With impedance type starters: Measuring units have to be directional as impedance starters are non-directional.

The under impedance in conjunction with the directional relay also can be used as starter which will then function similar to the Mho starter.

ii) Measuring units: They are generally of a mho or reactance or a combination of mho, reactance and resistance types.

Phase Fault Units:-

These measuring units are fed with line to line voltages (such as V_a , V_b) and difference between line currents (I_a - I_b). They measure the positive sequence impedance from the relay location to the fault point. Three such relays respond correctly to all possible single line to ground faults line to line faults, double line to ground faults and 3-phase faults. They however do not respond correctly to earth faults.

Earth Fault Units: -

These measuring units utilize line to neutral voltage (V_{an} , V_{bn} , V_{cn}) and phase currents (I_a , I_b , I_c). In order to make these units measure the positive sequence impedance correctly, a zero sequence current compensation is to be provided which is obtained by:

$KN = (Z_0 - Z_1) / 3 * Z_1$ (where Z_1 = positive sequence impedance of line. Z_0 = Zero sequence impedance of line)

In the current circuit $(1 + KN) I_a$ will be fed for the above measurement.

iii) Timers: Timer relays when initiated by starters provide the time lag required for zones. They also will be used for zone extension purpose whenever required.

iv) Auxiliary relays: Distance scheme comprises of several auxiliary relays, which perform functions such as flag indications, trippings, signaling, alarm etc.

Additional Features in distance schemes: -

- i) Power Swing blocking relay**
- ii) VT fuse failure relay.**
- iii) Switch onto fault relay**
- iv) Fault locator**
- v) Auto-reclosing scheme.**
- vi) Carrier communication scheme**

i) Power Swing blocking:

Distance relay which respond to balanced 3-phase changes in the impedance will be affected by power swings. These swings or oscillations occur following a system disturbance such as major load change or a dip in voltage due to delayed fault clearance.

As generators in the system strive to find a stable operating angle relative to each other, the

distance relays enroute on the line may see these conditions as three phase fault and falsely operate to trip their breakers. To avoid such operation, power swing blocking relays is used.

In case of fault, the transition from period of impedance locations (25 to 33% of starter impedance) to fault impedance (starter impedance) is sudden whereas during power swings, the transition to swing impedance is slow; the PSB relays use this difference to block the tripping during swings.

While the old schemes have blocking in all three zones, new static / Numerical schemes have the feature of blocking any particular zone of our choice.

ii) VT fuse failure relay:

The distance relays being voltage restraint O/C relays, loss of voltage due to main PT fuse failure or inadvertent removal of fuse in one or more phases will cause the relay operation. The fuse failure relay will sense such condition by the presence of residual voltage without residual current and blocks the relay.

iii) Switch onto fault:

Under normal service conditions, a close- by 3-phase fault will be seen by the relays in zone-1 and clear the fault instantaneously. But when the line is switched on to a close by fault (say after line clear with earth switch closed), the voltage at the relaying point will be zero. Faults of this type will normally be cleared by backup zones.

The voltage applied to the relay is low and this condition occurring simultaneously with the operation of starter will cause instantaneous trip by SOTF relay. This SOTF feature will be effective only for about 1-2 seconds after the line is charged. Faults occurring after this time will be measured in the normal way.

iv) Fault locator:

It measures the distance between the relay location and fault location in terms of Z in Ohms, or length in KM or percentage of line length.

This relay gets same inputs as the distance relay (connected in series with one of the main relays). The measurement is initiated by trip signal from distance relays.

While the distance relay provides general idea of the zone in which fault has occurred, the fault locator gives the exact location of the fault, thereby reducing the time of restoration.

Auto Reclosing Schemes:-

Types of faults:-

- i) Transient Faults: These are cleared by the immediate tripping of circuit breakers and do not recur when the line is re-energized
- ii) Semi-Permanent Faults: These require a time interval to disappear before a line is charged again.
- iii) Permanent Faults: These are to be located and repaired before the line is re-energized

About 80-90% of the faults occurring are transient in nature. Hence automatic reclosure of breaker (after tripping on fault) will result in the line being successfully re- energized, thereby

- a) Decreasing outage time
- b) Improving reliability
- c) Improving system stability

Dead Time: The time between auto-reclose scheme being energized and the operation of the contacts which energize the circuit breaker closing circuit.

Reclaim Time: The time following a successful closing operation measured from the instant the auto-reclosing relay contacts make which must elapse before the auto-reclosing relay initiates another reclosing attempt. In other words, it may be said to be the time between first and second auto-reclosure.

Types of Auto-reclosing schemes (based on phase):

a) Three Phase Auto-reclosing:-

This type of auto-reclosing causes an immediate drift apart of the two systems and hence no interchange of synchronizing power can take place during the dead time.

b) Single Phase Auto-reclosing:-

In this, only the faulty phase (which already has tripped on SLG fault) is reclosed without causing interruption in interchange of synchronizing power between two systems through other two healthy phases.

Types of Auto-reclosing schemes (based on attempts of reclosure)

a) Single shot Auto-reclosing:-

In this scheme, breaker is reclosed only once on a given fault before lockout of circuit breaker occurs. High speed auto-reclosing for EHV system is invariably single shot.

b) Multi-shot Auto-reclosing:-

In this scheme, more than once reclosing attempt is made for a given fault before lockout of the circuit breaker occurs. Repeated closure attempts with high fault level would seriously affect the circuit breaker, equipment and system stability. Factors that must be taken into account:-

i) Circuit Breaker Limitations:

Ability of circuit breaker to perform several trip close operations in quick succession.

ii) System conditions

If the percentage of the semi-permanent faults (which could be burnt out) is moderate, for example on the lines through the forest, multishot auto-reclosing is followed.

Types of Auto-reclosing (depending on speed)

i) High speed Auto-reclosing

This aids in fast restoration of supply but should be done, taking into account the following factors:-

- System disturbance time can be tolerated without loss of system stability
- Characteristics of protection schemes and circuit breaker.

ii) Low speed or Delayed Auto-reclosing:-

This is suitable for highly interconnected systems where the loss of a single line is unlikely to cause two sections of the system to drift apart and lose synchronism.

For EHV Systems

1) Choice of Dead time:

Lower limit is decided by de-ionising time of circuit breaker.

Upper limit is decided by transient stability and synchronism

Long transmission lines require longer dead time for single phase faults.

The dead time for high speed auto-reclosing scheme with EHV system is 0.3-0.8 Sec.

2) Choice for reclaim time:-

This should not be set to such a low value that the operating cycle of breaker is exceeded when two fault incidents occur close together. The reclaim time will be in the range of 10-30 Secs. depending on the breaker opening and closing mechanisms.

3) Carrier Communication Schemes

The main disadvantage of conventional time-stepped distance protection is that the instantaneous zone-1 of the protective scheme at each end of the protected line is set to cover 80% of the line and hence faults in the balance 20% of the line (at each end) are cleared in zone-2 time, which is undesirable.

The desirable scheme is the one wherein the relays clear the faults on the 100% of the protected line instantaneously and also provide backup for uncleared faults on adjacent lines. This can be achieved by interconnecting the distance relays at each end of the line by a signaling channel (which can be either pilots, a power line carrier communication channel, a radio link or a microwave channel).

The purpose of the signaling channel is to transmit the information about the system conditions at one end of the protected line to the other end and initiate or prevent tripping of the remote circuit breaker. The former arrangement is referred to as a "Transfer trip scheme" while the latter is known as a "blocking scheme".

a) Transfer trip scheme

In this scheme, the distance relay at one end of the protected lines sends a carrier signal to the relay at other end of the line for inter-tripping, thereby clearing the faults on entire line

instantaneously. Transfer trip schemes are of two types:

i) Under-reaching scheme:

The scheme in which the zone-1 relay (set to cover about 80% of ZL) is used to send a signal to the remote end of the feeder for inter-tripping is termed as transfer trip under- reaching scheme. To avoid mal-operation due to receipt of false signal, the receiving end relay operation is inter-locked with its Zone3 / starter operation i.e., the scheme operates either by its own Zone-1 relay operation or by receipt of carrier command and its Zone-3 / Starter operation.

ii) Over-reaching scheme:-

This scheme is suitable for short lines where an under-reaching zone-1 would be too short to be of any practical use. In this scheme the relay set to reach beyond 100% of the line, is used to send an inter-tripping signal to the remote end of the line. It is essential that the received relay contact be monitored by a directional relay to ensure that tripping does not take place unless the fault is within the protected section. The disadvantage of this scheme is that there is no independent Zone-1 tripping. The fast tripping therefore realize entirely on signaling channel.

The disadvantage of these schemes is that the signal is transmitted over the faulty line section. Distortion of the signal may occur due to attenuation introduced into the line by the fault.

b) Blocking schemes:-

In this scheme, a blocking signal is sent by the reverse looking directional unit ZR to prevent instantaneous tripping for Zone-2 & Zone-3 faults, external to the protected line. Here ZR must operate faster than forward looking Zone-3 units and the signaling channel must also be extremely fast in operation.

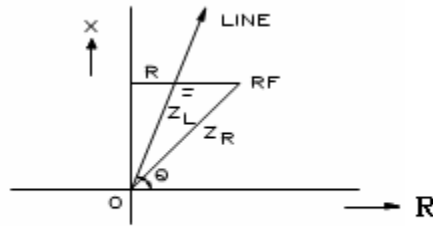
Factors affecting distance relay operation:-

- i) Fault resistance.**
- ii) Infeed effect.**
- iii) Branching-off effect.**
- iv) Load encroachment.**

i) Fault resistance: Fault resistance has two components:

- a) Arc resistance. b) Ground resistance.

In a fault between phases, only arc resistance is involved.



EFFECT OF FAULT RESISTANCE

For a fault at F, the actual line impedance = $R + jX = Z_L$

Due to the presence of fault resistance, the impedance measured by the relay = $R + jX + R_F = Z_R$ (where $Z_R > Z_L$)

Fault arc resistance is given by Warrington's formula:

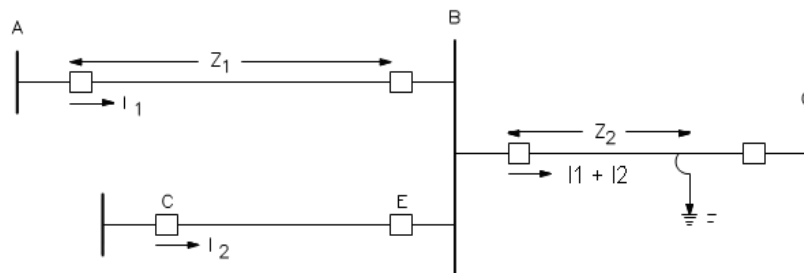
$$R_{\text{arc}} = 8750 \times L / I^{1.4}$$

where L = length of arc in ft, I = fault current in Amps

The arc resistance has little effect on accuracy of zone-1 unit as it operates instantaneously before the arc can stretch appreciably except in case of short lines. Reactance relays are therefore used for short lines where the fault resistance may be comparable with that of the protected lines and also for ground faults where the ground resistance is high.

The arc resistance will have greater impact on accuracy of backup zones (time delayed) as the arc stretches appreciably.

ii) Infeed effect: The effect of intermediate current source between relay location and fault point is termed as infeed effect. Consider the following example:



INFEEED EFFECT

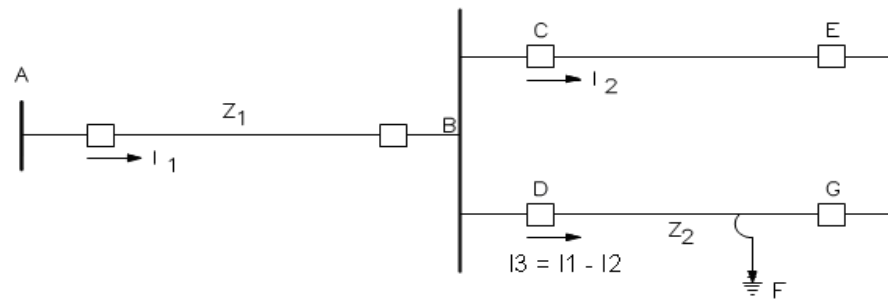
A fault at F on the line BC is at a distance of $Z_1 + Z_2$ for the relay at station A. But when current I_2 flows from bus D, the impedance to the fault as seen by the relay at A is

$$Z_1 + Z_2 + Z_2 \times (I_2/I_1).$$

Thus the fault is seen by the relay as farther than what it really is, i.e. distance relay under reaches due to the infeed effect.

The effect of infeed becomes more pronounced with more interconnections at station- B.

iii) Branching-off effect: Consider the following example:



BRANCHING OFF EFFECT

A fault at F is at the distance of $Z_1 + Z_2$ for the relay at station A. But when current I_1 gets distributed as I_2 & I_3 at station B, the impedance to fault seen by the relay at station A will be $(Z_1 + I_3/I_1 * Z_2)$ which is less than $(Z_1 + Z_2)$.

Then the fault is seen by the relay as nearer than what it really is i.e. distance relay overreaches due to branching-off effect. This overreaching tendency will cause the relay to lose its selectivity.

iv) Load encroachment: While protecting long lines the necessary reach may be so large that the minimum service impedance (or load impedance) falls within the region of the starter. This would result in tripping without there being any fault. The two conditions i.e. operation at heavy load and short circuit differ by virtue of phase angle between voltage and current. For the load impedance, the phase angle will be within $+30$ to -30 Deg. While during short circuits, the fault impedance has a phase angle of 60 to 80 deg. (i.e. line angle).

Load encroachment problem is more pronounced in case of under impedance starters and gets lessened in case of mho, elliptical, lens etc, type of starters. Relays with suitable characteristic on R-X diagram have to be carefully chosen to protect long and heavily loaded lines, and this becomes easily possible with microprocessor based numerical relays.

Non-switched scheme vs. Switched scheme:

In an ideal Non-switched scheme, there will be 6 starters, 3 for phase faults and 3 for ground faults. There will be independent measuring units for both phase faults and earth fault for each phase, for all three zones, totaling to 18 units. This scheme is faster and more accurate but is costly.

In the switched scheme, only one measuring unit will be used for all types of faults. This single measuring unit is switched to the correct fault loop impedance by switching-in the respective

voltages and currents by the starter.

The reach of the measuring element gets extended to zone-2 and zone-3 after the elapse of corresponding timings through zone extension process. Switched scheme is relatively slow in operation and has the risk of total scheme failure in the event of failure of the only one measuring unit available.

Zone extension schemes:

As a via media between non-switched and switched schemes, there are schemes with zone extension facility (such as EE make MM3V & MR3V relays). These schemes consist of 3 measuring units for phase faults and 3 measuring units for earth faults (apart from 3 starters).

The reach of the measuring unit gets extended to zone-2 and zone-3 after elapse of corresponding timings through a zone extension process.

4.1.5.5 Development in Relay technology

Till 1980 almost all the relays available were electromechanical. Later 80s static relays were introduced. Early 90s Microprocessor based relays came into existence. Numerical relays are in extensive use from later 90s.

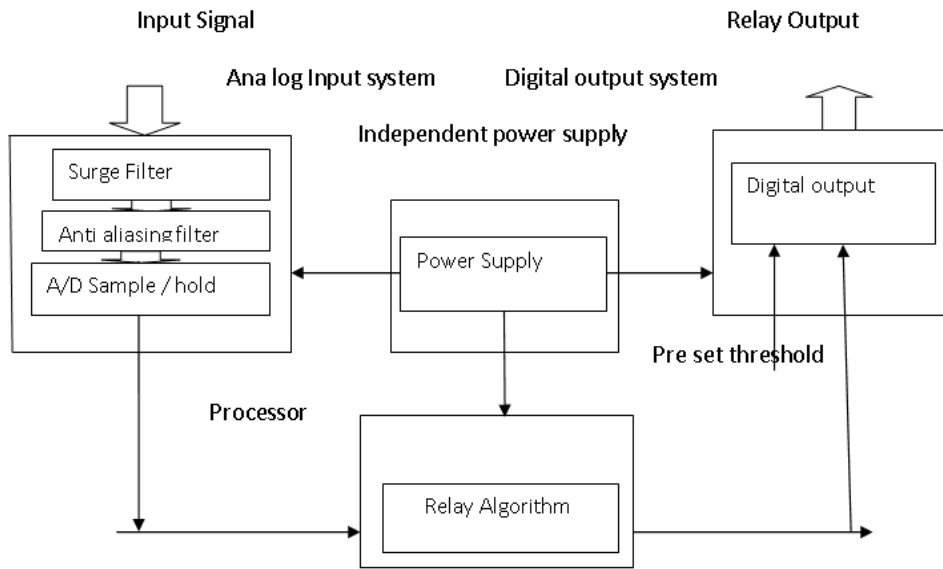
STATIC RELAY: In the solid state relays current signals get converted to voltage signals. Inputs to the relay are fed through the electronic circuits. Output features depend on the rectified DC output. No moving parts are available in these relays. They consume less power to operate and are very fast during switching operations when compared to the Electro mechanical relays.

These relays may malfunction due to transients if present in the inputs. Electronic components may drift due to high ambient temperatures and aging. The switches in the relay have leakage currents irrespective of the switches position.

DIGITAL RELAYS: Filtered signals are converted into wave forms, Calculations are done based on the phase angle comparison and either logics or microprocessors are used in the relay. High speed processors made the relay very fast in its operation. Protection, metering, communication and indication can be integrated in a single chip. Commissioning is easy due to less wiring and few components. Outage time of Feeder/ Transformer gets reduced because of fault locators integrated inside. These relays are small in size and easy to replace.

NUMERICAL RELAYS: Filtered signals are converted into numerical values at each sampling point. Calculations are made in real time using microprocessors.

Block diagram of a typical numerical relay



The numerical relay is a multi function device which supports numerous features like protection, control and communication. Analog inputs (Current and/or Voltages) fed to the relay are converted into digital signals and these signals are filtered in the anti-aliasing filter to eliminate any transients present in the signals. The signal i.e. sampling frequency of analog signal is more than 2000 Hz apart from the electric net work frequency. The processor containing the relay algorithm is the controller of the numerical relay. All features like control, computation, self test, communication etc. are carried out by the Relay algorithm unit. The signal from the input unit is compared with the pre -threshold value in the digital output system.

Numerical relays are normally self-test relays, occupy less space, fast acting when compared with the electromechanical relays. They can store data on Pre-fault as well as post-fault condition. Any CT primary/secondary ratios can be matched. They have less aging problems, better flexibility and number of auxiliary relays can be reduced. Storage of Fault Disturbances is available to study the fault levels as well as status of the CB (values of the current and voltage). The disturbances can be downloaded for analysis. Any change in any digital input signal or protection element output signal is recorded.

Relay settings can be entered through front end panel with a Laptop or HMI. The keypad is normally provided with arrows for menu navigation and for changing the settings. Front port is normally provided with 9-pin straight or cross cable RS 232 serial port for laptop communication. Settings can be saved in 4 to 5 groups and any group can be kept in service. PSL (Programmable and fixed scheme logics) and Topology algorithms needs laptop and soft ware for any modifications. The numerical relays can communicate with other relay or device through Ethernet / Optical fibre cable. These relays can be tested with normal ZFB / OCB or Universal test kits.

SETTINGS AND TESTING OF DISTANCE SCHEME

Distance Relay settings are communicated by the Power Systems wing by considering length of the line, Conductor parameters, loading of the line, instrument transformers available ratios and the distance schemes. After adopting the settings communicated by the Power Systems wing, the schemes will be tested by the MRT wing with a Universal Relay testing kit.

Three phase voltage and current sources are required to test the distance scheme. As per the relay manual and settings communicated by the power systems wing all zone values of Phase to Phase & Phase to ground Faults will be calculated before simulating the fault conditions. Relay characteristics given by the manufacturer will be verified with universal testing kit.

The following points should be observed while testing.

1. Reach check for all zones including reverse zone if provided.
2. Switch on to fault, power swing blocking, Stub Protection, Fault locator initiation, Fuse failure, LBB relay operation and Auto reclose functioning.
3. Trip and annunciation check.

DISTANCE RELAY TESTING

In testing high speed distance relays, it is important to apply simulated fault conditions suddenly; otherwise the behavior of the relay in service may be different from its behavior in test. Checking the relay characteristic by reducing the voltage or increasing the current until the relay operates is not realistic, as the voltage and current change instantaneously in magnitude and phase angle when a fault occurs in service. This causes transient mechanical, electrical and magnetic conditions in the relay which may cause it to over-reach unless its operating time exceeds 4 cycles, during which time the conditions will have disappeared.

Distance relay testing equipment (EE make type ZEB)/ Universal relay test kit is commonly used for testing the distance relays.

Caution: Wherever Main-II relays are being tested, the LBB relay for that breaker should be disabled lest it would operate the busbar protection.

4.1.5.6 TRANSFORMER PROTECTION

Differential relays

A simple differential relay compares the current at both ends of a protected element as indicated below:

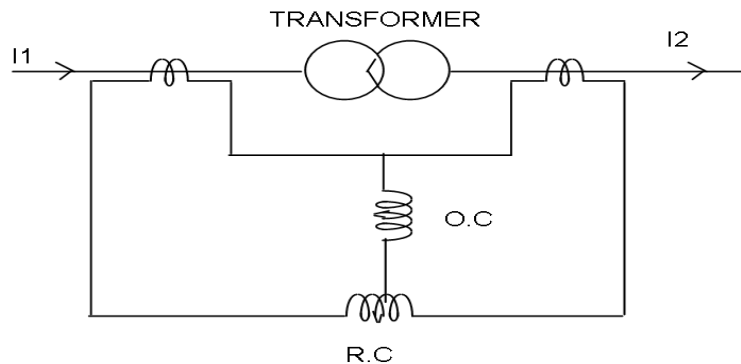
As long as there is no fault within the protected equipment the current circulates between the two CTs and no current flows through the differential element. But for internal faults the sum of the CTs secondary currents will flow through the differential relay making it to operate

PERCENTAGE DIFFERENTIAL RELAY:

Two basic requirements of a differential relay are:

1. It must not operate for load or external faults
2. It must operate for internal faults

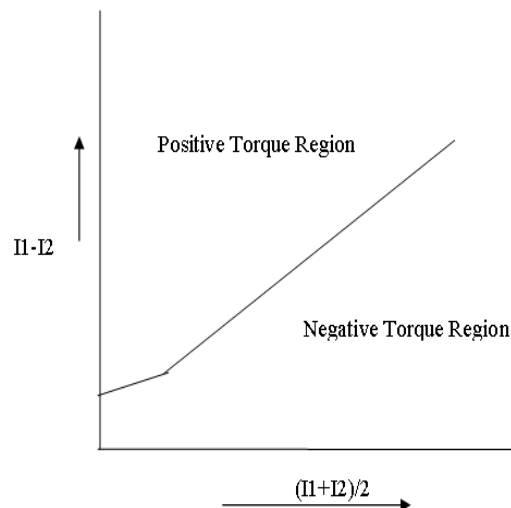
Percentage Differential Relay in a Two Terminal Circuit



As on-load tap change facilities are invariably provided in the grid transformers, any variation from the nominal tap position will result in spill currents in the relay circuits. Further, the CTs are often of different types and have dissimilar magnetization characteristics, again resulting in spill current during heavy through fault conditions.

To avoid unwanted relays operation under the above two conditions a “Percentage bias” differential relays is used.

The operating characteristic of percentage bias differential relay is shown in following figure



In general the transformer primary currents do not equal their secondary current and the connections of the secondary winding do not correspond to those of the primary. In order that the current flowing through the relay should nearly equal zero during normal operating conditions and when external short circuit appear, it is necessary to do everything to have secondary current of the current transformers on the transformer primary and secondary sides of equal order and coincide in phase. This is achieved by accordingly selecting the current transformer ratios, having the method of connection of CTs made in conformity with the vector group of the 3-phase power transformer and by the use of additional auxiliary CTs in the scheme.

SETTINGS AND TESTING OF DIFFERENTIAL RELAY

Differential Relay settings are communicated by the Power Systems wing by considering Power transformer rating, Percentage and number of taps available, current transformers available ratios and the Differential scheme. After adopting the settings communicated by the Power Systems wing the relay will be tested by the MRT wing with a Universal Relay testing kit.

Three phase or Single phase current source is required to test the differential relay. As per the relay manual and settings communicated, the relays will be tested after simulating the fault conditions. Two numbers single phase/three phase current sources are required to test the relay stability. Current inputs are injected into the differential relay of same magnitude and 180 deg phase shift in the same phase to test the stability of differential relay.

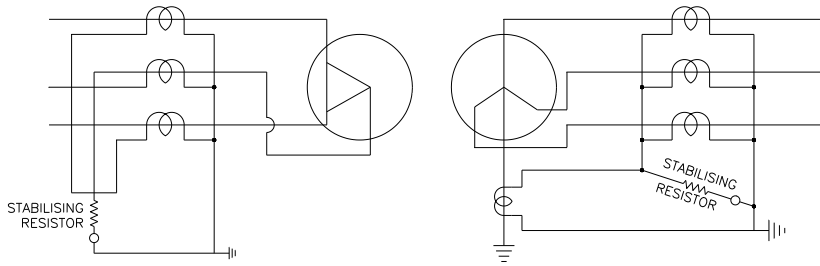
The following points should be observed while testing.

1. Pick up current at the fixed and selected setting
2. Operation of high set element at fixed and selected setting
3. Through current stability check on the existing load
4. Operation of trip and alarm contacts.

Restricted Earth Fault Protection (REF):

An earth fault in the winding is the most common type of transformer fault and is best detected by using a 'restricted' form of earth fault protection. In this way time and current setting can be made independent of other protection systems, thus low settings and fast operating times can be achieved.

The restricted scheme is a balanced system of protection and can be applied to either Star or Delta windings. The scheme connections of either types of winding are shown in figure.



RESTRICTED EARTH FAULT PROTECTION OF TRANSFORMER

For the star winding, three line current transformers are balanced against a current transformer in the neutral connection; while on the delta side, the three line current transformers are connected in parallel.

An external fault on the star side will result in current flowing in the line current transformer of the affected phase and a balancing current in the neutral current transformer, the resultant current in the relay is therefore zero and hence the relay is stable. During an internal fault, the line current on the line CT gets reversed and hence relay operates.

The arrangement of residually connected CTs on the delta side of a transformer is only sensitive to earth faults on the delta side because zero sequence currents are blocked by the delta winding. For example, an earth fault on the star side transferred through transformer appears on the delta as a phase fault. Therefore the arrangement is an inherently restricted earth fault scheme in this application.

For external faults no current flows through REF unless a CT gets saturated. Hence minimum pickup current setting is adopted (10% or 20% I_n) on REF relay. Based on the through fault current, the stabilizing resistor is set such that the relay will not operate for external fault when a CT gets saturated. This relay operates only for internal earth faults, instantaneously.

Modern practice is to employ a voltage operated (high-impedance principle) relay for the application. The relay is set to operate with a certain minimum voltage across its terminals. The value of this operating voltage is chosen to be slightly higher than the maximum voltage which can possibly appear across the relay terminals during external fault conditions.

TESTING OF REF Relay: Same as that of Differential Relay.

The following points should be observed while testing.

1. Pick up current at the fixed and selected setting
2. Operation of high set element at fixed and selected setting
3. Through current stability check on the existing load
4. Operation of trip and alarm contacts.

Over fluxing Protection:

Induced EMF in a transformer is given by the equation $E = 4.44 \times \Phi \times f \times t$
(where Φ = flux generated, f = frequency and t = no. of turns)

$$\text{Flux } \Phi = K (E/f)$$

The Over fluxing condition in a transformer can occur during system over voltage and/or under frequency conditions (V/F). This will cause disproportionately great increase in magnetizing current and iron loss. In addition flux is diverted from the laminated core structure into the steel structural parts. In particular, under condition of over-excitation of core, the core bolts which normally carry little flux may be subjected to large component of flux diverted from highly saturated and constricted region of core along side. Under such condition the bolts may be rapidly heated to a temperature which destroys their own insulation and will damage the coil insulation if the condition continues.

The Over fluxing condition does not call for high speed tripping. The tripping can be delayed for a minute or two by which time, the conditions may tend to normal.

Over fluxing relay : In a typical over fluxing relay, over fluxing withstand time of Transformer is generally found to be varying inversely with the working flux density in the core.

The relay with inverse time characterizing measuring element is designed to detect the over fluxing conditions taking into account the over fluxing withstand capability of the Transformer. The highset element provides protection against severe over fluxing condition (which can be blocked when not required)

Setting ranges:

V/F (inverse) K1 : 1 – 1.25 times rated V/F (highest) K2 : 1.0 to 1.5 times K1

Operating times:

Alarm : 0.5 Sec (Fixed)

Time delayed Unit: It follows inverse time characteristic curve. Typical operating timers are as follows:

V/F	1.01	1.05	1.1	1.15	1.2	1.25	1.3
Time in Sec.	605	149	55	24.7	9.3	5.8	4.3

Testing of over fluxing relay: A variable voltage source (Variac) is required to test the over fluxing relay. A variable voltage is applied on the relay with the available frequency V/f ratio characteristics and tested for alarm as well as tripping for the set timings.

4.1.5.7 O/L & E/L RELAYS

Types of O/L relays:-

1) Inverse definite minimum type relays (IDMT)

a) Normal Inverse:-

- i) 3.0 sec relay – i.e., 3.0 Sec., at ten times pick-up with T.L of 1.0
- ii) 1.3 sec. relay – i.e., 1.3 sec at 10 times pick-up

b) Very inverse relays

c) Extremely inverse relays

2) Definite time relays

Instantaneous highset O/L relay supplementing the above O/L relays.

The O/L, E/L relays are used for line protection (for 11 KV to 132 KV) and for Transformer Protection.

O/C relaying is very well suited to distribution system protection for the following reasons:-

- 1) It is basically simple and inexpensive
- 2) Very often the relays do not need to be directional and hence no PT supply is required
- 3) It is possible to use a set of two O/C relays for protection against inter- phase faults and a separate O/C relay for ground faults.

Relay settings:

i) Pick-up settings: For coordination of the inverse time O/C relays, the pick-up current and time delay settings are to be chosen. The pick-up of the relay must be chosen such that it will operate for all short circuits in its own line and provide back-up for adjoining lines.

In choosing the pick-up of the O/C relay, we must also consider that under minimum fault current conditions, the multiple of pick-up (ratio of actual current to pick-up value) is not less than 1.5 so that the relay will operate reliably under such conditions. The pick- up of the phase O/C relay is selected as:

$$I_p = K_{sf} \times I_L (\text{Max}) / K_d$$

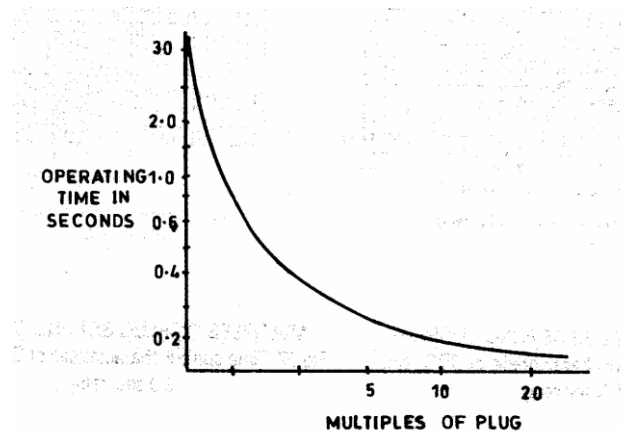
Where I_p = Pick up current, $I_L (\text{Max})$ = Maximum load current anticipated

K_{sf} = Safety factor (1.15 to 1.3) and K_d = Drop out to pick up ratio of the relay(0.9 to 0.95)

For the E/F relay, the load current is not a factor in the selection of pickup settings (for the Transformers and EHV lines), and is normally set at 20% of rated current. For distribution lines it is desirable to have higher setting since there will be a ground current normally because of unbalanced load.

ii) Time Setting: The actual operating time of the O/C relay can be varied by proper selection of the “Time Dial Setting” which is selectable from 0.1 to 1.0.

Time Characteristics: A typical time characteristic of an IDMT relay is shown below:

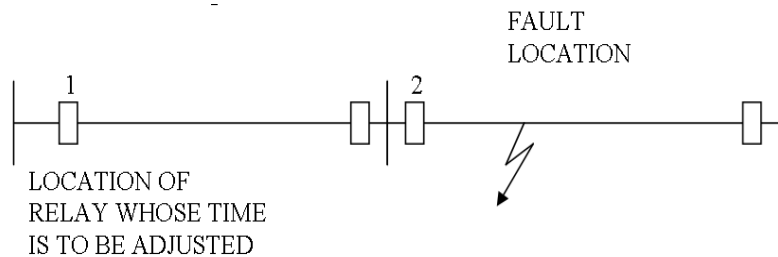


$$PSM = I_f (\text{Fault current}) / I_p (\text{Pickup current})$$

Where PSM is plug setting multiplier.

Selective time interval: The time interval between two successive breakers to provide the required selectivity is termed as selective time interval.

Consider the following:



The operating time of the relay at 1 $t_1 = t_2 + b_2 + O_1 + f$

Where t_2 = operating time of relay at 2

b_2 = breaker operating time at 2

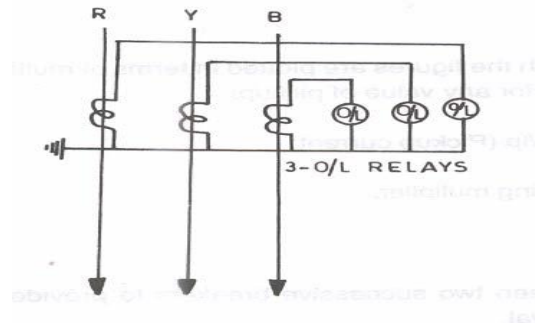
f = factor of safety time

O_1 = over travel time of relay at 1

The selective time interval $S = b_2 + O_1 + f = 0.3 \text{ to } 0.4 \text{ Sec.}$

Current Transformers and Relay Connections:-

i) Three over current relays for affording protection against both phase and earth faults:-



For 3-phase faults the overcurrent relays in all the 3-phases act. For phase to phase faults the relays in only the affected phases operate. For single line to ground faults only the relay in the faulty phase gets the fault current and operates. Even then with 3-O/L relays, the sensitivity desired and obtainable with earth leakage overcurrent relays cannot be obtained in as much as the high current setting will have to be necessarily adopted for the O/L relays to avoid operation under maximum load condition. Overcurrent relays generally have 50% to 200% setting while earth leakage overcurrent relays have either 10% to 40% or 20% to 80% current settings. One important thing to be noted here is that the connection of the star points of both the C.T. secondaries and relay windings by a neutral conductor should be made. A scheme without the neutral conductor will be unable to ensure reliable relay operation in the event of single phase to earth faults because the secondary current in this case (without star-point interconnection) completes its circuit through relay and C.T. windings which present large impedance. This may lead to failure of protection and sharp decrease in reduction of secondary currents by CTs. It is not sufficient if the neutral of the CTs and neutral of the relays are separately earthed. A conductor should be run as stated earlier.

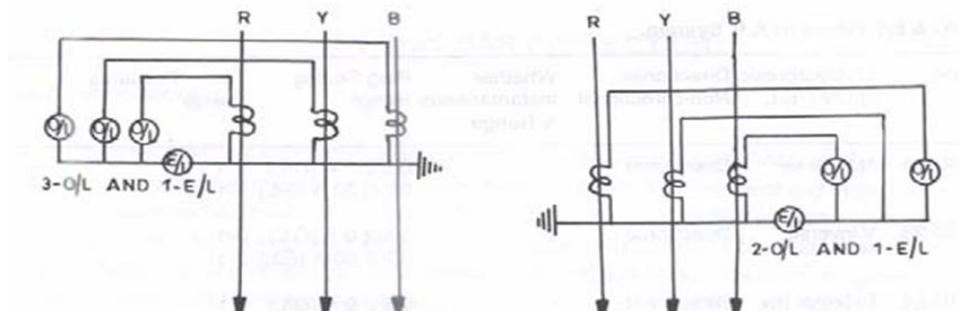
ii) Three overcurrent relays and one earth fault overcurrent relays (3-O/L & 1-E/L):

The scheme of connection for 3-O/L and 1-E/L relays is shown in figure. Under normal operating conditions and three phase fault conditions the current in the 3-phase are equal and symmetrically displaced by 120 degrees. Hence the sum of these three currents is zero. No current flow through the earth fault relay. In case of phase to phase faults (say a short between R and Y phases) the current flows from R-phase up to the point of fault and returns through 'Y' phase. Thus only O/L relays in R and Y phases get the fault and operate. Only earth faults cause currents to flow through E/L relay. A note of caution is necessary here. Only either C.T secondary star point or relay winding star point should be earthed. Earthing of both will short circuit the E/L relay and make it inoperative for faults.

iii) Two overcurrent relays and one earth fault relay:

The two overcurrent relays in R&B phases will respond to phase faults. At least one relay will operate for fault involving two phases. For fault involving ground reliance is placed on earth fault relay. This is an economical version of 3-O/L and 1-E/L type of protection as one overcurrent

relay is saved. With the protection scheme as shown in Figure complete protection against phase and ground fault is afforded



4.1.5.8 Directional O/L & E/L relays:

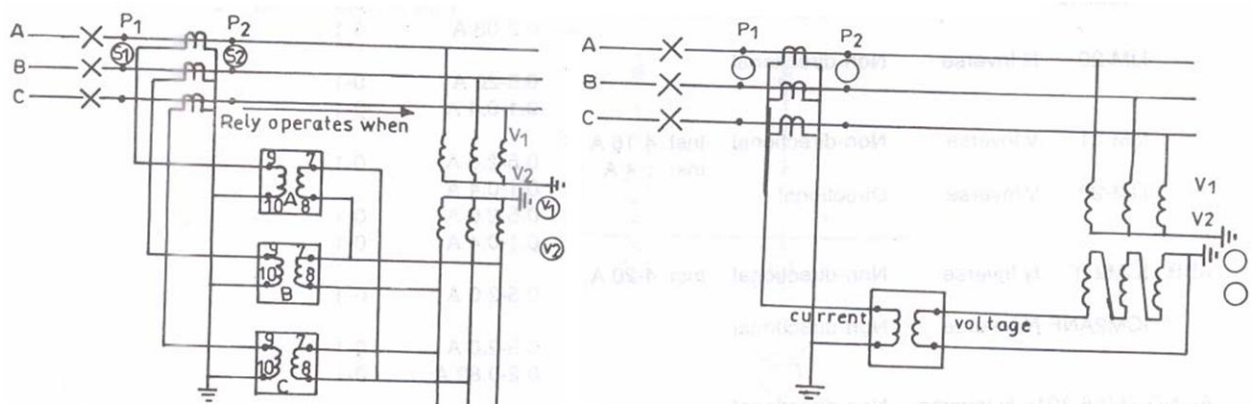
Except at locations where fault power can flow in only one direction, O/C relays must be supplemented by directional elements. They have to be used to discriminate between faults for which a relay should trip and those for which it should not trip according to direction of fault. The tripping direction of the relay is away from the bus, looking into the equipment to be protected.

The directional O/L, E/L relays have to be supplied with both current and voltage. Directional O/L & E/L relays are used for all 132 KV lines as a backup protection.

Directional E/L relays are used on HV side of 132/33/11 KV Transformers and on both HV & LV side of 220/132 KV 100 MVA transformers. On 400/220 KV, 315MVA Transformers directional O/L & E/L relays are used on both HV & LV sides.

For all 33 & 11 KV feeders and lower capacity transformers non-directional O/L & E/L relays are used.

The connection diagrams for directional O/L & E/L relays are shown in figure.



Highset (Instantaneous) O/C relay

A highset instantaneous relay is provided in addition to the IDMT relays for the Transformer Protection.

Highset elements in conjunction with IDMT relays may be used on the 33kV and 11 KV feeders for faster clearance of heavy faults.

Testing of O/L and E/L relays

Non Directional O/L & E/L Relays are tested using OCB Kit to check the Pickup value of current and Operating characteristics of relay by injecting the current above the Plug setting value. Relay characteristics also tested with current injection and Timings with Timer.

Characteristics of Standard Inverse (3 secs) relay are given in the table below.

PSM value	1.35 times	2 times	5 times	10 times
Time(sec) at TL=1.0	30	10	4.3	3

Example: If an Over current relay settings are PSM=100% and TL=0.1

The calculated values are given in the table for checking of relay characteristics.

Current Injected	Time as per TL	Observed Timing
1.35	3	
2.0	1	
5.0	0.43	
10.0	0.3	

For directional O/L & E/L relays voltage source with phase shifter also required for testing of the relay and its characteristics.

The following points should be observed while testing.

1. Starting and Pick up current of the relay as per the plug setting
2. Operation of high set element at fixed and selected setting, if applicable
3. Time of operation as per the relay characteristic
4. Operation of trip and alarm contacts.

4.1.5.8 BUS BAR PROTECTION

Introduction

In olden days, the clearance of busbar faults was done by time delayed distance relays or overcurrent relays, resulting in extension of fault for longer duration of time. In present day's networks, which are highly interconnected, having numerous infeeds and consisting of line sections of varying lengths, clearance of bus faults in zone-2 or zone-3 of a distance relay cannot be tolerated. Also selective tripping becomes a problem on installations having different bus sections. In order to maintain system stability and minimize fault damage due to high fault levels, time delayed tripping for busbar faults is no longer acceptable. It is therefore necessary to detect busbar faults selectively with a unit form of protection scheme.

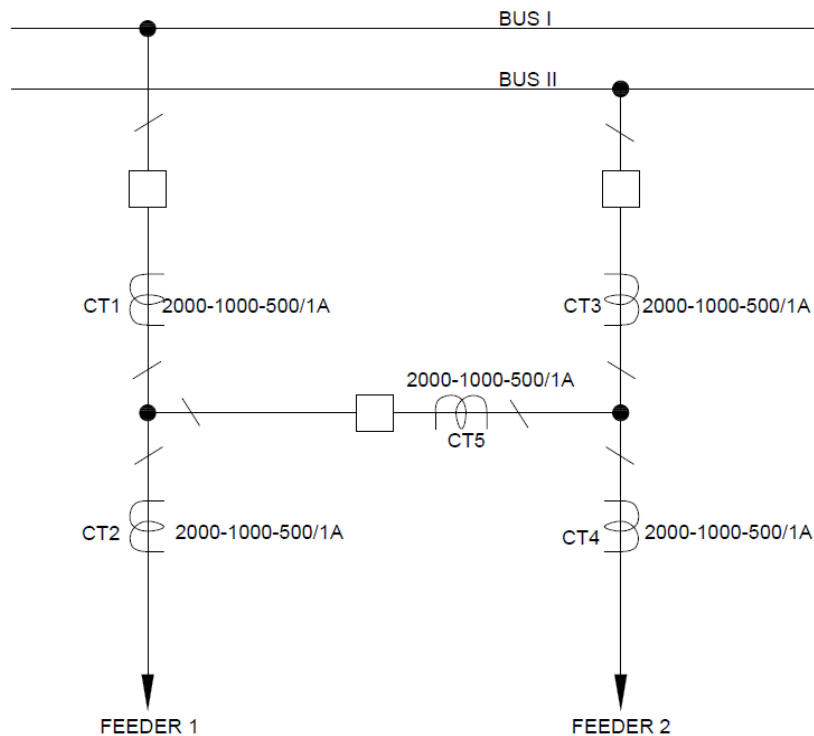
Busbar protection scheme should possess following:

- i) It should be completely reliable
- ii) It should be absolutely stable under all types of severe through fault conditions.
- iii) It should provide discrimination between sections of the bus bars to ensure that circuits connected to fault busbar alone are isolated
- iv) It should be of high speed protection so as to minimize damage and maintain system stability

Advantages of Breaker and a half arrangement: - (One and half Breaker arrangement)

- 1) It has 3 breakers for two connections. Each circuit is connected to a particular bus.
- 2) No changeover of line from one bus to the other is required.
- 3) This pairing is done such that one is a source and the other a load.
- 4) For breaker maintenance of any line, the load gets transferred to the other bus.
- 5) On occurrence of a bus fault or for maintenance all the interconnections will be on healthy bus.
- 6) Even if both buses become dead, lines can still be in service through the tiebreakers.

ONE AND HALF BREAKER SCHEME WITH 5 CT METHOD



400 KV System Protection:

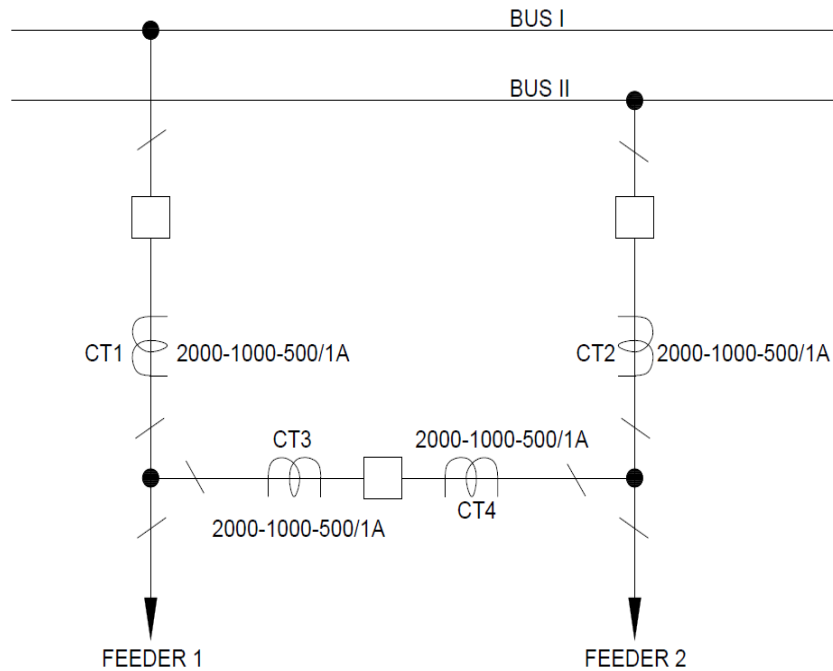
Generally the 400 KV Substations are provided with breaker and half arrangement. In breaker and half scheme five CTs method or four CTs method will be adopted for protection.

Five CTs Method:

The CTs arrangement is shown in the figure for 5 CTs method in breaker and half scheme.

- Line side CTs will be utilized for Line Protection
- Bus side CTs will be utilized for bus protection.
- Teed Protection will be used to cover blind area between bus CTs, Line CTs and Tie Breaker CT.
- Two differential relays are provided for each T-Section by summing the three concerned CTs i.e. CT1, CT2 & CT5 for T-Section of feeder-1 and CT3, CT4 and CT5 for T-Section of feeder-2.

ONE AND HALF BREAKER SCHEME WITH 4 CT METHOD



Four CTs method:

The CTs arrangement is shown in the figure for 4 CTs method in breaker and half scheme.

- a) For feeder protection both bus CT and opposite tie breaker CT will be summated and connected to the relay (CT1 & CT4 for feeder-1, CT2 & CT3 for feeder-2).
- b) Bus side CTs will be utilized for bus bar protection.
- c) There is no uncovered zone in 4 CTs method.

BUSBAR PROTECTION SCHEMES: Principles & Applications

- i) High impedance circulating current scheme
- ii) Biased differential or low impedance circulating scheme.

High Impedance circulating current protection

a) Operating Principles:

This is a unit type of protective scheme in which the currents entering and leaving the busbar installations are compared continuously. The objective is to provide fast operation at a low fault

setting for internal faults and yet retain stability up to the highest possible value of short circuit current on through faults. Current transformers on each circuit of the busbar are connected in parallel (phase-segregated), which will provide a resultant current to operate a relay for faults internal to the bus bars installations only.

Theoretically, such a system is unaffected by through faults, but in practice, the associated current transformers may not behave ideally when the current exceeds a certain value. Errors in transformation due to saturation on the CT cores may be sufficient to cause mal operation if special precautions are not taken.

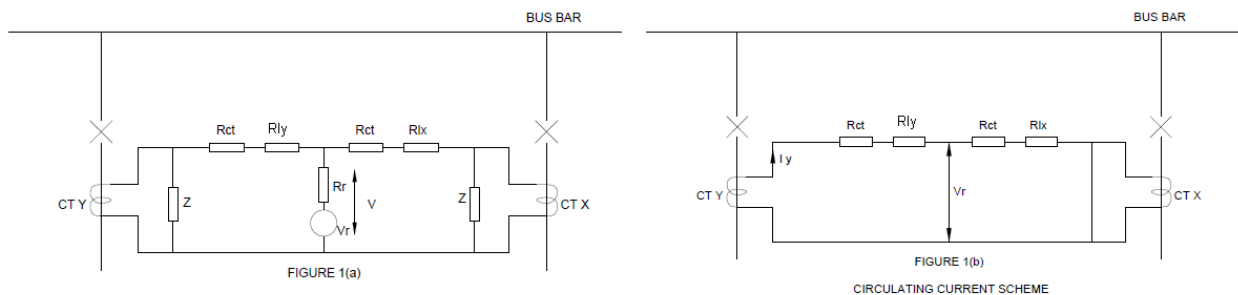
Consider the figures 1 (a) & 1 (b). Assuming that due to external fault on line X, CT X gets saturated (i.e.) produces no output. This is represented by short circuit as indicated in figure (b). This is the worst condition for the relay from stability point of view, since the spill current is maximum. The high impedance principle involves choosing impedance high enough to stabilize the relay for this worst condition.

Assuming that current I_y flows through the saturated CT only. This will develop voltage V_r given by

$$V_r = I_y (R_{ct} + R_{lx})$$

Where I_y = Fault current in Amps,

R_{ct} = CT secondary resistance & R_{lx} = Lead resistance



The relay circuit impedance is then adjusted so that the necessary voltage to operate the relay is greater than the voltage V_r .

$$V_s = I_r * R$$

Where V_s = Setting voltage

I_r = Relay current setting

R = Relay branch impedance

To avoid relay operation for inter faults $V_s > V_r$

For this, an additional resistor called stabilizing resistor R_{st} is used in series with relay coil resistance R_r **Thus $R = R_{st} + R_r$**

During an internal fault the CTs will attempt to transform the full fault current and pass this through relay circuit. This will be many times the setting current and hence voltage output required

from CTs will be of the order of many kVs. Practically this is not possible and CTs may get saturated. To enable faster operation of relay, these CTs should have a knee point voltage equal to at least twice the relay setting voltage V_s .

b) Through Fault Stability

The stability limit of the scheme is based on the maximum through fault current. As shown previously, the stability limit is governed by the relay setting voltage. This must not be less than the stability voltage of the system, which is calculated by assuming that maximum through fault current flows through one CT and out through a second one, the latter being the most remote (and hence maximum lead resistance) from the relay associated with the Zone considered. It is further assumed that the DC component of the offset primary current completely saturates the second CT, while the first one continues to transform perfectly.

c) Check Feature

A second line of defence is considered good practice in most schemes of busbar protection, not to give security against mal-operation of the primary protection, but to prevent incorrect tripping due to damage to wiring and equipment from extraneous sources. A check feature is provided by duplication of the primary protection using a second set of current transformers on all circuits other than bus section and bus coupler units. The check system is arranged in a similar manner of the primary protection, but forms one zone only covering the whole of the bus bars and does not discriminate between faults in various sections of the bus bars.

d) Use of Non-linear Resistors

Under internal fault conditions the high impedance relays circuit constitutes an excessive burden to the CTs, leading to development of high voltage. The insulation of CT secondary winding and the relay will not be able to withstand these high voltages, hence it is limited to less than 3 KV peak by use of non-linear resistors called metrosils connected in parallel with the relay circuits

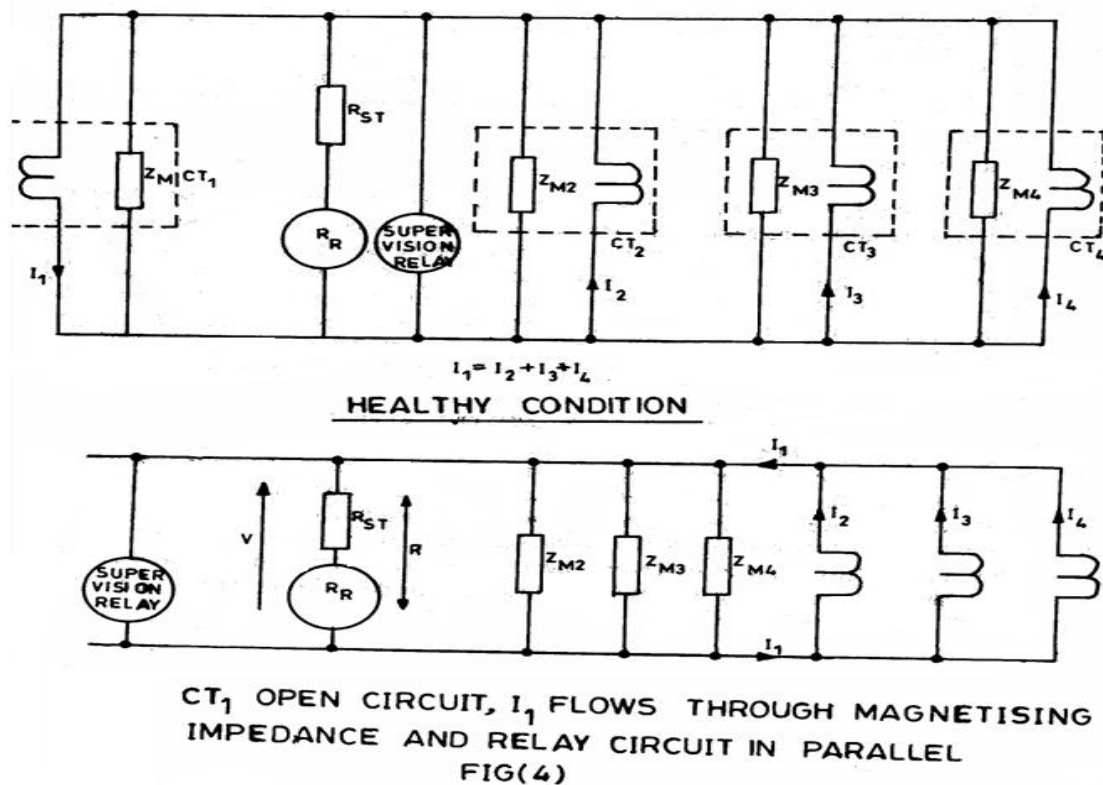
e) Supervision

When a CT secondary winding or connections between CT and the relay circuit get open circuited, the resultant out of balance current will flow through the parallel combination of the relay, metrosil and the CT magnetizing impedance. This may cause unwanted operation of the relay for load or through faults depending on the effective primary setting. This condition of an open circuit can be detected by measuring the voltage across the relay circuit by a sensitive voltage operated relay as shown in Figure. This relay is set to operate when the out-of-balance current equals about 10% of the least loaded feeder connected to the busbar or 25 amperes, whichever is greater.

Operation of the supervision relay is arranged to give an alarm that the busbar protection is faulty, and to short circuit the bus wires for this is necessary to prevent damage to the protective relay and stabilizing resistors.

When the busbar protection has a fault setting below full load of the connected feeders, it is very likely to operate due to an open circuited current transformer. In this case, a check feature is required to prevent tripping. At the same time, it is important that the bus wires are short circuited via the supervision relay to prevent thermal damages to the relay and stabilizing resistors which would otherwise remain continuously picked up under load conditions.

The supervision must be time delayed to avoid a false alarm during genuine fault conditions, typically three seconds is adopted.



Low impedance biased differential relays : Principle.

An alternative to the high impedance protection described above is the biased differential relay. This type of protection makes use of the fact that during system conditions that give rise to high spill current (namely, heavy through faults), there is high amount of circulating current as well between the in-feeding and out-feeding CT secondaries. The operating quantity in the scheme is the same as before – the secondary differential current. The total value of fault current is usually obtained by means of diodes which route all the secondary currents through the bias circuit. The resultant bias is proportional to the arithmetic sum of all the circuit current, whereas the operating circuit is energized by the vector sum of all the circuit currents. In a biased differential relay, the operating current is arranged to increase proportionally to the load (circulating) current.

Many of the considerations applicable to high impedance schemes are applicable here as well.

For example independent check zone in addition to the main zone and supervision element are provided in this scheme

High impedance vs. Low impedance Schemes:

High impedance as well as low impedance schemes have their own advantages. Both are well-tried, proven methods of providing protection for the busbar.

The most obvious advantage of a high impedance scheme is the fact that it combines sensitivity to internal faults and stability during through faults. The scheme may be made stable to any through fault level, and yet retain sufficient sensitivity for internal faults with week infeeds.

As it requires only very nominal current for operation, it can deal with internal faults that result in saturation of the CT. The scheme is simple and straightforward to apply.

A true low impedance scheme has the advantage that it can work with CTs of moderate output compared to a high impedance scheme. The scheme does not impose a high burden on the CT.

Also, the scheme can work with CTs of unequal ratio, which is of use in some situations.

In most substations, two nos.class PS cores per feeder are used for busbar protection – one for the main zone and the other for the check zone. Whenever two cores are available, a protection scheme that utilizes both the cores must be employed for busbar protection. Otherwise, one is compromising the security of the protection, as well as underutilizing available resources. A scheme that uses only one core has an inherent disadvantage - its setting must be such that no mal-operation occurs when there is an open circuitry of the CT secondary or the secondary leads.

Under this condition, the concerned zone will see an unbalance current equal to the load current flowing in the relevant feeder. To avoid unnecessary operation of the scheme, the zone settings or the setting of the check relay must be more than the maximum expected load current on any feeder in the substation. Thus, in the case of schemes that utilize only one CT core, the basic sensitivity is poorer than the load current.

When the scheme involves two CT cores, one feeding the main zone and the other feeding the check zone, the above problem does not arise. Open circuiting will affect only on the zones, and the tripping will not be through since the other zone remains stable. The chances of open circuitry occurring in two CT cores simultaneously is very remote. Hence in such a scheme, setting much lower than load current is possible.

In the same connection, it must be pointed out that schemes have check zone fed off Independent CT cores are clearly superior to schemes that do not have check zones or those that cannot accommodate separate inputs for the main and check zones. First and foremost, a check zone contributes significantly to the security of the scheme.

Testing of Busbar Protection:

A Current source is required to test the Bus bar differential relay. Stability test also conducted on

the bus bar differential relay similar to normal differential relay. ABB Make RADSS Differential relay requires variable voltage source (0-400 volts) for testing of the relay.

4.1.5.9 BREAKER FAILURE PROTECTION

Main protective schemes provided for the line/transformer/generator are required to operate and clear the fault immediately, isolating the faulty section of the system. It is then important that the circuit breaker operates correctly, clearing the fault quickly by tripping. However, if a breaker does not trip in time or fails to trip (either due to mechanical sluggishness or due to inability to interrupt heavy fault current), then the fault gets cleared by backup relays at remote stations.

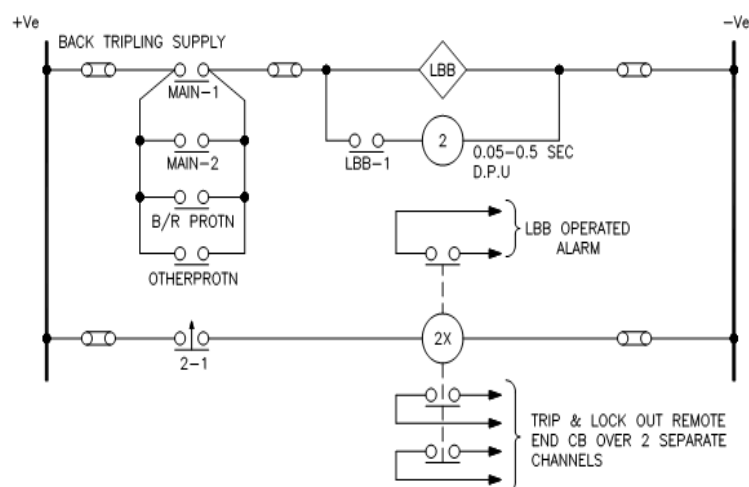
Increasing power system complexity demands shorter fault clearing times. It is therefore necessary to provide breaker failure relay (also called “Local breaker backup relay” or

“stuck breaker protection”). This scheme will isolate the bus to which the stuck breaker is connected, faster. It comprises of O/L & E/L relays with a timer. The LBB relay is energized by trip command of main protection schemes and thus initiate busbar protection scheme after lapse of specified time. Then all the breakers connected to the bus get tripped, thus isolating faulty element.

The general practice is to set the current setting = 20% of I_n and Time setting = 200 m Sec. The schematic diagrams for the application of the LBB relay (type CTIG) are indicated in the figure (a) below.

Even if the busbar protection scheme is not available, the LBB scheme can be made use of by providing special trip circuit and trip relays similar to that of bus protection trip circuits for each line. A schematic for such applications is indicated in figure (b) below.

BACK TRIPPING LBB THROUGH BUSBAR PROTN, CKTS.

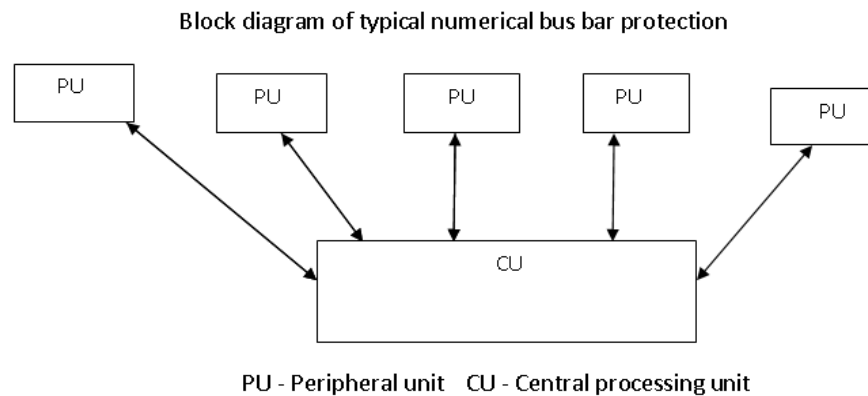


Testing of breaker failure relay(LBB):

A current source with timer is required for testing of breaker failure relay. After operating the Master Trip relay, current required for the set value is injected into the LBB relay and the operation of the LBB Relay is verified as per the time setting.

4.1.5.10 NUMERICAL BUS BAR PROTECTION:

Numerical busbar protection relays are compact, having CT switching, check supervision, breaker failure back up and main busbar differential functions all housed in a single unit.



Each Feeder / Transformer connected to the bus has its own processing unit (PU), which collects information on the status of feeder (Currents, voltages, status of CB and isolator etc...) and communicates it over high speed fibre optic data links to the central unit (CU). The PU collects data (i.e. currents, voltages, status of CB and isolator etc) and processes it to digital form and transmits to central unit (CU). Algorithms are carried out in the CU.

In the Numerical bus bar protection internal LBB feature is available, hence external LBB relay can be avoided in the relay panel. Re-trip as well as back-trip features are available. When a Feeder/ Transformer receives trip command on any protection, the same command will be sent to PU through Master trip relay. After a given time lapse if current is available in the PU (after the receipt of signal from the master trip), PU will give the trip command to the particular Feeder/Transformer which is under fault feeding condition. This feature is called re-trip. After lapsing of internal LBB set time, if currents are available in the same PU, then the PU will send the command to the CU. The CU will initiate trip command to all the Feeders / Transformers connected to the bus to which the faulty breaker is connected; through individual PU. Any external damage of external LBB may lead to trip the all Feeders/Transformers in the conventional / static bus bar protections. The same can be eliminated by using internal LBB feature which is available in the Numerical bus bar protection.

4.1.5.11 UNDER VOLTAGE PROTECTION

Under voltage protection is usually provided for Capacitor banks to protect capacitor units from

high charging currents during low voltages. Unlike O/L & E/L Relays (IDMT characteristics) under voltage relay is meant for instantaneous operation.

Under voltage setting can be kept in the range of 70 -100%

Testing of under voltage relays:

Under voltage relays can be tested by using a Variable Voltage Source (Variac). Predetermined under voltage as per the set value on the relay is applied to the relay by Variac & operation of relay is verified.

4.1.5.12 OVER VOLTAGE PROTECTION

Over voltage protection is required to protect the equipment from voltages above the rated value. Over voltage protection is provided for capacitor banks, Power Transformers, Transmission Lines.

Over voltage setting can be kept in the range of 105-135%

Testing of over voltage relay: Same as that of under voltage relay.

The following points should be observed while testing under voltage /over voltage relays.

1. Starting and Pick up Voltage of the relay as per the plug setting
2. Operation of high set element at fixed and selected setting, if applicable
3. Time of operation as per the relay characteristic
4. Operation of trip and alarm contacts.

Testing of Fuse Failure Relay

Remove main fuse of each phase voltage input to the Distance protection one by one in the relay panel, check for the VT fuse fail alarm and distance protection in block mode.

4.1.6 SURGE ARRESTERS (LAs)

Physical checking of all stacks for cracks/ breakages if any should be done. Proper mounting and tightness of bolts between units, support structures and foundations shall be ensured. All electrical connections, position of voltage grading rings, connection to individual earth electrodes should be checked. The following checks should be done.

- Measurement of insulation resistance of each stack separately and then on the complete arrester
- Check for leakage current
- Testing of counter and leakage current meters
- Checking of earth connection between surge arrester, surge monitor and earth

After initial charging, leakage current flowing through the arrester may be checked and compared with factory value. This shall be reference value for future comparisons during maintenance.

4.1.7 DISCONNECTORS (ISOLATORS) / EARTH SWITCHES

Erection of isolators for correct alignment and tightness of the foundation bolts of the support structure to the foundation and tightness of bolts of the unit to the support structure should be ensured. The following checks shall be done.

- Close/Open operations shall be checked manually and electrically both in local and remote positions. Check for simultaneous making/breaking of contacts in all the phases
- Measurement of contact resistance of the moving and fixed contacts in closed position
- Measurement of insulation resistance of phase to body and between phases
- Check for required rotation of drum switch
- Check for correct operation of the auxiliary switch contacts
- Check for interlock between the isolator and the earth switch (Isolator can not be closed when earth switch is in closed position / Earth switch can not be closed when isolator is in closed position)
- Check for start and running of the drive motor on giving a close/open command and stop automatically after completing close/open operation. Correct functioning of limit switches should be checked
- Interlock between the breaker and the isolator should be checked (Isolator can not be opened when breaker is in closed position)
- Check for corona shield condition where provided
- Check for earth connection from blade to earth for earth switch

4.1.8 DC SYSTEM – BATTERIES AND CHARGERS

- Cells should be erected in row and tier system to facilitate working at a comfortable height. Visual observation of the cell containers, electrolyte leakage, battery room ventilation, air and fumes exhaust arrangements etc.
- Inter cell, inter tier and inter row connections should be checked for proper tightness
- Initial charging of the battery to be done
- Test for Battery capacity
- Test for Battery discharge. Measurement of temperature during discharge test
- Check for electrolyte level up to the mark
- Measurement of specific gravity and voltage of each cell
- Check for working of all panel meters, control switches MCBs etc. on battery charger
- Check for proper working of battery charger operations in both float and boost modes
- Testing of DC earth leakage protection
- Check for working of DC lighting system in the control room

Some Guide lines:

(i)When the battery has to be stored for long period before putting into service, necessary care has to be taken for proper storage, other-wise there may be possibility of oxidation which may have adverse impact on the porosity of the plates. The Cells will develop uniform porosity only after repeated charge/discharge cycles and adjustment of specific gravity has to be made thereafter in all the Cells.

(ii) Variation in the quantity of Distilled water while topping up or failure to top up some cells may also contribute to the variations in cell voltage and specific gravity

(iii) After installation of the battery, if each cell voltage and specific gravity is not uniform and varying then equalizing charge shall be made by adjustment of electrolyte, i.e. addition or removal of electrolyte and/or distilled water is made until the specific gravities are uniform. This adjustment may be repeated after some cycles of operation i.e., after 30 or 45 days.

(iv) Batteries should not be kept under continuous Boost Charge. Batteries shall be on float charge only. After sufficient discharge of the Battery (as indicated by the Voltage and specific gravity of the Cell, Battery shall be kept under Boost charge for the required number of hours only to get the normal voltage and specific gravity.

Sealed Maintenance Free Batteries (Valve Regulated Lead Acid Batteries):

VRLA batteries are normally supplied in fully charged condition. They can be installed and put into service immediately. If these batteries are stored for a long time, self discharge due to internal chemical process takes place and if the discharge is not timely compensated by adequate charge, the battery may not pick up charge even in the boost mode later. Life of such battery gets reduced. Delivery of VRLA battery should therefore be so planned that the battery can be commissioned within a reasonable time (say one or two months time) after its receipt from the

works. Alternately the battery may be kept on trickle (float) charge to compensate for the internal discharge and voltage of each cell monitored till the battery is commissioned. VRLA batteries are compact and temperature sensitive. Hence they need to be installed in a temperature controlled area, preferably in control room which is air-conditioned.

4.1.9 CAPACITOR BANKS

Installation:

- Clean capacitors thoroughly
- Tighten up all electrical connections and other screws and nuts
- Measure the IR values with a 500 V megger between terminals and earth. Minimum value shall be 50M Ω . Do not put a unit with less than 50 M Ω into service
- Ensure free circulation of air around capacitor units. Adequate clearances as per the drawing shall be maintained
- Temperature of atmosphere surrounding capacitor units shall be within their temperature category under steady working conditions.
- Adequate earthing of capacitor banks (structures etc.) to be ensured.
- Neutral of star connected capacitor banks with residual voltage transformer should not be earthed.
- Before commissioning a capacitor bank, capacitance of each capacitor shall be measured with a capacitance meter. These shall be compared with the value obtained by calculation using the formula

$$C = \frac{\text{KVAR} \times 10^9}{2 \pi f (V)^2} \quad \text{micro farads}$$

where V is the rated voltage of capacitor and KVAR is the rated KVAR of capacitor. As per IS the tolerance in the capacitance value for a capacitor unit is + 10% to - 5%

Operating Instructions: The following points may be checked before energizing the capacitors:

- a) Supply voltage, frequency and temperature of the area
- b) Ensure no hardware or tools are left inside the rack assembly. This may cause short circuit and breakdown.
- c) Ensure proper ventilation
- d) Ensure all electrical and mechanical connections are done properly and tightly.
- e) Ensure that there is no oil leakage from terminal at collar of the bushing and welded seam of the capacitor unit

After charging the capacitors, the following checks shall be made:

- a) Voltage : Within 110% of rated voltage especially during light load periods
- b) KVAR : Operation KVAR is within 130% of the rated KVAR at the highest system voltage
- c) Temperature rise: Container temperature should not exceed 75 Deg. C. This should be measured by having a thermometer fixed with the wall of the container, keeping the bulbs at one quarter of height of capacitor box down from the top edge.
- d) Fuse: ensure correct type and rating of fuse
- e) Light Load: At light load capacitors cause voltage rise in the system exceeding the permissible value some times. They may have harmful effects on capacitor or on other electrical equipment. Voltage at no time should go beyond the rated voltage by more than 10%.

For capacitor banks operated with series reactors, operating the bank with less number of units than originally supplied may cause the capacitor with series reactor tuned to fifth harmonics.

Best way to check the healthiness of a capacitor is to check the capacitance with a capacitance meter, partial or complete failure of a capacitor can be established from this. Shorting of one internal series group on a capacitor results in a predictable increase in the capacitance level. This is the basis for the capacitances of partially failed capacitors.

4.1.10 GENERAL CHECKS

General checks to be made on various other equipment/ items before commissioning of a substation are given hereunder.

Earthing: Check for earth mat spread covering the entire yard as per the drawing and the mat is buried at least 500mm below the ground surface. Check whether all the joints between

horizontal and vertical strips are welded. Check each earth pit for the size and materials used as per the drawing.

Ensure that metal structures, metal boxes/kiosks, bodies of the equipment, neutrals of power and station transformers, surge arresters etc. are properly connected to the earth mats and earth electrodes with adequate size GI/MS flats as per the drawings. Measure the earth resistance of individual earth electrodes and the combined earth resistance of the station and record these values for future reference. Ensure that the combined resistance is less than 1 ohm.

Control Cables: Check for proper laying of cables in the cable trenches and providing of identification tags on the cables at either end. Ferrules must be provided on each core of the cable at both ends for easy identification during maintenance.

Statutory Clearances: Spacing between adjacent equipment in the switch yard shall be checked for adequacy as per standards and as shown in the drawings. Clearances between live part to ground and between phases shall be measured for adoption as per standards. Phase to phase and phase to ground clearances of main and auxiliary buses should be checked.

Lighting: Yard lighting distribution in the switch yard, in the control room and in the other areas of the substation premises should be checked for adequacy and for proper working, including control and protection.

Fire Protection System: Correct working of Compressors should be checked. Oil level, condition of valve plates, gaskets etc should be checked. Working of Diesel Engine, Jockey pump, V-belt drive should be ascertained. Check the healthiness of battery and working of fire alarm system. Auto start of Hydrant pumps, Diesel Engines etc. to be checked. Operation of Deluge system, outlet pressure, alarms, starting of diesel/electrical pumps etc. to be checked. CO₂, Foam and any other type fire extinguishers installed in the substation should be checked for the weights of gas, operation of regulating valves etc.

Standby Diesel Generator set: Check for oil leaks, and all gasketed joints. Air intake system, cooling system, fuel system, Exhaust etc. should be checked for proper working. Main Generator's condition and IR values to be checked. Control and protective relays of generator to be tested.

4.1.11 COMMUNICATION:

Power Line Carrier Communication (PLCC) cubicles/ Optic fibre Termination Equipment (OTE) and other electronic equipment intended for Automation should be installed in an air-conditioned room and should work in a dust free environment. Proper connections to the equipment to be checked. Battery (48V/24V) for communication can be installed in the main battery room housing the station battery. Proper working of other accessories such as Exchanges, battery and chargers, Motor-Generator sets etc. should be checked.

Apart from the above public telephone, either a land line or a cell phone to be provided in the substation. Working of the entire communication system well before the commissioning of the

substation should be ensured. Communication should be established with Load dispatch centre and the controlling stations and should be working before the SS is programmed for commissioning. This helps in receiving directions from load dispatch and concerned control wings at head quarters for compliance and carrying out control and relays operation requiring on line communication.

Any defects/omissions noticed during checks and testing of relays should be reported to construction unit (EE/SE TLC). The TLC unit shall arrange for rectification of all such defects/omissions through the supplier/contractor as the case may be and report compliance to the TL&SS unit. After ensuring every thing in a fit shape, the SE (TL&SS) shall inform the TLC unit, zonal CE, CE (Transmission), CE (Construction/head quarters) and the Grid operation unit (CE G.O) for arranging charging of the new Substation/bay/transformer duly giving the programme. The programme should be coordinated with the service personnel of the manufacturers/ contractors for testing and commissioning of the transformers/other equipment as per the provisions of contract.

On receiving the intimation for charging a new installation from the field, the Grid Operation Unit, will arrange to coordinate with other concerned units (Power systems, Communication, construction etc.) in preparing the charging instructions and communicate to field. Charging operations shall be carried out strictly in accordance with the charging instructions communicated by the Grid Operation Unit.

Communication between the LD center and the new installation should be ensured before charging. Steps indicated in the charging instructions should be followed in correct sequence with due intimation to the load dispatch center. In case of an interconnected substation, it is desirable to charge the Power transformer from the low voltage side.

Power transformer should be initially charged on no load (idle charge), preferably at rated or reduced voltage and the noise from the transformer (humming) should be observed. It should be uniform from all sides of transformer. Oil and winding temperatures should be monitored at regular intervals. It is likely that during filtration at site in the pre-commissioning stage air might have got trapped inside the transformer. It is prudent to switch off the transformer after a few hours of idle charge (4to6 hours) and open the air release valves provided on the equalizer pipes and on the top of main tank to allow the trapped air to escape. This is indicated by oil gushing out freely from the valves without any bubbles, after which the air valves should be closed tightly. After release of air the transformer may be charged and kept under idle charge for few more hours (say 8 hours) and temperatures monitored. Transformer may be loaded after ascertaining normal temperature rise.

4.2 LINES

4.2.1 Checking of lines

During the last stages of completion of the line or immediately after completion of construction, statutory inspection of the line should be arranged by DE/SE (O&M) through the maintenance staff to check the fitness in all aspects for charging the line. Any defects/omissions noticed should be immediately reported to the construction unit [EE/SE (TLC)]. The SE/EE (TLC) should arrange for rectification/replacement of defects/omissions through the contracting agency/through the construction staff, in the shortest possible time before the contractor winds up the work, and make the line fit in all respects for charging.

Various checks to be done during statutory inspection are mentioned below:

- i) Right of way/way leave/electrical clearance
- ii) Foundation and Revetments/Protection Work
- iii) Tower and Tower accessories
- iv) Hardware Fittings
- v) Insulators
- vi) Conductors and Earthwire
- vii) Accessories for conductor and Earthwire
- viii) Aviation Warning Signals (Lights/globules/painting)

4.2.1.1 Right of way/Way leave/Electrical clearance:

Minimum right of way (in metres) for lines of various transmission voltages, Electrical clearances for power line crossings as per the standards and as given in the tables already should be inspected and ensured for compliance with the standards.

Check that Jumpers in the tension tower are properly intact with conductor and form a parabolic shape in order to achieve adequate clearance from support steel structure.

Ground clearance

Normally at the time of construction adequate clearance is provided between lowest conductor and ground, but due to delay in charging/commissioning there are chances of dumping/heaping soil, earth and concrete etc. or stacking bricks etc. which may cause reduction in ground clearance. In such cases the stored materials shall be removed.

Ensure that there is no temporary or permanent construction of houses or shades below the line. If the same has been constructed and are found to create clearance problem they shall be removed before charging.

Ensure that all clearances as per the approved drawings are adopted.

The ground profile at the time of commissioning shall be checked with the profile approved at the time of check survey.

Ground clearance of lowest conductors at critical points/where ever the lowest conductor is touching the ground shall be checked in the field from any of the prevalent method and the values of ground clearance at these critical points shall be recorded in the prescribed format.

In case of hilly Terrain and for building clearance, the side clearance from conductors and jumpers at critical points shall also be checked and recorded for all phases of conductor/earthwire towards hill/ building side.

4.2.1.2 Foundation and Revetments/Protection work:

Foundation:

There shall not be any damage/uneven settlement of foundations. For this, tolerances in levels of all four stubs should not exceed the criteria provided in the Annexure-C of IS -5613 (Part - 3/Section 2):1989.

It is to be ensured that back filling of foundation is properly done. Soil shall be filled over all legs up to ground level.

Extra surface earth after foundation back filling shall be removed from legs of the tower beyond a lead distance of 30 mtrs.

Any crack or break in chimney, if found, shall be repaired.

Revetments/Protection:

Cracks/damages to revetments shall be repaired. Weep holes shall have slope such as to flush out the deposited water away from tower platform.

In case of hilly terrain, the benching area should be leveled properly. The area around tower shall have proper slope for drainage of rain water.

4.2.1.3 Tower and Accessories:

Normal Tower

After completion of a transmission line, all the towers shall be thoroughly checked before charging the line. Special attention shall be given to the points as mentioned below:-

Deformed/Buckled/missing/Rusted Members and Nuts and Bolts

It is to be ensured that no members bent, deformed or rusted have been used in towers and if so, the same shall be replaced.

If any members is found missing, a new member shall be Fixed as per erection drawing of Towers.

Nuts shall be sufficiently tightened for the required Torque. Minimum 2 to 3 complete threads shall be projected outside the nut. All bolts shall have their nuts facing outside of the tower for Horizontal connection and Downwards for Vertical connections.

Nuts & bolts shall be properly tack welded/punched as per the specification and proper zinc rich paint shall be applied. It shall be ensured that the circular length of each welding shall be at least 10mm.

It shall also be ensured that all extra blank holes provided on tower members are filled with correct size of nuts & bolts.

Special Towers

In addition to the above checks for towers, ladders and platforms provided in special towers shall be properly tightened and no foreign material shall be left out on such platforms.

Earthing of Towers

Ensure that proper earthing of tower has been done and earthing strip is neither damaged nor broken and is properly fixed to the stub.

In case of counter poise earthing, it is to be ensured that earthwire is sufficiently buried in the ground and no where it has drag out during cultivation. The length of counter-poise is normally 30 mtrs as per specification.

Before charging of the line, ensure that resistance is below 10 ohms. If the value (before stringing) has been recorded higher than 10 ohm earthing shall be changed to counterpoise type.

Earthing of special towers shall be verified as per approved drawings applicable for special towers/special foundation. (In case of anchor foundation bolt/anchor plate welded with last leg of special tower.)

4.2.1.4 Tower accessories

All the danger plates, number plates, circuit plates, and phase plates shall be in position & as per the specification.

All plates shall be properly tightened.

It shall be ensured that phase plates are fixed in correct phase sequence, especially at transposition towers, the phase plates in the correct phase sequence shall be provided at each tower or end tower as per the specification.

It shall be ensured that the anti-climbing device (ACD) is provided, at suit-able height of tower. In case of barbed wire ACD, barbed wire shall be tightly fixed. In case of spike type ACD, all spikes shall be properly fixed and oriented towards outer face of tower.

It shall be ensured that the step bolts (for normal towers) are provided up to the peak of tower. Any missing step bolts shall be replaced.

Fixing of birds guards (up to 220 kV/wherever applicable) shall be ensured.

4.2.1.5 Hardware Fittings:

Tightening of all bolts and nuts are to be checked up to specified torque.

Check the fixing of all security clips (W/R type clips).

Surface condition of corona control rings and distance/alignment between Tower side arcing horn (wherever applicable) and line side arcing horn/corona control ring to be checked as per approved drawings.

Ensure that, no. of insulators per string is lesser by one number as compared to no. of discs in normal string (up to 220 kV) at approach spans to the terminal ends (approx last 1.5 KM).

To restrict the swing of jumpers, the provision of Pilot strings in case of Tension Towers shall be verified from the approved drawings.

4.2.1.6 Insulators:

All the damaged/broken insulator discs shall be replaced.

Unusual deflection in suspension strings if observed shall be rectified.

The insulators shall be cleaned before charging.

IR value of individual disc of at least 5 insulators at random shall be checked by 5/10 kV Megger.

4.2.1.7 Conductors and Earth wires:

Surface of the conductors shall be free from scratches/rubs

Ensure that conductor strands are not cut and opened up. Wherever strands are found cut/damaged/scratched, they must be repaired with repair sleeves/repair protective rods in case the nos. of damaged strands are within specified limits (normally up to 1/6th nos. of strands in the outer layer).

4.2.1.8 Accessories for Conductor and Earth wires:

Joints

All joints on conductor/earthwires shall be away from the tower at a distance of at least 30 metres or as provided in the Technical specification.

Ensure that not more than one joint in a conductor is provided in one span.

Ensure that no mid span joint is provided in major crossings for main roads, railway crossing and major rivers etc. or as provided in specification.

Ensure that all mid span joints on conductors/earthwire and repair sleeves of compression type are free from sharp edges, rust and dust.

Clipping

Ensure that conductor is not over tightened in the suspension clamps.

Spacers, vibration dampers and copper bonds

Placement and no. of dampers on each phase shall be verified as per damper placement chart.

Spacing of Vibration dampers from the tower and spacing between damper to damper in case two Vibration Dampers (VD) were provided, shall be verified as per the damper placement chart. All loose/ displaced VD shall be properly tightened/relocated and missing VDs shall be provided. Ensure that no copper bond is loose/missing.

Jumpers

Verify Electrical clearance of jumpers to tower body as per design. All the jumpers shall be checked properly. In case, jumpers (conductor/earthwire) are found loose, they shall be tightened sufficiently.

Foreign material

Ensure that all foreign materials viz dead bird, fallen tree branches, bird nests etc. on conductors, earthwires, Jumper, insulator string, cross arms are re-moved.

Others

It shall be ensured that all temporary/local earthing, guys, T&P (Tools and Plants), foreign material and other loose material which were used during stringing/tower erection have been removed.

In case there is any change in the ground profile before commissioning of line from the approved profile, the extra earth/obstruction/temporary sheds/any other construction shall be removed.

4.2.2 Pre-commissioning Testing and Charging Procedure

First the construction unit should ascertain that the transmission line to be energized is ready for operation and has been properly handed over (released) in writing. This will include all safety aspects, Electrical inspector clearance, Statutory clearance, and final inspection, if any.

All the concerned authorities shall be informed before commissioning the lines and their approval obtained in accordance with Indian Electricity Act, 1910 and Indian Electricity Rules, 1956. Electricity Supply Act 1948 and Electricity Act 2003. Before charging of the line PTCC approval from P&T Dept. shall be obtained.

Line charging instructions received from CE/Grid are clearly understood by the project in charge and DE/SE (O&M) and doubts, if any, are to be got clarified prior to the energization of the line.

Once the line is handed over for charging no work shall be permitted without a valid **Line Clear (Work Permit)**.

When the whole system has been energized, including the AC line, it will be kept in this state for 8 hours or more for "soaking" with continuous inspection and monitoring. However recommendations of CE/Grid may be checked. Otherwise it may be put into continuous operation.

4.2.2.1 Safety Procedures:

Energization implies an abrupt and serious change of the working conditions in the plant.

In order to avoid serious accidents, thorough information must be given to all personnel involved in the construction of transmission line. EE/SE, construction concerned with the project, must ensure that due publicity has been made to the public in all the villages/areas along the line route cautioning them against climbing the towers etc. and intimating about the date on which the line

will be charged. It is also to be confirmed that the Contractor shall not carry out any job on the said line without a valid line clear.

It shall be ensured before charging that all men, material, Tools and plants and any temporary earthing on any part of the entire length of line are removed.

It must be ensured that any power supply / low voltage charging used as anti-theft measure must be disconnected and isolated to avoid accidental connection.

All equipment tests and pre-commissioning tests must have been completed, reconnected (in case cables were isolated for testing purpose) and documented.

The system must be formally declared ready for energization and handed over for operation in writing.

4.2.2.2 Handing over:

The transmission line shall be inspected prior to energization and a formal handing over document to be jointly signed by the representative of SUPPLIER (if available), Contractor , and EE construction concerned. However all contractual taking over has to be resolved separately as per the terms and conditions of the contract. This Handing over shall be limited to the extent of completion of erection and readiness for energization.

Any balance activities remaining to be done, are to be listed jointly by EE (construction) and contractor and signed jointly. These documents are also to be retained at field with a copy to Head Quarter. These balance works are mentioned in the following category.

- i) List of balance works in any part of the line
- ii) A list of temporary arrangements introduced.
- iii) Check list records properly documented, completed and signed.
- iv) Original tracing of Profile, Route Alignment, Tower Design, Structural Drawings, Bill of Materials, Shop Drawings, Stringing charts (initial and final as applicable) etc. of all towers/line submitted to KSKMPCL.

Whether the balance activities mentioned above are solved or whether any minor points which do not influence charging of the line remain shall be recorded. In case of such minor issues, handing over of the transmission line shall be accepted by the pre-commissioning team. This handing over only for energization with or without remaining activities shall be made by the EE/SE construction to the SE (O&M) and the CE zone concerned in writing.

4.2.2.3 Control and Protection System:

Before energization it must be ascertained that all control and protective systems for the unit to be energized are operative. This includes confirmation that the protections have been properly tested and that the tests have been documented.

It also includes verification by inspection or otherwise, if necessary by repetition of trip test, that the protections are actually functionally enabled, as counter check.

4.2.2.4 Despatch Procedures:

All operational activities (switching etc.) must be coordinated and communicated with the State Load Despatch Centre.

4.2.2.5 Switching Procedures:

For each activity the instructions to the operators and the communications to the dispatchers will be made in writing or by confirmed telephone messages. The switching procedures first to be properly documented step by step and understood by everybody involved in the switching operation prior to the energization. Any clarification required in the procedures must be resolved.

The implication of this is that each and every activity must be listed and described, so that complete information is available for detail investigation, if required in future.

4.2.2.6 Testing and Measurement Procedure:

Before commissioning of the line following tests may be carried out

Earth Resistance Measurement: Prior to the testing of soil resistivity and earth resistance the operation manual of the testing instrument available at site may be referred and procedures to be adopted for measurement of soil resistivity and earth resistance followed.

Insulation Resistance Test: This test may be carried out with the help of a 10 or 12 KV megger preferably power driven to ascertain the insulation condition of the line. In case 5 kV megger is used, it shall be ensured that the induced voltage (CVT reading) is LESS than the instrument withstanding capacity otherwise it is likely that the instrument may be damaged.

This Test is to be carried out First prior to the continuity test.

Conductor Continuity Test: The objective of this test is to verify that each conductor of the overhead line is properly connected electrically (the value of electrical resistance of line does not vary abnormally from that of a continuous conductor of the same size and length). The electrical resistance of the conductor shall be measured with a Whetstone bridge or other suitable instrument, if available taking the safety aspects of Equipment as well as testing Engineer.

A simple method of continuity test is illustrated below :

Once the insulation test is completed and the results confirms no short circuit check the following :

<u>Sending End</u>	<u>Receiving End</u>	<u>Results</u>
CLOSE R-Ph GS	MEGGER R- Ph	ZERO/LOW
OPEN Y – Ph GS	MEGGER Y-Ph	HIGH
OPEN B-Ph GS	MEGGER B-Ph	HIGH
OPEN R-Ph GS	MEGGER R-Ph	HIGH
CLOSE Y – Ph GS	MEGGER Y-Ph	ZERO/LOW
OPEN B-Ph GS	MEGGER B-Ph	HIGH
OPEN R-Ph GS	MEGGER R-Ph	HIGH
OPEN Y–Ph GS	MEGGER Y-Ph	HIGH
CLOSE B-Ph GS	MEGGER B-Ph	ZERO/LOW
(ALL GS OPEN CONDITION)		

GS means GROUND SWITCH

Test results as above indicate continuity of the line.

The continuity Test of the line with proper phase indication or phase marking can be checked by continuity test as described below:

Sending End	Receiving End Megger between	Results
CONNECT R&Y PHASE B-PHASE & ALL GS OPEN	R PHASE & Y PH Y PHASE & B PH B PHASE & R PH	ZERO OR LOW HIGH HIGH
CONNECT R & B PHASE Y PHASE & ALL GS OPEN	R PHASE & Y PH Y PHASE & B PH B PHASE & R PH	HIGH HIGH ZERO OR LOW
CONNECT Y & B PHASE R-PHASE & ALL GS OPEN	R PHASE & Y PH Y PHASE & B PH B PHASE & R PH	HIGH ZERO OR LOW HIGH

Test results as above indicate it correct marking of the phases.

Phase Sequence

Once the line is charged from one end, without closing the Breaker at the other end the Phase sequence is to be checked from the CVT output by the help of Phase Sequence Meter. In case there is other feeder/feeders available Phase sequence is to be rechecked by the measurement of secondary voltage of both the Feeders (New line & existing charged line).

Let the secondary Voltage of CVT be 110 volts (ph to ph) for both the Circuits. In case of correct Phase Sequence the voltage reading shall be as follows:

NEW CIRCUIT	EXISTING CIRCUIT	VOLTAGE
R-Phase	R-Phase	0
R-Phase	Y-Phase	110
R-Phase	B-Phase	110
Y-Phase	R-Phase	110
Y-Phase	Y-Phase	0
Y-Phase	B-Phase	110
B-Phase	R-Phase	110
B-Phase	Y-Phase	110
B-Phase	B-Phase	0

In case the results are not matching the phase sequence is to be rechecked and reconfirmed before closing the breaker.

Signature Analysis: There could be in-homogeneities on the line due to improper joints in the conductor, loose jumpers, leakage points, electrical path to ground due to disc puncture etc. To check the condition of the line, signature analysis of the line may be carried out using an off-line fault locator. Signature analyzer indicates the degree of faults from the minimum to the major fault in progressive numbers. A no fault line or uniform line is indicated as “-”. All types of fault can be detected with an accuracy of +/- 100mtrs.

After attending to rectification of all defects noticed, the condition of the line may be verified using the fault locator and the signature so obtained may be recorded as reference for comparison with the values observed during maintenance later.

Before conducting the signature analysis, isolators should be kept open at both ends. Earth switch should be closed. After connecting the fault locator unit to system ground, connections to the overhead lines should be given. Before commencing the test, the line earth switch should be opened. All safety precautions such as wearing gloves, rubber shoes etc. should be taken.

4.2.2.7 Energization:

After completion of all the required tests and checks satisfactorily, the SE/DE (O&M) will fix programme for charging the line in consultation with the EE/ SE (Construction), who will

arrange to get the service persons from contractor/supplier for supervision of testing and commissioning of the line as per the provisions of contract. Test reports and the programme for charging should be intimated well in advance to zonal CE, CE (construction), and CE (GO). The Grid operation unit will prepare charging instructions in consultation with communication, power systems and construction units, and communicate the same to SEs TL&SS and TLC. Suitable charging instructions will be prepared depending on the type of line to be charged, viz. radial line/ inter connecting line/ power evacuation line etc. Charging instructions shall be strictly followed in correct sequence while charging the line.

4.2.2.8 Observation and Duration:

The line may be charged on no load at power frequency voltage preferably for 24 hours and monitored for any abnormalities.

Visual and audible inspection of the relevant equipment and reading of permanent instrumentation will be made.

The system shall be idle charged at least for 8 hours. During this time continuous monitoring and inspection will be done in control room, auxiliary systems areas and switch yards.

This will include frequent, scheduled inspection of all equipment and reading of all permanent instruments and recorders, and surge arrester counters, especially system parameters.

4.2.2.9 Passing Criteria:

Neither insulation breakdown nor actuation of protective system must occur. Observe for equipment behavior, noise, vibration, temperature rise etc. Any abnormalities should be noted and corrected.

Corona discharges may not be “unreasonable”. Local discharges that may be attributable to sharp points shall be carefully located and recorded. After termination of the energization the equipment shall be closely inspected and the points rounded or covered.

No unscheduled changes of system nor of equipment is permitted during the 8 hour energized condition.

4.2.2.10 Documentation:

Switching and operational activities and all readings of permanent instruments will be recorded in a regular manner in the operators log. Copies of this log, notes on special observations from inspections and other measurements will constitute the test records.

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MAINTENANCE PROCEDURES:

Introduction:

Proper maintenance of electrical systems helps in minimizing/preventing unwarranted breakdowns of equipment/ lines improving the reliability and generating revenue. Periodical or preventive maintenance is normally followed to keep the equipment continuously in service for desired output. Condition based maintenance is the most accepted and adopted concept in maintenance now a days which helps in providing advance information about the health of the equipment to take corrective action in advance.

As the system is growing, it is getting more and more complex. Due to stringent regulations the utility cannot afford to have breakdowns in the system resulting in interruption of power supply to the consumer. On the other hand equipments are getting older and are more prone to failure. Equipment overhaul and major maintenance are also expensive and need to be planned based on the condition of the equipment rather than on a periodic basis as a routine.

5.1 SUBSTATIONS

5.1.1 PREVENTIVE MAINTENANCE PROCEDURES:

5.1.1.1 General Instructions for Maintenance of Switch Yard Equipment:

External Cleaning: The insulators of the transformer bushings; circuit breaker; CT; CVT; isolator shall be cleaned from salt and dirt/dust deposition together with the cleaning of the other insulators in the substation. Frequency of this cleaning depends on the polluting atmosphere. For installations with higher atmospheric/saline pollution, cleaning frequency may be increased and these may be suitably protected against pollution.

Rust Protection: All steel enclosures such as marshalling kiosks, boxes parts of the operating mechanism are made of steel and are surface treated against rust. In spite of the good rust protection, minor corrosion will occur after some years, especially when these are standing in strong corrosive surroundings. The rust stains shall be sand papered away and new rust protection shall be painted or sprayed on. As rust protection, grease G or Tectyl 506 is recommended.

Lubrication: For lubrication, the lubricants recommended by manufacturers shall primarily be used. This is especially important in cold climates with temperatures below - 25°C. The bearings of the breaker and operating mechanism of isolator and breaker are to be lubricated with grease G although these normally do not need lubrication before the major overhauls. Plain bearings in mechanism details such as arms, links and link gears are also to be lubricated with grease G. These bearings shall be regularly lubricated with a few drops of oil B. The teeth in the gear shall be lubricated with grease G. Dryness of driving mechanism may lead to mal-operation and failure.

Treatment of Contact Surfaces: The contacts of breaker / isolator / ground switch shall be treated according to the following directions:

- Silvered contact surfaces: Silvered contact surfaces shall be cleaned, if necessary, with a soft cloth and solvent (Trichloroethane). Steel brushing or grinding is not allowed.
- Copper surface: Copper surfaces shall be clean and oxide free. If necessary, they shall be cleaned with cloth and solvent (Trichloroethane) or steel brushing. After steel brushing, the surface shall be cleaned of loose particles and dust.
- Aluminum surface: Aluminum contact surfaces shall be cleaned with steel brush or emery cloth. After making the surface dry and free of dust by wiping with a dry cloth, a thin layer of Vaseline shall be applied. The joint shall be assembled within 15 minutes.

Moving Contact Surfaces:

- Silvered: Cleaned if necessary, with soft cloth and solvent (trichloro ethane). No steel brushing.
- Non-silver coated: Cleaned as silvered surfaces, can be steel brushed. After steel brushing they shall be thoroughly cleaned of loose particles and dust
- Lubrication: Lubricant – grease K is applied in a very thin layer on the surfaces of the male contact and the puffer cylinder. The superfluous grease is carefully removed.

Safety: Before taking up any work in close proximity of live equipment or any work on a top of transformer where safety clearance is not sufficient, proper line clear (permit to work) shall be taken. Person authorized to issue such clearance and the authorized person who receives it shall independently ensure that proper isolation has been carried out and earthing provided at appropriate locations. Whenever earthing needs to be removed to conduct any test on equipment, the same shall be done after obtaining the permission from the person issuing line clear.

Precautions: Maintenance shall be carried out by skilled persons having adequate knowledge and experience on the equipment. Maintenance Engineer shall be aware of the concepts of condition monitoring tests and update himself with the developments in condition monitoring methods. Maintenance Engineer should have knowledge of the equipment and the testing instruments used so as to safeguard the equipment, testing instrument and more important, human life. The boundary of work area shall clearly be identified and caution to be exercised not to inadvertently contact the live neighboring components. Proper isolation of AC and DC power supply shall be ensured to avoid electric shock. Always ensure using proper ladder and other safety equipments while climbing to higher places. Make shift arrangements may lead to accident.

Analysis of Test Results: All test results are to be carefully analyzed and preferably compared with earlier test results and pre-commissioning test results to arrive at conclusion. A trend analysis is more important to identify the evolving defects and to take corrective action.

5.1.1.2 TRANSFORMERS AND REACTORS:

In order to provide long and trouble free service, it is important that a careful and regular supervision and maintenance of the transformer and its components is carried out. The frequency and extent of such a supervision and maintenance is dependent on the experience, climatic conditions, environment, service conditions, loading pattern etc. All work done on transformers should be recorded in history register for future reference.

General Supervision:

Dirt and Dust: The external transformer surfaces shall be inspected regularly; and when required cleaned of dust, insects and other air borne dirt. Transformers/reactors installed near polluting industry/cement plants, etc., need special care and more frequent cleaning of the bushings and other components. All Marshalling Boxes and OLTC cubicle are to be kept properly closed so that there will not be entry of dust inside, which is difficult to clean.

Rust and Treatment: A regular inspection is to be done on the external surface of the transformer tank and radiators. Possible rust damages shall be removed and the surface restored to original state by means of the primer and finish-paints of the transformer to minimize the risk of corrosion and its subsequent spreading. These checks also include looking for signs of oil leaks on gasket areas and welded areas containing oil. The touch-up paint' as and when required as per site condition and re-painting is to be done once in five years. However transformers in coastal areas and more corrosive atmosphere may require more frequent painting.

Steel wire brush and abrasive/emery paper no.100, 150/180 and 320 general purpose thinner, synthetic enamel paint of approved shade (IS: 2932), Zinc chromate primer (IS: 104) and paint brush may be required for the above work.

Using a wire brush, remove all loose flakes of paint, ensuring that the surrounding areas are given attention. Using the abrasive paper, rub the damaged areas so that all contours to the edges are smooth. Prominent dent marks and pits on external surfaces are to be filled up with knifing putty. When putty is dry, smoothen it with emery paper and clean with clean rag. Clean the local area with a suitable solvent like methyl alcohol that contains no salts.

Depending upon the extent of the damage, i.e., depth, apply the necessary number of coats of paint to build up the overall thickness (min. 80 microns). One undercoat and one top coat after two coats of primer is to be given.

Paint should be applied so that the layers feather in with each other and there should not be any steps in layers. For radiators, spray painting (50-60 psi) should only be applied.

Allow each coat of paint to dry before the next coat. This procedure must only be carried out either in warm, dry weather or while under cover with clean plastic sheet.

Mechanical Damage: Checks must be carried out for mechanical damage to the fabrications and associated equipment. Particular attention should be given to vulnerable areas such as radiators. If

damage is seen on the equipment, a decision must be taken as to its seriousness. It may be necessary to take corrective actions such as replacement of an item of equipment.

Check out all Joints for Signs of Leakage: All joints, both welded and gasketed, must be checked for signs of oil leakage. If there is any doubt of a leak, the area must be cleaned of oil, using a suitable solvent (methyl alcohol) and sprayed with liquid chalk. This will promote the flow of the leak and give a good indication as to the exact location of the leak, if there is one. If a leak is suspected on a gasket, the joint must be tightened until such time that it can be changed with a new gasket. If a leak is apparent at a welded joint once again clean the area and apply liquid chalk and allow to dry. This will highlight the point exactly if in fact there is a leak. It must be properly repaired with welding procedures when convenient. Prior to leaving the leak, it must be highlighted with a marker, or something similar, so it is not lost when permanent repair takes place.

Other areas commonly associated with oil leaks are drain plugs in radiators, valves in the oil management and cooling system and the gas and oil actuated relay.

Check for Oil Level: All oil levels associated with the equipment including oil conservator and all oil filled bushings shall be checked. Also the oil in the oil seal should be maintained. Some bushings in transformers will be below the conservator oil level and some above. If there is leakage in bushing at the oil end, the level will be low or high depending upon the level of conservator. External leak on bushing will lead to indicate low oil level. This is to be observed accordingly and if there is leak, action is to be initiated immediately as bushing failure may lead to failure of entire transformer.

OLTC oil conservators are always kept at lower level compared to the main conservator tank so that OLTC oil will not mix with main tank oil. An increase in level of oil in OLTC conservator tank indicates internal leakage and action is to be taken accordingly. After energizing of the transformer, a certain settling may appear in sealing joints. This applies especially to sealing joints with plain gaskets that are not placed in grooves. These should therefore be re-tightened. For correct torque for tightening the bolt, the manufacturer's recommendations are to be followed.

After completing all the checks ensure that all materials or tools, used for maintenance work, have been removed. All clothes and other debris must be disposed off. The transformer compound should be left in a clean and tidy condition.

Silica Gel Breather: In open breathing transformer, the breather plays active role in maintaining the transformer dry by admitting dry air when transformer breathes. In transformers having air cell or diaphragm, the breather ensures dry air inside the air cell or above the diaphragm. The silica gel inside the breather becomes pink from bottom to top over a period of time.

Any de-colorization at top or sides indicates leakage in container and needs to be attended immediately. In order to prevent severe deterioration of the silica gel, it is recommended that it is replaced when half to two thirds of the silica gel has become pink in color. Failure to do so will severely retard the drying efficiency of the breather. The silica gel can be reactivated by heating it

to 130°C-140°C in a ventilated oven until it has achieved the bright blue color. Check that the oil level is correct in the Oil Cup at the breather base and fill oil if the level is found low.

Note: Do not exceed the temperature stated above, otherwise the color impregnation will be destroyed and the silica gel will turn black.

Immediately after re-activation the loose silica gel must be placed in a sealed container to prevent absorption of moisture on cooling. The silica gel should be stored in sealed condition until required for use.

Self indicating (blue) silica gel contains the dye cobalt chloride which has been classified carcinogenic by a European Commission directive and is a banned substance because of its potential health hazards. In Europe the silica gel breathers are to be disposed in 'Class I' disposal locations for hazardous waste products or incinerated.

Drycol Breather Check: Drycol breathers are provided in some transformers where air cell is not provided. It condenses the moisture inside the conservator and brings it out as water droplets. Silica gel breather will also be provided for these transformers.

The following checks need to be carried out for Drycol breathers:

Operation of counter reading: Check on a regular basis that the counter is functioning. Record the figures each time a check is made so that a progressive check is recorded.

Defrost current condition indicates that water is still being ejected from the breather

Press the test button and check that a defrost current is being indicated. Check that the two red neon lights are ON and the amber neon light is OFF.

Release the test button and check that the counter has advanced one count and that freeze current is indicated.

Checks for conservator:

Visual Check for Conservator Oil Level: The transformer oil conservator is provided with an oil-level indicator indicating "low" to "full" with grading. These indications are relative to temperature of the operating equipment. The oil level indicated should be recorded along with top oil temperature.

If corrected oil level is normal, no additional action is required, whereas if it is above or below the normal level, it may be necessary to remove or add some oil. The correct oil-filling level is specified on an information plate that is placed on the transformer rating plate panel. At an oil temperature of + 45°C, the conservator should be half filled; if the level exceeds the "full", oil must be drained off. If the value is "low" or "min", oil must be filled in.

Leakage Test for Air Cell:

Normally leakage test for air cell fitted inside the conservator is carried out before installing the conservator in its position or at the time of major overhaul. During service, the leakage in the cell or in the sealing of the conservator can be detected by the oil level in the prismatic oil level indicator, if provided, on the conservator. If there is no leakage, the prismatic oil level indicator will show "Full" oil level. However, in case of leakage, the oil level in the prismatic oil level gauge shall be lower than "Full" level.

For releasing air from Conservator fitted with Air Cell: Pressurize the Air Cell up to the maximum pressure specified by the manufacturer and open the air vent valves provided on the top of the conservator until oil starts coming out. Then close the valves. Release pressure from the Air cell and refit breather.

For releasing air from Conservator fitted with Diaphragm type Air Sealing: Open the air release valve provided on the top of the diaphragm and start filling oil into the conservator, preferably from the valve provided at the bottom of the conservator. Filling of oil from oil filling valve at the bottom of transformer tank is avoided because it may result in entry of air into the transformer and may get trapped and result in unnecessary accumulation of air in the Buchholz relay at a later stage.

Continue filling oil into conservator until it is full and oil starts coming out of the air release valve. Close the air release valve after ensuring that entire air has come out from the oil portion below the diaphragm.

Slowly drain the oil from the conservator until the oil level as indicated on the oil level gauge corresponds to the transformer oil temperature.

Before making the leakage test of air cell for the transformer in service, oil should be drained out to the lower level of conservator. Apply pressure as specified by the manufacturers to inflate the air cell. Adjust the pressure after 6 hrs, if required. Check temperature and maintain the air cell at almost the same temperature for 24 hrs. If there is no loss of pressure during 24 hrs, it means the air cell is not having leak.

Any heating process like welding, grinding etc. are not allowed on the assembled conservator fitted with air cell diaphragm as it is highly sensitive to heat.

Marshalling kiosks/Cubicles: Checks on physical parameters like condition of paint, condition of door seal, lights and heaters, cable tightness etc shall be done.

Operation of alarms and indicating lamps to cover all system functions shall be ensured.

Valve Operational Checks: Transformer and associated equipment must be out of service, isolated and earthed while carrying out these checks. Valve operational checks are done at the time of erection or at the time of major overhaul.

The checks include checking each valve for free operation, adequate greasing and for padlocking wherever provided.

Each valve shall be returned to its “in service” operating position (open or closed) and locked after the checks have been completed.

Checks for Auxiliaries

Cooling System: The cooling surfaces of radiators shall be inspected regularly and cleaned of dust and dirt. The cleaning is suitably carried out by means of water flushing at high pressure. Precaution should be taken to cover the fan-motor so that water may not go inside. Alternatively cleaning can be done with cleaning solution and cloth.

The fan-motors are provided with permanent - lubricated bearings and double sealing rings. The motor bearings are axially clamped with spring-washers. If the sound level of the fan increases, then first tighten all mounting supports and in case any abnormal sound is noticed in fan motor, then action should be taken for repair/ replacement.

Cooling System-Fans-Controls: Fan controls are designed to operate both manually and automatically with set temperature. Manual, Control is to be turned 'ON' to operate cooling system for checking. Oil pumps need to be checked by observing their flow gauges. Measurement of pump current reveals any abnormality. Any significant imbalance of current between the terminals greater than 15-20% is indicative of the problem with the pump motor. Checking for correct rotation of fans and pumps to be ensured as reverse rotation may not provide desired result.

Calibration of OTI/ WTI: Temperature indicators in transformers are used for both indication purpose and as protective device. The accuracy of these devices is to be ensured for correct operation of alarm and tripping and also to prevent mal operation. The Indicator temperature bulb is to be removed from its well on the side/ top of transformer. Using a temperature controlled calibration instrument in oil bath the temperature of the bulb should be slowly raised in steps of 5°C and observed for temperature reading. If the temperature deviation is more than $\pm 5^{\circ}\text{C}$ compared to the standard thermometer reading, the thermometers are to be replaced with healthy one.

Checking of Cooler Control, Alarm and Trip Settings: Setting of temperature should be as per approved scheme. Access the local winding / oil temperature indicator and rotate the temperature indicator pointer slowly to the first stage cooling value (say 65°C). Check that the fans of those coolers set to first stage are operating. Continue rotating the pointer to the second stage cooling value (say 80°C). Check that the fans of those coolers set to second stage are operating. Continue rotating the pointer to the alarm value (say 110°C). Continue rotating the pointer to the trip value (say 125°C). Observe for alarm and trip signals in the panel.

Pressure Relief Device: The Pressure Relief Valve (PRV) is mounted at the transformer top body. Internal arcing in oil inside transformer generates excessive gas pressures that can severely damage equipment and cause extreme hazards to personnel. The pressure relief device is intended to minimize the extent of damage by quickly operating and venting out the pressure. It will reset

when the pressure becomes normal. A pointer is provided to indicate the operation of this relay and the relay is connected for tripping the transformer on operation. There will be oil spillage whenever the relay operates. Smaller transformers are provided with explosion vent where the diaphragm will rupture due to heavy internal pressure and releases the pressure. The diaphragm needs to be replaced when it operates. There are some transformers fitted with sensitive sudden pressure relay, which operates on rate of change of differential pressure and trips the equipment.

Buchholz Relays: The use of gas-operated relay as protection for oil-immersed transformers is based on the fact that faults as flashover, short-circuit and local overheating normally result in gas-generation. The gas-bubbles gathering in the gas-operated relay affect a float-controlled contact that gives an alarm signal.

For testing of the contact functions, buchholz relays are provided with a test knob on the cover. Unscrew the protective cap and press down the knob by hand. The spring loaded knob with a pin inside the relay actuates first the alarm device and then the tripping device. After testing, screw on the protective cap again.

Checking the operation of Buchholz relay in case of low oil level is carried out by closing step valve in both sides of the relay and draining of oil through oil drain valve provided in Buchholz relay. First alarm and then trip contact should operate to indicate healthiness.

To check the relay for oil surge, manufacturer's recommendations for particular relays have to be followed.

Bushings: Bushings are most failure prone in any transformer/ reactor. Failure of bushings could lead to the fire in transformer and total damage. For uniform voltage distribution across capacitance graded bushings, bushing porcelains shall be cleaned from dust and dirt during shutdown maintenance. In areas where the air contains impurities such as salt, cement dust, smoke or chemical substances, shorter intervals are required.

On Load Tap Changer: To enable operation of taps during service, On- Load Tap Changers (OLTC) are provided in EHV transformers. OLTCs may be located either on the high voltage winding or the low voltage winding, depending on the requirements of the user, the cost effectiveness of the application and tap changer availability. OLTC being a current interrupting device requires periodic inspection and maintenance. The frequency of inspection is based on time in service, range of use and number of operations.

Precautions: Testing of OLTC shall be done under shutdown i.e. after de-energizing the transformer by isolating the transformer from all sides.

Tap Changer Hand Operation: Check hand operation of the tap changer up and down the full range before electrical operation is attempted and that the handle interlock switch does not allow electrical operation while the handle is inserted. In addition where single phase tap changers are employed check their tap positions agree and are reached simultaneously at motor drive unit head. Continuity check should be done for any discontinuity during tap changing operation by connecting an analogue multi meter across HV and IV bushing in case of auto transformers and

relevant winding in case of two winding transformers and change the tap positions from maximum to minimum.

Check for proper operation of out of step relay, tap changer surge relay and remote operation and tap indication of tap changer.

Inspection and Maintenance of OLTCs: Normally the temperature of the OLTC compartment may be few degrees Celsius less than the main tank. Any temperature approaching or above that of the main tank indicates an internal problem. Prior to opening the OLTC compartment, it should be inspected for external symptoms of potential problems. Such things as integrity of paint, weld leaks, oil seal integrity, pressure relief device and liquid level gauge are all items which should be inspected prior to entering the OLTC.

Following de-energization, close all valves between oil conservator, transformer tank and tap-changer head, then lower the oil level in the diverter switch oil compartment by draining of oil for internal inspection. Upon opening the OLTC compartment, the door gasket should be inspected for debris that might indicate abnormal wear and sliding surfaces should be inspected for signs of excessive wear.

Finally, the tap selector compartment should be flushed with clean transformer oil and all carbonization which may have been deposited, should be removed. Minimum BDV should be 50kV and moisture content should be less than 20 PPM.

5.1.1.3 CIRCUIT BREAKERS:

Main parts of a circuit breaker are interrupting chambers and the operating mechanism. The interrupting chambers normally do not require routine preventive maintenance other than cleaning but operating mechanism does require proper upkeep.

Interrupting Chamber: Interrupting chamber is an enclosed unit mostly filled with oil or SF₆ gas. 33kV and below Circuit breakers have vacuum interrupting chambers also. There is stress on the contacts during fault current interruption and damages may happen to arcing contacts or main contacts. The breaker interrupting chamber is recommended to be opened only based on condition monitoring tests or as per advice of the manufacturers.

In SF₆ circuit breaker, whenever there is fault interruption, there is formation of metallic fluoride inside the arcing chamber. This fine white/ gray powder has high dielectric strength when it is dry. Moisture absorbent material is provided in circuit breaker to keep the gas dry. The absorbent material is to be changed as per advice of manufacturers. The absorbents are normally packed in air tight sealed container and it should not be exposed to atmosphere for long time (not more than 15 m) as it may absorb moisture from air. SF₆ pressure and dew point also should be monitored since these parameters are vital for successful fault clearance by the breaker. If there is loss of SF₆ gas pressure, then leakage test with halogen leak detector is to be carried out to identify the leak area for rectification.

In minimum oil circuit breakers, breather is provided to keep the breaker free from moisture. Breather silica gel need to be monitored and changed when ever required. The level and quality of oil are also to be monitored.

Operating Mechanisms: Normally circuit breakers have pneumatic, hydraulic and spring operating mechanisms. As operating force is required for closing and tripping of circuit breakers there can be combination of these mechanisms in one circuit breaker. Since operating mechanisms have a number of moving parts, they need more maintenance such as greasing, lubrication, cleaning, setting of limit switches, etc. Compressors/ oil pumps/ spring charging motors also require maintenance. Other maintenance on particular operating mechanism such as air compressor maintenance, nitrogen priming pressure checking in hydraulic mechanism, checking of over travel, checking of gaps in operating plunger of close/ trip coils etc. are to be carried out as specified by the manufacturers.

SF₆ Gas: The density of SF₆ gas is about five times that of air and heat dissipation is also much more than air. At atmospheric pressure, dielectric strength of SF₆ gas is about 2.4 times that of air and at 'about 3 kg/cm² it is same as that of oil. As SF₆ is Green House gas, it needs to be handled carefully and should not be let in to the atmosphere.

Emptying and Re-filling of Gas: The breaker is evacuated by means of the gas treatment equipment that purifies and also compresses the gas for storage, so that it can be reapplied. For economic and ecological reasons, SF₆ contained in electrical equipments, should not be vented into atmosphere. Prior to the gas removal, the quality of the SF₆ gas should be tested.

Operational contamination should be absorbed with suitable filter unit provided in the gas handling plant. Such filters/ sieves should already be installed into the SF₆ gas maintenance/ handling unit. When SF₆ is suctioned from a gas compartment, the gas is passed automatically through filters, which dry and purify the gas.

After maintenance/ overhaul of the circuit breaker, it should be evacuated by vacuum pump before filling in the SF₆ gas so that SF₆ gas does not mix with ambient air and also humidity and dust particles are removed from the Breaker. With vacuum pump a final vacuum must be reached less than 5 mbar.

Grading Capacitors: Grading capacitors are provided in multiple break Circuit Breakers to equalize potential difference across the breaks. If grading capacitors are provided, it is to be ensured that they are properly connected and there is no leakage of oil from the grading capacitors. The insulator porcelain should be kept clean and condition monitoring tests are to be carried out to identify the healthiness.

Pre-insertion Resistors: Pre-insertion Resistors (PIR) are provided in circuit breakers to limit surges during switching. Unless any abnormality is noticed during condition monitoring tests, no internal inspection of the PIR contacts of resistors is required. The insulators are to be kept clean and proper tight connection with the circuit breaker has to be ensured.

5.1.1.4 CURRENT TRANSFORMERS:

Visual Inspection: Current transformers are normally filled with oil and have oil impregnated paper insulation for both primary and secondary winding. Careful inspection is to be made for any trace of oil leakages. Oil leakages are more prone through cemented joints or secondary terminal box due to improper sealing of terminal studs. As CTs have less oil quantity small leakage may lead to exposure of paper insulation and subsequent moisture absorption.

If bellows are provided in CTs, the position of bellow indicates either leakage of oil or expansion due to internal gas generation. Both the conditions are serious for the life of the CTs and immediate action to be initiated for rectification.

Visual inspection is also to be carried out on the healthiness of terminal connections, condition of porcelain, development of cracks, chippings, cleanliness of insulator surface etc.

Maintenance of Gaskets: Marshalling boxes, CT terminal boxes are to be properly sealed to prevent any dust, rain water and insects. Door gaskets are to be changed periodically to give proper sealing. All door bolts/ latches are to be properly tightened and never left loose.

Secondary Terminals Connections: Stud type terminals are preferred in Marshalling box cable terminals. This gives better grip even if more than one wire is connected to one terminal. But pin type terminals are also provided in some cases. Since wires may get loose due to vibration, climatic condition, it is required to check tightness of terminals periodically to avoid mal-operation/ non-operation due to improper contacts. All terminals of unused CT secondary terminals are to be properly shorted to avoid development of abnormal voltage and subsequent failure of CTs in case they are left open. The tan δ test tap is to be properly earthed to avoid damage to insulation.

Primary Terminals: Thermo vision scanning indicates proper connection of primary terminal. If thermo vision is not carried out, physical checking of terminal connection is to be done with proper torque. All corona shields are to be provided and any damaged corona shield to be replaced with new one. As CT primary carries heavy current, any loose joint may lead to arcing and welding of terminal connectors.

In coastal and industrial areas where pollution levels are high, due to saline atmosphere/ chemical contamination, porcelain insulators of electrical equipment shall have higher creepages.

5.1.1.5 CAPACITOR VOLTAGE TRANSFORMERS/ POTENTIAL TRANSFORMERS/ COUPLING CAPACITORS:

Visual Inspection: The bellows provided in most of the CVTs are not visible from outside. CVTs/ PTs and CC are also oil filled equipments and oil leak is to be observed. If oil leak is observed in anyone stack, the entire CVT is to be replaced. CVTs are tuned units and replacement of anyone stack is not recommended to avoid phase angle errors.

Electro-Magnetic Unit: Electro-Magnetic Unit (EMU) of CVT houses the secondary transformer, Compensating reactor and Ferro resonance suppression circuit. The colour of oil indicated through the gauge glass gives some indication of the healthiness of the internal components. Any abnormal heating may also be observed through Thermo vision scanning.

Secondary Voltage: Deviation in secondary Voltage of CVT is clear indication of failure of capacitor elements. Action shall be taken to replace CVT if secondary voltage in any one CVT is abnormal (may be +2volts and - 4volts). Continuing the equipment in service beyond this stage may lead to failure/ bursting of CVTs.

Other Maintenance: Maintenance of Marshalling box gaskets, tightening of secondary terminal connections and tightening of primary terminal connections, etc., are also to be ensured for healthy operation. It is to be ensured that all extra holes at Marshalling boxes are properly plugged and the boxes made vermin proof. The anti--condensation heater and the thermostat are to be kept in working condition to keep inside of the panel dry.

5.1.1.6 DISCONNECTORS:

Disconnectors have main current carrying arms and operating mechanism for connection and disconnection. Being off-line devices, they are normally air break type. Normally horizontal double break, Horizontal center break, Pantograph, Vertical break Disconnectors are in use in EHV substations.

The alignment of Disconnectors is very important for smooth operation. The limit switches, the healthiness of auxiliary contacts needs to be checked periodically. The main contacts are to be inspected and made smooth if any pitting marks seen. The corona shields are to be kept smooth and shining and checked for tightness of fitting. Damaged corona rings should be replaced. All moving parts are to be lubricated for smooth operation. The gear mechanism and motor normally do not require any maintenance and manufacturer's recommendation should be referred for maintenance of gears.

Earth Switches: The earth switch is a safety device and smooth operation is to be ensured by proper alignment. The earth blade contacts are to be cleaned properly for proper contact and contact resistance to be measured to ensure healthiness. The earth connection from blade to earth is to be carefully checked. All the joints should be tightened. Flexible copper braid connections are provided and healthiness ensured. All moving parts should be lubricated for smooth operation.

5.1.1.7 LIGHTNING (SURGE) ARRESTERS:

Surge arresters are to be maintained to give protection to other connected switch yard equipments. Cleaning of porcelain insulators is necessary for uniform voltage distribution. Voltage grading rings are to be properly positioned and checked for tightness and any damaged rings to be replaced. Healthiness of surge monitors is to be checked and if found defective the same may either be replaced with healthy one or shorted to minimize earth resistance. Healthiness of earth connection is to be checked as it plays a vital role on the operation of the surge arrester. Failure of

one stack causes over stressing of remaining stacks. Whenever one stack fails, it is better to change the entire arrester as otherwise the stressed stacks will start failing along with the new stack.

5.1.1.8 BATTERY AND BATTERY CHARGERS:

Substations generally use Lead Acid batteries / Nickel-Cadmium batteries for DC supply. Valve regulated lead acid batteries (maintenance free batteries) are also in use for substation applications.

Cell containers are to be kept always clean to avoid surface leakage. Any leakage is to be attended immediately. Vaseline / white petroleum jelly is to be applied on battery terminal and inter-cell connectors, nuts and bolts to avoid sulphate deposit. The rubber seal at the base of the terminals and on cell lid is to be fitted properly and to be replaced if damaged. All connections are to be checked for tightness. Maintaining level of electrolyte in flooded cells is very important to avoid sulphation and permanent damage of the cells. Distilled water is to be added to make up to the level.

VRLA batteries need controlled temperature. Where VRLA battery is used, the battery room temperature is to be maintained -using air conditioner as the temperature plays vital role on the performance of the battery.

Battery Chargers: Battery charger is to be maintained for keeping the battery always charged and also to supply normal DC load for operation. If the charge / discharge ammeter does not show current on the charge side, then the float charger is not giving output. Defect should be located and corrected. In case of failure of float charger, the boost charger may be used as float charger as per design.

Charger panel is to be kept clean, free from dust and all terminals to be checked periodically for tightness. The battery maintenance and condition monitoring is to be carried out as per schedule to keep the DC system in healthy condition.

Battery Capacity Testing:

Initial Requirements: The following list gives the initial requirements for all battery capacity tests except as otherwise noted.

- a) Equalize the battery if recommended by the manufacturer and then return it to float for a minimum of 72 h, within 30 days, prior to the start of the test.
- b) Check all battery connections and ensure that all connections are proper and clean.
- c) Record the specific gravity and float voltage of each cell just prior to the test
- d) Record the electrolyte temperature of 10% or more of the cells to establish an average temperature.
- e) Record the battery terminal float voltage

- f) Take adequate precautions (such as isolating the battery to be tested from other batteries and critical loads) to ensure that a failure will not jeopardize other systems or equipment.

Discharge Test: The ampere-hour capacity of a battery varies with the rate of discharge. The capacity is more at slower rates of discharge and less at higher rate of discharge. The Indian Standards adopt 10 hr. rate as the standard rate of discharge for specifying the AH capacity of stationary batteries.

- a) Disconnect the charging source, connect the load bank to the battery, start the timing, and continue to maintain the selected discharge rate.
- b) Maintain the discharge rate until the battery terminal voltage decreases to a value equal to the minimum average voltage per cell as specified by the design of the installation (e.g. 1.75 V) times the number of cells.
- c) Read and record the individual cell voltages and the battery terminal voltage. The readings should be taken while the load is applied at the beginning of the test, at specified intervals, and at the completion of the test. The readings are to be taken on hourly basis.
- d) If one or more cells is approaching reversal of its polarity (+ 1 V or less) and the test nears the 90-95% expected completion time, continue the test until the specified terminal voltage is reached.
- e) If earlier in the test an individual cell is approaching reversal of its polarity (+ 1 V or less) but the terminal voltage has not yet reached its test limit, the test should be stopped, and the weak cell should be disconnected from the battery string and bypassed with a jumper of adequate conductor capacity. The new minimum terminal voltage should be determined based on the remaining cells. The test should then be continued in order to determine the capacity of the remaining cells. The time required to disconnect the cell, install the jumper, and restart the test shall not exceed 10% of the total test duration or 6 min, whichever is shorter. This "downtime" shall not be included in the test discharge period (i.e., the capacity determination shall be based on the actual test time).

Note: IEEE recommends not more than one "downtime" period when a battery is being tested. The battery may show higher than its normal capacity (especially during short-duration testing) if the battery is subjected to more than one "downtime period".

- f) Observe the battery for inter-cell Connector heating and if possible do thermo scanning of the Connectors during test to establish healthiness of inter-cell connection.
- g) At the conclusion of the test, determine the battery capacity as per the formula given below:
$$\text{capacity} = (T_a / T_s) \times 100$$

Where T_a - is actual time of test to specified terminal voltage, T_s - is rated time to specified terminal voltage

Note: If after the test one or more of the reversed cells are replaced, the benchmark capacity of the battery can be reestablished by either retesting the battery or by analysis. If the problem that caused the cell to reverse is identified and corrected, the cell can be reinstalled into the battery and the battery can be retested to establish the benchmark capacity, or the cell can be

discharged independently, recharged, reinstalled into the bank and the benchmark capacity reestablished by analysis.

Determining Battery Capacity: % capacity at 25°C (77 °F) = $(T_a / T_s) \times 100$

T_a is actual time of test to specified terminal voltage, T_s is rated time to specified terminal voltage.

The discharge rate and test length shall be taken as 10% of the rated capacity and 10 hrs duration for substation batteries.

Effect of Temperature on Discharge Rate: The rated AH capacity of lead acid battery is specified corresponding to a reference temperature of 27°C. The capacity is reduced with lower temperature of the electrolyte and increased with increase in temperature at the rate of 0.43% for tubular and Plate cells per °C variation in temperature for 10 hr discharge rate.

$$\text{Capacity at } 27^\circ\text{C} = C_t + [C \times R \times (27 - T)]$$

Where C_t - Observed capacity at t° C

R - Variation factor of 0.43% for 10 hrs discharge

T - Average electrolyte temperature

Although capacity of battery increases with increase in electrolyte temperature, higher electrolyte temperature accelerates corrosion of the grids and deterioration of separators, thereby affecting the battery life.

5.1.2 CONDITION BASED MAINTENANCE PROCEDURES

As untimely equipment failure is a cause of concern for the reliability of the system, it is prudent to assess the health of the equipment to take corrective action in advance. Over a period various techniques have been developed and are being adopted in condition based maintenance.

While doing condition monitoring tests, proper precautions as demanded by those tests are to be strictly taken into consideration, since any compromise of the requirement may lead to wrong test results and wrong conclusion.

Testing instruments play a vital role in condition monitoring. If working in a charged switchyard, equipments which are not tested for Electro Magnetic interference/Electro Magnetic Compatibility (EMI/EMC) for such level may not give reliable test results. Calibration of Testing Instruments is also to be ensured for reliability of assessment. A thorough knowledge on the testing is required for carrying out any assessment. Test results are always to be compared with the pre-commissioning/ Factory test results to assess the present condition. A complete data base of the test results and history of the equipment are to be maintained for proper evaluation of the results. Computer Software is also available for evaluation of condition monitoring test results which are to be used with proper knowledge.

5.1.2.1 TRANSFORMERS AND REACTORS:

Measurement of Insulation Resistance: Insulation resistance (IR) measurement is the basic test to check the soundness of transformer solid insulation. This test generally reveals the condition of insulation (i.e., degree of dryness of paper insulation), presence of any contaminants in oil and also any gross defect inside the transformer. IR value measurements of EHV transformers shall preferably be done with 5 kV motorized megger. This will help constant application of voltage for a longer period for evaluation of Polarization Index.

Precautions: Jumpers are to be disconnected for performing this test so that lightning arrestors and associated equipments are not connected with the transformer. As any dirt on bushings may result in erroneous results, the bushing porcelains are to be cleaned by wiping with a piece of dry cloth. When using a megger, observe the usual accident preventive rules as it operates on High Voltage Direct Current. Transformer windings possess a substantial capacitance and therefore, the current carrying parts can only be touched after discharging them. If moisture condensation is suspected on porcelain surface, provide aluminum foil taping below the lower most porcelain shed. (Esp. for small bushings like Neutral Bushing) Connect the foil to the guard terminal of megger. Lead wires from the bushing line lead and tank earth to megger shall be as short as possible without joints and shall not touch tank or each other.

Testing Procedure: IR measurements shall be taken between the windings to body (i.e. to earthed tank). Windings on each side HV, IV and LV shall be connected together. Following measurements shall be taken.

Auto-transformer	Shunt Reactor	Two winding transformer	Three winding transformer
HV+IV to LV	Winding to E	HV to LV	HV+IV to LV
HV+IV to E		HV to E	HV+LV to IV
LV to E		LV to E	HV+IV+LV to E

HV- High voltage, IV -Intermediate voltage, LV -Low voltage/ Tertiary voltage windings, E-Earth

Date and time of measurement, Sl.No. Make of megger; oil temperature and IR values at intervals of 15 seconds, 1 minute and 10 minutes should be recorded.

Min insulation resistance values for one minute measurements for transformers may be determined by using the following empirical formula:

$IR = CE / \sqrt{KVA}$ where IR = Insulation Resistance, in $M\Omega$

C = 1.5 for oil filled transformers at 20 °C, assuming that transformer oil is dry, acid free and sludge free.

= 30.0 for un-tanked oil-impregnated transformers

E= Voltage rating, in V, of the windings (ph-to-ph for delta connected and ph-to-neutral for star connected transformers)

KVA = Rated capacity of the winding under test (If the winding under test is three-phase and the three individual windings are being tested as one, rated capacity of the three phase winding is used).

IR test results below this minimum value would indicate probable insulation breakdown. A zero or a very low value of ohms would indicate a grounded winding, a winding-to-winding short or heavy carbon tracking.

The following IR values as a thumb rule may be considered as the minimum satisfactory values at 30°C (one minute measurements) at the time of commissioning. Even if the insulation is dry, IR values will be low if the resistivity of oil is poor.

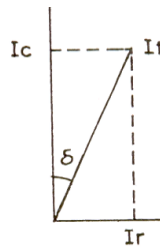
11kV = 300M Ω , 33kV = 400 M Ω , 66kV and above = 500 M Ω

With the duration of application of voltage, IR value increases. The increase in insulation resistance is an indication of dryness of insulation. The ratio of 60 seconds insulation resistance to 15 seconds insulation resistance value is called Absorption Coefficient and the ratio of 600 seconds insulation resistance to 60 seconds insulation resistance value is called Polarization Index. The following table gives a general guideline for evaluation of insulation.

Polarization Index	Insulation Condition
Less than 1	Wet
1.0-1.1	Poor
1-1.25	Fair
1.25-2.0	Good
Above 2.0	Dry

Tan δ and Capacitance Measurement:

Dielectric Dissipation Factor: Dissipation or loss factor (tan d) is defined as the ratio of the resistive component of (I_r) of current to the capacitive current(I_c) flowing in an insulating material (see figure below). The more the resistive component of current, the more is the dissipation of dielectric indicating deterioration of insulation.



Power factor is the ratio of resistive current to that of total current. For very low value of resistive currents, the capacitive current will be almost equal to the total current and hence values of

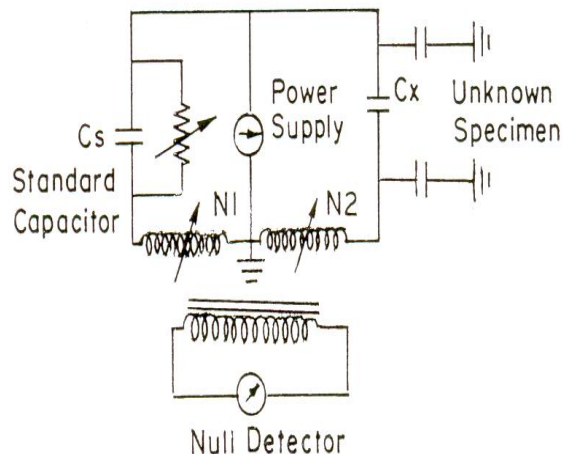
dissipation factor and power factor are same Insulation power factor or dissipation factor (Tan delta) and capacitance measurement of bushings provide an indication of the quality of the insulation in the bushing.

Adverse Effects of Moisture in Paper Insulation: Dielectric strength of insulation decreases with increase in moisture content. And also, moisture in cellulose insulation can lead to bubble formation under high load conditions. Moisture accelerates the ageing of paper insulation. If moisture content in paper insulation increases from 1 % to about 2%, it will lead to increase in ageing of the insulation by almost two times.

At high temperature, moisture is pushed out of the paper insulation into the oil. As insulation cools down, water begins to migrate slowly from the oil into the paper. The time for the temperature drop in the oil may be much quicker than the water can return to the cellulose insulation. Hence depending upon these conditions, dissipation factor also changes.

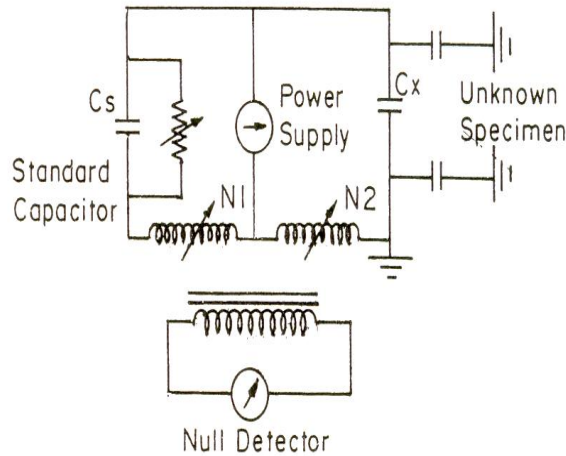
Modes of Selection for $\tan\delta$ Measurement:

(a) Ungrounded Specimen Test (UST): Test set connected for ungrounded specimen test mode. This is used when specimen is isolated from earth, e.g., Transformer bushing, CTs with test tap, CVTs, etc. In this mode of measurement, the current which flows to the ground will not enter the measurement winding (N2) and directed straight to the source as shown in Fig. below. For UST mode of measurement, removal of jumpers from the termination of the equipment has less influence compared to the other mode of $\tan\delta$ and capacitance measurement.

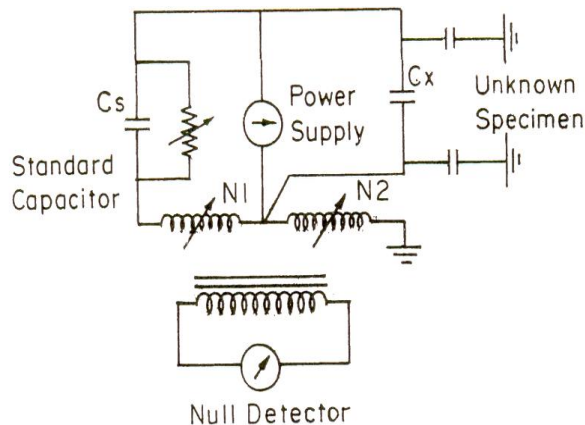


(b) Grounded Specimen Test (GST): Test set connected for grounded specimen test mode. This is used when specimen do not have two specific points isolated from ground for $\tan\delta$ measurement, e.g., Transformer/ Reactor windings, CTs without test tap etc. Here Capacitance and $\tan\delta$ is measured using GST mode. As shown in Fig. below, during GST mode operation, all current which flows to ground shall pass through the measurement winding and -influence the reading. In GST mode measurement, it is necessary to isolate the measuring portion from other parallel ground path by-removing the connected terminal jumper connections. In this measurement

capacitance for the parallel combination of HV to earth and between the windings shall be obtained.



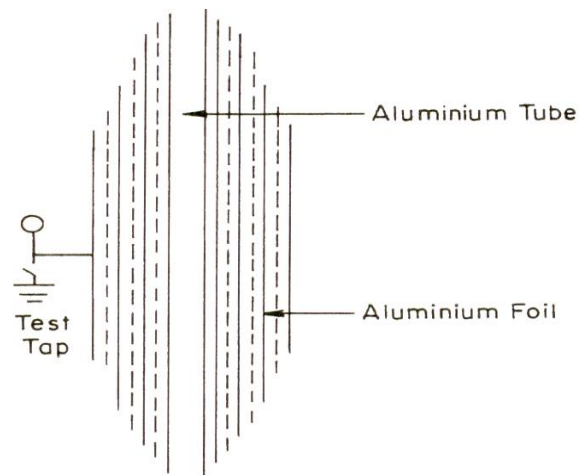
(c) Grounded Specimen Test with guard (GSTg): Grounded Specimen Test mode is used whenever a portion of the test specimen is required to be eliminated from the measurement. It also separates the total values of a GST test into separate parts for better analysis. The connection in the measurement kit shall be as shown in fig below. The current flowing through the guarded portion is directed towards the source and it will not influence the measurement. In GSTg measurement, HV to Earth Capacitance is measured. By interchanging the HV and LV leads of the kit LV to earth capacitance can be measured directly.



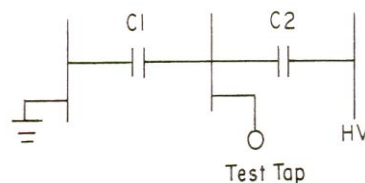
The three capacitors shown in unknown specimen in the above figures are generally HV winding to ground, HV winding to LV winding and LV winding to ground. For measurement on transformers with more than two windings, the figure shall be made accordingly for proper measurement. Measurement of capacitance and $\tan\delta$ between windings is carried out in UST mode and measurement of capacitance and $\tan\delta$ from windings to ground is measured in GSTg/ GST mode.

Interference Suppressor: This circuit permits suppression of power frequency interference signal to the bridge signal. There are measurement kits that operate at other than power frequency to avoid interference, but compute the capacitance and $\tan\delta$ at power frequency using software. If interference is more in the switch yard, balancing of the kit at highest sensitivity will be difficult and readings may not be accurate.

$\tan\delta$ and Capacitance of Bushings: In bushing, conducting layers are arranged within the insulating material for the purpose of uniform distribution of the electric field in the bushing as shown in the figure. Bushing test tap is a connection to the last of the conducting layers of a capacitance graded bushing to ground, with a disconnecter for measurement of partial discharge, power factor and capacitance values of the bushings.



The main Capacitance, C_2 , of a bushing is the capacitance between the high-voltage conductor and the test tap. The tap capacitance C_1 , of a capacitance-graded bushing is the capacitance between the test tap and mounting flange (Ground) as shown in Fig.



The capacitance C of a bushing without a voltage or test tap is the capacitance between the high-voltage conductor and mounting flange (ground).

For measurement of $\tan\delta$ and capacitance of bushings it is strongly advised to short HV terminals of all bushings of the same winding and all other winding bushing terminals be shorted and grounded to avoid influence of capacitance of other windings.

Measurement of C_1 capacitance and $\tan\delta$: HV lead of the test kit to be connected to the shorted bushing top and LV lead to be connected to the test tap of the bushing under test: Test is to be carried out in ungrounded specimen test mode at the rated test voltage of the kit.

Measurement of C2 capacitance and $\tan\delta$: HV lead to be connected to the test tap of the bushing under test (if required additional crocodile type clip may be used) and LV of the kit to be connected to the ground. HV of the bushing is to be connected to the Guard terminal of the test kit. Test to be carried out in GSTg mode at 1.0 kV.

Precautions: The test set is a source of high voltage electrical energy and operator must use all practical safety precautions to prevent contact with energized parts of the test equipment and related circuits. The ground cable must be connected first and removed last. It should also be ensured that test specimen is de-energized and grounded before making any further connection and no person may come in contact with HV output terminal or any material energized by the output.

All the jumpers connected on the bushings are to be removed to have proper isolation and removal of parallel paths in case of measurement in GST and GSTg mode. In case tertiary is also connected, ensure the isolation of the same prior to commencement of test.

Tan δ and Capacitance of Winding Insulation: Dissipation factor/ Loss factor and capacitance measurement of winding is carried out to ascertain the general healthiness of the ground and inter-winding insulation of transformer and reactors.

Measurement Combination: The combination for $\tan\delta$ measurement of winding is same as that of measurement of IR value. The probable combination is given below:

Auto-transformer (Two winding)	Test mode	Shunt reactor	Test mode	3 winding transformer	Test mode
HV + IV to LV	UST	HV to E	GST	H V to LV I	UST
HV + IV to E	GSTg			H V to LV 2	UST
LV to E	GSTg			LV I to LV 2	UST
				HV to Ground	GSTg
				LV I to Ground	GSTg
				LV 2 to Ground	GSTg

Test Voltage: Normally C and Tan δ measurement can be performed at site at about 10 kV to 12 kV. It is a good practice to have $\tan\delta$ and capacitance tested at factory at these voltages to have reference. Testing shall be done under shutdown. Transformer/Reactor shall be isolated from service and isolators opened on all sides. Test shall not be carried out when there is condensation on the porcelain. Tests shall not also be carried out when the relative humidity is in excess of 75%.

Effect of Ambient Temperature: At 20° C, value of tan delta (Dissipation Factor) should not be more than 0.007. If tan delta measurement is carried out at temperature other than 20°C, then correction factor furnished by manufacturer are to be applied. It is however advisable to carryout the test between 20°C to 40°C of winding temperature as ,in this range the values are almost constant and do not vary much.

Evaluation of Test Results: An increase of Dissipation Factor accompanied by a marked increase in Capacitance usually indicates excessive moisture in the insulation. Increase of DF alone may be caused by thermal deterioration or by contamination other than water. The changes in C and Tan δ values are caused by deterioration of the insulation, contamination or physical damage.

Maximum values of Dissipation Factor (Tan delta) of class A insulation, e.g., oil impregnated insulation is 0.007. Rate of change of tan delta and capacitance is very important. Comparison of test results with earlier results and that of pre-commissioning test results shall give desired information for trend analysis. Winding temperature correction to be applied only if indicated by the manufacturer. It is always desirable to test at about same temperature for better comparison.

Winding Resistance Measurement: Winding resistance is measured at site in order to check for any abnormalities due to loose connections, broken strands and high contact resistance in tap changers as a pre-commissioning check and compare the measured values with the factory test values.

Precautions: As the transformer windings have low resistance, measurement shall be done with Kelvin Double Bridge/Transformer ohm meter. To reduce the high inductance effect it is advised to use a sufficiently high current to saturate the core. This will reduce the time required to get a stabilized reading. It is essential to note the temperature of the windings as the resistance varies in proportion to temperature.

Care shall be taken to ensure that direct current circulating in the windings has settled down before the measurement is done. In some cases this may take several minutes depending on the winding inductance.

Test Procedure: For star connected winding with neutral brought out, the resistance shall be measured between the line and neutral terminal and average of three sets of readings shall be the tested value. For star connected auto-transformers the resistance of the HV side is measured between HV terminal and IV terminal, then between IV terminal and the neutral. For delta connected windings, such as tertiary winding of auto-transformers, measurement shall be done between pairs of line terminals and resistance per winding shall be calculated as per the following formula:

Resistance per winding = $1.5 \times \text{Measured value}$

Winding temperature to be calculated at 75°C using the following formula:

$$R_{75} = R_t (235+75) / (235+t)$$

R_{75} = Resistance at 75°C;

R_t = Resistance at measured temperature

t = Measured Winding temperature

Evaluation of Test results: Since it is difficult for precise winding temperature measurement at field, the expected deviation for this test with respect to the factory test result is about 5%. The values obtained also should not be more than 5% of other phases. As winding resistance are temperature sensitive, it is to be measured when equipment is stable in temperature and the values to be converted to 75°C.

Magnetic Balance Test: Magnetic Balance Test is conducted only in three phase transformers to check the imbalance in the magnetic circuit and to evaluate its healthiness. No winding terminal should be grounded; otherwise results would be erratic and confusing.

Test Procedure: Transformer shall be in normal tap position, and neutral disconnected from ground. Single phase 230 V is applied across one phase of Intermediate Voltage (IV) winding terminal and neutral (call it V1) then voltage to be measured in other two IV terminals across neutral (call them V2 and V3 respectively). Test to be repeated for each of the three phases. Test to be repeated for the HV winding also.

Evaluation of Test Results: From the measurement carried out ensure that, $V1 = V2 + V3$ respectively. Zero voltage or very negligible voltage induced in any winding should be investigated.

Also the applied voltage may be expressed as 100% and the induced voltages as percentage of applied voltage. This will help in comparison of two results when applied voltages are different.

Magnetizing Current Measurement: Excitation/ magnetizing current test is performed to locate defect in magnetic core structure, shifting of windings, failures in turn to turn insulation or problems in tap changers.

Magnetizing current measurement should be taken before measuring DC Winding resistance to have better results which are not influenced by the residual magnetism.

Test Procedure: Transformer tap position is to be kept at the lowest position and IV and LV terminals open. 3-phase 415 V is applied on HV terminals. Measure the voltages applied on each phase (Phase-Phase) on HV terminals and Current in each phase of HV terminal. Repeat the measurement for Normal and Highest tap position. It is advisable to do measurement at all taps during thorough investigation of the transformer. Test to be repeated for IV winding keeping HV and LV open.

Evaluation of Test Results: The set of readings for current measurement in each of the tap position are to be equal. Unequal currents shall indicate possible short circuits in winding.

Results between similar single-phase units should not vary more than 10% .The test values on the outer limbs should be within 15% of each other, and values for the centre leg should not be more than either on the outer limbs for a three-phase transformer. Results compared to previous tests made under the same conditions should not vary more than 5%. The comparison of the test values of healthy condition with the faulty condition help in locating the trouble spots.

If a reading beyond permissible tolerance is observed when turns ratio, winding resistance, and impedance tests are normal, it may be due to residual magnetism. Residual magnetism may be eliminated or reduced by applying a dc voltage to the windings through a voltage divider. The voltage should be raised from zero to a maximum value that will yield a current of no more than 10A through the winding and then return to zero. Care must be taken not to break the circuit while dc current is flowing in the winding. The polarity should then be reversed and the procedure repeated. The process is repeated several times, each time reducing the magnitude of current and each time reversing the polarity. The excitation current test should then be repeated.

Voltage Ratio Test: Voltage Ratio test is performed to determine the turns ratio of transformers to identify any abnormality in tap changers/ shorted or open turns etc. The voltage should be applied only in the high voltage winding in order to avoid unsafe voltage.

Test Procedure: Transformer tap position is to be kept in the lowest position and HV and LV terminals open. Apply 3-phase 415 V supply on HV terminals. Measure the voltages applied on each phase (Phase-Phase) on HV and IV terminals simultaneously. Repeat test for each of the tap position separately.

The above tests can also be performed by portable Transformer turns ratio (TTR) meter. They have an in built power supply, with the voltages commonly used being very low, such as 8-10 V and 50 Hz. Two windings on one phase of a transformer are connected to the instrument, and the internal bridge elements are varied to produce a null indication on the detector. Exciting current is also being measured in most cases.

The turns ratio tolerance should be within 0.5% of the nominal ratio. For three phase star connected winding this tolerance applies to phase to neutral voltage.

If there are shorted winding turns, the measured ratio will be affected. Out-of-tolerance ratio measurements could be due to shorted turns, especially if there is an associated high excitation current. Out-of-tolerance readings should be compared with previous test results, because in some instances, the design turns ratio may vary from the nameplate voltage ratio on some taps because of the need to utilize an incremental number of winding turns to make up the taps while nameplate voltage increments may not exactly correspond. This error may combine with measurement error to give a misleading out-of-tolerance reading.

Ratio measurements must be made on all taps to confirm the proper alignment and operation of the tap changers.

Open turns in the excited winding will indicate very low exciting current and no output voltage. Open turns in the output winding will be indicated by normal levels of exciting current, but very low levels of unstable output voltage. The turns ratio test also detects high resistance connections in the lead circuitry or high contact resistance in tap changers by higher excitation current and a difficulty in balancing the bridge.

Vibration Measurement on Oil Immersed Shunt Reactor: Movement of the core-coil assembly and shielding structure caused by the time-varying magnetic forces, results in vibration of the tank

and ancillary equipment. These vibrations have detrimental effects such as excessive stress on the core-coil assembly. The shunt reactor shall be energized at rated voltage and frequency and these values to be noted down during measurement for future reference.

The vibration of shunt reactor shall be measured using transducers, optical detectors or equivalent measuring devices. The measuring equipment should be accurate within $\pm 10\%$ of 2nd harmonic of the exciting frequency. The peak-to-peak amplitude shall be determined by direct measurement or calculated from acceleration or velocity measurement.

Readings are to be taken in as many points as possible. The points of measurement are to be marked permanently on the wall of reactor for taking measurement at the same location subsequently.

The average amplitude of all local maximum points shall not exceed 60 μm (2.36 mils) peak to peak. The maximum amplitude within any individual reading shall not exceed 200 μm (7.87 mils) peak to peak.

Testing of Buchholz Relay: The use of the gas detector relay (Buchholz relay) in oil immersed transformers/ reactors is based on the fact that fault in the transformer, such as arcing, partial discharges or local overheating, normally result in generation of gas. This gas is collected in the relay housing and actuates an alarm contact.

The gas detector relay also includes a device, which responds to the abnormally high gas flow from the main transformer tank to the conservator, which occurs when the transformer develops a serious fault. This device actuates a trip contact, which is connected to the trip circuit of the transformer.

If the transformer suffers a loss of oil causing oil level to drop below the level of the relay, alarm as well as trip contacts close and the transformer is tripped.

An inspection window is fitted on either side of the relay and is graduated in cubic centimeters to measure the volume of the gas accumulated.

While conducting testing on the buchholz relays, trip circuit shall be disconnected. Since 220 V DC is available at the relay while carrying out the test, it should be ensured that there should not be any accidental contact with DC.

Test Procedure: For testing of the contact functions, the Buchholz relay is provided with a test knob. With the help of the test knob we can actuate both alarm and trip contact. First actuate the alarm contact and check whether the auxiliary relay operates and gives annunciation in the control room. Then actuate the trip contact, which in turn should operate the trip relay as well as gives annunciation in control room.

The relay shall also be tested by injecting air into the relay from the pet valve provided at the top of the relay using a foot pump or compressed air to simulate gas accumulation. The annunciation

of the relay to be checked in this way and after the test the air should be released and the pet cock to be closed or connected to the gas-collecting device.

The annunciation and tripping of the relay be tested by draining of the oil from the relay after closing the gate valves provided on both the sides of the relay in the connecting pipeline. The pet valve as well as the drain valve is opened to drain the oil. When the oil level in the relay falls, the annunciation will appear and further draining the oil will operate the trip contact of the relay.

Testing of Pressure Relief Device (PRD) / Sudden Pressure Relay (SPR): Pressure Relief Device / Sudden Pressure Relay is intended to protect power transformers/ reactors from excessive pressure that may develop inside due to internal fault.

If a short circuit occurs inside a transformer, the arc vaporizes the transformer oil and a heavy pressure is built up. If the pressure is not released immediately (within a few milli seconds), the transformer tank will get bulged and ruptured with oil spreading everywhere creating a fire hazard.

When pressure inside the transformer tank rises above pre-determined safe limit, a spring mounted diaphragm lifts from its seat for releasing the oil, vapor or gases to reduce the pressure. The diaphragm restores to its original position as soon as the pressure in the tank drops below set limit.

The lifting of the diaphragm also operates a flag indicator and a micro switch which is connected for annunciation /tripping. The flag and the micro switch remains operated until they are manually reset.

The pressure limits are set at factory. The flag unit is very delicate and care must be taken while handling the same. Gasket to be changed when cable terminal box is fitted back after the test is over. Read the manufacturer's instruction before any operation.

Test Procedure: Only operation of the micro switch and the associated cabling and correct operation of the relays are tested during routine maintenance. Actuating the flag by lifting the operating rod manually tests the functioning of the switch operation or as advised by the manufacturer and the annunciation in the control panel as well as the extension of the trip command to be monitored.

The Sudden Pressure relays (SPR), provided in some of the equipments, are to be tested in the same way as we test the pressure relief device during routine maintenance. Normally the mechanical flag indication is not provided in the SPR. The terminals are shorted to activate the trip and annunciation relays and the whole scheme is tested. The gas release valve can also be used for pressing air into the gas detector relay to simulate gas accumulation. A pump with a check valve or a container with compressed air is recommended. Release the air after testing.

Dissolved Gas Analysis (DGA): Transformer undergoes electrical, chemical and thermal stresses during its service life which may result in slow evolving incipient faults inside the transformer. The gases generated under abnormal electrical or thermal stresses are Hydrogen (H₂), Methane (CH₄), Ethane (C₂H₆), Ethylene (C₂H₄), Acetylene (C₂H₂), Carbon monoxide (CO), Carbon dioxide (CO₂), Nitrogen (N₂) and Oxygen (O₂) which get dissolved in oil. Collectively these gases are

known as **fault gases**, which are routinely detected and quantified at extremely low level, typically in parts per million (ppm) in dissolved Gas Analysis (DGA). Most commonly used method to determine the content of these gases in oil is using a vacuum Gas Extraction apparatus/ Head Space Sampler and gas chromatograph.

DGA is a powerful diagnostic technique for detection of slow evolving faults inside the transformer by analyzing the gases generated during the fault which get dissolved in the oil. For Dissolved Gas Analysis to be both useful and reliable, it is essential that sample taken for DGA should be representative of lot, no dissolved gas be lost during transportation and laboratory analysis be precise and accurate. Effective fault gas interpretation should basically tell us first of all, whether there is any incipient fault present in the transformer, and if so what kind of fault it is. It should also indicate the seriousness of the fault warranting taking out the transformer from service for further investigation.

DGA can identify deterioration of insulation oil and hot-spots, partial discharge, and arcing. The health of oil is reflective of the health of the transformer itself. DGA analysis helps the user to identify the reason for gas formation and materials involved and indicate urgency of corrective action to be taken.

The evolution of individual gas concentrations and total dissolved combustible gas (TDCG) generation over time and the rate of change (based on IEC 60599 and IEEE C 57-104 standards) are the key indicators of a developing problem. Some of the recognized interpretation techniques are explained below.

Individual Fault Gases Acceptable Limits: When no previous DGA history of transformer is available, the DGA results are compared with the gassing characteristics exhibited by the majority of similar transformers of normal population. As the transformer ages and gases are generated, the normal levels for 90% of a typical transformer population can be determined. From these values and based on experience, acceptable limits or threshold levels have been determined as given in table (as per IEC 60599) below:

Transformer Type	Fault Gases (µl/l)						
	H ₂	CH ₄	C ₂ H ₆	C ₂ H ₄	C ₂ H ₂	CO	CO ₂
Non communicating OLTC	60-150	40-110	50-90	60-280	3-50	540-900	5100-13000
Communicating OLTC	75-150	35-130	50-70	110-250	80-270	400-850	5300-12000

"Communicating OLTC" means that some oil and /or gas communication is possible between the OLTC compartment and the main tank or between the respective conservators. These gases may contaminate the oil in the main tank and affect the normal values in these types of equipment.

However it is improper to apply threshold level concept without considering the rate of change of the gas concentration in Dissolved Gas Analysis. When an abnormal situation is indicated by above table, a testing schedule is devised, with increased sampling frequency.

Total Dissolved Combustible Gas (TDCG) Limits: The presence of an incipient fault can also be evaluated by the total dissolved combustible gas (TDCG) present. Limits for TDCG are as given in table below based on IEEE standard C-57.1 04-1999. An increasing gas generation rate indicates a problem in transformer.

TDCG limits, PPM	Action
< or = 720	Satisfactory operation. Unless Individual gas acceptance values are exceeded
721 - 1920	Normal ageing/slight decomposition. Trend to be established to see if any evolving incipient fault is present
1921 -4630	Significant decomposition. Immediate action to establish trend to see if fault is progressively becoming worse
<4630	Substantial decomposition. Gassing rate and cause of gassing should be identified and appropriate corrective action such as removal from service may be taken

TDCG includes all hydrocarbons, CO and H₂ and does not include CO₂ which is not a combustible gas.

Evaluation of Gases: Relationship with temperature of different fault gasses is given below

Methane CH₄ > 120° C Ethane (C₂H₆) > 120⁰ C
 Ethylene (C₂H₄) > 150°C Acetylene (C₂H₂) > 700⁰ C

Faults Associated with Different Gases

Oil Overheating	C ₂ H ₄ , C ₂ H ₆ , CH ₄
Overheated Cellulose Traces of acetylene with smaller quantity of Hydrogen may be evolved. Large quantity of Carbon-Di-oxide (CO ₂) and Carbon Monoxide (CO) are evolved from over heated cellulose. Hydro carbon gases such as Methane and Ethylene will be formed if the fault involves oil impregnated structure.	CO
Partial discharge in Oil (Corona) Ionization of high stressed area where gas / vapour are present or 'wet spot' produces Hydrogen and methane and small quantity of other hydrocarbons like ethane and ethylene.	H ₂ , CH ₄

Comparable amounts of carbon mono-oxide and di-oxide may result due to discharges in cellulose.	
Arcing in Oil Large amount of Hydrogen and acetylene are produced with minor quantities of methane and ethylene in case of arcing between the leads, lead to coil and high stressed area. Small amounts of carbon mono-oxide and di-oxide may also be formed, if fault involves cellulose.	C_2H_2 , H_2

It is to be understood that there is no definite interpretation method available, which can indicate the exact location and type of the fault. The different interpretation methods only provide guidelines to make expert interpretation about the equipment. Apart from the DGA results various other factors are taken into consideration such as past history of the transformer, grid condition, loading patterns, voltage and frequency profile, etc.

Ratio Methods: Several well-known methods/criteria (like Rogers ratio, IEC 60599, Dornenberg, Key gas etc.) are being used by utilities to interpret the DGA results, based mostly on the relative concentrations (i.e. ratios) of the constituent gases. These ratios generally give an indication of the existence and nature of a problem. Some of the interpretation methods used for DGA is discussed here under:

(i) IEC 60599 method

This method is applicable only when the fault gas results are ten times the sensitivity limit of the Gas Chromatograph (GC). As per IEC 60567 the sensitivity limit for the GC should be maximum 1 ppm for all the hydrocarbons and 5 ppm for Hydrogen. In this method three ratios viz. C_2H_2/C_2H_4 , CH_4/H_2 and C_2H_4/C_2H_6 are used for interpretation. Various combinations of the ratios are used for diagnosis of type of fault such as PD, Discharge of low energy, Discharge of high energy, Thermal fault $< 300^\circ C$, Thermal fault $300 - 700^\circ C$ and Thermal fault $> 700^\circ C$. The table (as per IEC 60599) showing different type of faults depending upon the three key ratios is given below:

DGA Interpretation Table

Case	Characteristic fault	C_2H_2/C_2H_4	CH_4/H_2	C_2H_4/C_2H_6
PD	Partial discharges	NS	<0.1	<0.2
DI	Discharges of low energy	>1	$0.1-0.5$	>1
D2	Discharges of high energy	$0.6-2.5$	$0.1 - I$	>2
T1	Thermal fault $T < 300^\circ C$	NS^1	>1 but NS^1	<1
T2	Thermal fault $300^\circ C < T < 700^\circ C$	<0.1	>1	$1-4$
T3	Thermal fault	<0.22	>1	>4

(Source IEC60599 – 1999)

Note 1: In some countries, the ratio C_2H_2/C_2H_6 is used, rather than the ratio CH_4/H_2 . Also in some countries, slightly different ratio limits are used.

Note2: The above ratios are significant and should be calculated only if at least one of the gases is at a concentration and a rate of gas increase above typical values.

Note3: $\text{CH}_4 / \text{H}_2 < 0.2$ for partial discharges in instrument transformers. $\text{CH}_4/\text{H}_2 > 0.007$ for partial discharges in bushings.

Note4: Gas decomposition patterns similar to partial discharges have been reported as a result of the decomposition of thin oil film between over-heated core laminates at temperatures of 140 °C and above

NS = Non- significant whatever the value

An increasing value of the amount of C_2H_2 may indicate that the hot spot temperature is higher than 1000°C

Though this method is quite comprehensive, still there are cases where it does not fit into any of the cases listed in the diagnosis table. These cases should be dealt through trend analysis and other interpretation methods. Again interpretation through the above method is meaningless unless it is correlated with the earlier sample results.

(ii)IEEE method-C57-/04/1991

- (a) Key gas method: Characteristic "Key Gases" have been used to identify particular type of fault. Laboratory simulations and comparison of results of DGA tests combined with observations from the tear down of failed transformers have permitted the development of a diagnostic scheme of the characteristic gases generated from thermal and electrical (Corona and arcing) deterioration of electrical insulation. Table given below lists the key gases for the conditions of arcing, corona, overheating in oil and overheating in paper in the order of decreasing severity.

Key gases associated with typical fault

Fault type	Key gases
Arcing	Acetylene(C_2H_2), Hydrogen(H_2)
Corona	Hydrogen (H_2)
Overheated Oil	Ethylene (C_2H_4), Methane(CH_4)
Overheated Cellulose	Carbon Monoxide (CO) and Dioxide(CO_2)

- (b) Ratio Method: These methods help in assessing the type of fault by comparing ratios of characteristic gases generated under incipient fault conditions. The advantages to the ratio methods are that they are quantitative, independent of transformer capacity and can be computer programmed. The disadvantages are that they may not always yield an analysis or

may give an incorrect one. Therefore it is always used in conjunction with other diagnostic-methods such as key gas method.

- (i) The Doernenberg ratio method is used when prescribed normal levels of gassing are exceeded. It provides a simple scheme for distinguishing between pyrolysis (overheating) and PD (corona and arcing). In this method four ratios viz CH_4 / H_2 , $\text{C}_2\text{H}_2 / \text{C}_2\text{H}_4$, $\text{C}_2\text{H}_6 / \text{C}_2\text{H}_2$ and $\text{C}_2\text{H}_2 / \text{CH}_4$ are used.

Ratios for key gases – Doernenburg

Suggested Fault Diagnosis	Ratio 1 (R1) CH_4 / H_2	Ratio 2 (R2) $\text{C}_2\text{H}_2 / \text{C}_2\text{H}_4$	Ratio3 (R3) $\text{C}_2\text{H}_2 / \text{CH}_4$	Ratio4 (R4) $\text{C}_2\text{H}_6 / \text{C}_2\text{H}_2$
1-Thermal Decomposition	> 1.0	< 0.75	< 0.3	> 0.4
2-Corona (Low Intensity PD)	0.1	Not Significant	< 0.3	> 0.4
3-Arcing(High Intensity PD)	> 0.1	> 0.75	> 0.3	< 0.4

Concentrations of Dissolved Gas

Key Gas	Concentration LI (in ppm)
Hydrogen(H_2)	100
Methane (CH_4)	120
Carbon Monoxide (CO)	350
Acetylene (C_2H_2)	35
Ethylene(C_2H_4)	50
Ethane (C_2H_6 .)	65

In Doernenburg's method for declaring the unit faulty at least one of the gas concentrations (in ppm) for H_2 , CH_4 , C_2H_2 and C_2H_4 should exceed twice the values from limit LI and one of the other three should exceed the values for Limit LI. Having established that the unit is faulty, for determining the validity of ratio procedure at least one of the gases in each ratio R1, R2, R3 or R4 should exceed limit LI. Otherwise the unit should be re-sampled and investigated by alternative procedures.

- (a) The Rogers Ratio method is a more comprehensive scheme using only three ratios viz. CH_4 / H_2 , $\text{C}_2\text{H}_2 / \text{C}_2\text{H}_4$ and $\text{C}_2\text{H}_4 / \text{C}_2\text{H}_6$, which details temperature ranges for overheating conditions based on Halstead's research and some distinction of the severity of incipient electrical fault conditions. Table below lists the ratio for key gases. A normal condition is also listed.

(b) Rogers Ratio for Key Gases

Case	R2 (C2H2/C2H4)	RI (CH4/H2)	R5 (C2H4/C2H6)	Suggested Fault Diagnosis
0	<0.1	>0.1	<0.1	Unit normal
I	<0.1	<0.1	<0.1	Low-energy density arcing -PD (See Note)
2	0.1-3.0	0.1-1.0	>3.0	Arcing - High energy discharge
3	<0.1	>0.1 <1.0	1.0-3.0	Low temperature thermal
4	<0.1	>1.0	1.0-3.0	Thermal <700°C
5	<0.1	>1.0	>3.0	Thermal > 700°C

Note: There will be a tendency for the ratios R2 and R5 to increase to a ratio above 3 as the discharge develops in intensity.

IEEE C57.104 - 1991 gives an elaborate way of analyzing the type of fault using Doernenberg, Rogers's method and TDCG limits.

However, it is again emphasized that DGA is likely to give misleading results unless certain precautions are taken. These are proper sampling procedure, Type of sampling bottle, cleanliness of bottle, Duration of storage, method of gas extraction, good testing equipment and skilled manpower.

Trend Analysis: Transformers from same manufacturers and of same type some time exhibit initially specific pattern of gas evolution which subsequently slows down (or plateau's) is called Fingerprints or Normal characteristics, which are characteristic to the transformer and do not represent an incipient fault condition.

When a possible incipient fault condition is identified for first time, it is advised to determine gassing trend with subsequent analysis giving information such as which gases are being generated and rate of generation of these gases. The level of gases generated in subsequent analysis provides a baseline from which future judgment can be made. In the examination of trends, Key gases, TDCG, CCVCO ratio, rate of gas generation and fingerprints (of normal trends) of particular transformer should also be considered.

The ratio of gas generation is a function of load supplied by the transformers and this information is vital in determining the severity of fault condition and decision of removal of the equipment from service for further investigation. Two methods have been suggested in literatures for assessing the gassing rate:

- Change of concentration of gas in ppm
- Determination of actual amount of gas generated

General guidelines for rate of gas generation in case of removal of transformer from service are 100 ppm/day and 0.1 cub feet (0.003 m³) gas per day.

Furfuraldehyde Analysis: Degradation of insulating paper can be ascertained by direct or indirect methods. Direct method employs measuring Degree of Polymerization (DP), which requires a physical paper sample from the winding. However this being destructive to transformer cannot be employed as a routine condition monitoring method.

It is known that in addition to CO and CO₂ the ageing process of the paper produces several oil soluble by-products, most notably the furanoid compounds (FFA). The monitoring of furanic compounds by sampling of the oil and its analysis using High Performance Liquid Chromatography (HPLC) has been used for condition monitoring on a routine basis for some years.

Generally FFAs are extracted from the oil either by solvent extraction or solid phase extraction and measured by HPLC by UV detector. The major FFA in oil is 2-Furfural and others are present in very low or undetected levels. 2-Furfural can be measured colorimetrically using spectrophotometer. This method is rapid and accurate and measures only 2-Furfural in oil. This technique is useful for quick screening of FFA in transformer oil. The relationship between the generation of these by-products and condition of in service paper is not well established. However, it has generally been seen that there is a linear relationship between FFA and DP. FFA may be used as a complimentary technique to DGA for condition monitoring.

Recovery Voltage Measurement:

Recovery Voltage Measurement (RVM) is being carried out on transformers for estimating the moisture content in solid insulation.

Test Principle: 2 kV DC voltage is applied on the solid insulation of the transformer for a pre determined time (tc). After the application of the voltage the terminal is shorted for half of the tc time (td). Then shorting is removed and the recovery voltage is measured till building up of the peak voltage using a recovery voltage meter. Then after a relaxation time, voltage is again applied for a time (tc₁) which is more than tc. Then again the process of shorting for half the time of tc₁, that is td₁ and measuring of recovery voltage is continued.

This process is continued for about 2000 to 5000 sec of tc. And at each interval of time the peak recovery voltage is plotted in a graph against tc. The peak in the graph represents the peak recovery voltage. If the insulation is wet, the time constant for the peak is more. Software is used for computing the recovery voltage based on the values obtained.

Test Procedure: Before carrying out RVM, all terminals of each winding are to be shorted together. One of the winding combinations is grounded along with transformer tank. To avoid interference effect, voltage is injected from the low voltage winding and high voltage winding is earthed. If LV winding is more susceptible to interference, then LV could be connected to ground and voltage is applied through HV winding. It is recommended that no forced cooling is applied during the application of the test voltage. Bushings should be clean. It is recommended to start the test after about 8-10 hrs after taking shut down on the transformer to have uniform heat

distribution and winding resistance test is recommended to be conducted after R VM test. As there should not be any interruption of power supply during the test, an uninterrupted power supply to RVM kit is ensured. The test kit automatically applies voltage (2 kV) for time t_c and Short for time t_d and measure peak recovery voltage (U_r max). The time interval of t_c is automatically increased and plot of t_c vs U_r max is plotted by the software.

Evaluation of Test Result: RVM estimates the polarization spectrum of oil-paper insulation. The qualitative evaluation of the insulation is primarily focused on the state of ageing represented by a single peak in the curve of t_c vs. U_r max. The more the time constant the better is the insulation. RVM software also indicates the percentage moisture of the paper insulation based on the curve. The results could be well validated using 'relative saturation' measurement of transformer oil or using the standard curve as stated in IEEE C –57 to evaluate water content in paper insulation based on water content in oil at different temperatures. The correlations may not equate one to one but an expert analysis of the result is required before taking further action.

The appearance of more than one peak indicates an inhomogeneous state of ageing or inhomogeneous distribution of moisture in paper. New transformers have limited reasons for inhomogeneous RVM spectrum. The cause may be mainly due to inadequate drying of transformers. Used transformers show a wider variety of causes for inhomogenities due to hot spots, de-polymerization, non equilibrium of paper and oil moisture etc.

Frequency Response Analysis: Frequency Response Analysis (FRA) is done to assess the mechanical integrity of the transformer. Transformer while experiencing severity of short circuit current loses its mechanical property by way of deformation of the winding or core. These changes cannot be detected through conventional condition monitoring techniques such as Dissolved Gas Analysis, Winding Resistance Measurement, Capacitance and Tan Delta Measurement etc. Some times even transportation without proper precaution may cause some internal mechanical damages. FRA measurement, which is signature analysis, provides vital information of the internal condition of the equipment so that early corrective action could be initiated.

Test Principle and Measurement: Short circuit forces can cause winding movement and changes in winding inductance or capacitance in Power Transformers. Recording the frequency response with these changes gives information regarding the internal condition of the equipment. Frequency Response Analysis (FRA) has proved to be an effective tool to detect such changes.

Sinusoidal signal output of approximately 2 V rms from the Frequency Response Analyzer is applied and one measuring input (R1) is connected to the end of a winding and the other measuring input (T1) is connected to the other end of the winding. The voltage is applied and measured with respect to the earthed transformer tank. The voltage transfer function $T1/R1$ is measured for each winding for five standard frequency scans from 5 Hz to 10 MHz and amplitude and phase shift results are recorded. While the low frequency analysis reveals the winding movements, the high frequency analysis reveals the condition of joints.

Pre-caution should be taken to see that winding which is not under test is kept in open condition in order to avoid response difference among the three phases. The same procedure is followed on subsequent tests on the same or similar transformer, to ensure that measurements are entirely repeatable.

The voltage transfer function Tl/Rl is measured for each winding for four standard frequency scans from 5 Hz to 2 MHz and amplitude and phase shift results are recorded for subsequent analysis.

Analysis of Measured Frequency Responses: As FRA is signature analysis, data of signature of the equipment when in healthy condition is required for proper analysis. Signatures could also be compared with unit of same internal design or with other phases of the same unit. Normally measured responses are analyzed for any of the following:

- Changes in the response of the winding with earlier signature.
- Variation in the responses of the three phases of the same transformer.
- Variation in the responses of transformers of the same design.

In all the above cases the appearance of new features or major frequency shifts are causes for concern. The phase responses are also being recorded but normally it is sufficient to consider only amplitude responses.

5.1.2.2 CIRCUIT BREAKERS:

Capacitance and $\tan\delta$ of CB Voltage Grading Capacitor

Circuit Breaker grading capacitors have oil filled paper capacitor elements. The healthiness of the capacitor elements could be checked by measurement of Capacitance and $\tan\delta$.

Test Procedure: Connect LV cable to the middle of the double interrupter. Connect HV cable to the other end of the Grading capacitor to be tested. The opposite ends of the grading capacitor have to be grounded using earth switch. Before applying HV, interference is to be nullified using Interference suppression unit (ISU). Measurements have to be taken in UST Mode only. Disconnect the HV cable and connect the same to the other grading capacitor and ground the previous grading capacitor. Now the second grading capacitor is ready for testing. Standard procedure (as specified by kit supplier) for measuring capacitance and tan delta in charged switchyard/induced voltage conditions should be followed. Carry out the measurements in main and reverse mode/polarity and then compute the average value.

Evaluation of Test Results: Increase in the value of $\tan\delta$ will indicate Chemical deterioration due to age and temperature, including certain cases of acute deterioration due to localized overheating, Contamination by water, carbon deposits, bad oil, dirt and other chemicals or ionization. The acceptable value is 0.007 but any increase in $\tan\delta$ and any change in capacitance value is to be analyzed.

Dew Point Measurement of SF₆ Gas/ Operating Air for CBs

Dew Point: Dew Point is the temperature at which moisture content in SF₆ gas/air starts condensing.

Dew Point when measured keeping regulating valve in service at the outlet of dew point kit to allow required flow rate of gas/air, is called low point at rated pressure of CB. Dew point when

measured by regulating the gas flow at the inlet of dew point kit and keeping outlet regulating valve (if provided) in fully open condition so that flow rate of gas/air is maintained as required, is called low point at atmospheric pressure.

Test Procedure: Dew point measuring kit with associated accessories is used for testing. All the joints/connectors should be dust and moisture free. Dry the joints and pipe by dry air. Make the connections to the kit from CB pole ensuring that regulating valve is fully closed at the time of connections of the Dew point kit. By regulating the flow rate of SF₆ gas (0.2 liter/min to 0.5 liter/min - ref. IEC 480), the value of dew point is observed till it becomes stable. If the regulating valve is provided at outlet of the dew point kit, then dew point for rated pressure is to be monitored.

Evaluation of Test Results: Dew point measurement of SF₆ gas in a CB indicates the change in the value of dielectric properties of SF₆ gas. The dielectric properties of SF₆ gas do get changed with time due to mixing of impurities like moisture; decomposition products of SF₆ gas. There are two sources of moisture ingress in SF₆ gas after it is filled in CB. Exudation of moisture contained during manufacturing from insulation materials used in Circuit Breakers and permeation of moisture through sealed sections, i.e., gaskets, O-Rings, etc.

Sulphur Hexafluoride Gas: During Arc interruption in CBs, decomposition of SF₆ gas takes place which in presence of moisture, may result in deterioration of Organic Insulating materials inside interrupting chamber and also corrosion of metals due to formation of hydro fluorides. Therefore, in order to avoid dielectric failure of CBs, monitoring of moisture content in SF₆ gas is very important.

Dew Point of SF₆ gas varies with pressure at which measurement is being carried out. This is due to the fact that Saturation Vapor Pressure decreases with increase in Pressure of the SF₆ gas. Hence, dew point of SF₆ gas at higher pressure is lower than dew point at atmospheric pressure. Therefore, if measurement is done at a pressure other than the atmospheric pressure, same is to be converted to the atmospheric pressure. Dew points as recommended by manufacturers are given in Table below:

S1.No	Make of CB	Dew point at rated pressure	Dew point at atmospheric pressure	Remarks
1	BHEL	- 15° C	- 36° C	At the time of commissioning
		- 7° C		During O&M
		- 5° C		Critical
2	M and G		- 39° C	At the time of commissioning
			- 32° C	During O&M
3	CGL	- 15°C	- 35° C	At the time of commissioning
		- 10°C	-31 ° C	During O&M

4	ABB	-15°C	- 35° C	At the time of commissioning
		- 5° C	- 26°C	During O&M
5	NGEF	-15°C	- 36° C	At the time of commissioning
		- 7° C	- 29° C	During O&M
		- 5° C	- 27° C	Critical

Measurement of Dew Point of operating air in ABCBs indicates the moisture content in the air being used as insulating and arc quenching medium. The arc quenching/ dielectric properties of dry air do get changed with aging of CB and quality of air deteriorates as moist air travels to the interrupter of circuit breaker. This will result in deterioration of internal insulation which could possibly lead to unsuccessful arc quenching due to poor dielectric strength of interrupting medium. It is therefore, necessary to carry out measurement of Dew Point of air in ABCBs. If the dew point values are low (may be below -40°C) then the reason to be investigated and efforts to be made to keep the dryer in healthy condition.

Measurement of Circuit Breaker Operating Timings including Pre-insertion Timings

Circuit Breaker Operational Analyzer is used to measure Operating Timings of Circuit Breakers to evaluate the operational performance.

Testing Procedure: It is to be ensured that R, Y, B phase marking cables are connected with the proper place in the CB analyzer and colour codes are to be maintained for all the three poles of CB.

Give closing command to closing coil of CB and note down the PIR and main contact closing time. Take the print out from the analyzer. Give tripping command to trip coil-I of CB and note down the main contact tripping time. Give tripping command to trip coil-II of CB and note down the main contact closing time. Note down the timings for 'CO', 'OC' and "OCO" by giving respective commands.

Closing time of EHV CBs should not exceed 200 ms and discrepancy should not be there between main contacts and PIR contacts. Discrepancy in operating times of PIR and main contacts should not exceed the permissible limits.

In any case, main contacts should not close prior to closing of PIR contacts and PIR contacts should not open prior to closing of main contacts. In case, contact bouncing is observed in operating timings for PIR and main contacts, same is to be rectified.

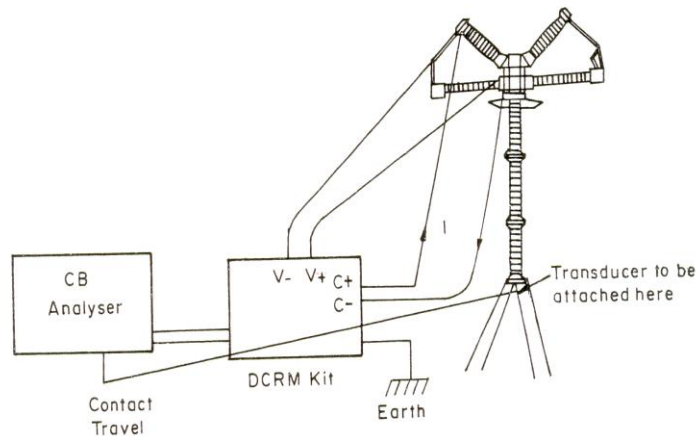
Opening time for EHV CBs should not exceed beyond 35 ms. Discrepancy in operating timings for Pole to Pole and Break to Break should not be allowed beyond permissible limits which is 3.33ms and 2.5 ms respectively.

In case, operating times of different poles/breaks are not within permissible limits, Dynamic Contact Resistance measurement should be made to see the healthiness of main contacts. CO timings should be within permissible limits as specified by different manufacturers.

Measurement of Dynamic Contact Resistance of EHV Circuit Breakers

Measurement of dynamic resistance, with the help of DCRM kit with CB Operational Analyzer is done to monitor condition of CB main and arcing contacts without opening the interrupter.

Testing Procedure: CB should be in open position, Isolator of both sides of CB should be in open position and Earth switch of one side of CB should be in open position. The tightness of connections at CB flanges is most important to ensure error free measurement. CB during CO operation generates lot of vibrations and failure of connections during this period can dramatically change the dynamic resistance of CB. Typical arrangement of DCRM is given below:



Typical arrangement for DCRM

Incoming and outgoing flanges of CB to be cleaned with polish paper to remove paint, oxidation, etc., at points where current clamps are mounted. Select this point of connection, as close as possible to the end of porcelain insulator to ensure that minimum resistance is offered by flanges, bolts, terminal connectors, etc.

Evaluation of Test Results: Condition of contacts can be monitored by comparing DCRM signatures taken at the time pre-commissioning and during service. If there are wide variations in resistance value from the pre-commissioning value, it indicates erosion of contacts. DCRM is also helpful in monitoring length of arcing contacts by measuring contact travel and dynamic contact resistance. The contact travel from the point of opening of main contacts to opening of arcing contacts is length of arcing contact. During service due to erosion of contacts, length of the same get shortened to the extent that it may lead to commutation failure, hence, monitoring length of arcing contacts is very important.

Measurement of Contact Resistance of Circuit Breaker: Contact resistance of main contacts is measured with a Micro ohm meter of 100A and above with associated accessories.

CB should be in close position and Isolators on both side of CB should be open. The ohm meter operates on four wire measurement principle. To measure the contact resistance connect the respective leads and adjust the variac so that 100 amperes current flows through the CB contacts. Value of contact resistance is directly displayed on the digital LED display screen.

Contact resistance of the CB contacts indicates wear out and misalignment of the main contacts. If the value of contact resistance exceeds the permissible limit, i.e., 150 μ ohms, this could result in overheating of the contacts. Therefore, the problem of high contact resistance should be attended immediately by making proper alignment of contacts or by replacing arcing/main contacts.

Checking of Pole Discrepancy Relay and Timer for Circuit Breakers

Pole discrepancy is defined as the difference in closing and opening timings of different poles of CB.

For checking the pole discrepancy, Isolators on both sides of CB should be kept open and Earth switch closed.

- a) Keep the CB in open position. Extend closing command to close one pole, say R-Pole, of CB. After it is closed, this Pole should automatically open after 2.5 seconds (as per pole discrepancy timer settings). Repeat the test for remaining two poles of CB.
- b) Keep the CB in closed position. Extend Tripping command to trip one pole, say R-Pole, of CB. Remaining Y and B- Poles of CB should automatically open after 2.5 seconds. Repeat the same test for remaining two poles of CB.
- c) Timer checking: Connect standard timer in parallel with CB timer. Extend 220 volt DC to both the timers and note down the timings at which output contacts of timer (which are going to pole discrepancy trip relay) gets closed. If there is a difference between timing readings of two timers, adjust the CB timer's settings accordingly.

Permissible value of pole discrepancy between two poles of CB is 3.33 m/sec. However, timer is set to trip the remaining poles taking into consideration the auto reclose scheme adopted by the utilities.

Checking of Operational Lockout for Circuit Breakers

Operational lockouts are provided in circuit breakers to prevent the operation of the breaker during deficiency in the circuit breaker or its operating mechanism. The lockouts provided in CBs are to be tested to check for any drift/ non-function as they are safety devices to prevent improper operation leading to failure.

Low Gas Pressure Alarm: Close isolation valve between CB Pole and density monitor. Start releasing SF₆ gas from density monitor till the low pressure gas alarm contacts are closed which is detected by Multimeter. Note down the pressure and temperature at which the contacts get closed.

Operational Lockout Alarm: Continue releasing SF₆ gas from isolated zone till the operational lockout alarm contacts are actuated which are detected by multimeter. Note down the pressure and temperature at which the contacts get actuated. Gas is to be taken in to gas evacuating unit and after checking, gas is to be filled to the rated pressure in the CB.

Pneumatic Operating System Lockout:

- a) Compressor START/STOP Switch: Close the isolating valve of CB. Release air into atmosphere from the compressor. Note down the value of pressure at which compressor starts building up air pressure and pressure at which compressor stops.
- b) CB auto reclose (AR) lockout: Close Isolation valve between pneumatic system and pressure switches. Release air from the isolated zone to atmosphere. Note down pressure at which AR L/O contacts of pressure switch get actuated which are detected by multimeter. The leads of the multi meter should be connected to the contactor where the AR L/O of CB is made.
- c) CB closing lockout: Release air from the isolated zone to atmosphere. Note down pressure at which CB Closing L/O contacts of pressure switch get actuated which are detected by multimeter.
- d) CB operational lockout: Release air from the isolated zone to atmosphere. Note down pressure at which CB Operational L/O contacts of pressure switch get actuated which are detected by multimeter.
- e) Mechanical Closing Interlock (MCI) (FOR ABB CBs ONLY): CB should be in closed position. Release air from pneumatic system of CB to atmosphere and observe whether CB poles start opening, if so, note down the pressure at which tie rod starts coming down, the movement to stop after a few millimetres. The MCI is provided to prevent opening of the CB. Non operation of MCI is to be investigated.
- f) Hydraulic operating system lockout: By opening pressure release valve, note down the pressure at which pump starts building up oil pressure and pressure at which pump stops.
- g) CB auto reclose lockout: Close Isolation valve between hydraulic system and pressure switches. Release oil from the isolated zone to oil tank. Note down pressure at which AR L/O contacts of pressure switch get actuated which are detected by multimeter.
- h) CB closing lockout: Release oil from the isolated zone to oil tank. Note down pressure at which CB Closing L/O contacts of pressure switch get actuated which are detected by multimeter.

All the SF₆ gas pressure lockout switch settings should be checked and corrected with ambient temperature. Settings should be within $\pm 0.1 \text{ bar/kg/cm}^2$ of the set value (after taking into account the temperature correction factor).

All the air/oil pressure lockout switches settings should be checked and corrected and should be within $\pm 0.1 \text{ bar/ kg/cm}^2$ of the set value.

5.1.2.3 CURRENT TRANSFORMERS

Capacitance and Tan δ Measurement

Capacitance and tan δ measurement on CTs is done to evaluate the healthiness of solid insulation. As most of the CTs have oil impregnated paper as solid insulation, capacitance and tan δ measurement indicates the amount of deterioration. The test procedure is similar to the test described under transformer bushings.

CT is to be isolated from supply for carrying out this test. Terminal jumper is to be disconnected from HV side of CT if test tap is not provided. If test tap is provided, test tap should be disconnected from ground before measurement and to be grounded after the measurement is completed. Measurement is to be carried out at 10 kV or 12 kV level with highest sensitivity level. As CTs are in high induction area, testing instrument should be able to suppress the interference.

Test procedure

- a) CTs with test tap: High voltage from tan delta test kit should be applied to primary (HV) terminal and LV should be connected to tan delta test tap. Measurements have to be taken in UST mode.
- b) CTs without test tap: High voltage from tan delta kit should be applied to primary (HV) Terminal and LV should be connected to the ground/earth. Measurements have to be taken in GST mode.

In both the above cases, before applying HV, interference is to be nullified using interference suppression unit (ISU). Standard procedure (as specified by kit supplier) for measuring capacitance and tan delta in charged switchyard/ induced voltage conditions should be followed. Measurements are to be carried out in main and reverse mode and then the average value to be computed.

The permissible values of capacitance and dissipation factor of class A insulation, e.g., Paper insulation impregnated in oil is 0.007 at 20°C. Tan delta value should not exceed the permissible limit. A record of the measured values of capacitance and tan δ is to be maintained for monitoring the variation in the values (trend). It is all the more important to monitor the rate of change of Tan delta and capacitance. Tan delta value should not increase by more than 0.1 % per year and capacitance value by 1% per year. So before taking any decision about condition of CT above facts need to be considered. Change in capacitance values can be within + 1 0%, to -5% of the original value.

An increase in only tan δ value (not appreciable change in capacitance value) indicates deterioration of cellulose insulation whereas increase in both tan delta and capacitance values indicates ingress of moisture in the insulation.

Main reason for increase of tan delta value is because of presence of inherent air voids which are created during manufacturing process. In course of application of high voltage, these voids are ionized which result in deterioration of insulating properties of the insulation.

Insulation Resistance Measurement for Current Transformers

IR values between primary terminals to earth are measured with a 5 kV megger and associated accessories like test leads etc. Motorized insulation tester is preferred for better results.

Before testing, associated Circuit Breaker and the isolators from both sides of CT should be in open position. Earth switch should be open at the time of IR measurement.

Testing Procedure: HV terminal of the megger is to be connected to the Primary terminal of CT by using crocodile clip for firm grip and LV terminal to be connected to ground. A test voltage as specified is applied and successive readings are taken. Values of IR are to be recorded after 15 seconds, 60 seconds and 600 seconds. Ambient temperature and weather conditions are to be recorded.

Changes in the normal IR value of CT indicate abnormal conditions such as presence of moisture, dirt, dust, crack in insulator of CT and degradation of insulation. Changes in the IR value of CT may be due to the weather conditions also. It is advised to carry out IR measurement during sunny and dry weather preferably. Insulation Resistance changes with deterioration in insulating properties. Absolute value of IR is important to monitor but the rate of change is equally important. Minimum value of 1000 M ohms is considered satisfactory.

If readings of IR increase with time, the insulation is good. However, if readings remain same over the time span, insulation is contaminated. This is due to the fact that charging current and absorption currents subside with time and only conduction current remains. This indicates that total current taken by insulation changes with time. However, if there is no appreciable change in the total current drawn by the insulation, it is an indication of domination of conduction current over charging and absorption currents. Factors to be monitored for these abnormalities are briefly given below:

$$\text{Dielectric Absorption ratio} = \frac{\text{IR value after 60 seconds}}{\text{IR value after 15 seconds}}$$

$$\text{Polarization Index} = \frac{\text{IR value after 600 seconds}}{\text{IR value after 60 seconds}}$$

If Dielectric Absorption Ratio is above 1.5 then insulation quality is considered to be good. If Polarization Index is more than 1.3 then also insulation quality is considered to be good.

Measurement of Secondary Winding Resistance for Current Transformers

Secondary winding resistance of CTs is measured with a digital or analogue Ohm meter with leads. While taking the measurement the CB and Isolators from both sides of CT should be in open position. Test links to be opened in the CT MB prior to measurement of secondary resistance. It is to be ensured that associated CTs are not in charged condition. For example, main and tie CTs for differential relays should not be in charged condition. Earth provided if any in the secondary circuit of CT, should be removed prior to measurement.

Leads of ohm meter should be connected between different terminals of CT secondary cores. Select suitable range on ohm meter. Record the winding resistance values.

Value of secondary winding resistance should be within acceptable limits. Extreme low value of resistance indicates turn to turn shorting and a high value indicates loose connection which is to be identified and tightened before repeating the measurement.

Magnetization Characteristics of Cores for Current Transformers

Saturation level is an important magnetization characteristic of CT cores.

Knee Point Voltage: Knee Point Voltage is defined as the voltage at which a 10 % increase in flux density (Voltage) would cause 30% to 50% increase in exciting ampere-turns (current).

Equipment required for testing are Voltage source of 5 kV, Voltmeter of range 0 to 5 kV, Ammeter of range 0 to 100 Amps, testing leads/cables, etc.

CB and Isolators from both sides of CT should be in open position. Test links should be opened in the CT MB prior to test. All the associated CTs shall also be not in charged condition. For example, main and tie CTs for differential relays should not be in charged condition. If any earth is provided in the secondary circuit of CT, same is to be removed prior to measurement. Applied voltage to the CT core should not exceed the rated Knee Point Voltage of the CT.

Voltage is injected in the secondary after making proper connections. Applied voltage is increased from zero to rated Knee Point Voltage in steps of 25%, 50%, 75% and 100%. Measure the Current drawn by the CT secondary core at respective applied voltages and record the test results.

The magnetization test is conducted in order to see the condition of turns of CT secondary. This test gives an indication regarding shorting of turns CT secondary winding. Magnetization characteristic also indicates the healthiness of CT.

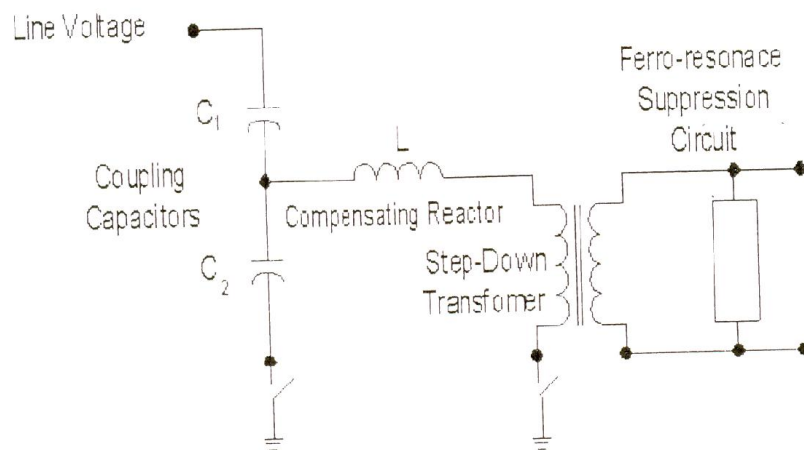
The magnetization current at rated Knee Point Voltage should not be more than the specified/designed value. A curve can be drawn between applied voltage and magnetizing current.

From the curve it can be observed that up to rated KPV (Knee Point Voltage), the VI curve is almost a straight line. However, if this line is not linear, this indicates that the magnetizing characteristics are not desirable. If the slope of the curve starts increasing, it indicates that magnetizing induction becomes low and total primary current is utilized in exciting the core alone. Consequently, output of CT secondary will be erratic.

5.1.2.4 CAPACITIVE VOLTAGE TRANSFORMERS

Measurement of Secondary Voltage

As CVTs are made up of capacitor elements, any puncturing of element will alter the secondary voltage of CVT. Capacitor elements in CVTs are designated as C1 and C2 as shown in the figure below. In 400 kV CVTs, there are about 280 - 300 elements in C1 and C2 out of which C1 has about 260 to 280 elements and C2 about 15 to 20 elements leaving ratio of C1/ C2 to about 20 as tap voltage. Puncturing of one capacitor element in C1 side is likely to increase secondary voltage by about 0.35 to 0.45% (0.22 - 0.28 V) and failure of one capacitor element in C2 side is likely to decrease secondary voltage by 5 to 6% (3.2 - 3.8 V)



CVT Basic Circuit

Periodic measurement of secondary voltage is to be done to check the healthiness of the capacitor elements. The measured voltage is to be compared with other phases of the same CVT and in case of doubt, simultaneous measurement to be carried out with another feeder/ Bus CVT. A precision multimeter of accuracy of 0.5 class or better for AC voltage should be used.

Any drift in secondary voltage of CVT has to be analyzed and action taken accordingly. There may be difference in secondary voltage due to unbalance in primary voltage also. This will be marginal and simultaneous measurement with another healthy CVT could help identify the problem. The following table gives a broad guideline for action to be taken to identify the defective CVTs and to eliminate the defect from service.

SI .No.	Drift in secondary voltages	Condition of CVT	Measurement frequency
1.	Up to ± 0.5 volts	Healthy	Six Monthly
2.	± 0.5 to ± 0.8 volts	Needs monitoring	Three Monthly
3.	+0.8 to + 1.2 volts	Needs close monitoring	Monthly
4.	+ 1.2 to +2.0 volts	Needs close monitoring	15 days
5.	Above +2.0 volts	Alarming! Critical	Needs replacement*.
6.	-0.8 to - 4.0 volts	Needs close monitoring	15days
7.	Less than - 4.0	Alarming	Needs replacement*

***Before replacement of CVT, voltage drift is to be reconfirmed by simultaneous measurement of voltage w.r.t. other feeder CVT of same phase.**

Capacitance and Tan δ Measurement

A large number of equipment insulation failures can be identified in advance by carrying out Tan δ and capacitance measurement. Changes in the value of capacitance indicate abnormal conditions such as presence of moisture, layer short circuits or open circuits in the capacitor elements of CVT stacks.

Measurement is to be carried out by 10 kV or 12 kV test kit. As there will be induction at switchyard, kits with induction suppression facility must be used.

Jumper is to be disconnected from HV terminal. PLCC connection/earth connection is to be removed from HF point/bushing and earth connection to be removed from neutral point of EMU tank.

Before carrying out the measurement, the insulator petticoats of CVTs should be thoroughly cleaned to remove moisture, sand, dust particles or salt deposition etc. as presence of these may influence the measured values. All safety precautions pertaining to the high voltage kit used to be observed.

HF point should be disconnected from ground/ PLCC. Neutral/ LV of Intermediate voltage - transformer should be disconnected from ground. High voltage from tan delta kit should be applied to primary (HV) Terminal and LV should be connected to the HF point of the CVT. Before applying HV, interference is to be nullified using interference suppression unit (ISU). Measurement has to be taken in UST - Mode. Standard procedure (as specified by kit supplier) for measuring capacitance and tan delta in charged switchyard/induced voltage conditions should be followed. Measurements are to be carried out in main and reverse mode/polarity and then the average value to be computed.

Evaluation of the test results:

SI. No.	Parameter	Change of the measurement parameter from the pre-commissioning value	Remarks
I.	Capacitance	Up to $\pm 2\%$	Normal
		$\pm 2\%$ to $\pm 3\%$	Yearly measurement
		Above $\pm 6\%$	Needs replacement
2.	Tan Delta	Up to $+0.002$	Normal
		$+0.002$ to $+0.003$	Yearly measurement
		Above $+0.003$	Needs replacement

Note: If only Tan Delta values exceeds $+0.003$ (increase from the pre-commission values) and other parameters like drift in secondary voltages and capacitance values are within acceptable norms, the Test results are to be reviewed for further action by experts.

5.1.2.5 DISCONNECTORS (ISOLATORS)

Contact resistance of disconnector switch main contacts should be measured to check the healthiness of the current carrying parts. Micro ohm meter of 100 A or more current injection capacity with accessories is required for this test.

CB is to be in open position and other side disconnector switch of CB also to be in open position. High voltage plugs should be free from moisture during installation and operation. At the time of connections, both sides of disconnector switch should be earthed by closing earth switches or by temporary earths. After making the connections, earthing is to be removed.

The ohm meter operates on the four wire measurement principle. To measure the contact resistance connect the respective leads and adjust the variac so that app. 100 amps current flow through the contacts. Value of contact resistance is directly displayed on the digital LED display screen. By using four terminal method, we can nullify the resistance of test leads if input impedance of measuring device (IC) is very high.

Contact resistance of the main contacts indicates wear out and misalignment of the main contacts. If the value of contact resistance exceeds the permissible limit, i.e., 300 micro ohms this could result in overheating of the contacts. Therefore, the problem of high contact resistance should be attended immediately by making proper alignment of contacts or by replacing finger contacts.

5.1.2.6 SURGE ARRESTERS

Surge Arrestors installed in the substation are intended to divert surges to earth and thus protect costly switchyard equipments. Proper insulation coordination is necessary for enhancing life span of costly substation equipments.

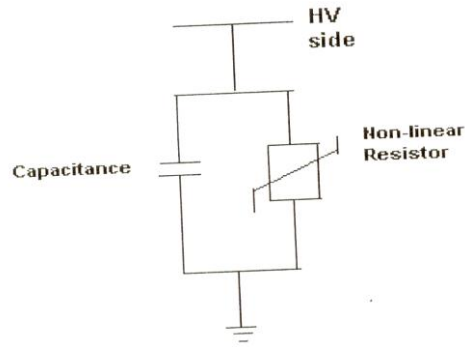
Surge Arrestors are monitored basically using three tests to evaluate their condition. Leakage current monitoring, Insulation resistance measurement and thermo vision scanning would indicate any deterioration in surge arresters. Out of these, leakage current measurement and thermo-vision scanning are on-line measurement and shut down is required for IR measurement. As system availability is crucial for utilities, more emphasis is to be given for on-line measurements.

Leakage Current Measurement: As per IEC-60099(5), the following condition monitoring techniques for the surge arresters in service are suggested:

- Total leakage current measurement
- Watt loss measurement
- Insulation resistance measurement
- Third harmonic resistive current (THRC) monitoring with compensation for third harmonics in system voltage.

Total leakage current measurement is not sensitive to the deterioration of the arrester discs as this does not indicate severity of ZnO disc degradation as resistive current is only 20-30% of the total leakage current and a sharp increase in resistive current due to degradation of arresters discs do not affect the total leakage current considerably. Watt loss measurement is a useful method but it involves a separate voltage source and test results are affected by phase shifts introduced by CVT/PT. The harmonics present in the system voltage may create capacitive harmonic currents, which may be comparable with the harmonic currents generated by the non-linear resistance of the surge arrester. As a result, the error in the measured harmonic current may be considerable. The error in the measured third harmonic current may be up to 100% with 1 % third harmonic present in the system voltage. Hence, reliable monitoring of surge arresters is possible through such test kits which provide for compensation for harmonics present in the system voltage.

The equivalent circuit of surge arrester is parallel combination of capacitance and variable resistance (as shown in figure). The current flowing through the zinc oxide discs is the total leakage current (I_h), having capacitive leakage current (I_c) and resistive leakage current (I_r) components. Normal operating voltages causes ageing of ZnO discs whereas switching/ lightning over voltages may cause over loading of all or part of the ZnO blocks. The increase in resistive leakage current (I_r) due to above reasons may bring the arrester to thermal instability and may result in complete arrester breakdown. Hence, monitoring of leakage resistive current (I_r) is very important.

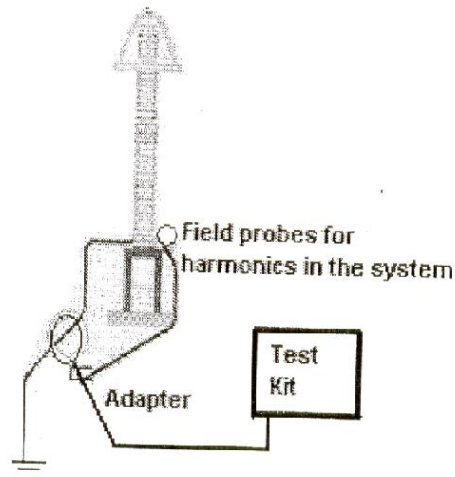


Harmonics are created in leakage current on application of fundamental frequency, due to non-linear voltage-current characteristic of surge arresters. Third harmonic is the largest harmonic component of the resistive current. Third harmonic in system voltage creates capacitive harmonic currents which affect the measured value. Error in the measured values may be considerable. As reported, 1% third harmonic in system voltage may introduce error up to 100% in the measured value.

Resistive current consists of fundamental, third harmonic, fifth harmonic and seventh harmonic components. The harmonic content depends on the magnitude of the resistive current and on the degree of Non-linearity of the voltage-current (V-I) characteristics. The harmonic content also varies with the voltage and temperature of the surge arrester.

The third harmonic is the largest harmonic component of the resistive current and is most commonly used for diagnostic measurements. No reference is needed for measurement of third harmonic resistive current (THRC) since it is assumed that all harmonics arise from the nonlinear resistive current. The conversion from harmonic to resistive current level, if required, relies on information supplied by surge arrester manufacturer or from measurements in the laboratory. Basic-principle of this technique lies in the measurement of third harmonic resistive current duly compensated for third harmonics present in system voltage. A trend analysis of the 3rd harmonic resistive current is necessary to observe periodical changes due to normal/abnormal ageing. Sudden rise in THRC or very high value of third harmonic resistive current indicates degradation of ZnO discs and inspections/corrective actions are required to be taken in advance to prevent catastrophic failures.

The total current (I_t) through the Surge Arrester having Capacitive component (I_c) and Resistive current (I_r) flows through the Leakage Current Monitor. The I_r component has 3rd, 5th harmonic and other harmonics present in it. However, when degradation of ZnO discs occur, the variation of 3rd Harmonic Resistive Current is more pronounced than other harmonics currents, total current (I_t) and total capacitive current (I_c).



The connection arrangement for the instrument is quite simple as shown in above Figure. Connecting a clamp type CT probe to the ground wire allows the leakage current to be detected. Probe output passes through a shielded cable to the detector unit. A band pass filter is built into the initial stage to pass the third harmonic and to cut off the fifth and higher harmonics. After the third harmonic is selected, it is amplified and then displayed. Compensating antenna is also provided, output of which is fed to the test kit to compensate for the harmonics present in the system voltage.

The harmonics present in the EHV system are compensated and filter circuits are provided for bypassing undesired currents and only 3rd harmonic resistive current is measured.

Insulation Resistance Measurement: Insulation resistance measurement is to be first carried out on individual stacks and then carried out the complete arrester. As this is off line test, the arrester is to be taken out of service for such measurement.

IR test proves good to find out any moisture entry through sealing inside the arresters. Keeping a stack with low LR value will stress the other stack also and failure is more prone on the other stacks also. Corrective action is to be taken immediately.

Thermo-vision Scanning: Thermo-vision scanning helps in identifying defects in EHV switchyard. As it requires no shut down of switchyard equipment, it can be widely used on condition monitoring. Any loose joint, improper isolator contacts and current transfer parts could be identified using thermo-vision scanning.

Thermo-vision scanning also helps in identifying defects in surge arresters. This may not be true always but if there is defect and more current is passing through the arrester, then the temperature inside arrester will increase and could be detected by thermo-vision scanning. It is advisable to carryout this test during maximum voltage condition of the switchyard unlike thermo-vision scanning of other current carrying components during maximum current flow condition. This test followed by IR measurement $\tan\delta$ and capacitance measurement shall indicate healthiness of surge arresters.

5.1.2.7 Earth Resistance Measurement

The resistance to earth of an earth' electrode may change under different soil moisture condition and over a period of time. Establishment of satisfactory earthing systems (low total resistance to earth) is essential to ensure safety to the equipment and operating personnel. Measurement of the resistance of earth electrodes is done to see that they meet and remain within the required resistance limits.

Earth tester manual or automatic, analogue or digital along with following accessories is required for measuring earth resistance.

Hammer 1.13kg – 1no, Galvanized steel spikes 12 mm square section 450mm long - 4nos,
Spike extractors – 2nos, Cable complete with connector and clip – 30m (1 no.), 50m (1 no.)

Safety Precaution: It should be strongly impressed on all test personnel that a high potential (of the order of 1 kV to 10 kV) can exist between the station ground and a remote ground, if a power system fault involving the station ground (though the chances are remote) occurs while ground tests are being made and therefore insulating shoes, gloves and other protective devices may be used by the testing crew whenever measurements are carried out in an energized substation and handling the test leads.

Method of Testing using the earth Testing Megger: The earth testing megger consists of basically a moving coil meter with two coils at right angle. A control coil is arranged to be in series with the current probes. The movement of the pointer is then dependent on the ratio of currents in the two coils and is thus dependent on resistance. Terminals P1 and C1 should be connected to main station earth E by separate copper wires (E is the substation earth mat electrode). A current probe, usually a 12 mm square section, 450 mm long galvanized steel spike is connected to a cable which is run out a distance of 5 times, the length of the longest diagonal of substation (should this be physically impossible then the maximum obtainable distance should be used), the other end of the cable being attached to terminal C2. Another probe P (again 450 mm long, galvanized steel spike of 12 mm square section) is attached by another cable to terminal P2, completing the connections required for measurement. When running wires to the electrodes they should be laid at least 2m apart to minimize inductive coupling.

In carrying out earth resistance checks it should be remembered that overhead lines with their aerial earth wires can provide a path for the earth megger current, so giving a false reading. The electrode should therefore be run out in a direction to avoid any incoming line routes and if possible tests should be made in different direction.

At least 10 measurements are to be made at intervals from the C2 electrode inwards as far as practicable. The resistance/distance curve so obtained should show a "plateau" region. The resistance of this region is taken to be true earth resistance of the rod or plate. If a plateau region is not obtained, the test should be repeated with the C2 spike further away typically 500 m away from the substation.

However three measurements are recommended for simplicity with moving potential electrode P say by 6 m away from E and 6 m nearer to E and average can be taken.

Testing steps – Fall of potential Method: P1 and C1 terminal is sometimes named as terminal X which is connected to earth electrode E. Connect C2 terminal to remote current spike C, at least 100 m away from any part of the earthing system. In addition it should not be in line with any overhead transmission line, buried cable, metal water pipe or other earthed electrode. Connect P2 terminal to remote potential spike P, 61.8% of total distance d away from earth electrode E so that interference of electromagnetic field if any do not affect readings. Make the first measurement- R1.

Move the potential spike P nearer to electrode E by a fixed step (say 6 m). Make the second measurement- R2. Move the potential spike P further away from electrode E by 6 m (the other side of the centre position). Make the third measurement- R3. Resistance of the earth electrode is the average (RA) of these three results (provided they agree within the specification limits of the electrode system).

$$RA = (R1+R2+R3) / 3$$

Any error in earth testing measurement is due to mainly low value of testing current used and maximum sensitivity of any instrument. On large electrode systems the instrument is working at the extreme end of its designed range and should the earthing system exhibit a high reactance, then the true impedance is not measured.

An ideal grounding should provide a near zero resistance to remote earth. In practice, the ground potential rise at the station site increases proportionally to the fault current. The higher the current, the lower value of a total system resistance thus has to be obtained. For most transmission and other large grid substations, the ground resistance should be less than 1 ohm. In smaller distribution substations, the usually acceptable range is from 1 to 5 ohm depending on the local conditions (as per ANSI/IEEE 80/1986). The value measured should be within 20% of the previous value or if no previous history is available, it should be compared with the resistance of a similar rod or plate on the same site.

5.1.2.8 MAINTENANCE OF GAS INSULATED SWITCHGEAR (GIS)

Before taking up the maintenance of GIS, safety rules as recommended by the manufacturer shall be adhered to. Some of them are listed below

(a) The maintenance programme and periodicity specified/no. of operations whichever is earlier should form the basis of maintenance.

(b) The following shall be strictly followed:

- Maintenance shall be carried out by authorized persons only.
- Parts supplied by original manufacturers only should be used.

- Equipment to be maintained should be de-energized/de-gassed, isolated and earthed on all sides of the work zone.
- Necessary tools and tackle such as slings, platforms, electrical equipment and tools should be kept ready and should be in good condition

Condition Monitoring of GIS: GIS requires very little maintenance. Monitoring the SF₆ gas pressure and quality is considered sufficient. Regular inspections, Routine scheduled maintenance and overhaul maintenance as specified by the manufacturers should be followed. The maintenance to be carried out and their periodicity is indicated in the "Maintenance Schedule". Manufacturer's instructions are to be followed for special tests, if any, for a particular make of GIS substation.

SF₆ Gas: As SF₆ gas is used in all chambers of GIS, monitoring of pressure and quality of gas is important. As per IEC 62271-203/2003 the leakage rate from any single compartment of GIS to atmosphere and between compartments shall not exceed 0.5% per year for the service life of the equipment. The pressure inside a GIS may vary from the rated filling pressure level due to different service conditions. Pressure increase due to temperature and leakage between compartments may impose additional mechanical stresses. Pressure decrease due, to leakage may reduce the insulation properties. Further the quality and dew point of SF₆ gas should also be monitored as the property of SF₆ is related to its insulation quality.

Partial Discharge Measurement: Electrical Ultra High Frequency (UHF) or Acoustic PD measurement techniques are being employed. Electrical UHF technique gives higher sensitivity and PD detection necessitates the installation of sensors inside the gas compartment during manufacture. Acoustic methods employ sensors which are fixed outside the enclosure. For both the methods the sensitivity depends on the distance between the defect and the sensor.

UHF Partial Discharge Measurement: The partial discharge signals in the range 1000 MHz to 2000MHz can be detected in the time domain or frequency domain by means of sensors usually installed inside the chambers. Due to the complexity of the resonance pattern, the magnitude of the detected PD signal depends strongly on the location.

Acoustic Partial Discharge Measurement: Acoustic signals are emitted from defects in a GIS mainly by the floating particles emitting a mechanical wave in the enclosure when they impinge on it. Discharges from the fixed defects create a pressure wave in the gas, which is then transferred to the enclosure. The resulting signal will depend on the source and the propagating path. As the enclosures are normally made of aluminum or steel, the damping of the signals is quite small.

Acoustic signals can be picked up by means of externally mounted sensors. The location of the defect can be found by searching for the acoustic signal with highest amplitude or time travel measurements with two sensors. Bouncing particles producing discharges in the 5pC range can be detected with a high signal to noise ratio. Sensitivity decreases with distance because the acoustic signals are absorbed and attenuated as they propagate in the GIS. Acoustic measurement is immune to electromagnetic noise in the substation. The acoustic sensitivity to bouncing particles is much higher than the sensitivity of any other method. **PD** measurement in a GIS installation is recommended once in 5 years.

In GIS substation some of the equipments like Bushings, Surge Arresters, and Transformers shall be provided outside the GIS area. Condition monitoring of these equipment is to be carried out as followed for conventional substation equipment.

5.2 TRANSMISSION LINES

5.2.1 Preventive Maintenance Procedures:

5.2.1.1 Periodical maintenance:

Normal ground patrolling of lines should be conducted by lines maintenance crew periodically. Periodicity will be decided on the basis of importance of the line, terrain condition, and proximity of the line to habitations, forests, gardens, water borne areas etc. and environmental impact on the line.

During ground patrolling of the line, the patrolman should check for the following

- Location no; type of tower (tangent/angle, normal/extension), location address.
- Clearances of the line, both to ground and in air.
- Availability of all tower parts and their condition. Obstructions in the proximity of the line (within line corridor) like trees, branches, structures etc. location wise should be noted.
- Condition of foundations such as chimneys, copings and consolidation of foundation pits. Defects noticed should be recorded.
- Observing the condition of insulators, conductors, earth wire, jumpers, clamps, dampers, spacers etc., with binoculars, from ground level/nearest possible elevated level.

Observations made location wise by the patrolman should be noted in a diary and presented to the Engineer concerned within two days. Any specific observation warranting immediate action should be brought to the notice of the Engineer through mobile phone or immediately on return from patrolling.

Phase to ground faults on lines such as birds shorting the live point to ground, flash over of insulators, tree branches/levels coming into close proximity of the line (ionized zone) may cause momentary tripping of the lines.

5.2.1.2 Special patrolling of the line should be done after momentary tripping of the line on fault, for any defects. Defects noticed shall be rectified immediately if this can be attended while the line is live or at the earliest by availing shutdown, any way, before the defect develops into a major one causing breakdown. Proper planning of materials and manpower is required in order to carryout rectification under shutdown in minimum time to avoid/minimize interruption to loads.

5.2.1.3 Break down maintenance: When a permanent/semi permanent fault occurs on the line, the line may break down causing interruption of longer duration. The faults could be snapping of conductors, disconnection of jumpers, cross-arms/ towers twisting or tower collapse with or

without damage to foundation. This may be due to various reasons like heavy wind due to storms, weakening of tower legs due to rusting and chemical pollution, accidents, thefts etc.

In olden days ground patrolling was arranged in the territories of concerned subdivisions to physically inspect the line to identify the fault. After identifying the faulty location and nature of fault through the nearest public telephone to the concerned, who would then arrange for mobilization of required materials, tools and tackle and necessary manpower and proceed to the location for rectification.

Introduction of Static/ Numerical relays replacing the old electro-mechanical relays, facilitated indication of distance to fault location in proportion to the impedance to fault on line. The accuracy of this measurement depended largely on the accuracy of the relays in measuring correct reach and the nature of fault.

Digital off-line fault locators are now in use in APTRANSCO for measurement of distance to the fault. After the line is declared faulty, the line is isolated. Off-line fault locator is connected on the faulty line and tested for measurement of distance to fault. This instrument indicates the distance to an accuracy of 100metres.

5.2.1.4 IT tools such as Transmission Network Asset Management System (TNAMS) developed in 2003 and Maintenance module in Enterprise Resource Programme (ERP) developed in 2007, provide and display relevant geographic and technical information of the assets of Transco as follows:

Substations: Single line diagram of the SS, Nameplate details of each electrical equipment connected in the SS. Date of commissioning of each equipment and various maintenance schedules for the equipment and the dates on which they are due and the dates when maintenance was done and the results of maintenance. Type of earthing and earth layout and earth resistance of each electrode and combined earth resistance and maintenance details as above.

Lines: Line route giving geographic details such as location no. significant land marks near the location viz; rail, road, power line/ P&T line crossings, river, streams, tanks, hill slopes, forests gardens, habitations, longitude and latitude of the location obtained through GPS and technical details such as type of tower (tangent/angle, normal/extension), type of foundation adopted, bill of materials for the tower, size and configuration of the conductors and earth wire, type and no. of insulators and their technical details, vibration dampers, spacers, prefabricated armored suspension grips etc. Maintenance schedules for the lines, dates due and dates done along with the results are also displayed.

The entire system can be monitored and reviewed by the concerned authorities at field and headquarters.

Immediately after finding the faulty location distance through fault locator and identifying the approach to the location with the help of TNAMS/ERP, the AE/ADE along with maintenance crew will proceed to the location along with essential materials like conductor bits, insulators, clamps bolts& nuts, ropes and slings, earth discharge rods, compression joints, hydraulic compressors etc.

They shall carry with them torch lights to facilitate checking the locations and working in the nights. After identifying the fault, the AE/ADE with their crew should take up rectification with the available men and materials duly giving intimation to the DE and obtaining line clear. Line should be discharged and the work spot should be earthed on both sides to avoid induction from the adjacent lines, before working on the line. Assistance of local labor may be taken if required depending on the need. Where the fault is major one and cannot be rectified for want of major spares and more man power and machinery or where civil works like foundations are involved, description of such faults and the materials required for rectification shall be intimated to the ADE/DE concerned over mobile phones. DE will immediately assess the type of materials required based on the nature of fault reported and the technical details of the location available in the TNAMS/ERP, and plan for mobilization of men, materials and machinery for taking up rectification.

Use of off-line fault locator and IT tools save considerable time in identifying the faulty location and assessment of material and man power required.

5.2.2 Condition Monitoring Procedures

5.2.2.1 Condition monitoring is useful in identifying some of the defects on conductor and insulators, which is not possible through visual ground inspection. Assessment of nature of defect helps in taking preventive action. Possible breakdowns due to defective joints, punctured insulators etc. can be avoided.

Various condition monitoring methods are:

On Line Techniques -- Coronagraphy
-- Thermo vision scanning
-- On line puncture insulator detection test

Off Line Techniques -- Pollution measurement of insulators
-- IR measurement of insulators
-- Contact resistance measurement
-- Signature print outs by using off-line fault locator

5.2.2.2 Coronagraphy: Corona discharge is a luminous partial discharge from conductors, and insulators due to ionization of air where field intensity exceeds a critical value. Corona discharge is severe at sharp edges and generates corrosive material which reduces life of components. Corona radiations are in 280 nm – 405 nm of the spectral range and are not visible to naked eye. However they can be seen to certain extent in pitch dark during nights.

Coronagraphy is a technique used to observe corona on various transmission line components under live condition. Sophisticated camera enables to observe corona even during day time. With the help of this technique line components generating corona can be detected during normal patrolling and rectification / replacement of such components can be done during subsequent shutdown on the line.

5.2.2.3 Thermo-vision scanning: Current flow in the conductors generates heat in various electrical components. Intensity of current varies depending on the contact resistance and quantity of current flow. Most of the heat generated is in the infra-red range and hence not visible to naked eye. Amount of infra-red energy generated is proportional to the temperature. Detection and rectification of hot spots in early stages prevent breakdowns such as snapping of conductors etc.

Thermo-vision scanning/ thermal imaging/ thermography is a technique which produces an image of invisible infrared light emitted by objects due to their conditions. Sophisticated cameras can actually measure the temperatures of any object's surface in the image and produce false color images that make interpretation of thermal patterns easier.

Thermo-vision scanning systems can be used as hand held portable cameras, fixed monitoring systems as aircraft/vehicle mounted systems to cover a wide range of applications. The cameras provide accurate information about severity of the hotspots observed and time allowable for rectification.

With the latest version of Inframatics 760 system with Thermotronics software, the condition of the line jumpers, insulators, metal parts, connectors of transformers and current transformers, where the change of temperature is there, can be identified well in advance and behavior of the metal part can be analyzed in the computer. The temperature rise of any connector after detection can be rectified in advance even before deformity or red hot occurs for the clamp or connector.

5.2.2.4 On Line Puncture Insulator Detection Test: The strength of an insulator can be measured by its IR value. The insulator string efficiency depends on the uniform distribution of electric field across the insulators. Any variation in the field strength across the string will indicate the healthiness of the insulator. It is practically not possible to measure IR values of each insulator in a string which is live. Degradation of insulating material may result in puncture of the insulator. When an insulator starts conducting due to puncture the field intensity across that insulator reduces. This change in electric field intensity across the insulators will be used to diagnose the healthiness of the insulator.

There are two test methods to detect insulator puncture on line:

(a) Voltage detection method - In this method a hot line stick mounted with a voltage recorder is moved across each insulator to record the voltage across it. The disc having voltage of above 11kV will be regarded as a healthy insulator.

(b) Electric field measurement method – The detector test kit consists of an electric field detector mounted on a plastic support. Test kit will be moved across the insulator string from top to bottom and vice versa. The field intensity across each disc will be recorded in the memory of the kit which can be down loaded into PC through a serial port. A graph is plotted with insulator no. on X- axis and log of electric field intensity on Y-axis. Comparison between the healthy insulator and the defective one is made.

5.2.2.5 Off Line Fault Locator: Digital off line fault locator works on the principle of wave reflection. High frequency high power signal is injected into the transmission line from one end of the line. This high frequency signal on its way to the other end encounters wave reflection or refraction depending on the nature of the fault. This echo of the wave is utilized to determine the fault location. Signature analyzer indicates the degree of faults from the minimum to the major

fault in progressive numbers. A no fault line or uniform line is indicated as “-”. All types of fault can be detected with an accuracy of +/- 100mtrs.

Inhomogeneities in the line could be due to improper joints in the conductor, hot spots due to loose jumpers, leakage points, Disc puncture where there is electrical path to ground and heating over 5 deg ambient, Crossing of another EHT line, Steep changes in terrain inclination or severe phase sag. If left undetected, these may turn into major problems resulting in outage of line. Fault locator can be used as a condition monitoring tool to provide signature analysis of the transmission lines to trace inhomogeneities existing in the line so as to help in taking suitable preventive measures to minimize the possible outages. Main components of a fault locator are Fault locator unit, Signature Analyzer, Line Simulator Unit and supply and grounding units.

Before conducting the signature analysis, the line should be de energized and isolators opened at both ends. Earth switch should be closed. After connecting the fault locator unit to system ground, connections to the overhead lines should be given. Before commencing the test, the line earth switch should be opened. All safety precautions such as wearing gloves, rubber shoes etc. should be taken.

5.2.2.6 TRANSMISSION LINE MAINTENANCE BY HOT LINE TECHNIQUES

Hot line means energized electrical power line. Minor damages noticed on the line with the help of condition monitoring tools or other wise need to be attended in time to prevent breakdown. Timely attending of these minor problems may require shut down on the lines causing interruption of power supply and consequential revenue loss. Live line maintenance provides a solution to such problems. Live line maintenance or rectification of minor damages on live line is done using hot line techniques, by skilled and trained professionals.

Hot line Techniques: preventive hot line maintenance is carried out using Hot stick / bare hand techniques. Hot stick/Bare hand technique can be used from 11kV to 220 kV where as only bare hand method can be used for lines from 400kV and above.

Hot Stick Method: Hot stick is basically a wooden stick with exceptionally good insulating property, light in weight and having high mechanical strength. Laminated light wood like SITCA Spruce and Himalayan Spruce are used in the preparation of Tie sticks, Wire Tongs, Flexible wrenches etc.

Tie stick is used for tying or untying the insulator bindings where the pin bindings are taken up. Wire tong holds the conductor or jumper and moves them for a safe clearance of the crew handling the works.

Flexible wrench – By fixing suitable sockets of required size, bolt and nuts of pad clamps, T clamps etc. can be tightened or loosened.

The above wood tools have an inherent property of absorbing moisture, which reduces the insulation level and hence need to be dried before attending to the hot line work. This requires heating chambers, air tight chambers and continuous insulation monitoring.

In spite of ensuring dryness before taking up the work, if the working time on the hot line is extended, the wood sticks absorb moisture from atmosphere, intensity depending on the humidity in air. This is dangerous to the crew working on the line and may cause breakdown of the line.

To overcome the above constraints Glass fibre is used in place of wood stick. The glass fibres are soaked with Epoxy resin and wound to produce a hollow stick. The hollow portion is filled with a unicellular foam to prevent external moisture from entering the inside stick and thus the insulation value of Epoxy glass stick is maintained. Because of this property, use of this stick is a safe option for the operating crew. Maintenance of glass fibre hollow stick is easy as just wiping the stick with moisture eater solution and a little drying in Sun is all that is required to make the stick fit for work.

Different suitable metal heads are fitted to the hot sticks for carrying out number of operations like changing of broken insulators, flashed over insulators and all the connected parts of tension and suspension points of the live lines without interruption to the power. Also tightening or loosening of cut point jumper bolt and nuts, replacing vibration dampers, replacing suspension shoe clamps etc., of the EHT lines and Lifting up of the conductors, changing of cross arms up to 11 KV and 33 KV can be carried out by Hot Stick method.

Bare Hand Technique:

Bare Hand Technique means carrying out work on a charged line with hands by person who stands charged to the required voltage level on an insulated platform. The person is either traversed by insulated ladder or by raising through an insulated boom. The chargeable person will wear a conductive suit comprising of cotton, asbestos and stainless steel threads, along with conductive shoes of copper threaded carbon sole with conductive socks and conductive hand gloves. Total continuity will be maintained from 'Head to Toe' covering the head with hood except the face.

The Bare Hand Technique is not a single man operation; it requires both Hot Stick Method as explained above and a person working with bare hands.

This method can be effectively utilized for connecting bus isolators of additional transformers and other equipment like capacitor banks in 220 kV and 132 kV Sub-stations to the live bus without interruption to any equipment or without Bus shut down.

By this Bare Hand Technique damaged Bus jumpers, T Clamps, Isolator Pad Clamps, Female Contacts can be replaced without the interruption to the bus bars, and conductor damages also can be attended when sufficient clearances are there for operation.

In addition to the above two techniques employed for carrying out hot line works, special works like removing and cleaning of the saline contamination of insulators, cement dust deposits and chemical deposits on insulators can also be carried out on live lines. Three methods are available for carrying out the cleaning.

- a) Dry washing b) Hot Spraying c) Wet washing

Dry Washing: The Dry Washing and Spraying will be undertaken with huge hot air along with

com husk or paddy husk on peanut husk with lime stone granules. The hot spray of air through nozzles will clean the cement contamination.

Hot Spraying: To avoid cement dust pollution and other chemical pollution, spraying of chemical on the insulators will be taken up. When once the cleaning of the insulators by dry washing is completed a thin film of silicon compound will be deposited on the insulators by Hot Spray.

Wet Washing: Previously the wet washing of the live insulators used to be carried out by a small cylinder with carbon dioxide along with water to a limited extent.

With latest equipment and trigger controls etc. available to day, ordinary water having the conductivity of less than 2 mhos is being sprayed directly on the live insulator to clear the salt contamination, dust and chemical contamination which is soluble in water.

The above works are essentially to be taken up periodically in high polluted industrial areas and coastal areas, where cement, chemical and saline deposits are a regular feature.

Persons working on hotlines are required to be trained and should possess a certificate issued by competent authority. Hot line Training Centre of National Power Training Institute in Bangalore is imparting training in hotline works and issuing a certificate.

Staff will be initially trained in hot stick method. After gaining some experience they can be further trained in Bare hand techniques. While working in Switchyards using bare hand technique, extra precaution shall be taken as the area is congested with equipment all around reducing clearance.

5.2.2.7 XLPE CABLES:

Once the cable is laid under ground following standard procedure and buried, no frequent inspection of the cable is necessary after charging during its life period.

Maintenance staff should be in possession of as built drawings for the cable laid showing land marks of the route.

Manuals and manufacturer's instructions for maintenance and jointing should be kept with the maintenance unit for any reference.

Coordination with other utilities whose under ground systems run in close proximity to the cable (such as water supply, sewerage pipes, communication cables, other power cables etc) is required to make sure that no interference or inconvenience is caused due to maintenance / service of their systems. As built drawings of cable route should be communicated to these utilities for identification of cable route while taking up of their works.

The following checks on the cables may be carried out periodically, to ensure that no damage to the insulation is caused by any other under ground system running in close proximity to the cable:

- Patrolling along the cable route to verify exposure of cable in any locations or interference with other under ground systems

- HVDC test should be done at every section to check the healthiness of sheath insulation
- Check the condition of link boxes at the jointing locations for tightness and sealing against seepage of moisture
- Check the IR values of the Surge Voltage Limiters (SVL) provided in the link boxes at the cross bonded joints.
- Also check for the proper working of SVL, by applying AC voltage in steps up to its rated voltage and check the leakage current. Keep a record of the test results for future reference.
- Also keep a record of nature of faults occurred in the cable system and the details of rectification carried out to provide an input for analysis and preventive measures for future. This would help in revising the maintenance practices based on experience.

5.3 MAINTENANCE SCHEDULES

SUBSTATIONS

Schedules for necessary preventive maintenance tests and condition monitoring tests for each switchyard equipment and transmission line and the adoptable frequency in which the tests are to be carried out are given here under. The schedule includes condition assessment tests and regular maintenance checks for each switchyard equipment and protection scheme. These maintenance schedules are to be adhered to by the Operation and Maintenance staff of the sub station and observations so made during such inspections have to be properly recorded giving complete details of the activity, observed parameters, remarks/views about the checks carried out. Such observations are to be duly signed by the maintenance engineer in-charge of the sub-station and deviations with reference to acceptable norms/limits are to be approved by the competent authority having requisite experience and expertise. Typical formats for inspection checks for various equipment covered below checks for various equipment covered below may be modified as required by site conditions.

Although it is difficult to prepare a single schedule for equipments from 33 kV class up to 400 kV class, the basic tests covered are same for all EHV equipments except for a few advanced Condition Monitoring checks which are more relevant for higher voltage levels.

The condition monitoring tests mentioned in the schedules require analysis of test results by expert engineers for evaluation of the condition of the equipments. The test results obtained during the maintenance activity have to be approved by the appropriate authority.

The tests should be carried out using reliable and calibrated testing instruments of proven credentials as well as accuracy of repeatability so that there may not be any doubt on the results obtained. The requirement of the testing instruments may also vary depending on the voltage range as only properly shielded equipment designed for immunity from Electromagnetic Induction will work in high induction areas.

Obsolete equipment like bulk oil circuit breakers have not been considered in the schedule. Minimum frequency of maintenance has been given for the purpose of recording. Frequency of some of the activities, which require to be monitored more closely, should be increased. Any abnormality observed by shift/ Operation staff during daily visual inspections should be recorded for corrective action by the maintenance staff.

Typical formats indicating scheduled maintenance activities, periodicities and observations/remarks for each equipment are given below.

1. TRANSFORMERS AND REACTORS

(a) Monthly Maintenance - Activities not requiring shut down

Sl.No	Activity	ICT	Bus Reactor	Line Reactor	Observations & Remarks
1	Date of commissioning				
2	Make				
3	Rating				
4	Sl.No.				
5	Bay location				
6	Bushing oil level				
7	Oil level in main & OLTC Conservators				
8	Manual starting of oil pumps and fans				
9	Check for oil leaks				
10	Oil level in breather oil seal				
11	Colour of silica gel				
Signature of AE/ADE (O&M)			Signature of ADE/DE (O&M)		

Note: No. of columns may be adjusted to suit the no. of transformers/ reactors

(b) Half yearly Maintenance

(i) Measurement of IR values - Megger-(Make/Sl.No./Scale)

Date Temperature at the time of measurement Weather condition

Between	IR value after 15 Seconds		IR value after 60 Seconds		IR value after 600 Seconds		IR60/IR15 (DA ratio)	IR600/IR60 (P1)
	Pre-Comm /Temp	Actual	Pre-Comm /Temp	Actual	Pre-Comm /Temp	Actual		
HV-Tank								
LV-Tank								
HV-LV								

- (ii) Check for trapped air: To ensure that oil comes out freely when air release valves are opened
- (iii) Checking OTI and WTI for set temperature for coolers running, alarms and trips.

(c) Yearly Maintenance

Date of commissioning Make Rating Sl.No. Bay location

Due month Done on Line Clear (Permit to Work) No.
(Wherever shutdown is availed)

(i) Auto starting of fans and pumps: Done / Not Done

(ii) Measurement of BDV of OLTC Oil Permissible limits: Min – 50kV

R phase	Y phase	B phase	Remarks

(iii) External Cleaning of (i) Radiators (ii) Bushings -----

(iv) Maintenance of OLTC Drive Mechanism

Date:

Sl. No.	Description	Status		Remarks
		OK	Not OK	
1	Visual inspection of equipment			
2	Hand operation on all taps& handle inter lock switch			
3	Checking correct working of OLTC counter			
4	Over load device of Driving motor			
5	Local& Remote operation(Electrical) & L/R switch			
6	Stepping relay in remote operation			
7	Correct operation of tap position indicator			

(v) Checking of Remote indications of WTI/Tap indication: OK/Not OK

(vi) Alarm/Trip Test

Date

Alarm Test						Trip Test							
Main Bucholz	OLT C Surge	WT I	OT I	PR D	MO G Low oil level	Diff . Trip	O/ C trip	Main Bucholz	OLT C surge R/Y/ B	WT I	OT I	PR D	MO G low oil level

(vii) Marshalling Box- maintenance

Date

Description	Tightening of termination Done / Not Done	Cleaning Done/Not Done	Checking of contactors, Space heater & Illumination
MB of OLTC			
MB of reactor			
MB of NGR			
TB of PRD			
TB of Bucholz relay			
TB of Oil Surge relay			
TB of SPR (if provided)			
TB of bushing CT			

(d) 2-Yearly Maintenance record

(i)Vibration Measurement (For Reactors only)

Make/Sl.No.

Bay location no.

Measurement of vibration to be done (Indicating the drawing with location of testing marked)

Due date

Done on

Testing kit make/Sl.No

System voltage

Ambient temperature

System frequency

WTI / OTI reading

Zone No.	Location of measurement vibration (in micron)																
	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q
1																	
2																	
3																	

(ii) WTI and OTI Settings Date Temp. ICT No.

WTI	SET FOR	TEST VALUE		OTI	SET FOR	TEST VALUE	
		Actual	Remarks			Actual	remarks
Alarm				Alarm			
Trip				Trip			
Fan start				OTI NGR,			
Pump start				Alarm			
				Trip			

(iii) Tan δ Measurement for bushings

Test kit Make & Sl.No:

Ambient temperature:

Condenser Bushings		Capacitance				Tan δ				Remarks
		Pre-commg * Values		Measure d Value		Pre-commg * Values		Measured Value		Measurement to be taken after cleaning
Transformer Bushings		C1	C2	C1	C2	Tan δ 1	Tan δ 2	Tan δ 1	Tan δ 2	Tan δ at 20degC = 0.007 Rate of rise of tan d per year = 0.001Max
HV	R $\emptyset$ /Y $\emptyset$ /B $\emptyset$									
LV	R $\emptyset$ /Y $\emptyset$ /B $\emptyset$									
Ter.	R $\emptyset$ /Y $\emptyset$ /B $\emptyset$									Rate of rise of Capacitance value per year = +/- 1%
Line Reactors Bushings										
R $\emptyset$ /Y $\emptyset$ /B $\emptyset$										
145kV Neutral Bushing										
NGR145kV-Mains-Comm										

Where pre-commissioning values are not available, Comparison with previous year test results may be done

Note: For measurement of C1 values of the bushings, connection will be between HV and Test tap and measurements in UST mode at 10.0 kV.

For measurement of C2 value of bushings, connection will be between Test tap and Ground and HV will be connected to guard. Measurement will be carried out in GSTg mode and test voltage will be 1.0kV.

(e) 4 YEARLY MAINTENANCE RECORD

S/D-Activity

LC.No.

DATE

(ii) Checking and Cleaning of Diverter Switch Contacts (After 50,000 operations or SOS)

(ii) Tans δ and Capacitance Measurement of Windings

Date of Measurement

Ambient Temp

Test kit Make/Sl.No.

Test Modes	Pre-Commissioning Values		Actual Measurement		Remarks
	Capacitance	Tan δ	Capacitance	Tan δ	
HV-LV in UST Mode					Note: Jumpers should be disconnected from all the Bushings before start of the Tests and all Bushings of particular windings are shorted.
HV-Ground in GSTg Mode					
LV-Tank in GSTg Mode					

(iii) Winding Resistance Measurement

Make of winding Resistance Measurement Kit

Auto Transformers

MEASUREMENT OF HV SIDE WDG RESISTANCE AT ALL TAPS (in milli ohms)									
TAP POSN.	FACTORY TEST VALUES @ 75° C			MEASURED WDG. RESISTANCE (IN OHM)			WDG RESISTANCE AT 75 DEG C		
	R	Y	B	1R1 – 2R1	1Y1 – 2Y1	1B1 – 2B1	R	Y	B
MIN									
NORMAL									
MAX									

Note: In a two winding / three winding transformer winding resistance measurement on HV side (star connected) shall be done on each phase of the winding i.e. 1R-N, 1Y-N, and 1B-N.

MEASUREMNT OF WDG RESISTANCE (IN Mohm) – IV SIDE				
BETWN. WDGs	RESISTANCE SITE VALUE	RESISTANCE AT 75 DEG C		REMARKS & OBSERVATIONS
2R 1 – N				
2Y 1 – N				
2B 1 – N				

MEASUREMNT OF WDG RESISTANCE (IN M OHM) – LV SIDE				
BETWN. WDGs	RESISTANCE SITE VALUE	RESISTANCE AT 75 DEG C		REMARKS & OBSERVATIONS
3R 1 – 3B1				
3Y 1 – 3R1				
3B 1 – 3Y1				

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Sig. of ADE/DE(TL&SS).....

(e) Other Maintenance works

(i)	Testing of oil for DGA and other oil parameters	HY
(ii)	Testing of main tank oil for BDV, moisture content, tan δ , resistivity, IFT etc.	HY
(iii)	Lubricating/greasing of moving parts of OLTC, pumps etc.	HY
(iv)	Electrical checking/testing of pressure relief device, bucholz relay, OLTC surge relay, and checking/replacement of the gaskets of terminal box	Y
(v)	Checking/testing of Bucholz rely by oil draining	Y
(vi)	Frequency response analysis	SOS
(vii)	Recovery voltage measurement	SOS
(viii)	Checking and cleaning of diverter contacts	2Y
(ix)	Filtration and degassing of main tank oil	SOS
(x)	Testing of bushing CTs	SOS
(xi)	Filtration/replacement of oil of OLTC	SOS
(xii)	Measurement of ratio of windings	SOS
(xi)	Checking of earth connection	Y

M-monthly, QY-quarterly, Y-yearly, 2Y- once in two years, 3Y-once in three years, 4Y-once in four years, SOS-as and when required

Note: Insulation resistance measurement, tan δ of winding/bushings, winding resistance at all taps to be carried out once before expiry of warranty period and then to be continued as per schedule.

Vibration measurement on reactor should be carried out initially after 3 months and 6 months after commissioning and then to be carried out as per schedule.

FRA at factory and as a pre-commissioning test before commissioning may be done to serve as base signature.

Visual observation of transformers and Reactors by going round, should be made daily to check for any variations in noise, vibrations and any abnormality/leakages from cooler fans, oil pumps, radiators, valves etc.

2. CIRCUIT BREAKERS

(a) Monthly Maintenance Record

Dt. of Commissioning MAKE RATING.....
 Sl.No..... Bay Loc.....
 Monthly Maintenance without Shutdown Date.....

ACTIVITY	OBSERVATION & REMARKS
Oil Leakage in Operating Mechanism Oil Level (Top, up, if required) Air pressure/leakage in ABCB Oil level in MOCB Oil Leaks from Grading Capacitors	

(b) Half Yearly Maintenance – W-S/D Activity

LC.NO..... DATE
 SF6 CIRCUIT BREAKER (PNEUMATIC OPERATING MECHANISM) W-S/D

Maintenance of AIR DRYER – as per manufacturer's recommendations

(c) Yearly Maintenance – S/D Activity

(i) SF6 CIRCUIT BEAKER

Functional checking of Auto-Starting of Air Compressor
 Pressure Drop during duty cycle operation – O-0.3 S-CO

	OIL PRESSURE		AIR PRESSURE	
	Pre-Commg / Previous Results	Actual	Pre-Commg / Previous Results	Actual
Before Operation				
After Operation				

Checking of Hydraulic pump operation

	START (Pressure)	Stop (Pressure)
Pre Commg.		
Actual		

ii) AIR BLAST CIRCUIT BREAKER – W-S/D

Humidity (DEW POINT) Measurement of operating air

VALUE Temp Ambient

Permissible Limit: -45⁰ C at atmospheric Pressure

(iii) MINIMUM OIL CIRCUIT BREAKER (MOCB) – W S/D

BDV of Oil - KV (Avg of Six Readings)

(iv) BREAKER OPERATION CHECKS – S/D ACTIVITY

(a) CB timing including PIR checks

Make & Sl.No. of test kit

PHASE	Break	Close	Trip		Close USING	Trip *	Remakrs & Observations
			Trip-I	Trip-II		Trip-II	
R – phase main contact R – phase pir Pir & main contacts overlap time/pir opening time prior to main contacts R – phase auxiliary contact	Break 1						
R – phase main contact R – phase pir Pir & main contacts overlap time/pir opening time prior to main contacts	Break 2						
Y – phase main contact Y – phase pir Pir & main contacts overlap time/pir opening time prior to main contacts Y – phase auxiliary contact	Break 1						

Y – phase main contact Y – phase pir Pir & main contacts overlap time/pir opening time prior to main contacts	Break 2						
B – phase main contact B – phase pir Pir & main contacts overlap time/pir opening time prior to main contacts B – phase auxiliary contact	Break 1						
B – phase main contact B – phase pir Pir & main contacts overlap time/pir opening time prior to main contacts	Break 2						

* - CO Time is to be measured with simultaneous Close – Trip commands

(b) Checking Pressure setting of switches

CB Pole	SF6 Pressures Switch Setting		SF6 Pressures Switch Actual		Ambient Temp
	ALARM	LOCKOUT	ALARM	LOCKOUT	
R					
Y					
B					

Pressure Switch setting should be within +/- 0.1 Bar of set value

(c) Checking of Pole Discrepancy Relay

TRIP 'R' ph	Measure Tripping Time of Y&B pole	
	Set Value in sec	Operating Value in sec
PRECOMMG		
ACTUAL		

Close any one pole and observe the tripping of same pole

CLOSE 'R' pole	Measure Tripping Time of R pole	
	Set Value in sec	Operating Value in sec
PRECOMMG		
ACTUAL		

(d) Duty Cycle operating including rapid re-closing

O-0.3 S-CO	Timings in msec			
POLE	Break 1		Break 2	
	PRECOMG.	ACTUAL	PRECOMG.	ACTUAL
R				
Y				
B				

(e) Check of Interlocks- In case Pressure reduces in **ABCB**

(i) Local closing Interlock

(ii) Closing of Line Isolator

(f) Check of Operational Lockouts

Sl.No.	Test-Description	Pressures Values					
		A/R Lockout		Closing L/O		Operational Lockout	
		Set value	Actual	Set value	Actual	Set value	Actual
1.	Driving mechanism (Hydraulic/ pneumatic)						

(g) Cleaning of Breaker Pole

DONE / NOT DONE

(i) SUPPORT INSULATORS

DONE / NOT DONE

(ii) PIR AND GRADING CAPACITOR-

DONE / NOT DONE

(iii) INTERRUPTER CHAMBER

DONE / NOT DONE

(h) Checking of close/trip coils

CB POLE	CURRENT DRAWN BY THE COIL IN AMPERES		
	Closing Coil	Trip Coil – 1	Trip Coil – 2
R ph			
Y ph			
B ph			

(i) Healthiness of Operation Counter

R phase

OK / Not OK

REMEDIAL ACTION TAKEN

Y phase

OK / Not OK

REMEDIAL ACTION TAKEN

B phase

OK / Not OK

REMEDIAL ACTION TAKEN

(j) Control Cabinet Maintenance

- Checking of tightness of all terminations in MB
- Checking of Door gaskets and replacement there of, if necessary
- General cleaning of MB and Repainting of Metallic Surfaces, if required
- Check functioning of space heater / illumination

(D) 2 – YEARLY MAINTENANCE RECORD

Measurement of Static Contact Resistance:

Max Contact Resistance Acceptable For all breaks: 150 Micro Ohms

CB POLES	CONTACT RESISTANCE IN MICRO OHMS			
	Interrupter 1 (CT SIDE)	Interrupter 2	Interrupter 3	Interrupter 4
R phase				
Y phase				
B phase				

(E) 3 – YEARLY MAINTENANCE RECORD

- (i) Dynamic Contact resistance and contact travel measurement

CB POLES	Break	Contact wipe	Arcing Contact Length	Observation & remarks
R phase	Break 1			
	Break 2			
Y phase	Break 1			
	Break 2			
B phase	Break 1			
	Break 2			

Dynamic contact resistance signature for CO operation for all the breakers of CB to be recorded and compared with the earlier signatures. Minimum CO time should be 300 ms.

- (ii) Measurement of dew point in SF6 Gas (For SF6 CB) DATE

CB POLE	DEW POINT MEASUREMENT			
	PRE-COMG		ACTUAL	
	DEG C	PRESSURE	DEG C	PRESSURE
R phase				
Y phase				
B phase				

(F) 4 YEARLY MAINTENANCE RECORD

(a) Capacitance & Tan δ Measurement of Grading capacitor

LC.No

Date

Make & Sl.No. of kit

Ambient Temp. Deg C

Description	INTERRUPTER 1			INTERRUPTER 2		
	R – PH	Y – PH	B – PH	R – PH	Y – PH	B – PH
Capacitance						
Pre-comm value						
Measured value						
Tan δ						
Pre-comm value						
Measured value						

Note: Normally capacitance and Tan δ measurement is to be carried out in UST mode but if interference is more then, same may be done in GSTg mode with one side grading capacitor grounded and other side connected to guard.

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In addition to the above, the following checks also may be conducted periodically.

(a) SF6 circuit breakers

1	Checking of oil leaks from grading capacitors	M
2	SF6 gas leakage test	SOS
3	Dew point measurement of SF6 gas	3Y
4	Checking tightness of foundation bolts	Y

(b) Air blast circuit breakers

1	Checking of oil leak from grading capacitors	M
2	Checking of air compressor for oil level, oil quality, air filter, V-belt tension	QY
3	Checking of air pressure drop during duty cycle operation	Y
4	Dew point measurement of operating air at the outlet of air dryer	Y
5	Checking of tightness of foundation bolts	Y
6	Air (pressure) leakage check	SOS
7	Overhauling of compressors	SOS

(c) Minimum oil circuit breakers

1	Checking of oil leak from grading capacitors	M
2	Checking for oil leakage/oil level and N2 pressure (if applicable)	M
3	Testing of oil for BDV	After 15 fault trips or yearly
4	Maintenance of breather and change of silica gel	SOS

(d) Vacuum circuit breakers

1	Cleaning of control cubicle and checking for loose connections	QY
2	Checking of ON/OFF indicator, spring charge indicator and checking manual and electrical operation	HY
3	Checking vacuum of interrupter by application of high voltage by disengaging with operating mechanism	Y
4	Checking erosion of contacts by erosion mark on operating rod or measurement of gap specified in closed position of contacts(whenever provided)	Y
5	Checking tightness of foundation bolts	Y
6	Replacement of vacuum interrupter	SOS

(e) Hydraulic operating mechanism

1	Checking of oil level oil leaks and replenishment/topping up, if necessary	M
2	Checking of oil pressure drop during duty cycle operation check	Y
3	Checking of auto starting/stopping of oil pump, pressure switch setting etc.	Y
4	Checking of healthiness of accumulator by checking the pre-charging pressure when building up pressure from zero	Y
5	Checking of operation of safety valve	Y

(f) Pneumatic operating mechanism

1	Checking of air compressor for oil level, oil quality, air filter, V-belt tension	QY
2	Maintenance of air dryer, where provided	HY
3	Functional checking of auto starting of air compressor and dryers	Y
4	Checking of air pressure drop during duty cycle operation	Y
5	Overhauling of compressors	SOS

(g) Spring operated mechanism

1	Oil leakages from close and open dashpots, replace if leaking	Y
2	Greasing/lubrication of gears and various latches in the operating mechanism	Y
3	Checking of play of gaps in catch gears	Y
4	Maintenance of spring charging motors, cleaning of carbon brushes and contactors	Y
5	Replacement of oil in dashpot	SOS

3. CURRENT TRANSFORMERS

Date of Commissioning..... Make..... Rating/Type.....
Sl.No..... Bay Loc.....
Date of test Phase:

(a) Monthly Maintenance – without shutdown

Visual inspection of CT for oil leakage and cracks in insulators
Checking of bellow for expansion
Marshalling / Secondary Terminal Box
Check for any oil leakage from Secondary Terminal Box
Checking of healthiness of gaskets

(b) YEARLY MAINTENANCE RECORD

Date of test

(i) MARSHALLING BOX

- Cleaning of MB
- Checking the tightness of all electrical connections including earthing of MB
- Cleaning and tightness of CT secondary terminals and checking healthiness of sec terminal bushing
- Checking of Space Heater & Illumination

(ii) Thermo vision scanning of CT & Top dome

Kit used: Load:

	Ambient Temp	Scanned Temp. R Phase	Scanned Temp. Y Phase	Scanned Temp. B Phase	Remarks
CT Tank					
Top Dome					

(iii) Capacitance & Tan δ Measurement Date Make of the kit

Sl.No.	Phase	Capacitance		Tan δ		Remarks
		Pre-Commg Values	Measured Value	Pre-Commg Values	Measured Value	
	R $\emptyset$					Measurement to be taken after cleaning the porcelain surface
	Y $\emptyset$					
	B $\emptyset$					

Permissible Tan δ at 20 Deg C = 0.007 Max Rate of rise of Tan δ per year = 0.001 Max
Rate of rise of Capacitance value per year = +/- 1% Max.

(iv) Nitrogen Pressure Checking

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The following checks also should be conducted

i	Checking of primary connection strips, if provided externally	Y
ii	IR measurement(Dielectric Absorption Ratio)	Y
iii	Measurement of secondary resistance	SOS
iv	Magnetization characteristics	SOS
v	CT ratio test	SOS
vi	DGA and testing other parameters of oil	SOS
vii	Checking of secondary winding burden	SOS

4. POTENTIAL TRANSFORMERS/CAPACITANCE VOLTAGE TRANSFORMERS/COUPLING CAPACITORS

Date of Commissioning.....

Make..... Rating/Type..... Sl.No..... Bay Loc..... Date of test

A. Monthly Maintenance – without shutdown

(i) Checking of Oil Leaks

B. Quarterly Maintenance

Date of test

Measurement of voltage at switchyard MB (in volts)

CORE No.	CONNECTION	VALUE IN VOLTS		
CORE-1	PHASE-N	R PHASE	R PHASE	R PHASE
CORE-2	PHASE-N			
CORE-3	PHASE-N			

Note: Maintenance Record is similar to Inductive Voltage Transformer (PTs) Items to the extent applicable may be recorded.

C. YEARLY MAINTENANCE

- i) Visual checking of Earthing of HF Point – (IN CASE IT IS NOT USED FOR PLCC)
- ii) Checking of any breakage or cracks in HF bushing.
- iii) Cleaning of CVT Capacitor Stacks and tightness of terminal connections

iv) **Thermo vision scanning of Capacitor Stacks**

Camera used **Ambient Temperature**

	R-Phase	Y-Phase	B-Phase	Remarks
Top Stack				
Middle Stack				
Bottom Stack				
EMU Tank				

v) **Checking of Neutral Earthing in CVT MB and Tightness of All connections**

vi) **Cleaning of Marshaling Box & Junction Box**

vii) **Checking of Space heater & illumination**

viii) **Checking healthiness of all gaskets**

D. 3 Yearly Maintenance – S/D Activity

LC.No..... Date

Capacitance & Tan δ Measurement of CVT (All stacks Measured Together between HV and HF point) If discrepancy is found in the reading then measurement of each stack should be done, while measuring the capacitance of middle stack, short Top stack

Across Stack	Pre commissioning						Measured Values					
	Capacitance			Tan δ			Capacitance			Tan δ		
Top	R Ph	Y Ph	B Ph	R Ph	Y Ph	B Ph	R Ph	Y Ph	B Ph	R Ph	Y Ph	B Ph
Middle												
Bottom												
Total												

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The following checks also may be done

1	Testing of EMU tank oil for BDV(if oil found discoloured)	SOS
2	Checking for rust and painting	SOS

5. DISCONNECTORS AND EARTH SWITCHES

Date of Commissioning Make
 Rating/Type Sl.No. Bay Loc

 (A) Yearly Maintenance – S/D Activity LC.No..... Date.....

CONDITION REMARKS

(i) OPERATING MECHANISM

Maintenance of Linkages including transmission gears

–

- ▮ Maintenance of Stopper bolts –
- Cleaning of Aux. switch contacts & Greasing with Silicon Grease –
- ▮ Checking of Electrical/Mechanical Interlock with E/S & CB –
- Lubrication of operating Mechanism hinges, Lock Joints on Levers, Bearings. –
- Checking & Tightening of all the mounting bolts –

(ii) MAIN CONTACTS

Cleaning and Lubrication of Main Contacts

- ▮ Alignment
- Tightening of Bolts & Nuts, Pins Etc.
- ▮ Cleaning of Support Insulators and Check for cracks in insulators, if any
- Checking of interlocks

(iii) MARSHALLING BOXES OF ISOLATORS AND EARTH SWITCHES

Checking of space heater & illumination

- ▮ Checking of healthiness of Rubber Gaskets
- Visual Check of auxiliary contacts
- ▮ Cleaning and tightness of all terminations

(iv) EARTH SWITCH

Checking and Alignment of Earthing Blades

- ▮ Cleaning of Contacts
- Operation of Earth Switch
- ▮ Checking of Aluminum/Copper flexible conductor
- Checking of earth connections of structure & MOM box

(B) 4 Yearly Maintenance – S/D Activity

LC.No.

Date

	Measured Contact Resistance (in Micro ohms)			Pre Commissioning Values (in Micro ohms)		
	R Ø	Y Ø	B Ø	R Ø	Y Ø	B Ø
Disconnecter						
Earth Switch						

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Signature of ADE/DE (O&M)

6. SURGE ARRESTERS

Date of Commissioning

Make

Rating/Type

Sl.No.

Bay Loc

(A) Yearly Maintenance

(a) Checking of Leakage by Current Analyzer (mA) after cleaning the porcelain surface

PHASE	TOTAL CURRENT	3 RD HARMONIC RESISTIVE CURRENT (13 R) in μ A	REMARKS
R			13R=500 μ A Max. for Gapless Type 13R=1000 μ A Max. for Gapped Type Arresters
Y			
B			

(b) Testing by surge Monitor kit – Counter and meter tests

(c) Cleaning of LA insulators

Signature of AE/ADE (O&M)

Signature of ADE/DE (O&M)

Note: Measurement of capacitance and $\tan\delta$ and IR of each stack may be done depending on the requirement (SOS)

7. BUS-BAR JUMPERS, CONNECTORS, CLAMPS, SWITCHYARD ILLUMINATION, ETC.

Yearly Maintenance of Bus Bar & Bus Post Insulators

Sl. No.	Activity	Scheduled/ actual date	Measured value	Remarks
1.	Measurement of station earth resistance			
2.	Thermo Vision scanning of all Conductor Joints and Terminal Connectors/Clamps			* See table below
3.	Cleaning of Insulators and checking for cracks		Done/ not done	

THERMOVISION SCANNING OF SWITCHYARD – MAINTENANCE RECORD

Name of Substation:

Name of Bay

Date of measurement:

Ambient Temperature

Sl. No.	Point of Measurement	R Phase	Y Phase	B Phase	Remarks
(I)	Main Bay EQUIPMENTS				
1	Connector/Clamp of Wave Trap				
	a) Towards line side				
	b) Towards bus side				
2	CVT				
	a) Top clamp				
	b) first joint				
	c) Second joint				
	d) Electro Magnetic Unit				
3	Connector/clamp of Shunt reactor bushings, disconnecting switches, disconnecting switch contacts				
4	Connector/Clamp of all disconnecting switches in the bay				
5	Connector/Clamps of CTs, Circuit breakers, in the bay				
(II)	TIE BAY EQUIPMENTS				
1	Connector/clamps of circuit Breaker, CTs, disconnecting switches				
(III)	All jumper/Dropper Joints related to Main bay, Tie bay, Strung bay, Rigid bus (IPS Tube)				

The above format is only indicative. To be modified depending on the equipment located as per the site layout. Points of connection of each equipment to the other equipment/ bus should be listed out and measurement phase wise done and recorded in the table.

Note: Permissible limits for thermo vision scanning:-

- Temp. up to 15 deg c (above ambient) – Normal
- Temp. above 15-50 deg C (above ambient) – Alert
- Temp. above 50 deg C (above ambient) – To be attended immediately

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Signature of ADE/DE (O&M)

The following checks may also be carried out

i)	Removal of hot spots	SOS
ii)	Clearing the switch yard of all weeds, plants and shrubs	SOS
iii)	Repainting, rust removal of all structures, equipments etc.	SOS
iv)	Checking of switch yard lighting	SOS

8. MAINTENANCE RECORD OF WAVE TRAP

Yearly Maintenance

Sl.No.	Activity	Scheduled date	Actual date	Remarks
1.	Tightness and Cleanliness			
2.	General inspection/ Cleaning of Tuning Unit			

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Signature of ADE/DE (O&M)

9. YEARLY MAINTENANCE FORMAT FOR SUB-STATION ILLUMINATION SYSTEM

Date of Maintenance:

Date

LC No:

132kV/220kV/400kV/YARD

Sl. No.	Job Description	Remarks & Observation	Date	Signature
1.	Check healthiness of light fittings in all circuits in the station bldg. PH, and DGS bldg. Repair, replace as required			
2.	Check if all switchyard fittings are in working condition (_____ nos. as per list). Repair, replace as required.			
3.	Check Lighting panel, receptacle panel tightening of terminals.			
4.	Check OUTPUT SUPPLY after fuse in receptacle panel			

Signature of AE/ADE (O&M)

Signature of ADE/DE (O&M)

10. PROTECTION SYSTEMS

1	Testing of Disturbance recorder and event logger with time synchronization unit	M
2	Testing of all protective relays	Y
3	Checking of DC logic circuits for trip and annunciations including timers by simulation	Y
4	Calibration of boundary meters	Y
5	Calibration of all indicating instruments along with the transducers on all control panels	3Y

Annual testing of relays should include the following:

- (a) **Distance protection:** reach check for all 4 zones {Z1, Z2, Z3 and Z4 (reverse)} including time measurement. Checks on power swing block, switch on to fault, fuse failure, polarization and negative phase sequence detector.

The above checks are generic in nature. Manufacturer's maintenance instructions for any particular make of relay shall be referred while testing. Whenever relays are tested on-line,

proper isolation of the relay under test to be ensured. Stand by protection should be healthy and in service before taking any protective relay for on-line testing.

The following common checks for distance and unit protections should also be made.
Trip and annunciation check

Check for carrier send for remote trip, auxiliary relays healthiness, fault locator initiation
Check over voltage relays, LBB backup, and DR/EL initiation
Check for STUB protection
Check for auto reclose function

- (b) **Bus-bar protection:** In addition to checking relay and DC logic circuits yearly, primary injection tests and protection stability and sensitivity checks should be done as and when required (whenever protection AC circuits are disturbed like addition of new bays).
- (c) **Differential relays:** Pick up current, operation of highset element/instantaneous element at the adopted setting. Operation of the relay at the selected restraint bias setting. Operation of 2nd harmonic current restraint feature, alarm and trip contacts. Checks for through current stability on the existing load.
- (d) **Under voltage relay/ Over voltage relay:** Starting and pick up of the relay as per plug setting, Relay operating time as per relay characteristic, operation of alarm and trip contacts, and verification of input voltage on relay terminals.
- (e) **Neutral displacement relay:** In addition to checks indicated in (d) above, verification of continuity of input circuit (for RVT/NCT secondary circuit in case of capacitor banks, under shutdown), Verification of open delta voltage input by by-passing PT secondary supply one phase at a time.
- (f) **Over current and Earth fault relays:** In addition to checks indicated in (d) above, verification of input currents directional feature if applicable.
- (g) **Under frequency relay:** Pick up value of the relay at its settings by slowly decreasing the frequency from 50Hz. Drop off value of the relay at its settings by slowly increasing the frequency from pick up value. Verification of df/dt feature of relay where applicable. Operation of alarm and trip contacts and verification of input voltage on relay terminals.
- (h) **Over fluxing relay:** Operating of over flux alarm as per relay setting by varying the voltage and frequency one at a time. Operating of over flux trip features as applicable for IDMT characteristic, instantaneous element and fixed time setting. Operation of alarm and trip contacts and verification of input voltage on relay terminals.
- (i) **Local breaker back up protection, Restricted earth fault(REF) and other instantaneous current operated relays:** Pick up value of the relay at the selected setting, operating time of the relay, operation of alarm and trip contacts, verification of input currents, checks for through current stability on the existing load in case of REF/ circulating current differential protection.

- (j) **Fuse failure relay:** Main fuse of each phase voltage input to the distance protection scheme to be removed one by one in the relay panel and check for operation of the “VT Fuse Fail Alarm”. Check that the distance protection does not operate.

11. AIR CONDITIONING PLANT

(i) Compressors

1	Checking of belt tension, alignment safety guard	M
2	Leakage checks for refrigerants and oil	M
3	Check oil level, top up if required	M
4	Checking of tightness of flywheel, bolted joints, leakages of oil etc.	QY
5	Checking of oil pressure switch, LP/HP, cut-out switches, solenoid valve, thermostat, Humidistat etc.	Y

(ii) Condenser Unit

1	Checking for water leaks	M
2	Operations of inlet/outlet valve	M
3	Checking of water pressure – inlet/outlet and cleaning of side plates	HY
4	De-scaling of cooling water circuit	SOS

(iii) Water treatment Plant

1	Cleaning of Soft water tank and regeneration of chemicals	M
2	Checking operation of level switch	HY
3	Checking water quality	HY

(iv) Cooling towers

1	Cleaning of sediment	M
2	Cleaning of nozzles for clogging	QY
3	Flow switch performance checking	QY

(v) Electrical motors

1	Lubrication of moving parts	HY
2	Terminal connection checking	HY
3	Overhauling	SOS

(vi) LT Panels

1	Cleaning of bus bars, insulators etc.	Y
2	Tightness of the connections	Y

(vii) Air handling units

1	Cleaning of suction air filters	QY
2	Checking of all interlocks	Y

12. BATTERY&DC DISTRIBUTION SYSTEM

1	Measurement of specific gravity and voltage of cell	M
2	Checking electrolyte level and topping up with DM water, if required	M
3	Checking of Emergency DC lightings to control room	M
4	Checking of any earth fault (If E/F relay not provided)	M
5	Checking of electrical connections of charger panel and DCDB panels for tightness and cleanliness	Y
6	Checking of electrical connections for batteries and application of petroleum jelly on cell terminal, if required	Y
7	Checking control cards of charger and measurement of test point voltage values	Y
8	Battery impedance testing (Optional)	Y
9	Testing of DC E/F and under voltage relays	Y
10	IR measurement of charger transformer ----- MΩ	Y
11	Discharge test of battery set	3Y

1.	Maintenance	a) Keep the battery room well ventilated b) Keep the battery and its surrounding dry & clean c) Check and keep the electrical connections always tight d) Always keep the top surface of the battery clean and dry e) The joints and cell connections shall be kept clean and smeared with Vaseline and petroleum jelly f) Remove traces of corrosion promptly by cleaning with distilled water g) Metal vessels should not be used topping up h) Protective measures (wearing apron & rubber gloves) should be taken when handling concentrated acid electrolyte i) Care must be taken when using metal tools to prevent them from coming into accidental contact with connectors and causing short circuit j) Naked lights, smoking of cigarettes or anything which may create a spark should be avoided in battery room.
2.	Temperature correction	If cell temperature is different from 27°C correction to gravity to be applied is +/-0.0007 for every degree variation above or below 27°C respectively

3.	Topping up	a) Top up often as necessary with distilled water (as per IS: 1069) or de mineralised water to avoid adding a large quantity of water at one time which would cause Result in pronounced drop in the specific gravity b) Top up till the black mark of the float is just visible above the surface of the float guide and the level should never be allowed to go so low that the red mar on the float-steer comes in line with the top surface of the plug. c) It is advisable, if necessary to top up cells during early part of charging or before charges so that the water would link (mix) with the electrolyte during charge
4.	Weak Cells	Cells which do not pick up specific gravity in spite of repeated charging are called "WEAK CELLS" The weak cells must be removed from the battery and charged separately at normal charging rate until gassing point is reached and the reduced to half the normal rate. When the cells appear to be in fully charged condition (i.e.) specific gravity of the acid seems to be stationary the charging should be stopped for an hour and then be resumed at half the normal rate until free gassing again takes place. Again after another one hour stop, charging should be resumed at half the normal rate. These stops of one hour duration alternated by charging should be repeated.
	Caution	While preparing the acid solution (electrolyte) it is very much important to note that always acid is added to the water and not water to the acid.

TROUBLE SHOOTING

Sl. No.	Battery Troubles	Symptoms/Cause	Remedies
1.	Over charging	a) Excessive gassing b) Falling active positive plates c) Buckling of plates d) Increased temperature	a) Reduce the Boost / Float voltage or charging rate reduced to lower value till the specific gravity attains 1.200. b) Add distilled water c) Check the accuracy of voltmeter in the charger if necessary
2.	Under charging	a) Low Specific gravity	a) Increase the float voltage 2.16 to 2.20 volts per cell or increase the charging rate till the specific gravity attains 1.200 b) Check for leakage of electrolyte of current conductors in the charge and battery circuit c) Reversal of cell voltage d) Buckling of plates
3.	Corrosion of plates	Electrolyte impure	a) Remove electrolyte b) Flush with distilled water c) Refill with pure electrolyte

4.	Shedding of active material	a) Over charging of plates b) Charging done at high rate c) Material improperly applied on plates	Charging and discharging limits should be maintained at 2.40 volts and 1.85 volts respectively
5.	a) Loss of voltage b) Battery voltage falling too rapidly on discharge	Excessive sulphation a) Loose connections b) Corroded terminals	Sulphation at initial stage can be cured by low rate of repeated charging and discharging. Contact manufacturer / supplier for special treatment a) Check up connections b) Corroded parts should be cleaned with warm distilled water and coated with Vaseline
6.	Continuous lowering level of electrolyte	a) Leakage of electrolyte b) Loss of water in the electrolyte due to evaporation by too high floating voltage or excessive charging	a) Replace container immediately in case of leakage b) Addition of distilled water to maintain the electrolyte level in the leaking cell will result in diminution of capacity and continuous lowering of specific gravity
7.	Overflowing in cells due to increase in electrolyte level even without the addition of distilled water	Due to damp atmosphere in the battery room causing condensation on the cell covers	Improve ventilation in the Battery Room

Special Note: The following are guidelines for maintaining voltage and specific gravity of the cells at a uniform value:

- a) When the battery is to be stored for long period, before putting into service, necessary care is to be taken for proper storage, other-wise there may be possibility of oxidation which may have adverse impact on the porosity of the plates. The Cells will develop uniform porosity only after repeated charge/discharge cycles and adjustment of specific gravity has to be made thereafter in all the Cells.
- b) Variation in the quantity of Distilled water while topping up or failure to tope up some cells may also contribute to the variations in cell voltage and specific gravity
- c) After installation of the battery, if voltages and specific gravities are not uniform and varying then equalizing charge shall be made by adjustment of electrolyte, ie., in addition or removal of electrolyte and/or addition of Distilled water is made until the specific gravities are uniform. This adjustment may be repeated after some cycles of operation ie., after 30 or 45 days.

Batteries should not be kept under continuous Boost Charge. Batteries shall be on float charge only. After sufficient discharge of the Battery (as indicated by the Voltage and specific gravity of the Cell, Battery shall be kept under Boost charge for the required number of hours only to get the normal voltage and specific gravity.

13. CAPACITORS

1	Checking for leakage of oil	M
2	Check unbalance in capacitors by checking open delta voltage/ by measuring neutral unbalance current	M
3	Physical checks, cleaning of insulators/bushings and tightening of connections	Y
4	IR value, leakage current measurement, capacitance measurement of capacitor cells	Y
5	Checking of protection relays with approved settings	Y
6	Checking tightness of earth connection and foundation bolts	Y

After initial charging the capacitors, the following checks shall be made:

- a) Voltage : Within 110% of rated voltage especially during light load periods
- b) KVAR : Operation KVAR are within 130% of the rated KVAR at the highest system voltage
- c) Temperature rise: Container temperature should not exceed 75 Deg. C. This should be measured by having a thermometer fixed with the wall of the container, keeping the bulbs at one quarter of height of capacitor box down from the top edge.
- d) Fuse: ensure correct type and rating of fuse
- e) Light Load: At light load capacitors cause voltage rise in the system exceeding the permissible value some times. They may have harmful effects on capacitor or on other electrical equipment. Voltage at no time should go beyond the rated voltage by more than 10%.

While removing the faulty/defective capacitor units, the remaining healthy capacitors are connected in such a way that all the phases are balanced with equal number of units and phase capacitance. Operation with unbalance phases may cause over stressing of some of the capacitors causing further damage.

For capacitor banks operated with series reactors, operating the bank with less number of units than originally supplied may cause the capacitor with series reactor tuned to fifth harmonics.

Best way to check the healthiness of a capacitor is to check the capacitance with a capacitance meter, partial or complete failure of a capacitor can be established from this. Shorting of one internal series group on a capacitor results in a predictable increase in the capacitance level. This is the basis for the capacitances of partially failed capacitors.

Defects in capacitors – causes and Remedy

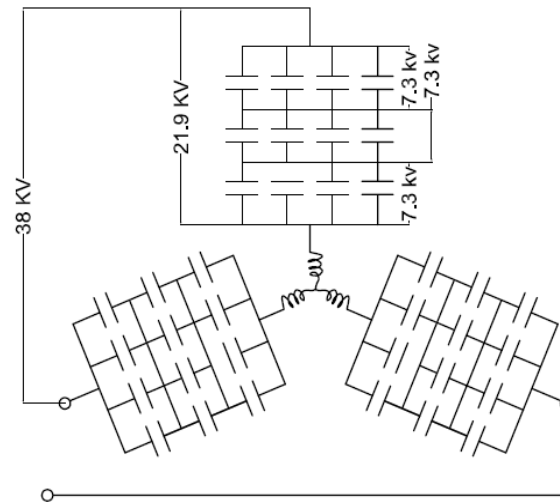
Sl. No.	Symptom	Cause	Remedy
1.	Leakage of impregnant	Leak in welded seam Leak from terminal cap	After cleaning and abrading by emery cloth apply Araldite or solder the spot carefully
2.	Overheating of units	a) Poor ventilation b) Excessive ambient temperature c) Over voltage	Increase spacing for free circulation of air Arrange for forced ventilation. Reduce voltage or switch of capacitors (OR) adjust over voltage relay tripping to achieve below 10% of rated voltage of bank
3.	Current below normal value	a) Low voltage b) Loose connection	Usual Tighten carefully
4.	Noise inside the unit	Internal fault	Disconnect the unit properly balance remaining units. Refer to company. Measure insulation resistance between terminals and case. If the reading is zero the units is shorted and not fit. No repair is possible.
5.	Fuse blowing	a) Short circuit in unit b) Over current due to over voltage and harmonics c) Short external to the unit	Reduce voltage and reduce/eliminate harmonics by adding suitable series reactors after advice by the company.
6.	Abnormal bulging/ bursting	Gas formation due to internal arcing causing unit to bulge or burst	Replace the unit. Refer to the manufacturer
7.	Capacitor Bank tripping on unbalanced protection but expulsion fuse not blown	Co-ordination of expulsion fuse blowing with neutral protection not proper	Check and contact manufacturer's application Engineers.

HV / EHV Capacitor Banks - Maintenance and balancing of capacitors in the event of failure of one or more capacitor units - guideline:

In the 33 kV / 132kV Capacitor banks existing at various substations, the capacitor units are connected in no. of series groups (eg. two or three in a 33kV bank) to maintain uniform voltage distribution depending upon the rated voltage of the capacitor units. Capacitor units are supplied at

rated voltage of 7.3 kV/10.97 kV/21.9kV. Required rating for Capacitor Bank is obtained by connecting capacitor units of smaller rating in parallel (numbering 2 to 9) in each series group.

Configuration of a typical 33kV capacitor bank is shown below.

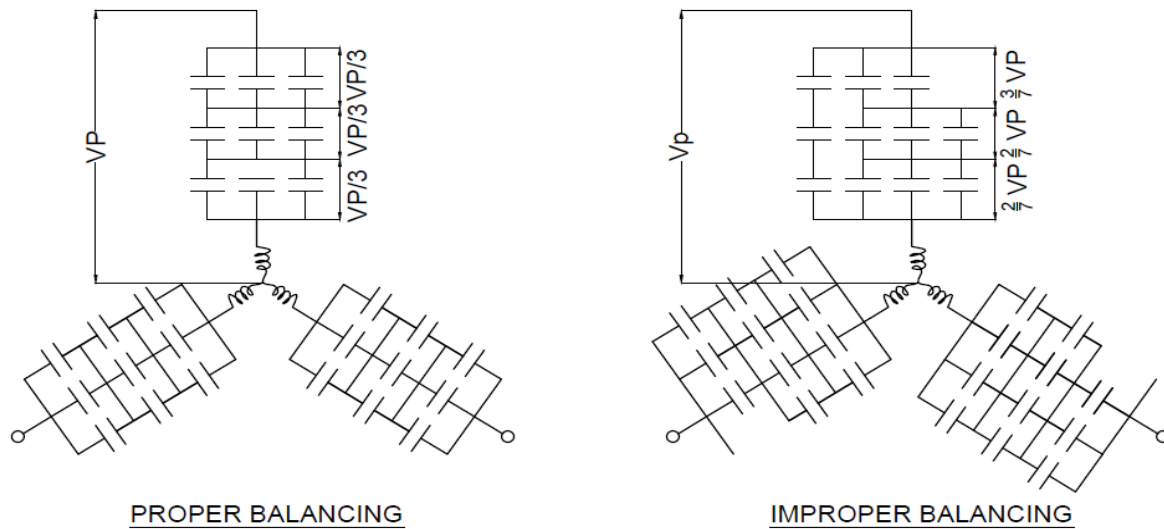


Whether it is single star or double star, the number of series groups per phase depends upon the rated voltage of the capacitor unit viz., 3 series groups if the rated voltage is 7.3 KV, 2 series groups if rated voltage is 10.3 KV and one group if rated voltage is 21.9kV, for 33kV bank.

In the event of failure of one capacitor unit (say in R-phase) it is observed that balancing is done by removing one capacitor each from Y and B-phases as shown in figure below. This arrangement is not correct, since it results in unequal voltage distribution between the capacitors in series groups.

It can be seen from the figure below that against a voltage distribution of $V_p/3$ across each series group, the series group containing less no. of capacitors in parallel gets $3V_p/7$ (i.e.) gets overstressed. Whereas, the other series groups have $2V_p/7$ (i.e.) are under stressed. This results in ultimate failure of the over-stressed capacitors.

Correct method of balancing is, to connect equal number of capacitors of identical rating in each series group in all the three phases on one star bank, to maintain equal voltage distribution across series groups.



The correct arrangement of capacitors in the given example is illustrated under “proper balancing” in the above figure.

14. FIRE PROTECTION SYSTEM

(i) Compressor

1	Cleaning/replacement of air filters	M
2	Checking of compressor oil and replace, if necessary	QY
3	Maintenance and cleaning of Compressor valves, gaskets, valve plates and replace, if necessary	QY
4	Operation check of low oil level switch	QY
5	Cleaning and checking for seating of the breather valve	QY
6	Cleaning of NR V/HP tank	Y
7	General overhaul	SOS

(ii) Fire alarm system

1	Sequence test for annunciation in control room panel	M
2	Smoke test	M
3	Cleaning	M
4	Battery electrolyte level checking	M

(iii) Diesel engine

1	Checking of auto starting of diesel engine	M
2	Check oil level, top up if required	M
3	Checking/replacement of fuel oil/lube oil/air filter	Y

(iv) Jockey pump

1	Check leakage and lubrication	M
2	Pump Overhauling	SOS

(v) V-Belt drive

1	Checking of belt tightness	QY

(vi) Strainers

1	Cleaning of oil strainer	QY

(vii) Motors

1	Checking of terminal connection	HY

(viii) Pumps

1	Checking of operation of Hydrant pumps sump pumps, jockey pumps	M
2	Adjustments of glands for leakages and tightening of nuts and bolts	HY
3	Checking of alignment of pump set	Y
4	Replenishment of grease	SOS
5	Overhauling	SOS

(ix) Hydrant system

1	Checking of pressure of the hydrant system at the remotest end, auto-starting of pumps, diesel engine, etc.	Y

(x) Deluge system

1	Operation of deluge system, check outlet pressure, check alarm, check starting of diesel/electrical pump.	Y

(xi) Electrical Panels

1	Cleaning and tightening of terminals	Y

(xii) General

1	Greasing of all Valves	HY
2	Painting of pipes, air lines, marshaling box	SOS

(xiii) Fire extinguishers

1	Re-filling of fire extinguishers	SOS
2	Check for sand availability in sand buckets	M

15. DIESEL GENERATOR SET

(i) Lubricating System

1	Check for oil leaks	M
2	Replacement of oil filter after recommended running hours	Y/SOS

(ii) Cooling system

1	Check for radiator air blocking and coolant level	M
2	Check for fan hub, drive pulley and water pump	Y

(iii) Air intake system

1	Check for air leaks	M
2	Cleaning of air filters	HY
3	Replacement of Air cleaning element	Y

(iv) Fuel system

1	Check for Governor linkages, fuel transfer pump, fuel line connections	Y
2	Drain Sediments from fuel tank, change fuel filter and clean fuel tank breather	Y

(v) Main generator

1	Check for air inlet restrictions	M
2	Check for electrical connections for tightness	HY
3	Stator winding IR measurement	Y
4	Checking/cleaning of slip ring and its brushes	Y
5	Testing of protection/control relays and alarms	Y

(vi) Exhaust

1	Check for air leaks and exhaust restrictions	Y
2	Tight exhaust manifold and turbo charge cap screw	Y

(vii) General

1	Battery voltage and specific gravity measurement	M
2	Check for performance of DG set by running the set	Weekly

16. LT SWITCHGEAR, LT TRANSFORMER, LT PANEL, ETC.

(i) LT panels

1	Cleaning of panels, bus bar insulators, etc.	Y
2	Relays testing	Y
3	Tightness of all electrical connections	Y
4	Checking of Indicating meters	Y
5	Check for change-over facility, if provided	Y
6	Check operation/indications in Off-load condition of air CB	Y
7	Check spring charging of air CB	Y

(ii) LT switchgears

1	Functional checking (Trip, close, etc.) of 33/11 kV CBs	Y
2	Measurement of operating timings	3Y
3	Cleaning of insulators and tightness of terminal connections of CBs. CTs. PTs, Isolators, etc.	Y
4	Alignment checking of isolators	Y

(iii) LT transformers

1	Testing of oil BDV	Y
2	IR measurement	Y
3	Testing/checking of OTI, WTI and Buchholz (if provided)	Y
4	1 Checking of healthiness of pressure relief diaphragm	Y
5	Checking healthiness of Buchholz relay	Y
6	Checking tightness of earthing connections	Y

17. GAS INSULATED SWITCHGEAR

Yearly visual inspection

Following visual inspection of the energized substation must be performed:

(i)	Activity
(ii)	SF6 pressure with permanent manometer (if applicable)
(iii)	Oil level in tank (Operating mechanism)
(iv)	Hydraulic circuits tightness (Operating mechanism)
(v)	Oil level in damping device (CB with spring operating mechanism and earthing switch with making capacity (if applicable))
(vi)	Heating of cubicles

Five Yearly Examination

Five yearly examination of the GIS is considered as minor examination and shall include but not limited to:

(i)	Activity
(ii)	Checking of pressure with tool
(iii)	Dew point of SF6 gas in CB chamber
(iv)	Density switch operation
(v)	Gas leakages
(vi)	Operating time of main and auxiliary contacts of CB, mechanical operation of dis-connector and earth switch
(vii)	Cleaning of air bushings
(viii)	Checking optical indicators and signaling contacts
(ix)	Labeling of operating mechanisms and gas filling valves
(x)	Checking of alarm functions
(xi)	Checking of operating rods for torques in CB poles, disconnectors, earth switches
(xii)	Maintenance of gas handling device
(xiii)	Check hydraulic oil in drives (if applicable).

*** If the compartment is not provided with an absorber**

Ten yearly maintenance

It is considered as major examination with small outage and shall include but not limited to:

	Activity
(i)	Dew point of gas
(ii)	Replace filters in operating mechanism
(iii)	Replace oil in operating mechanism
(iv)	Lubricate the rams
(v)	Lubrication of dis-connector operating mechanism
(vi)	Lubrication of earth switch operating mechanism
(vii)	CB operating arm linkage torque adjustment
(viii)	Torque adjustments for dis-connector operating rods.
(ix)	Cubicle tightness
(x)	Accoustic partial discharge measurement

Twenty yearly or later

It is considered major examination with prolonged outage and shall include the following but not limited to:

	Activity
(i)	Open CB pole and check
(ii)	Spring and pin replacement
(iii)	Maintenance of rams
(iv)	Open dis-connector pole
(v)	Open E/s pole

Notes:

- Normally depending on specifications all GIS CBs comply with IEC 62271-100 and would have been tested for about 10,000 operating cycles of mechanical duty without significant wear and tear. A random inspection could be done at every 5000 close-open cycles for CBs, 3000 for dis-connector and 1000 nos. for earth switches.
- For electrical wear and tear depending on fault level the manufacturer recommendation should be adhered to.
- On account of high reliability of GIS, PD measurement it is not essentially warranted. In fact acoustic measurement offers better option for existing GIS for monitoring particle content and impurities, in place of PD measurement.

5.4.1 GUIDELINES FOR OPERATING PERSONNEL IN THE EHV SUBSTATIONS

1. Sub-station layout in detail including various equipment, particulars of Power Transformers, Breakers, CTs, PTs, Isolators, LAs, Batteries and Battery Charges, Station Transformers, Fire fighting equipment, Capacitor banks etc., shall be made available in the control room. Also substation operating instructions record shall be made available in the control room for ready reference.
2. Normal in-feed and alternate in feeds – Clear idea of the grid and location of the substation with reference to grid. A grid map showing the in-feeding sources and important load centers connected to the substation to be prepared and displayed.
3. Should be familiar with various equipment available in the substation. Should be thorough about normal operations and emergency operations to be carried out.
4. Battery charger operation - change from Float to Boost and Boost to Float rates changing in each mode.
5. Paralleling and de-paralleling operation of transformers
6. Operating instructions for all contingencies including issue and receipt of line clear should be made available. Shift staff should be conversant with such operations.
7. Lock-out values of gas pressures minimum air pressure where compressors shall start automatically and hydraulic fluid pressure where pump shall start automatically for different makes of Circuit breakers. A chart showing make, type, reference to P.O of power transformers, and breakers and the available and set parameters such as temperature alarms, trips Auto start and stop of cooler fans in respect of power transformers and gas pressures, air/hydraulic pressures, densities in respect of breakers shall be displayed for ready

- reference.
8. CT available and adopted ratios, relay settings meaning of relay indications on all circuit breakers shall be available.
 9. Bucholz and differential relay indications. All annunciations and meaning and consequences of each.
 10. Knowledge of all the relays and their functioning, purpose and shall be able to interpret correctly to decide whether the equipment can be charged again or to be kept isolated for further inspection/check-up by the concerned Maintenance/MRT personnel (especially when lockout relays, pressure relief relays, temperature relays, bucholtz relay sand differential relays operate)
 11. Shift staff should follow the works being done by MRT/Maintenance staff in the sub-station.
 12. While taking over the shift duty, he shall go through the entire log of operations from the time last handed over to charge to know the important events happened, works done, condition of the equipment, line clears pending etc.
 13. While taking over shift duty he has to check condition of communication equipment, lines, battery charger, batteries, feeders and transformers, breakers gas pressures, air pressures, healthy trip circuits, any relay indications not reset etc.
 14. Whenever any feeder/equipment is loaded beyond normal load due to exigencies, such equipment shall be kept under close observation until normalcy is restored, temperature on transformers under such overloading conditions and cooler fans operation shall be constantly monitored.
 15. In case of certain exigencies where operations started in particular shift are likely to be carried out during next shift, the personnel of both the shifts shall be available till the operations are completed and normalcy is restored. Shift duties should not be handed over to successor staff in the middle of an exigency.
 16. ADEs/AEs posted to shift without earlier experience, shall be guided and assisted by senior personnel till such time they get acquainted with the equipment and operations in the substation (say for a fortnight).
 17. Red hot joints at the substation shall not be continued even for brief periods. They shall be attended on priority. Each day during evening peak hours, the yard lighting should be switched off for a while and bad clamps joints should be identified and intimated to maintenance staff. This may be in addition to thermo vision scanning done periodically.

5.4.2 Checks & Observations to be made during shifts:

1. Voltages at all levels shall be observed and to be maintained nearest to the rated values by operation of tap changes of transformers. A little higher voltage is to be maintained (not exceeding 10%) so that tail end voltages are normal. Constant monitoring of capacitor banks shall be done.
2. Healthy trips of all breakers shall be checked every hour. If healthy trip fails, the breaker shall immediately be hand tripped; fault in the healthy trip circuit shall be immediately

- attended and rectified. Only after ensuring DC supply, the breaker shall be closed. Healthy trip indicating lamps shall be in working condition.
3. Battery voltages, DC leakage, Charger condition, switch off AC supply to charger (once in a shift) and observe any fall in DC battery voltage.
 4. Communication equipment such as PLCC, P&T and wireless shall always be in working condition. They are to be treated on par with all other equipment at the Substations.
 5. Check the loading on the transformers and capacitor banks. Load current in all the three phases and in neutral circuit (wherever available) to be checked. Any difference in phase currents shall be brought to the notice of maintenance staff and the concerned transformer or capacitor bank shall be cut off from service for detailed examination.
 6. Note the oil and winding temperature and physically check-up by feeling the temperature of transformers by hand.
 7. Note the tap position of various transformers. The tap position of the transformers in parallel shall be same i.e., the voltage corresponding to the tap shall be same.
 8. Note the oil levels in conservator tanks
 9. Check up for any oil leaks and red hot spots.
 10. Check-up dehydrating breathers of transformers
 11. Ensure that alarms and indications on annunciation panel are working
 12. Check the diesel generator and trial run for 5 minutes daily once in the morning shift and note down the voltage.
 13. Check the condition of Air compressors provided either common or separately for each breaker and drain the moisture accumulated once in a day during morning shift. During Rainy season this should be done once in each shift. Drain sufficient air to ensure auto start of compressors.
 14. Running hours of each station compressors to be noted periodically and they shall be changed 'stand by' to 'running' to 'stand by'. Register of running hours of each station compressor shall be maintained.
 15. Check the entire yard for any unusual sounds, sparks and red hots during evening shift.
 16. Compressed air pipe lines to be checked for any air leakage. The oil levels in air compressors are to be checked
 17. Check oil levels and condition of breather if available for the MOCBs
 18. Check up gas pressures in SF 6 breakers.
 19. Check up for any sparking and flash over marks in the earth pits especially whenever feeders trip on faults.
 20. Watering of earth pits to be done daily.
 21. Ensure proper working of Energy meters on all CBs. If the energy meters are slow or not working, check the potential supply to the meters, fuses etc.
 22. Ensure the tripping of breakers on activation of relays whenever the LCs are issued on breakers.
 23. When LC is issued on Power Transformers, Alarms and Trips are to be invariably checked up with the assistance of MRT/maintenance personnel
 24. Check-up fire fighting equipment once in a week.
 25. OLTC counter reading to be noted.
 26. Ensure that lightning arrestor's leakage current (micro) ammeter reading is in safe zone (Green)
 27. Whenever feeders trip, find out the position of breakers at other end and note down relay

- indications if any at other end.
28. Check-up the marshalling boxes of breakers, CT junction boxes, PT junction boxes etc. and ensure that they are vermin proof.
 29. Check up the batteries, exhaust fans in the battery room for proper operation once in every shift, and report any abnormalities to the maintenance staff immediately.
 30. Ensure that hind doors of al control and relay panels are properly closed and the panels are properly sealed from the bottom and made vermin proof.

5.5 TRANSMISSION LINES

5.5.1 Normal Patrolling

Name of the line

Name&Designation:

Date

Sl. No.	Activity	Loc.No.	Type of tower	Observation	Remarks
1	Missing tower members				
2	Fixing bolts & nuts				
3	Foundation chimneys, copings and surroundings				
4	Insulators(Broken/ chipped)				
5	Clearances to ground& in air				
6	Obstacles (trees, dwellings, crossings, parallel lines etc.)				
7	Bird nests/ any foreign materials on the towers/conductors				

Note: Conductor size, configuration of line may be noted and the condition of conductor, earth wire, clamps and fittings, vibration dampers, spacers, armor grips etc. along the span between two locations may also be noted.

Signature of the patrol man

Signature of AE/ADE

5.5.2 Special Patrolling

Name of the line:

In addition to the activities indicated in normal patrolling, the following shall be carried out

Name and designation

Date

Activity	Loc. No.	Type of tower	Observation	Remarks
Observing Condition of insulators, jumpers, vibration dampers, spacers, clamps and fittings of ground wire and conductor and joints etc. closely with Binoculars				

5.5.3 Thermo vision scanning

Name of the line

Date

Loc. no.	Item	Normal temp. range	Observed temp.	Remarks
	Insulators			
	Line jumpers			
	Clamps & fittings			

5.5.4 Pre-monsoon Inspection:

Pre-monsoon inspection of all transmission lines in the jurisdiction should be conducted once every year, before the onset of monsoon to ensure total healthiness of the line and to prevent any tripping or break down on the line during summer and rainy seasons. Inspection of each location should be thoroughly done and all the defects noticed should be rectified before the summer season starts. A report on the line inspected, defects observed location wise and action proposed for rectification shall be submitted every fortnight by the AE/ADE in charge of maintenance of lines to the DE and SE (TL&SS). DE and SE (TL&SS) should review the report and initiate action for rectification of defects.

A monthly report on the points raised during pre-monsoon inspection, action proposed and action taken should be submitted by the SE (TL&SS) to the zonal CE. The CE should follow up for rectification of all defects and ensure that all defects are rectified without fail and send a report to the CE (Transmission) at headquarters. Regular pursuance both in field and at headquarters is required to ensure proper working of the lines.

5.6 Safety Considerations for O&M of substations and lines:

In order to mitigate the inherent risks associated with Transmission of Power, it is necessary to use protective equipment and follow systematic procedure to protect the equipment and men working on them. Correct use of proper protective equipment ensures protection of equipment. Work procedures, practices, rules should be framed for carrying out works under shutdown/breakdown.

Safety rules should be framed taking into account statutory requirements, in a brief and clearly understandable manner.

5.6.1 Working Procedures: Responsibility of every working personnel should be defined. Primary method of achieving safety is isolation from the system and earthing EHV/HV equipment before commencing the work. All isolation points, vents and earths should be locked. Staff should be trained on safety devices and procedures and in the application of rules.

5.6.2 Safety considerations: Maintenance staff should familiarize themselves with relevant portion of safety document, before taking up the maintenance/ testing work. Team leader (maintenance Engineer) should ensure that maintenance team members adopt general safety. All the members of the working team must ensure that their activities do not affect other work areas. Language used during communication with the workers should be easily understood by them.

5.6.3 Application of Safety rules and procedures:

- Safe distance has to be maintained from live parts in accordance with appropriate safety standards
- After isolation of equipment/line, if any exposed conductors need to be approached, make sure that safe clearance is maintained using approved voltage measuring device or earthing device to avoid coming into close proximity of charged conductors
- Line clear (LC or Permit to work) shall be issued when work or testing on the HV equipments does not require removal of primary earths. When the work requires removal of primary earths, it shall be ensured that the equipment is earthed after isolating it and then only the LC to be issued.
- Persons working on equipment/line should ensure providing earths on both sides at the work area
- When restoration of power is required for work/testing, supplies required must be stated on the requisition form in accordance with the safety instructions
- Personal protective equipment (Safety belt, safety shoes, industrial safety helmets etc.) shall be used by the persons at work without fail to provide additional protection against inherent dangers. Use inspected and tested Protective equipment to ensure desired protection.
- Only skilled and experienced persons with necessary technical knowledge should be allowed to carry out the work.

5.6.4 General Precautions:

- Work on a line/ equipment should be supervised by AE/ ADE
- The circuit/ zone of work should be clearly identified
- Appropriate personal protective equipment shall invariably be used
- A caution board indicating “DO NOT OPERATE – MEN AT WORK” should be displayed on the control panel, which controls the feeder/ equipment, on which work is to be carried out; after isolating the equipment/line and issuing the line clear
- Safe electrical distances should be maintained until conductors are earthed
- Soundness and continuity of earthing device should be examined before use.
- The earthing device should be connected first to an effective earth. The other end of the device should then be connected to the conductors to be earthed.

- Only earthing devices/switches specially meant for the purpose should be used while earthing.
- All earthing and short circuit devices in the working zone should be closed and locked. All the three phases should be earthed. Earthing and short circuiting devices should remain connected for full duration of the work except for the purpose of testing.
- After completing the work, connection to the conductors should be removed first and the connection to earth next.
- If earth gets detached/faulty, another additional earth should be provided before removing faulty earth. Persons attaching the second earth shall maintain safe electrical clearance until it is attached

Electrical Safety Clearance (Live Metal clearance)

Rated Voltage	Safety Clearance (metres)
Up to 33kV	0.8
66kV	1.0
132kV	1.4
220kV	2.4
400kV	3.1
765kV	5.6

Clearances

Voltage level (kV)	Minimum Right of way (Mtrs.)	Minimum ground Minimum Ground clearance (Mtrs.)	Telephone line crossing clearance (Mtrs.)
132	27	6.1	2.745
220	35	7.015	3.05
400	52	8.84	4.88
765	85	15.0	7.5

Electrical clearances for Transmission lines crossing each other

Voltage level in kV	132kV (in mm)	220kV (in mm)	400kV (in mm)	765kV (in mm)
132	3050	4580	5490	7940
220	4580	4580	5490	7940
400	5490	5490	5490	7940
765	7940	7940	7940	7940

Electrical clearance from Railway Tracks electrified on 25kV AC

Voltage level In kV	Inside station limit (mm)	Outside station limit (mm)
132	14000	12000

220	15300	13300
400	16300	14300
765	24700	24700

5.6.5 A Safety manual for O&M of Substations and Lines shall be prepared with the following contents.

- i) Procedure for obtaining permission to work for carrying out O&M of equipment.
- ii) Safety in O&M of various electro-mechanical equipment as per recommendations of manufacturers
- iii) Safety of structures/buildings
- iv) Safety in work shops and garages
- v) Safe handling, collection and disposal of hazardous waste
- vi) Safety in Substations/Switchyard/switch boards
 - Safe working clearance
 - Guarding of live apparatus
 - Operation on live apparatus
 - General provisions relating to maintenance
 - Working in areas containing exposed live HV/EHV conductors
 - Demarcation of work areas
 - Working on remotely controlled and automatically controlled equipment
 - Working on equipment containing or operated by compressed air
 - Working on CBs, Transformers, Isolators, Surge arresters, Instrument transformers,
 - Handling failed SF6 circuit breaker
 - Working on or near to Low, Medium, High and extra high voltage equipment
 - Procedure for adding/removing equipment to/from the HV/EHV system.
- vii) safety measures in overhead lines
- viii) Inspections and maintenance of steel towers and structures
- ix) Norms for patrolling of lines
- x) Classification of terrain of lines viz. Normal terrain/ vulnerable terrain
- xi) Tower top patrolling
- xii) Thermo vision scanning
- xiii) Punctured insulator detection
- xiv) Off-line fault location, signature analysis,
- xv) Maintenance schedule of electric line
- xvi) Safety in washing of live insulators and testing of insulators on live lines
- xvii) Hot line maintenance
- xviii) Safety in working in under ground systems

5.7 INSPECTION OF SUBSTATIONS AND LINES:

5.7.1 Checks and cross checks on the maintenance activities scheduled and carried out and action taken based on the results of maintenance within a given time frame, are essential for proper

upkeep of equipment and lines. Officers at various levels shall be entrusted with the role and responsibility in the maintenance management.

AE/ADE in charge of maintenance of substation/ lines shall be responsible for carrying out maintenance activities and updating the maintenance records. They shall also be responsible for general upkeep of substations/lines they maintain. Maintenance schedules shall be strictly adhered to, as per the periodicity and carried out on the due dates duly planning for shutdowns. Necessary t&p, consumables and spares shall be kept ready and they shall be in working condition. Reasons for deviations or delays if any shall be reported to next higher officers. The ADE and DE should take steps to provide all required tools, plant, and all other facilities to attend to maintenance as scheduled. Reasons for deviations in schedules and delays should be analyzed and steps taken to avoid delays in future.

Annual target for inspection of substations and lines to be conducted by senior officers (DE&SE) will be fixed by the zonal CE as recommended by the Management. Periodical inspection of substations and lines should be conducted by senior officers to ensure that all scheduled maintenance activities are carried out and the equipment and lines are in fit condition. They should also ensure the general upkeep of the installations including auxiliaries and civil structures. Norms in vogue for patrolling of lines and inspection of lines/substations by senior officers are indicated below.

5.7.2 Patrolling of lines: AE in charge of lines shall arrange for 100% normal patrolling of lines (all voltage classes) in his jurisdiction once in a year i.e. at 10% of the lines every month. Special patrolling of lines should be done immediately after tripping of line and send a report to the ADE and DE. Defects noticed should be rectified at the earliest. Pre-monsoon inspection covering all the lines in his area should be done in two/three months time between December to March and defects got rectified well before onset of monsoon.

5.7.3 Inspection of lines and substations:

<u>Cadre</u>	<u>132/220/400kV lines to be inspected</u>	<u>Substations to be inspected</u>
AE/Lines	10% every month	---
ADE/Lines	5% every month	---
DE /TL&SS	30 Km (to cover 6 different lines)	All the SSs in the jurisdiction every Six months (20% monthly)
SE / TL&SS	15 Km (to cover 3 different lines)	All the SSs in the jurisdiction in A year (10% monthly)

Various checks to be made and points to be covered during inspection are indicated in the format given below.

Name of the substation:

Date of inspection:

Due on

Sl. No	Item of inspection	Observation	Action required	
(i)	Check up of maintenance registers for maintenance works due and done			
(ii)	Check the combined earth resistance of station and earth resistance of individual electrodes			
(iii)	Physical condition of earth pits and watering arrangement			
(iv)	Working of battery-check voltage, discharge current after switching off charger. Check for DC earth leakage.			
(v)	Check battery charger and Dc distribution for proper function			
(vi)	Check control & relay panels for tightness of terminal connections, vermin proof arrangements			
(vii)	Working of Boundary meters and sealing arrangements			
(viii)	Working of feeder energy meters and analysis of energy audit			
(ix)	Check up of equipment in switchyard-surroundings, proper working etc.			
(x)	Oil leakage and oil spilling from equipment			
(xi)	Check up cable ducts, cables and cable duct covers			
(xii)	Check up clearances of bus, condition of terminations and connections between equipment – Hot spots			
(xiii)	Growth of weeds, water stagnation in ducts and drain arrangements			
(xiv)	Adequacy of yard lighting, check for proper working of yard lights, DC emergency lights			
(xv)	Check for cleanliness and condition of control room, battery room, roads and drains, security fencing and main gates, other civil structures			
(xvi)	Check for correct working of Compressors, Diesel generators, Fire protection system and other auxiliary devices			

Name of the Line:

Locations inspected

Date

Due on

Sl. No.	Item inspected	Loc. No.	Observation	Action required	
1	Activities covered in normal patrolling				
2	Cross check of specific items(viz. tree growth, clearances, condition of insulators, foundations etc.) reported by patrol men during normal patrolling at the location and action taken on these items				
3	Tower footing resistance at the locations where disc flashover is reported 132 & 220kV lines – DE/SE (TL&SS) 400 kV lines – SE / CE (TL&SS)				

Report on the inspections done during the month by the DE(TL&SS) and the SE(TL&SS) shall be sent to the zonal CE and the CE (Transmission) at headquarters who will prepare a consolidated report and put up for review by the Management. The reports should cover the status of the SS and Line inspected, observations made and action taken for rectification including the action taken on the points raised during the maintenance of the SSs and Lines by the maintenance staff.

5.8 System Availability:

5.8.1 Environment in which the substations and lines operate, system operating conditions (Frequency, voltage, active, reactive loads, temperature) and proper equipment maintenance, have an influence on the system reliability. Prevention/minimizing faults and reducing downtime due to outage of equipment/lines, by timely identification of defects and rectification of the same, help in increasing system availability. Strict adherence to condition monitoring and other maintenance schedules enable achieving this objective.

In the regulated regime of power sector, demand for reliable and quality power assumes significance. As per the provisions in the Electricity act-2003, the State Regulatory Commission set up performance standards for Transmission Utility. Transco should maintain a high standard for supply of reliable and quality power. Power system availability shall be not less than 99%. Transmission losses should be reduced every year by a percentage to be decided by the Regulatory Commission. Also the Commission reviews interruptions on EHV industrial feeders and breakdowns on EHV system components (Power transformers and transmission lines). Fire and accidents, causing damage to equipment/lines and loss of life or otherwise should be reported to Regulator.

5.8.2 In the wake of the norms for standards stipulated by regulations, time based maintenance and modern methods of condition based maintenance of system elements play a vital role in meeting the norms and sustaining the same. The following performance parameters approved by

APTRANSCO shall be monitored monthly at field level by the zonal CEs and to be reviewed by the Management periodically.

- **Interruptions to EHT Industrial Feeders and Railway Traction Feeders:** Feeder wise interruption to EHV industrial and traction feeders during the month should be recorded. Interruptions due to incoming supply failures, tripping of feeder due to momentary faults, faults at the substation, breakdowns, load relief, and due to faults at consumers premises shall be indicated with duration interruption. Reasons for the interruptions should be analyzed and measures to minimize the duration and prevent recurrence of similar faults should be taken. These details should be furnished in the format given below.
- **Line clears availed on EHT Feeders (Industrial & Traction):** All planned maintenance works in a substation or on a line affecting power supply to the industrial and traction consumers should be taken up after informing those consumers in advance and with their consent. Wherever possible alternate supply shall be arranged. The works shall be well planned. All required tools, spares, consumables and manpower should be kept ready to ensure that works are carried out well within the scheduled time to minimize interruption. Where consumer requests for line clear, planning of maintenance works on the connected feeder/ bay may be done to minimize interruption. All the details should be furnished in the formats given below.
- **Breakdowns on EHT Feeders:** Breakdowns on any equipment in the substation/ Transmission line shall be recorded in the substation and a monthly report on the breakdowns circle wise (SETL&SS) shall be sent to zonal CE and CE (Transmission) in the format given below. The report should contain time of occurrence of breakdown, identification of fault by fault locator/ patrolling, time required for rectification of fault and restoration of supply. Alternate supply should be arranged wherever possible and the time taken for extending alternate supply should be indicated. Duration of interruption and the extent of loads interrupted should be recorded. Reasons for the breakdown should be analyzed and steps taken to prevent such occurrences in future.
- **Monthly progress on testing of Capacitance and Tan δ of EHV CTs:** Variation in the trend of capacitance and tan δ of a CT in service reflects the condition of the CT. Higher tan δ value indicates deterioration of dielectric which may result in partial discharge and subsequent failure/explosion of conventional porcelain clad oil filled CT. Monitoring of CTs for capacitance and tan δ once in a year is to be done and values recorded. A programme for monthly testing of CTs in the circle shall be prepared so as to cover entire range of CTs within the jurisdiction of the circle in a year. Wherever the CTs show values above acceptable limits, frequency of testing should be increased i.e. those CTs should be tested for tan δ every fortnight/ month depending on the severity and trend in the variation should be monitored. Needless to mention that the testing should be done duly observing all the precautions and in permissible weather conditions. A report on the trend tests conducted and the values measured shall be sent circle wise by SE (TL&SS). This shall be reviewed by the zonal CE and CE (Transmission) and the course of action recommended based on the trend and put up to Management for taking a decision on continuance/ removal of the CT. The relevant format is given below.

- Monthly Power transformer failure and repair/overhaul status:** Power transformer is a major and costly equipment in a substation. Proper operation and maintenance is necessary to extend a reliable service. Power transformers should be monitored regularly, problems noticed should be attended on priority and rectified to the extent possible at site to minimize down time. Where the problems can be attended only in repair shops, action shall be taken to transport and arrange repairs either by the manufacturer or identified repairer registered with Transco. A report on failure of power transformers capacity wise and substation wise every month by the SE (TL&SS) in the format given below for review by Management to take prompt action. Reasons for failure should be analyzed and corrective steps taken to prevent failure.
- Monthly review of feeders with exceptional losses:** An over loaded transmission line causes increase in line losses. Proper planning and augmentation of transmission network help in meeting the demand without overloading the transmission system. A line is said to be healthy when it is free from loose joints, defective insulators, obstacles such as trees, dwellings in the proximity and having adequate clearance. When power flow on such line is uniform (without many peaks) line losses will be minimum. Targets for reduction in transmission losses are set by Regulator every year. In order to achieve the target, it is necessary to monitor losses in individual elements of transmission network i.e. transmission lines/ transformers. Loading is the main factor that affects the losses considerably. Condition of the line/transformer influences the losses. With a view to check the losses on each line and the transformer a limit on losses allowable on each line, voltage wise has to be set and monitored for variation every month. The limits of losses set in APTRANSCO are for 132kV – 3.5%, 220kV – 2.5% and 400kV – 2%. Digital energy meters of 0.2 class accuracy should be provided on all lines at both ends and on all power transformers. These meters must be suitable for remote communication of the data to the main control centre/ down loading the data with a MRI. The meters shall be time synchronized and should be able to store hourly data for at least 60 days so that data for a specified date and time is down loaded (Ex. 00hrs. on the first day and 24hrs. in the last day of a month) for accurate computation of line losses. A monthly report on the feeders on which losses observed for a month are beyond internal set target, shall be sent by SE(TL&SS) to the zonal CE and CE (Transmission) in the format given below for review by Management. Reasons for high losses should be analyzed and corrective action taken on such exceptional feeders to keep the losses at minimum.
- Transmission System availability for the month:** A high transmission system availability is an indicator of the reliability of the system. Main elements of network that govern the system are transformers, reactors, capacitors and transmission lines. Availability of individual elements in a month and the period of outage of the element during the month is noted down from the substation records. Availability of transmission system for the month is computed using the following formula:

$$(I) \% \text{ system available for the month} = \frac{o.Avo + p.avp + q.Avq + r.Avr}{o+p+q+r}$$

Where o = Total no. of Ac lines

p = Total no. of transformers
 q = Total no. of capacitors
 r = Total no. of reactors
 Avo = Availability factor of AC lines
 Avp = Availability factor of Transformers
 Avq = Availability factor of capacitors
 Avr = Availability factor of Reactors

$$\text{Weightage Factor} \times \frac{(\text{Availability in Hrs} - \text{Non availability in Hrs})}{\text{Availability in Hrs}}$$

$$\text{Availability factor (Avo or Avp or Avq or Avr)} = \frac{\text{Weightage Factor}}{\text{Weightage Factor}}$$

Weightage Factor = Length x Surge impedance loading (for AC lines)

Weightage Factor = Capacity of the equipment (for Transformers, Capacitors, Reactors)

System availability for the previous month and cumulative availability up to the previous month shall be computed. Analysis in the system availability should be made and action taken to minimize the outage time of system elements to improve system availability.

(II) %TAFM for a calendar month = (100 – 100 x NAFM), where TAFM is the total availability factor for the month and NAFM is the non-availability factor in per unit for the month of the transmission system.

$$\text{NAFM} = \left[\sum_{l=1}^L (\text{OHL} \times \text{Ckt kml} \times \text{NSC1}) + \sum_{t=1}^T (\text{OHt} \times \text{MVA}t \times 2.5) + \sum_{r=1}^R (\text{OHR} \times \text{MVAR} \times 4) \right] \div \text{THM} \times \left[\sum_{l=1}^L (\text{Ckt kml} \times \text{NSC1}) + \sum_{t=1}^T (\text{MVA}t \times 2.5) + \sum_{r=1}^R (\text{MVAR}r \times 4) \right]$$

Where

l identifies a transmission line circuit

t identifies a transformer / ICT

r identifies a bus reactor, switchable line reactor or SVC

L = Total number of line circuits

T = total number of transformers and ICTs

R = total number of bus reactors, switchable line reactors and SVCs

OH = Outage hours or hours of non-availability in the month

Ckt km = Length of a transmission line circuit in km

NSC = Number of sub conductors per phase

MVA = MVA rating of transformer / ICT

MVAR = MVAR rating of a bus reactor, switchable line reactor or a SVC

(in case of SVC it would be the sum of inductive and capacitive capabilities)

THM = Total hours in the month

NAFM for each HVDC system shall be calculated separately, as follows :

$$\text{NAFM} = \left[\sum (\text{TCR} \times \text{hours}) \right] \div \left[\text{THM} \times \text{RC} \right]$$

Where TCR = Transmission capability reduction of the system in MW

RC = Rated capacity of the system in MW

Note: For the above purpose, HVDC terminals and directly associated EHV/HVDC lines of a HVDC system shall be taken as one integrated system.

5.8.3 Interruptions on EHT Industrial feeders and Railway Traction feeders

Name of the circle

Month

Sl.No	Substation	Feeder	Date of interruption	Hours of interruption From - To	Duration Hrs/Mts.	Reasons
Incoming supply failure						
Momentary Tripping						
Breakdown						
Fault at Substation end						
Fault at consumer end						
Others (Load Relief etc.)						

5.8.4 Line clears on EHT feeders (Industrial & Traction)

Name of the circle

Month

Sl.No.	Substation	Feeder	Date of interruption	Hours of interruption From - To	Duration Hrs/Mts.	Reasons
Line Clear availed by APTRANSCO						
Line Clear availed by Consumer						

5.8.5 Status of Outages

Name of the circle

Month

Sl no .	Name of the feeder and length	Date and time of tripping	Alternate supply arranged Date & time	Extent of interruption to loads	Patrolling commenced at	Identification of fault by fault locator/ time.	Type of fault	Distance to fault	Men & material moved at

Line clear – Requisition time

Returned time

Duration

Line Charged at –

Reasons for delay in rectification

5.8.6 Current Transformers Tan Delta test results Trend

Month

Sl. No.	Name of the circle	Name of substation	CT location	No. of CTs	Monthly test values of Tan delta Phase Make YOM/YOC 1 st 2 nd 3 rd 4 th								Remarks
					Phase	Make	YOM/YOC	1 st	2 nd	3 rd	4 th		
CTs having tan delta values more than 3 and less than 5													
CTs having tan delta values more than 5 and less than 10													
CTS having tan delta values more than 10													

5.8.7 Status of failure of Power transformers

Month

Sl. No.	Transformer Rating	Failed during the month	Issued for repair/overhaul during the month	Repaired/Overhauled and allotted during the month

Details of failed power transformers during the month

Sl. No.	Details of failed transformer	Name of the substation	Remarks

Details of power transformers allotted for overhaul/repairs

Sl. No.	Details of power transformer	Name of repair agency	Remarks

Repaired/ Overhauled and allotted during the month

Sl. No.	Details of repaired/overhauled transformer	Allotted to	Status of the transformer allotted

5.8.8 Statement of Exceptional feeders voltage wise

Month

Sl. No.	Name of feeder	Length in CKM	Average load in MW	% loss in the month	Remarks

5.9 OVERHAUL OF MAJOR EQUIPMENT- PROCEDURES

Reliability of power supply depends on the proper performance of equipment in the network. The life of the equipment generally depends on:

- The working conditions in which the equipment operate, Stresses sustained depending on the severity of the faults faced , types of loads fed;
- The quality of the materials used in the manufacture, and manufacturer's workmanship;
- Care exercised in the pre-commissioning stage while commissioning the equipment;
- Periodic maintenance.

Failure of equipment some times may cause damage to other nearby equipment in the network.

The manufacturer also prescribes the overhauling of the equipment in the lifetime of the equipment. The overhauling process considerably enhances the life of the equipment.

Overhauling major equipment VIZ. Power transformers, Circuit breakers, Current / potential transformers are covered below.

5.9.1 POWER TRANSFORMER:

The life of the transformer is mainly dependant on the life of both solid and liquid insulation. Hence, it is very important that the insulation is properly maintained.

Condition monitoring indicates any deterioration inside the transformer including the primary insulation. The following condition monitoring test results are to be examined and interpreted carefully, before deciding to open any transformer:

- Dissolved gas analysis history and trend
- Oil quality analysis and trend
- Winding resistance and ratio tests
- Tan delta of winding and bushings
- Frequency response analysis
- Recovery voltage measurement
- Furfural content measurement

If none of the test results indicates any deviation trend, there is no need to open any transformer for internal inspection.

Whenever a transformer is opened moisture may enter the winding from atmosphere in spite of taking all the precautions. Complete removal of moisture at site is a difficult process and incomplete removal may result in faster deterioration of the transformer. A very careful judgment need to be exercised before opening of transformer at site.

Close monitoring of auxiliaries like bushings, tap changers, cooling system, protective devices etc. and timely rectification of any defects may extend life of the transformer. As transformer is a static device, its internal inspection may not yield any useful result if no abnormality is detected. Close monitoring of transformer oil prevents sludge formation inside the transformer. Any violation on the oil parameters such as resistivity, tan delta, inter facial tension, acidity can not be improved by oil filtration. Replacement of oil at the initial time of violation could increase the life of the transformer.

Normally, the manufacturers prescribe overhauling of the transformer at least after 10 years of service. During the overhauling process it is expected that the transformer is completely drained, and the core and coils are lifted for thorough inspection. But this need not be taken as mandatory if no abnormality is noticed during condition monitoring.

Internal inspection/overhauling can be taken up whenever the following abnormal conditions are noticed:

- Continuous and profuse oil leakage through gaskets and not able to arrest by all external means, requiring changing of all gaskets.
 - Increase in fault gases indicating fault inside the transformer
 - Problem in OLTC requiring opening of transformer
 - Changing of oil due to oil degradation
- The overhauling work is normally carried out in the repair shop. Wherever the repair shop is not available, the overhauling may be done at the substation itself by creating required facilities.

The following activities are normally associated with overhauling:

- Internal inspection.
- Flushing the core and windings with hot oil jet and cleaning the tank to remove any sludge, foreign particles, etc.
- Replacement of gaskets of all dismantled parts.
- Flushing the radiators; cleaning the conservator tank, headers, and all connecting pipelines.
- Tightening of all core and yoke clamps, spacers, winding jumpers to tap selectors and bushings, bottom guides and supports
- Overhauling all cooling fans, and oil pumps. Overhauling all valves.
- Attending to minor leakages in the radiators (which could be sealed by cold welding).
- Washing the OLTC with hot oil jet, overhauling the diverter switch, (This includes checking and cleaning all contacts, interchanging the worn out contacts) checking, cleaning the auxiliary contacts, cleaning and greasing of all mechanical parts, and also the gear box mechanism.
- Removal of moisture from windings and solid insulation by alternate vacuum and heat cycles and filtering the oil.
- Finally testing the transformer for $\tan \delta$, capacitance of bushing and winding, FRA, DGA of oil, etc. in addition to other routine tests.

Life Assessment: While carrying out diagnostic tests on equipments it is vital that the parameters are benchmarked/ permissible values noted, and the deviations are noted in order to study the trend in the behavior of the equipment, as these predictions are based on the deviations from the base values.

Restoration: In a transformer, restoration after major overhaul/internal inspection is very important. When oil is removed, the winding paper insulation absorbs moisture from the atmosphere. It is always required to use dry air inside transformer when oil is being removed. This helps in keeping the transformer paper insulation dry. Portable dry air generators are commercially available for this purpose. Dry air is also available in cylinders which could be used if dry air generator is not available.

After completion of work, the transformer is to be kept under vacuum to remove complete moisture with dry nitrogen purging and hot oil circulation. It needs to be ensured that the transformer is dry.

5.9.2 CIRCUIT BREAKER

SF₆ circuit breaker over the period develops problems like gas leakage, air pressure building up, etc. There are different operating mechanisms in SF₆ circuit breakers, such as pneumatic, hydraulic, and mechanical (spring). Manufacturers recommend overhauling of the circuit breakers after a service period of 10 years.

Unlike transformers, circuit breakers have moving components and they require more maintenance and periodic overhaul. The parts which require overhaul in circuit breakers are:

- Operating drive
- Interrupting chambers

Operating drive require maintenance depending on the number of operation or specific time period like greasing and changing of gaskets etc., as per manufacturers instructions and experience of the utility.

In EHV circuit breakers, operating mechanism requires more frequent maintenance than the main interrupting chambers provided the breaker is not subjected to fault trippings more often. Regular maintenance and condition monitoring checks are to be carried out to keep the circuit breakers in healthy condition. It is desirable to get confirmation from condition monitoring checks before opening interrupter assembly.

The overhauling schedule of circuit breakers is as follows:

- (i) Checking the arcing chamber, and overhauling all internal parts of the interrupter.
- (ii) Replacement of 'O' rings and gaskets.
- (iii) Checking the male, female contacts of the interrupter for erosion; checking the travel of the contacts, etc .
- (iv) Checking the working of all internal parts;
- (v) Checking PIR and grading capacitor;
- (vi) Checking the working of operating mechanism;
- (vii) Checking the tripping and closing timings of all interrupters;
- (viii) Measurement IR values of the breaker, both in open and close position;
- (ix) Checking the dynamic and static contact resistance.

The last three measurements are indicative of the working condition of the circuit breaker. Overhauling of interrupting chamber depends on number of operation and the amount of current interruption by the contacts. The decision for opening interrupting chambers is to be taken based on condition monitoring checks especially dynamic contact resistance -measurement (DCRM). Leakage of gas/air, discrepancies in timing, abnormal static contact resistance etc. All the defective components and all gaskets are to be replaced.

Need to take up overhauling, depends on the findings of the tests as above, irrespective of the manufacturer's recommendations. We may keep the operating part in trim condition in case the diagnostic/ indicative testing doesn't ring caution bell. It is, however, felt preferable that one or two interrupters may be opened on sample basis to assess the internal condition and based on the outcome opening of the remaining breakers could be decided.

5.9.3 CURRENT TRANSFORMER AND POTENTIAL TRANSFORMER/CVT:

For monitoring the performance of the CTs it is essential to watch the parameters like

- IR values; Tan δ & Capacitance values;
- Oil level;
- Inspection with thermo-vision camera for hot clamps, if any.
- Physical checking of terminal joints.

There are no specific set guidelines for overhauling / replacement of CTs. The CT/PT being static equipment does not have any mechanical wear and tear. If the parameters as above are regularly monitored the CTs, PTs can give long service.

If the CT shows a higher trend of Tan δ and capacitance values, deterioration of oil quality and oil DGA indicates violation it shall be taken out from service and overhauled/ minor damages if any are attended, before the CT fails. Failure of oil filled/porcelain housed CT normally associates with explosion causing damage to the adjacent equipment.

Overhauling of CT includes opening the CT, checking the windings, core, primary leads and the condenser portion, flushing the same with hot oil jet to remove sludge and foreign impurities. Core and windings and the condenser portion should be placed in a hot air chamber and subjected to alternate vacuum and heat cycles to eliminate moisture from the solid insulation. After ensuring drying out of moisture the components should be reassembled and oil filled and nitrogen sealed. Overhauling activity can be taken up at manufacturer's works or in a transformer repair shop where required facilities are available.

As CTs and PTs/CVTs are sealed units, it is not recommended to open these units at site.

5.9.4 RECOMMENDATIONS:

- (i) The overhauling process being a major activity as regards the life of the equipment in the network, it is very important to codify the process in very clear terms as regards the interval, the process and the expertise required.
- (ii) R&D activities in-house may be set up with the available expertise who can guide the field in interpretation of results of condition monitoring tests and advise on the condition of equipment and need and time for overhaul as overhauling requires considerable time resulting in interruption of supply/ reduced supply affecting the reliability. R&D activity should be well developed to define and adopt suitable maintenance and overhauling practices according to the needs and the environments. It is necessary to create a comprehensive database of the plant and equipment, failure reasons and frequency, remedial actions taken, manufacturing defect observed, etc.

5.10 LIMITS OF TEST VALUES AS PER STANDARDS:

To enhance the life and reliability of substation equipment, maintenance schedule and procedures, as discussed earlier, need to be followed meticulously. Any deviation from the earlier noted results may be looked into thoroughly in subsequent maintenance of sub-station equipment as per recommended maintenance schedule. The limits up to which deviations in the various parameters are not likely to hamper functioning of the main equipment are considered acceptable. Acceptable norms / permissible limits specified in various Standards, which are considered safe for keeping the equipment in service without sacrificing the reliability are furnished in the table.

Sl. No.	Property	New uninhibited	IS/IEC	At the time of first charging	During O&M	IS/IEC
i	Appearance	Clear & transparent, free from suspended matter/ sediments	IS335/1993	Clear, free from sediment and suspended matter	Clear without visible contamination	IS1866/2000
ii	Density@29° C (max)	0.89gm/cm ³	-do-	0.89 gm/cm ³	Not essential	-do-
iii	Kinematic viscosity at 27° C (Max)	27 cSt	-do-	27 cSt	Not essential	-do-
iv	Inter Facial Tension (IFT) at 27°C (Min)	0.04N/m	-do-	0.035N/m	0.015N/m	-do-
v	Flash point (Min)	140° C	-do-	140°C	Max decrease of 15°C from initial value	-do-
vi	Pour point (Max)	- 6°C	-do-	- 6°C	Not essential	-do-
vii	Neutralization value (acidity) (Max)	0.03mg KOH/gm	-do-	0.03mgKOH/gm	0.3mgKOH/gm	-do-
viii	Corrosive sulphur	Non-corrosive	-do-			
ix	Di-electric strength (BDV) New unfiltered After filtration	30kV rms min 60kVrms min	-do-	40kV for <72.5kV 50kV for 72.5 to 170kV 60kV for >170kV	30kV for <72.5kV 40kV for 72.5 to 170kV 50kV for >170kV	-do-
x	Dielectric Dissipation Factor (tanδ) at 90°C (Max)	0.03	-do-	0.015 for <170kV 0.01for 170kV and above	1.0for<170kV 0.2 for above 170kV	-do-

xi	Specific resistance (Resistivity) at 90° C 27° C	35x10 ¹² Ω cm min 1500x10 ¹² Ω cm min	-do-	6x 10 ¹² Ω cm	0.1x10 ¹² Ω cm 1.0x10 ¹² Ω cm	-do-
xii	Oxidation stability Acidity after oxidation (Max) Total sludge after oxidation (Max)	0.4mgKOH/g m 0.1% by Wt.	-do-	0.4mgKOH gm 0.1% by Wt.	Not essential Not essential	-do-
xiii	Aging characteristic after accelerated aging Sp.resistance @27°C DDF@900C Total acidity Total sludge Total Sulphur	2.5x10 ¹² Ω cm Min 1.02 Max 0.05mgKOH/g m Max 0.05% by Wt. Max 0.15% Max	-do-			
xiv	Water content (New unfiltered) (Max)	50ppm	-do-	20ppm for,72.5kV 15ppm for72.5 to 170kV 10ppm for >170kV	No free moisture for<72.5kV 40ppm for 72.5 to 170kV 20ppm for >170kV	-do-
xv	SK value	4 to 8% by mass Max	-do-			
xvi	PCA content (Poly Cyclic Aromatics)	3% by mass Max	-do-			
xvii	PCB content (poly Chlorinated Biphenyl)	Not detectable 0.1mg/Kg max	IEC 60296: 2003			
xviii	2 Furfural (Furan analysis-list method IEC-61198: 1993)	0.1mg/Kg Max	IEC 60296: 2003			
xix	Furfural (aging criteria) for oil immersed	Warning trouble	CIGRE Doc.No2 27- Life manage			

	Trs.		ment Techniq ue for Pr.Trs. Page-107			
xx	Total Furfural content	250 parts per Billion parts (ppb)	Tr.diagn osticUSB R June200 3-page 15			

Note: Oil shall not contain anti-oxidant additives. Value of 0.05% by mass (max) shall be treated as absence of Ditertiary Butyl Paracresol (DBPC)–phenolic type inhibitor

DISSOLVED GAS ANALYSIS

Typical rates of gas increase for Power transformers	Value in milliliters per day	Standard
Hydrogen (H ₂)	<5	IEC:60599- 1999
Methane (CH ₄)	<2	
Ethane (C ₂ H ₆)	<2	
Ethylene (C ₂ H ₄)	<2	
Acetylene (C ₂ H ₂)	<0.1	
Carbon Monoxide (CO)	<50	
Carbon Dioxide (CO ₂)	<200	

Note: Equation to calculate the rate of gas increase as per IEC 60599-1999

Rate = $(Y_2 - Y_1) m / \{ > (d_2 - d_1) \}$ ml/day

Where Y₁ = reference analysis, Y₂ = last analysis, m is the mass of oil, in Kilograms

P = mass density in Kg/m³, d₂= last date for Y₁ and d₁= date for Y₂

(Y₂ – Y₁) is the increase in micro- litres per litre

TRANSFORMER/REACTORS

Tan Delta for Bushing 20°C	0.007 at20°C	IEC-60137
Capacitance for Bushing	- 5 % to + 10 % Variation	
Contact Resistance of Bushing	10 Micro-Ohm /Connector	NGC,UK, Recommendation
Tan Delta for Windings at 20°C	0.007	IEEE/C57. 12.90.1999 9
Tan Delta for Windings at 20°C(Power Factor)	0.005	Transformer Diagnostic USBR, June 2003
Rate of Rise of Tan Delta(Bushing & Winding)	0.001 Per year (Max.)	
Magnetizing current Test (Excitation Current Test)	If the excitation current is less than 50 milli-amperes (mA) the	Transformer Diagnostic

	difference between the two higher currents should be less than 10%. If the excitation current is more than 50mA, the difference should be less than 5%. In general, if there is an internal problem, these differences will be greater.		USBR., June 2003,
Magnetic Balance Test (Three Phase) -	Value of supply voltage (230 V AC) in one phase is equal to sum voltage induced in other two phases. When supply voltage is in middle limb, voltage induced in outer limbs should equal and roughly half of the supply voltage.		
Winding resistance Transformer and Reactor (resistance converted to 75°C)	± 5% difference between phases or from Factory tests		
Voltage Ratio of Transformer (All Taps)	± 0.5% difference from Factory test results		
Transformer Neutral Resistance Value	Below 1 ohm		
IR value of windings (Min)	Rated voltage class of winding	Min desired IR value at 1 minute at 30°C (Mega ohm)	
	11 kV	300	
	33 kV	400	
	66 kV & above	500	
Polarization Index (Ratio of IR values at 600 seconds to 60 seconds)	Polarization Index	Insulation condition	
	Less than 1	Dangerous	
	1.0 – 1.1	Poor	
	1.1 – 1.25	Questionable	
	1.25 – 2.0	Fair	
	2.0 – 4.0	Good	
	Above 4.0	Excellent	
Core Insulation Test (Minimum) (between CL and CC + G with tank ungrounded)	1000 kilo ohms at 2.5/3.5kV DC for 1 minute		
Turret/ Neutral CT ratio errors	+ 3%		IS- 2705
Vibration level for Reactors	200 Microns (peak to peak) 60 Microns (Average)		
Sweep frequency response Analysis Tests	In general, changes of +/- 3 dB (or more) in following frequency		Euro-Doble Client Committee/ Transformer Diagnostic

(20Hz to 2 MHz)	range may indicate following results 5Hz to 2KHz – Shorted turns, open circuit, residual magnetism or core movement 50Hz to 20KHz – Bulk movement of windings relative to each other 500 Hz to 2 MHz – Deformation within a winding 25 Hz to 10 MHz – Problems with winding leads and/ or test lead placement		USBR, June 2003
Moisture measurement of winding (RVM measurement)			IEEE Std. 62 – 1995
Insulation condition	% Moisture by dry weight in paper (Wp)	% Water saturation of oil ()	CIGRE DOC.NO.227 Life Management Technique for Power Transformer – Page 119
Dry (at commissioning)	0.5 to 1.0%	< 5%	
Normal in operation	< 2%		
Wet	2 to 4 %	6-20%	
Extremely wet	> 4.5 %	> 30%	
Degree of Polymerization (DP)	New Insulation	1000 DP to 1400 DP	EPRI's guidelines for the life extension of substations, 2002 Update, chapter 3. Table 7 DP values for Estimating Remaining Paper Life
	60% to 66% life remaining	500 DP	
	30% life remaining	300 DP	
	0 life remaining	200 DP	

CIRCUIT BREAKERS

Dew point of SF6 Gas	Dew Point values as per Annexure-II			
Dew point of operating air	-450 at atmospheric Pressure			
(A) CB Operating Timings	400 KV	400 KV	400 KV	IEC-62271-100 (2001)
(a) Closing time (Max)	150 ms	150 ms	150 ms	
(b) Trip time (Max)	25 ms	35 ms	45 ms	IEC-62271-100 (2001)
(c) Close/Trip time pole discrepancy at rated operating pressure	5.0 ms	5.0 ms	5.0 ms	
- Phase to Phase (Max) close open	3.33 ms	3.33 ms	3.33 ms	

- Break to Break (Max) of same phase.	2.5 ms	2.5 ms	2.5 ms	IEC-62271-100 (2001) With simultaneous close & trip command.
	35 ms	35 ms	35 ms	
	300 ms	300 ms	300 ms	
	± 5 ms	± 5 ms	± 5 ms	
	± 3 ms	± 3 ms	± 3 ms	
(d) Trip delay time for DCRM test (CO operation) –				
(f) Deviation from standard Timings as per GTP of manufactures – close open				

(B) PIR time	<u>400 KV</u>	Manufacturer's Recommendations
BHEL make	12 – 16 ms	
CGL make	8 – 12 ms	
ABB make	8 – 10 ms	
NGEF make	8 – 12 ms	
M&G make	8 – 12 ms	Since temperature correction factor for Tan-Delta depends on make, type and also aging conditions, the correction factors for different types/ makes are different. Hence, no standard temperature error factors can be applied.
TELK make	8 – 12 ms	
Alstom make (HVDC)	8 – 12 ms	
ABB make (HVDC)	8 – 12 ms	
(C) PIR operating time prior to opening of main contacts (ABB, CGL, NGEF make CBs)	5 ms (Min) at rated pressure	
(D) PIR and main contacts overlap time (BHEL, M&G, ABB (imported make CBs)	5 ms (Min) at rated pressure	
(E) Tan delta of grading capacitors	0.007	
(F) Rate of rise in Tan Delta	0.001 per year (max)	
(G) Capacitance of grading capacitors	Within ±5% of the rated value	
(H) Contact Resistance of CB (in Micro-Ohm)	400kV 220kV 132kV 150 100 100	
(I) Contact Resistance of CB terminal connector	10 Micro-Ohm per connector	NGC, UK Recommendations
(J) Evacuation level before SF6 gas filling	5mbar (min)	

	(K) N2 leakage rate from N2 accumulator	3 bar per year (max)	
	(L) IR VALUE		
	Phase – Earth Across open contacts Control Cables	1000 M-Ohm (Min) by 5.0/10.0 kV megger 1000 M-Ohm (Min) by 5.0/10.0 kV megger 50 M-Ohm(Min) by 0.5 kV Megger	
	(M) PRESSURE SWITCH SETTINGS SF ₆ gas pressure switches Operating air pressure switches Operating oil pressure switches	Within ±0.1 Bar of set value Within ±0.1 Bar of set value Within ±1.0 Bar of set value	
	(N) BDV of oil used for MOCB - At the time of filling - During O&M	40kV at 2.5 MM GAP (Min) 20kV at 2.5 MM GAP (Min)	Manufacturers' Recommendations

CURRENT TRANSFORMERS

	(A) IR Value - Primary – Earth - Secondary – Earth -Control Cables	1000 M-OHM (Min) 50 M-OHM (Min) 50 M-OHM (Min)	by 5.0/10.0 kV Megger. by 0.5 kV Megger by 0.5kV Megger
	Tan delta value	0.007	Since temperature correction factor for Tan-Delta depends on make, type and also aging conditions, the correction factors for different types/ makes are different. Hence, no standard temperature error factors can be applied.
	Rate of rise in Tan Delta	0.001 per year (max)	
	(B) Monitoring of Tan delta Upto 0.007(rise @ 0.001) 0.007 to 0.011 0.011	Yearly monitoring Half yearly monitoring Replace the CT	
	Terminal connector contact resistance	10 Micro-Ohm per connector	NGC, UK Recommendations
	CT Ratio errors	± 3% protection cores ± 1% metering cores	IS-2705 -do-

CAPACITIVE VOLTAGE TRANSFORMERS

	(A) Tan delta value	0.007	Since temperature correction factor for Tan-Delta depends on make, type and also aging conditions, the correction factors for different types/ makes are different. Hence, no standard temperature error factors can be applied.
	(B) Rate of rise in Tan Delta	0.001 per year (max)	
	(C) Change in Tan δ from pre commissioning value	Measured value Frequency Up to + 0.002 - Three Yearly +0.002 to +0.003 - Yearly Above +0.003 - alarming	
	(D) Capacitance	Within $\pm 5\%$ of pre commissioning value	
	(E) Contact resistance of terminal connector.	10 Micro-OHM per connector	NGC, UK recommendations
	(F) Change in Capacitance from pre commissioning value	Measured Value Frequency Up to $\pm 2\%$ of - Three yearly $\pm 2\%$ to $\pm 3\%$ - Yearly Above $\pm 6\%$ - alarming (needs replacement)	
	(G) IR value - Primary to earth (Min) - Secondary to earth (Min) - Control cables (Min)	1000 MΩ by 5.0/10.0 kV Megger 50 MΩ by 0.5kV Megger 50 MΩ by 0.5kv Megger	
	(H) Drift in secondary Voltage (to be measured with a 0.2/0.5 class multimeter)	<u>Condition</u> <u>Measurement Frequency</u> Healthy - Six monthly To be monitored - 03 monthly Close monitoring - monthly Close monitoring - 15 days Alarming - replacement Close monitoring - 15 days Alarming - replacement	

	(I) EMU tank oil parameters BDV (Min) Moisture content (Max) Resistivity at 90°C Acidity IFT at 27°C Tan delta at 90°C Flash Point	30kV (2.5 mm gap) 35 PPM 0.1 * 10¹² Ohm-Cm 0.5 mg KOH gm (Max.) 0.018 NM (Min) 1.0 Max 125°C (Min)	IS-1866
	(J) CVT Voltage ratio errors	±5% protection cores ±0.5% metering cores	IEEE/C93.1.1190 IEC 186

DISCONNECTING SWITCHES

	(A) Contact resistance (B) Contact resistance of terminal connector. (C) IR Value - Phase – Earth (Min) - Across Open Contacts (Min) - Control cables (Min)	300 Micro-Ohm (Max) 10 Micro-Ohm per connector 1000 MΩ by 0.5/10.0 kV megger 1000 MΩ by 0.5/10.0 kV megger 50 MΩ by 0.5kV megger	NGC, UK recommendations

SURGE ARESTER

	(A) Third Harmonic Resistive Current (THRC) – for all makes Elpro / Alstom / Oblum / CGL - For new Las - For Las in service	• Upto 30 Micro-Ohm • (upto 150 Micro-Ohm)- Normal • (150 to 350 Micro-Ohm)- to be tested for insulation test & if value found low - to be removed from service • Beyond 350 Micro-Ohm (Gapless type) - to be removed from service • Beyond 500 Micro-Ohm (Gapless type) - to be removed from service	
	(B) IR Value	1000 Mega-Ohm (Min.)	

MISCELLANEOUS

	(A) Station Earth Resistance	1.0 Ohm (Max.)	IEEE/C 37.010.1979
	(B) Thermo vision Scanning - Temp up to 15°C (above ambient) - Temp above 15-50°C (above ambient) - Temp above 50°C (above ambient)	Normal Alert To be immediately attended	
	(C) Terminal connector resistance	10 Micro-Ohm per connector	
	(D) IR values - All Electrical Motors - Control Cables - LT Transformers - LT Switchgears	50 MΩ (Min) by 0.5 kV megger 50 MΩ (Min) by 0.5 kV megger 100 MΩ (Min) by 0.5 kV megger 100 MΩ (Min) by 0.5 kV megger	IS 900

BATTERIES

	(A) Terminal connector resistance	10 Micro-Ohm ±20%	ANSI/IEEE – 450-1987
	(B) Specific Gravity	1200 ± 5gm/litre at 27°C	

DG SET

	(A) Winding IR Value	50 MΩ	
	(B) Stator winding resistance	Within ±10% of the STD value	

5.11 Quality Control Checks on O&M of substations and Lines.

5.11.1 Quality is the total composite product and service characteristic of manufacturing and maintenance through which the product and service in use will meet the expectations of the organization.

Quality has four facets, viz. the quality that results from the best possible product design, quality due to conformance to product design, quality that results from the best construction practices and the quality that results from the best O&M practices.

Responsibility for carrying out operation and maintenance of substations and lines primarily rests with the maintenance units (TL&SS). AE/ADE in charge of substations/lines plan for executing the maintenance works as per the schedule and arrange to keep the materials ready for the works before commencement. They should also plan for required manpower ahead of works so that the

works are executed in time. The DE& SE (TL&SS) will inspect periodically and extend support in arranging all the men and material requirements and ensure compliance with the maintenance schedules and proper upkeep of the installations.

Performance of equipment/lines depends not only on best maintenance carried on them, but on proper operation of these equipment, environment and surroundings in which they work. It is necessary that proper upkeep of the premises such as cleaning and conditioning civil structures, roads, drainage system, security fencing, water supply, electrical distribution systems etc. is carried out in addition to maintenance of equipment, auxiliaries/ lines.

By proper operation it is meant that the equipment /lines are operated with in the specified parameters viz. voltage, current, load and temperatures and all statutory clearances are adhered to. Also all auxiliaries like cooling fans, oil pumps, are in working condition and the controls and protective devices are in trim condition. Standard operating instructions for carrying out day to day operations and the guide lines are made available with the shift staff to follow.

While the regular maintenance works are executed by the maintenance staff and periodically inspected by higher officers in maintenance organization, there is a need to cross check the works done with emphasis on the quality of work carried out and check on the compliance to the instructions by the operating staff and on the general upkeep and amenities provided. This task can be entrusted to an independent quality control team.

Various checks and cross checks to be made by the independent quality control team are as follows:

5.11.2 Maintenance of equipment in substations:

- Check for passage in the switch yard and the condition of the area surrounding the equipment.
- Observe the earthing arrangements made and adequacy of the same as per the standards. Check the condition of earth electrodes/ pits, earth mat and earth resistance values .Check for water supply arrangements to the earth pits. Also check whether earthing of the bodies of the equipment and all metal structures is made from two points to two different earth grid points nearby and tightness of connections. Also check whether connections between neutrals of transformers and LAs ground points are connected to independent earth electrodes.
- Verify the maintenance records for incorporation of all the standard maintenance schedules equipment wise and maintenance plan. Check for the availability of manufacturers' guide lines/ instructions on the equipment.
- Check the maintenance works carried out in the last one year or between the previous and present inspection dates. Attention should be paid to action pending on long pending observations/remarks.
- Check whether tests were done in a conducive weather and all the precautions for accurate testing were followed. Accuracy of test results obtained should be checked and any correction factors for temperature/pressure applied. Check for any deviation from the

standard permissible limits and the trend in the variations from the previous results and interpretation of the results from the trend.

- Battery, charger and DC distribution system performance: Connections between cells, condition of terminals, cell voltage, specific gravity and connections to charger should be checked. Charge and discharge currents, earth leakages etc. to be checked. Working of DC emergency lighting should be checked. Connected maintenance records may be examined to see the tests done and maintenance carried out as per schedules.
- Adequacy of yard lighting and its proper working should be observed.
- Working of all auxiliaries such as cooler fans, oil pumps, OLTC, oil & winding temperature indicators for transformers, air compressors etc. should be checked. Working of all pressure switches, monitors should be ensured.
- Availability of fire protective devices and their condition should be checked.
- Check for condition of cables, cable ducts, trenches in the yard and in the control room.

5.11.3 Operation of substation

- Ensure availability of document containing operating instructions for switching in/out of various equipment and lines, issuing of line clears, breakdown operations, communication with load dispatch etc. and that operation staff are conversant with operating instructions.
- Check that the load on feeders, transformers, voltages at different buses and temperatures on transformers are within permissible limits.

5.11.4 Miscellaneous checks

- Observe the condition of flooring, roof, walls, doors and windows, Ac system, C&R and other panels in the control room; ventilation and exhaust arrangements in the battery room and other buildings within the substation.
- Observe the condition of roads, drainage, culverts, security fence etc.
- Check the availability of required tools, spares and consumables for work at site or at any central place and their condition.
- Check for availability of personal protective equipment such as rubber gloves, shoes, safety belts etc. and earthing devices and their condition.
- Test equipment available may be inspected to ascertain their condition and their suitability.

5.11.5 Maintenance on Lines

- Check for approach to the location, area surrounding the tower base
- Check for condition of foundations, copings, chimneys, area around foundations for back fill etc.
- Check for missing members and the physical condition of the members, cohesiveness between adjacent members.
- Check for the correct earthing of tower at the location
- Check for the condition of conductors and earth wire/wires and clearances to ground and between phases and circuits

- Check for the availability and position of arcing horns, vibration dampers, spacers, clamps and connectors, armored grips etc. and their condition and dislocation of these if any.
- Check for the position and condition of the insulators and need to replace or rectify the same.
- Check for any obstacles viz. tree branches, dwellings etc. in the corridor causing unwarranted tripping of the line.

Checks listed above are indicative. Any additional checks to suit the site condition may be done and recorded.

5.12 Quality Control Checks on Meters and Metering System:

5.12.1 Electronic Energy meters are available at all EHV substations for recording energy transmitted and received at the substation feeder wise.

Electronic energy meters of 0.2 class accuracy shall be provided at all interface points between Generation – Transmission and Transmission – Distribution at the boundaries of generators and transmission substations and EHT consumers.

Since bulk energy is handled by TRANSCO, exact amount of total energy received from all generators including central generating stations, and neighbouring utilities, energy delivered to distribution companies, EHT consumers, Open Access consumers and energy transmitted on various transmission elements is to be accurately measured for computing the total energy input to Transco, energy delivered to discoms (output from Transco) and losses in transmission network. For this purpose very accurate electronic meters of 0.2 class accuracy with facility for storing all load survey data and compatible to both two part as well as ABT tariff are installed in Transco. Associated metering equipment viz. CTs and VTs of 0.2 class accuracy are installed.

The entire metering system needs to be regularly monitored to prevent any loss of revenue and to analyze transmission losses. Analysis of transmission losses helps in taking corrective steps in reduction of losses and improving the efficiency.

MRT unit under SE (TL&SS) will be normally testing the meters and the metering system periodically (once a year). Since the metering system at boundary points located at generating stations and at transmission substations have commercial implication, there should be proper sealing arrangement for meters and metering system to prevent any meddling by unauthorized persons. Authorized TL&SS staff should have access to downloading the data from meters. Meters should also be equipped with facility for remote communication of data to the controlling station for online analysis. Tamper proof arrangements should be available in the meters. All accessible points for data transfer (serial ports, modems remote communication ports etc) should have provision for sealing by authorized persons.

While regular testing and periodical checks and additional checks on specific complaints are made by MRT staff and readings are downloaded by authorized maintenance staff, random check on the entire metering system and the condition may be necessary to ensure regular attention to the metering system to prevent any leakages. This counter check may be carried out by a neutral

agency such as quality control unit. In APTRANSCO this activity is undertaken by MRT unit under the control of Joint Managing Director (Vigilance and Security).

5.12.2 Various checks and cross checks to be made by the independent team are as follows.

- Check for accuracy class of meters, metering CTs and VTs installed at the interconnecting points with reference to PPA/ metering code
- Check for foolproof arrangement of the metering cubicle.
- Check for proper earthing of system and safety earthing of meter body and metal bodies and structures of metering equipment. Also check that the star point of CT secondary winding is connected to ground at only one point preferably inside the metering cubicle.
- Check that no wires are seen from outside the test terminal block (TTB)
- Check for the due date of test of the meters as per periodicity and the date on which it was done and conformity of test results to standards.
- Cross check the working of meters and errors with actual generation / load with a ESS meter at site
- Check contracted maximum demand of EHT consumer
- The multiplication factors of the boundary meters will be verified with the data from field and data from EBC.
- During the general inspections of generators/ EHT consumers and also in the vendor registration inspections, the multiplication factors adopted will be checked and verified by calculating MF based on the ratio of CTs & PTs and ratio adopted in the energy meters.
- Analyze the energy losses on the feeders connected to the generating station/ EHV station under inspection, by comparing the meter readings of these feeders at the other ends

In addition to the above the following points may also be verified while inspecting the generator premises:

- Capacities of the generators, turbines and boilers etc.
- Auxiliary loads of the plant.
- Inter connected equipment.
- Type of fuel used for generation with reference to the sanction/agreement conditions.
- Inter connections with neighbouring premises/any processing plants.
- Fuel metering point, if any.
- Metering arrangement for measurement of energy for In-house consumption in case of Captive Power Plants.

After physical inspection, reports will be generated with reference to agreement conditions, energy transactions and other commercial aspects and the remarks will be communicated to the concerned after approval by JMD(V&S).

5.12.3 Random check of energy transactions of open access users:

- Collecting the details of Open Access Users and actual/Implemented schedules from Load Dispatch.
- Collecting MRI data of Open Access Users from EBC.
- Collecting JMRs from field.
- Estimation of UI Energies and comparing with EBC calculations.

5.12.4 Joint Inspection of Generator for processing Vendor Registration:

Vendor registration is made mandatory for all the Intra-state Generators who want to sell power to APPCC for short time. During the vendor registration process a joint inspection will be carried out with MRT Vigilance, IPC and concerned TL&SS unit. The following points will be observed during joint inspection.

- Availability of ABT compatible energy meters for metering.
- Exclusive metering system (CTs & PTs) for metering.
- Accuracy class of meter and CT&PTs shall be 0.2.
- Metering point is located at the Transco/Discom SS.
- Whether the generator is using the right fuel as per sanction.
- Capacities of generators, turbines, boilers and transformers which are connected to grid will be taken as indicated on the name plate.
- Total generation capacity, auxiliary consumption and ex-bus capacity will be verified.
- Fuel supply agreements will be verified.
- Test reports of the energy meters tested at the standard NABL accredited laboratory
- Test reports of CTs & PTs should be verified.

5.12.5 Booking of cases for tampering meters with assistance of Anti Power Theft Squad

(APTS):

MRT vigilance may be authorized to book cases on the generators/EHT consumers with the assistance of APTS in case any fraud like tampering the meters, deviation of agreement conditions etc is detected.

5.12.6 Witnessing Synchronization & COD of intrastate generators:

- Witness of the synchronization of the new intrastate generators will be carried out by the MRT vigilance and the aspects like capacity of the generators, turbines & boilers will be verified.
- The protection scheme settings will be verified as per the settings communicated by APTRANSCO.
- For declaration of the commercial operation date for the new generators who are entering into long term agreements with APPCC, Performance Acceptance Test will be conducted as per the standard practices. In the PAT, the generator has to prove the full capacity as per

the agreement conditions. This test will be witnessed by the MRT vigilance. This unit will ensure application of correction curves if any as per the EPC contract, for calculating full capacity of the generator.

- Reliability tests regarding capacity of the IPPs if any also will be witnessed as and when required as per the agreement conditions.

The MRT vigilance wing will obtain from EBC, MRI data for actual energy recorded in meters, schedules from Grid Operation, agreements from IPC / commercial wings and bills raised / claimed from Dy.CCA(PPS) etc.apart from the field information and review the proper working of all boundary meters, feeder energy meters, grid connectivity and regulations related to CPPs,IPP, Inter/Intra state OA transactions and UI transactions.

Observations made in respect of various checks and reviews by the quality control team should be recorded and referred to the concerned functional heads and compared with the maintenance reports maintained by the maintenance staff. If the observations are already reported by the maintenance staff, action taken in attending and rectifying the defects should be recorded.

Observations requiring attention should be divided into three categories:

- i) Most critical – warranting immediate action and rectification without time delay
- ii) Less critical – Action required within a specified time
- iii) Increase frequency of maintenance and monitor the trend

Item (i) should be reported immediately to the DE&SE (TL&SS), Zonal CE and the CE (Transmission). All efforts shall be made to attend to the defect promptly and compliance reported by the zonal CE and CE (Transmission) to the Board.

Item (ii) - plan of action should be prepared by the maintenance staff in consultation with the DE/SE (TL&SS) and rectification of defects done within the prescribed time

In respect of item (iii) since the defect observed is minor, the condition should be monitored more frequently and the trend observed and analyzed. When in dispute, analysis of the interpretation of results may be referred to a committee comprising of persons with expertise and experience on the subject.

A review on all the observations made by the quality control staff may be conducted at higher level (By the CMD) on a regular basis (once in three months), wherein actions proposed and action taken in a given time frame may be reviewed so as to ensure efficient working of the system.

Timely action on the defects identified, help in improving the performance of the equipment and in extending the life of the equipment.

5.13 Renovation and Modernization of Transmission System

Every equipment/Line has a useful life period. Depending on the environment in which they operate and the operating conditions and proper maintenance carried out they perform well during their life period and even beyond life period.

Insulation deterioration in electrical equipment takes place due to aging despite regular operation and maintenance. Degree of deterioration varies depending on the operation and maintenance levels. Operational efficiency and reliability get affected with deterioration.

To limit the interruptions, to improve the availability and to improve efficiency, it is necessary that the equipment / lines which have served their life period and which are nearing completion of their life period are identified and listed in the order of seniority and replaced.

Advancement in technology brought a revolution in the design and development of equipment giving more reliable, fast acting, more efficient, fail proof and compact equipment.

It is imperative that replacement of old and obsolete and outlived equipment is done with equipment with present day technology.

Also modernization of important and more significant stations, which are sufficiently old and which have old equipment, results in improvement in efficiency and reliability of the system. Such stations and lines also should be identified and replaced with modern equipment.

A list of equipment and lines substation wise where old, obsolete and outlived equipment and equipment whose life period is approaching should be prepared. Replacements/ modernization or renovation of such equipment shall be made seniority or priority wise and necessary estimates under the head “Renovation and Modernization” (R&M) prepared.

As it may not be possible to revamp all the old and obsolete system in one stroke, due to high costs involved and budget constraints, a plan for R&M shall be prepared on a five year basis and equipment/line proposed for replacement prioritized.

Budget allocation under R&M should be made every year and lists of outlived and obsolete equipment/lines updated after deleting the equipment/lines replaced. This way transmission system’s reliability can be improved. This task can be taken up by CE (Transmission) and reviewed from time to time by the Board.

5.14 Scrap Management & Disposal Procedure

5.14.1 Electrical equipment, working under normal operating conditions and with proper maintenance carried out periodically, perform satisfactorily through the entire life period. However they are susceptible to damages due to prolonged/continuous operation under stressed system conditions (such as sustained over loads, over fluxing due to over voltage and/ or under frequency) sustained faults, fires, bad maintenance etc. Damages could be minor or medium in nature depending on the intensity of faults, which can be repaired at site / at repair shop and the

equipment, can be put back into service. Major damage can leave the equipment beyond economical repairs and render the equipment unserviceable and reduces it to scrap. Economics of repairs should be worked out taking into consideration the type and number of components that have failed, remaining life of the failed equipment, cost of repairs considering the present market value of the equipment and expected life period after repairs.

Also such of those obsolete and outlived equipment not meeting the desired level of operation and not able to match with the present day power system requirements (viz. increased fault levels, reduced impedances, insulation levels etc.) which have been removed from service consequent to replacement under renovation and modernization schemes, become unserviceable and hence can be treated as scrap.

Scrap materials, if left to be accumulated in a substation, will be a potential fire hazard. Further they occupy considerable space hindering free movement for day to day works apart from presenting an untidy appearance. In addition, the condition of retrievable material in the scrapped equipment deteriorates with time and reduces its value. Therefore every effort shall be made by all concerned in the field for disposing of scrap materials at the earliest.

5.14.2 Immediately on failure of any equipment, the AE/ADE (maintenance) should take steps in getting it repaired. Where the damage is beyond economical repair, the equipment should be treated as scrap. Steps should be initiated for disposal of scrap. Survey report on proposed scrap equipment should be prepared giving full details about the equipment as given below.

- Date of first commissioning the equipment and date of commissioning at the present station where it failed and no. of years in service
- Details of equipment
- History of the performance of the equipment from first date of commissioning viz. results of maintenance, no. of failures previously and details of repairs done earlier,
- Total no. of years in service (can be checked from the name plate details)
- Reasons for present failure leading to damage beyond repairs along with log of events prior to, during and immediately after the failure
- Analysis of failure by the reporting officer
- Book value of the equipment or present market value
- Present condition of the damaged equipment and remnant (scrap) value of the materials like steel, copper, aluminium, brass, oil, at the present market rates.

Divisional Engineer concerned shall examine the survey report and send the same with his remarks to the Superintending Engineer concerned and the Chief Engineer of the zone. Proposals for survey report of failed equipment beyond repairs shall be sent by the DE (TL&SS) within one month.

All equipment other than power transformers and circuit breakers of 132kV and above (where the present market value of the damaged equipment is Rupees 5lakhs and below), shall be inspected by a committee consisting of SE, Senior Accounts officer of the zone and CEzone. Proposals for writing off of the scrap equipment will be put up by the concerned DE (TL&SS) to CE zone. The CE zone will examine the proposals received along with the remarks of SE (TL&SS) and approve for write off of damaged equipment. If the damage in the opinion of the committee is due to

negligence /error in judgment on the part of station staff or due to lapse in maintenance, the committee should bring out in detail all such issues in their report and submit a report to the CE / Transmission. CE/Transmission will examine all such proposals and circulate to Board for further action.

In case of power transformers/breakers of 132kV class and above, where the present market value is above Rupees 5 lakhs, survey report proposals should be sent by zonal Chief Engineer to the Chief Engineer (Transmission) after inspecting the damaged equipment, as mentioned above together with his assessment of circumstances leading to failure and consequential damage of the equipment and action proposed on the staff if any for any lapse. CE (Transmission) shall examine the survey report proposals and arrange for inspection of the damaged equipment by a committee to be proposed by him and approved by the Director concerned. The committee may be constituted with DE (TL&SS) concerned, one member of the rank of SE/DE, from CE (Transmission's office) and one member from Quality assurance wing as per the instructions issued in T.O.O. CE (Transmission) Ms.No. 159 dt.30-07-2010. The committee shall inspect the failed equipment and assess the condition and submit report to the zonal CE and CE (Transmission). CE (Transmission) will examine the proposals and put up for write off of such equipment for approval by the Board. Board's approval shall be communicated to the CE zone for initiating action for disposal of scrap.

5.14.3 Disposal Procedure:

After approval for write off of equipment is issued by CE zone/ APTRANSCO, depending on the value of the equipment as explained above, DE (TL&SS) concerned shall initiate for disposal of scrap. All the scrap items except power transformers shall be devoluted to stores as scrap. The CE zone shall arrange to invite bids for auctioning the scrap either through e-procurement or conventional process depending on the assessed value of scrap materials. Auction may be conducted once in six months or once a year depending on the volume of scrap materials accumulated in stores.

In respect of power transformers, after receipt of assessment of condition of transformer and its scrap value from the team and approval of the same, CE (Transmission) shall arrange auction of the transformer on e-procurement platform.

Auction shall be conducted for lifting of the scrap on as is where is basis. Further with a view to prevent deterioration of condition of scrap material and reduction in scrap value due to long storage, theft or fire; time period for disposal and responsibility for safe custody are fixed in the above T.O.O. as given below:

- Since scrap transformers are disposed off on as is where is basis, the concerned AE and/or ADE (Maintenance) and DE (TL&SS) shall be made responsible for physical custody of the same till disposed.
- DE (TL&SS) and CE (Transmission) shall be responsible for disposal of transformer scrap as early as possible i.e. within nine months from the date of approval of write off. Bids for auction shall be called within six months and finalized within next three months.
- The team constituted as per T.O.O. shall be responsible for assessment/ reassessment of scrap value within one month from the date of approval of write off and submit a report to

CE/Transmission. The assessment report should be followed by video/photos of components/items of power transformers considered for assessment.

5.15 Delegation of Powers to Officers

Field officers are delegated with certain powers for sanction of estimates, purchase of materials works and O&M. Latest delegation of powers communicated by APTRANSCO vide T.O.O. CE (Transmission) Ms.No.229 dt.18-09-2010 are given in the table below.

(All figures in rupees)

Sl. No	Type	CE	SE	DE
1. Purchase Powers (Clause No.10.2 of purchase Manual and description)				
i)	Open competitive bidding	7,00,000	5,00,000	25,000
ii)	Limited competitive bidding	1,00,000	50,000	10,000
iii)	Short notice bidding	50,000	25,000	Nil
iv)	Rate contract	Full powers	2,00,000	Nil
v)	Emergency purchase in open market for non-centralized items	Nil	20,000	10,000
vi)	Purchase on Nomination basis	Nil	Nil	Nil
vii)	Purchase of proprietary spares through single bid	5,00,000	10,000	Nil
2. Powers for award of work contract(Capital& O&M of Electrical and Civil works) (Item No.2: Clause No.10.2 of Purchase Manual)				
i)	Open competitive bidding	20,00,000	8,00,000	1,00,000
ii)	Nomination basis	Nil	Nil	Nil
3. Deposit contribution Works (Item No.4 of Delegation of powers)				
i)	Shifting of line structures, shifting of services etc.	Full powers	5,00,000	50,000
4. Technical Sanctions (Capital expenditure – Electrical&Civil works) (Item No. 16 of delegation of powers)				
i)	Technical sanctions under capital expenditure	Full powers	15,00,000	5,00,000
5. O&M/R&M expenditure (Electrical&Civil works) (item No.20 Of Delegation of powers)				
i)	Technical sanctions under O&M expenditure	Full powers	5,00,000	50,000
6. Electrical works: Non-Residential Buildings: (Item No.18(i) of Delegation of powers)				
i)	Non-residential buildings	Full powers	2,00,000	50,000
7. Repairs to the vehicles (Item No.20(ii) of delegation of powers)				
i)	Lorry	30,000	20,000	8,000 2,000(ADE)
ii)	Jeep	20,000	15,000	6,000 1,000(ADE)
8. Tools and Plant (T&P) (Item No.21(c) of delegation of powers)				
i)	Tools and Plant (T&P) chargeable to capital	2,00,000	25,000	10,000

9. Office furniture (per annum) (Item No.46 of delegation of powers)				
i)	Office furniture (per annum)	1,00,000	Nil	Nil
10. Computer Spares, Repairs (T.O.O.No. 146 dt. 22-10-2007)				
i)	Computer spares, repairs (per annum)	1,00,000	50,000	Nil
11. Printing (T.O.O.No. 146 dt. 22-10-2007)				
i)	Printing (per annum)	5,00,000	Nil	Nil

VOLUME - VI

MANUAL ON COMMERCIAL AND LOAD DESPATCH OPERATIONS

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6.1.1 INTERFACE METERS GENERATION–TRANSMISSION–DISTRIBUTION

6.1.1.1 Introduction:

Pursuant to the power sector reforms and restructuring Act 1999, Andhra Pradesh State Electricity Board (APSEB) was unbundled into separate generation, transmission and four distribution companies.

New responsibilities are added to APTRANSCO as bulk supplier of energy to account for the energy received from Generation and supply the energy to Distribution companies with emphasis on maintaining quality and reliable power supply.

Energy meters were installed at all the interfacing points between generation to transmission and transmission to distribution. As per the regulations, 0.2 class electronic meters were installed on all the generator transformers on the HV side to record the total energy generated. This value, less the energy drawn from the HV bus of the generating station is computed and is the energy delivered into transmission network through evacuation feeders. Similarly electronic meters of 0.2 class accuracy were installed at all the boundary points between transmission and distribution, i.e. on the LV sides of power transformers (132/33, 132/11, 220/33kV). This value, less the energy drawn from the LV bus (33, 11kV) for the EHV station consumption is the energy delivered to distribution companies through 33, 11kV feeders.

To perform the vital function of Bulk Supply Billing based on the transfer of energy at all APTRANSCO/Discom interface points, APTRANSCO established Energy Billing Centre (EBC) at the Corporate Office. There are currently a total of 1316 metering points in the system (As on end of June'10) located at G-T and T-D interface points.

Energy Billing and Load Research Center (EBC) has been established at the APTRANSCO's Corporate Office in Vidyut Soudha at Hyderabad, for development of complete Energy Billing System along with billing software and database.

EBC collects and maintains data on all types of T-D and G-T boundary metering points. To start with (between Dec.2000 to Aug 2001) Energy data from boundary metering points (between APTRANSCO & DISCOMs) was collected manually by respective CEs/SEs/DEs (TL&SS) in the field and collected at the EBC, where compiling and processing of data to produce bills was carried out. Software has been developed to enter and process all the data and to generate bills. This system, written in Developer 2000 with Oracle database, is now fully operational and bills have been generated and served to DISCOMs based on manual readings since April 2001. Initially the existing meters are used which are recording electronically/electro-mechanically data for month end energy bills.

Phase II: Data collection using Common Meter Reading Instrument (CMRI) was developed (Between September 2001- September 2002)

It was envisaged to implement a two-part tariff (Based on Energy and Demand) between transmission and distribution companies.

A CMRI based data collection system is being implemented to capture information and to collect it at Hyderabad.

The Data collection process is very tedious as Meter readers from remote locations are required to download meter data and bring them physically to EBC in Hyderabad. Any error in the download process causes repetition of the whole process. Limitation in storage capacity of meters requires meter reader to complete the process within three days of month end. Receipt of the month end data can be used as postmortem to what happened in the system and there is very limited opportunity for APTRANSCO and DISCOMs to take any corrective actions.

To speed up process of data collection, Regional Data Collection Centers (RDCCs) are made fully operational at five locations in the state viz. Warangal, Nunnna (Vijayawada), Chinakampally (Kadapa), Gazuwaka (Visakhapatnam) and Hyderabad (Vidyut Soudha).

All the RDCCs are connected to EBC in Hyderabad by a VSAT based communication network to upload data and minimize travel requirement by data collection staff. All Regional Data Collection Centers are being operated by APTRANSCO since July 2002.

Phase III: On-line Data Acquisition:

As per APERC directive all the boundary metering activity shall be with 0.2 class accuracy metering equipment and meters. In order to facilitate transmission of data on line APTRANSCO proposed to have on-line remote metering system. The bulk data downloaded through the communication network will be stored in the central server and software will be developed to process this data and generate/authenticate energy bills.

The transmission and distribution companies will share the data from the billing system. All the limitations of Phase-II will be eliminated in this phase. The system so implemented will be providing opportunities to the stakeholders in AP Power sector to realize an efficient and multi buyer-multi seller market and tariff implementation. On-line data acquisition will help APTRANSCO and other stake holders to manage the real-time generation and draws under Availability Based Tariff (ABT) regime more efficiently and accurately. It will enable APTRANSCO and DISCOMS to control their power purchase more effectively.

The system would be providing an opportunity for the transmission company to monitor and maintain quality of supply to its consumers.

6.1.1.2 Commercial activities dealt by EBC

- Collection and Validation of TRANSCO-to-DISCOM and GENCO-to-TRANSCO interface meters MRI data as well as manual monthly energy readings received from the field.
- Feeding manual energy readings received from field into Energy Billing System Database through billing system software and generation of T-D Energy Abstract for certification and onward billing.
- Conversion of all interface meters MRI data in to readable data and uploading to EBC Database.
- Generation of Manual Vs MRI energies comparison reports and its analysis and preparation of data substitution metering points.

- Review on working of meters and MRIs and pursuing with the field for prompt rectification/replacement.
- Calculation of Transmission Losses.
- Preparation of various energy and cost inputs for APBSC (Andhra Pradesh Balancing Settlement Committee) to carryout the Discom-to-Discom energy exchange and Cost adjustment settlements.
- Coordinating APBSC meeting for review and certification of D-D energy and cost settlement reports prepared by EBC.
- Submission of APBSC approved D-D settlements to APPCC for approval
Communication of approved D-D settlement reports to AP DISCOMs.
- Assisting SLDC and AP DISCOMs in Energy settlements of Intra State Open Access users as per Regulation No.2 of 2006.
- Coordinating the meeting for the present OA Users settlements in cooperation with SLDC & AP DISCOMs.

6.1.1.3 Procedure on collection of monthly manual energy meter readings of interface meters from the field:

Locations of boundary meters unit wise as on 30th June 2010 are as follows.

I. GENCO to TRANSCO interface meters:

a) APGENCO	:	90
b) PGCIL/CGS	:	41
c) NTPC	:	04
d) Inter-state	:	07
e) IPPs	:	19
f) CPPs	:	19
g) APGPCL	:	06
h) 132kV EHT PDs	:	13

II. TRANSCO to DISCOMS interface meters:

a) Sub-Station transformer LVs (220/33kV, 132/33kV, 132/66kV 132/11kV)	:	720
b) 220kV EHT Industrial Feeders	:	8
c) 132kV EHT Industrial Feeders	:	120
d) 132kV EHT Traction Feeders	:	62
e) 33kV and 11kV Private Developers	:	147
f) 33kV and 11kV Genco – Discom interface points	:	26
g) 33kV and 11kV Inter – Discom interface points	:	34

DEs in charge of O&M(DE/TL&SS) are authorized to record the energy meter readings manually from the boundary meters on the last day of the calendar and send this data to EBC

for preparation of energy accounting for certification of (i) Transco-to-Discoms energy (ii) APGenco-to-Transco energy.

The sample certifications are enclosed as annexure-1&2.

EBC will enter all the boundary meters readings in to Energy Billing System application for generation of Transco-to-Discoms and Genco-to-Transco energy certification reports for energy audit and billing purposes.

6.1.1.4 Procedure on collection and validation of Interface meters data recorded through MRI from the field

All the designated MRI readers (not below the rank of ADE/AE) will collect the boundary meters data for the previous calendar month, between 1st to 3rd of the current calendar month through CMRI. The data so collected should be submitted to EBC/RDCC before 3rd and in case of any missing data the same should be recollected and submitted to EBC in full-fledged manner along with control sheets, containing the status of MRI data collection, CT, PT values, MFs and also the interruption period details.

After receipt of the MRI data of all boundary meters from the meter readers, EBC will validate the data duly verifying the load survey graph available for entire calendar month before rescheduling the CMRI. During the validation of MRI data, if any discontinuity of load survey graph is observed, changes in MFs and augmentation of transformers etc. will be record by staff with reasons in the control sheets.

6.1.1.5 Procedure on conversion of MRI data into readable data and uploading to EBC database

Presently there are different make static interface meters in use in APTRANSCO viz., Secure, L&T, ABB, L&G & Elster. All these meters are MRI compatible. A common meter reading instrument (CMRI) can download and generally store 30 to 35 days load survey data from different meters. No. of days of data storage capacity depends on the integration period, number of load survey parameters and the memory capacity in the meter.

After successfully downloading the data from the meter, the MRI data is dumped into the PCs, through respective meter manufacturers' base computer software. Basically this MRI data will sit in the default folder in the PC with date and time stamping. This data generally known as raw data contains 6 to 8 files all generated in encrypted mode. After the MRI data is validated, it needs to be converted into readable format for further uploading the data to database and further usage of the data for real time applications.

The conversion of load survey data (MRI data) into readable format is different for different makes of meters. The MRI data should be segregated make wise and then converted into readable format using the set procedure for each make of meters.

6.1.1.6 Procedure on comparison of Manual and MRI collected meter readings on report generation

Once the conversion process is over, the data will be uploaded to EBS database through loading software. MRI data uploading process and the process of feeding boundary meters monthly manual readings into EBS application should be completed simultaneously.

Then Genco-to-Transco and Transco-to-Discoms manual Vs MRI energies report will be generated from the EBS application software.

The Manual energy is compared with MRI energy arrived from load survey data. If any differences are noticed beyond the tolerance of $\pm 3\%$, the MRI data of the respective metering point shall be checked again. An analysis on correctness of manual data/ MRI data should be made. If MRI data is incorrect, then manual data will be substituted in place of MRI data wherever it is applicable.

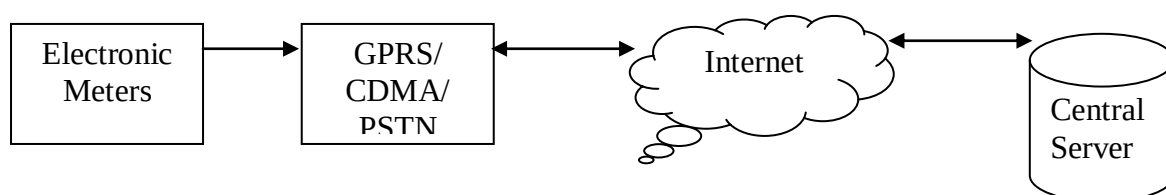
The EBC staff will prepare the DSM metering points and the list will be communicated to the concerned SEs/DEs (TL&SS) for taking necessary action to avoid repetition of the same in future.

6.1.2 Automatic Meter Reading:

Automatic meter reading involves the following;

- Meters with remote communicating facility to enable reading of metering data on line should be installed for various power developers, Open access Consumers, Traders etc geographically located across the Andhra Pradesh state.
- Similar meters installed at all boundary points between Generation - Transmission – Distribution facilitate energy billing and monitoring load survey data on line.
- There will be main and check meters at each location and data is required from both the meters.
- Meters of different makes/types having all the features required for automatic meter reading can be permitted to be connected.
- The data will be transmitted from each metering point to Data Center located at headquarters office (Vidyuth Soudha), Hyderabad by GPRS or combination of GPRS and PSTN.

The general Architecture of AMR system:



6.1.2.1 Main functions of the system include:

- i) Daily automatically scheduled collection of interval data from all the connected electronic meters.
- ii) The AMR module will transmit the raw metered data only to central database.
- iii) Storage and management of all meter base data, and meter reading data in a Central data base. Read meter data shall be converted to common format i.e. XML, which is made available to the billing software to the utility to generate bills. Further, the same data is also taken to other data analysis software.

6.1.2.2 The usage of AMR data for various applications as follows:

- i) The instantaneous meter readings collected at preset date and time shall be used for generation of bills and the bills will be paid to the Generators accordingly
- ii) The load survey data collected 15/30 minutes interval shall be used for calculating generators bills, transmission losses, inter discoms energy exchanges and their cost adjustments, Inter/Intra State Open Access users energy/cost settlements and can also be used for energy audit activity of APTRANSCO.
- iii) The load survey data received at Central Sever system can further be used for Analyzing availability of generators and scheduling preparation
- iv) Further the AMR load survey data is also useful in analyzing discoms drawl Positions with reference to, their load forecasts which help in checking the over drawls during low frequency periods and take steps to reduce the drawls to avoid/minimize the penal UI charges.
- v) Study of tamper events and further analysis.
- vi) The AMR data can be used for generation of various MIS reports as and when required by the management.

6.1.3 COMPUTATION OF TRANSMISSION LOSSES

Prior to 2005 transmission losses were calculated on manual basis. Accuracy of computation depended on accuracy in noting the meter readings at a fixed time at all points simultaneously. To overcome this problem and to improve the accuracy in computation, a methodology was developed for calculation of transmission losses based on the MRI data collected from all the boundary meters.

The transmission losses calculation methodology as approved by APTRANSCO is as follows:

The ‘Direct Method’ based on actual energy meter readings shall be adopted to calculate energy losses in transmission system.

$$\text{Total \% energy loss} = (E_I - E_O) \times 100 / E_I$$

(E_I) = Total Energy Input to the Transmission System at 400kV, 220kV, 132kV for the calendar month

Energy Output that is Energy delivered to the Discoms at EHT Sub-stations **(E_O)** = Total Energy Output from the Transmission System at 400kV, 220kV, 132kV, 33kV & 11kV for the calendar month.

$$E_I = \{E_{\text{APGENCO (I)}} + E_{\text{IPPs (I)}} + E_{\text{CPPs (I)}} + E_{\text{APGPCL (I)}} + E_{\text{CGS/NTPC(I)}} + E_{\text{EHT PDs (I)}} + E_{\text{LVs (I)}}\}$$

Where,

$E_{\text{APGENCO (I)}}$ = Gross energy import to APTransco system from Thermal and Hydel station of APGENCO at 400kV, 220kV, 132kV interface points excluding direct energy sale to Discoms at GENCO-Discom interface points

$E_{\text{IPPs (I)}}$ = Gross energy import to APTransco system from various Independent Power Producers (GVK, Spectrum, LANCO, BSES, LVS, Srivathsa, etc.,)

$E_{\text{CPPs (I)}}$ = Gross energy import to APTransco system from Captive Power Plants at 220kV & 132kV, which have agreement to sell power directly to APTransco (VSP and Others)

$E_{\text{APGPCL (I)}}$ = Gross energy import to APTransco system from APGPCL including wheeled energy

$E_{\text{CGS/NTPC (I)}}$ = Gross energy import to APTransco system from Central Generating Stations (CGS) at various PGCIL interface points including NTPC-Simhadri Super Thermal Power Station {Ramagundam, Ghanapur, Mamidipally, Tallapally (N’sagar), Chinakampally (Cuddapah), Gooty, Khammam, Nunna (Vijayawada), Gazuwaka (Vizag) and Kalapaka (Vizag)}

$E_{\text{EHT PDs (I)}}$ = Gross energy import to APTransco system from Conventional and Non-conventional Private Developers at 132kV

{Conventional: GBR Power, Sriba, RCL, NEGCL

Non-conventional: Ganapathi Sugars, Varalaxmi Sugars (GMR Technologies) and Kakatiya Cements & Sugars}

$E_{\text{LVs (I)}}$ = Gross energy import to APTransco system from 33kV or 11kV Bus to 132kV or 220kV Bus through power transformers, wherever applicable e.g. 220kV Ramagiri SS (energy measured in APTransco sub-station premises) [Mini hydels, wind mills, solar generation .]

$$E_O = \{E_{LVs(E)} + E_{EHT} + E_{EHT\ PDs(E)} + E_{GENCO-SLBPH(I)}\}$$

Where,

$E_{LVs(E)}$ = Gross Energy Supplied to various Discoms from LV side of power transformers (33kV, 11kV) (energy measured in APTransco sub-station premises)

E_{EHT} = Gross Energy Supplied direct to EHT consumers of various Discoms at 220kV and 132kV interface points (energy measured in APTransco sub-station premises)

$E_{EHT\ PDs(E)}$ = Gross energy export from APTransco system to Conventional and Non-conventional Private Developers at 132kV

{Conventional: GBR, Sriba, RCL and NEGCL

Non-conventional: Ganapathi Sugars, Varalaxmi Sugars (GMR Technologies) and Kakatiya Cements & Sugars}

It is unlikely that $E_{EHT\ PDs(E)}$ will need to be considered as the metered injection will be on a net energy basis and will already account for the exported energy

Private developers at 33kV and 11kV have not been considered as “Source of power to APTransco” because they are connected to the Discom network.

$E_{GENCO-SLBPH(I)}$ = Gross energy imported from CGS 400kv network for operation of APGenco Srisailam Left Bank Power house in Pumped mode operation to back lift the water from the storage pond and utilizing same for next day to meet the Peak Load demand.

For all the generators at 132kV and above having wheeling arrangements (third party sale or captive consumption), total energy pumped into the system including wheeled energy has been considered for loss calculation because that energy is being handled by transmission system.

6.1.4 Procedure for Determination of Transmission Charges

6.1.4.1 Introduction: Section 61 of the Electricity Act, 2003, provides that the Appropriate Commission shall, specify the terms and conditions for determination of tariff, while Section 62 of Act empowers the Commission to determine the tariffs, *inter-alia* for transmission of electricity and requires the Licensees to comply with such procedure as may be specified by the Commission for calculating the expected revenue from the tariff and charges which the Licensee is permitted to recover. The Commission formulated a draft Regulation specifying the Terms and Conditions for determination of Transmission Tariff including the procedure for calculating the expected revenue, published the same in A.P.Gazette on 18-10-05 and issued a press release seeking comments/suggestions from all stake holders and the public. The Commission after taking into consideration comments/suggestions received from public and State utility, issued a final Regulation vide APERC Regulation No. 5 of 2005 (**See Annexure-3**).

6.1.4.2 As per the Clause 3 of APERC Regulation 5 of 2005, the extent of application is as follows:

This Regulation shall apply to all transmission Licensees in the State.

1. The Commission shall determine the ARR for the Transmission Business of a Transmission Licensee, in accordance with the principles laid out in this Regulation.

2. The ARR determined in accordance with Regulations above will be the basis for the fixation of the Transmission Tariff/Charges for Electricity.

6.1.4.3 The principles for computation of Aggregate Revenue Requirement are as follows:

The main items of ARR are:-

- a. Operation and maintenance expenses;
- b. Return on capital employed;
- c. Depreciation;
- d. Taxes on Income;
- e. Corrections for “uncontrollable” items and “controllable” items (indexed to external parameters); and
- f. Any other relevant expenditure.

Further details on calculations of above items are envisaged in the **annexure-3** enclosed.

As per the clause 20 of APERC Regulation No. 5 of 2005, the formula for calculation of Transmission tariff payable by the transmission users (i.e. OA users, Discoms and OA Generators etc.) shall be determined in accordance with the following formula:

$$TR = \text{Net ARR} / (12 * TCC)$$

Where,

TR: Transmission Rate in Rs/kW/month

Net ARR: Net ARR, as determined under clause 8.3 of APERC Regulation No. 5 of 2005.

TCC: Total Contracted Capacity in kW of the Transmission system by all Long-Term Users.

Further each Transmission User (including the distribution Licensees) shall have to execute an agreement in terms of the Open Access Regulation duly mentioning, inter-alia, and contracted capacity with the Licensee. Variations in revenue recovery over approved revenue requirement on account of variations in transmission usage will be adjusted in subsequent Control Period with financing cost at average rate of borrowing during the year to which the variations relate.

It is also to be noted that notwithstanding anything contained in this Regulation, the Commission shall adopt the transmission tariff if such tariff for any particular system / network or part thereof has been determined through transparent process of bidding in accordance with the guidelines issued by the Central Government under section 63 of the Act.

Transmission Tariff Schedule, 2009-10 to 2013-14 as per APERC order:

Financial Year	Net ARR, In Rs. Cr.	Generation capacity, in MW	Transmission Tariff	
			Transmission Charges (Rs/kW/Month)	Transmission Loss (kind)
1	2	3	4= (3/2)	5
2009-10	788.13	13744	47.79	4.16%
2010-11	948.50	15542	50.86	4.13%
2011-12	1215.75	15963	6.47	4.10%
2012-13	1405.12	17877	65.50	4.06%
2013-14	1554.16	21222	61.03	4.02%
Note: Figures are rounded.				

Notes on Transmission Tariff:

1. The users of the transmission system shall pay transmission charge and bear the transmission loss in kind.
2. The Transmission charges payable and the energy losses to be borne shall be related to the contracted capacity in kW, at the entry point.
3. The other conditions applicable for levy and collection of these charges shall be as per the provisions of the Andhra Pradesh Electricity Regulatory Commission (Terms and conditions of Open Access to Intra-State Transmission and Distribution networks), Regulation, 2005 (No.2 of 2005) and the Balancing and settlement code, in force.

6.1.4.4 State Load Despatch Center fee & Charges

Introduction:

Sub-section (1) of section 31 of the Electricity Act, 2003, provides that the State Government shall establish a State Load Despatch Center (SLDC). Sub-section (2) of the Section 31 provides that the said SLDC shall be operated by a Government company/authority/corporation constituted by or under any State Act and that until such company/authority/corporation is notified by the State Government, the State Transmission Utility (STU) shall operate the SLDC. The Government of AP notified in GO Ms.No.8 dated 17-01-2004 that the existing SLDC shall continue as SLDC and be operated by the Transmission Corporation of AP Ltd., being the STU, until the State Government establishes a Government company or any authority or corporation. Section 32(3) of the Act provides for levy and collection of such fees and charges from the generating companies and licensees engaged in the intra-state transmission of electricity as may be specified by the State Commission.

Regulation No. 1 of 2006 of APERC provides for Levy and collection of fees and charges by State Load Despatch Centre (enclosed as annexure-3). Effective from 1st April 2007.

This Regulation shall be applicable to all generating companies and licensees engaged in Intra-State transmission of electricity in the State of Andhra Pradesh.

This Regulation does not apply to stand-alone generators, franchises, etc. not connected to the intra-state transmission network.

As per clause 3 of APERC Regulation No.1 of 2006,

1. All generating companies whose generating stations get connected to the intra-state transmission network shall be required to register their generating stations with SLDC on payment of Rs.1000 per generating station (irrespective of the installed capacity) as Registration fee.
2. The existing Generating Companies, Distribution Licensees and Trading Licensees connected to or intending to get connected to the State Grid shall register with SLDC by filing an application along with the above-mentioned fee within a month of coming into force of this Regulation.
3. The SLDC, after scrutinizing the application and after being satisfied of the completeness and correctness of the information furnished in the application, shall register the application in its records duly intimating the applicant about its acceptance and also file a copy thereof with the Commission
4. The SLDC shall file consolidated information about the Generating Companies and Licensees connected to the intra-State transmission network and being monitored/serviced by it, to the Commission every year by November 15th.

As per clause 4 of APERC Regulation No. 1 of 2006, the Annual fee and Operating charges calculation procedures are as follows:

1. Users shall pay to SLDC an annual fee and monthly operation charges leviable on the electricity transmitted, in MWs (mega-watts), subject to the charges for a minimum of one MW
2. Provided that for the purpose of billing and collection the above-mentioned fee and charges, a fraction of a MW shall be treated as one full MW
3. Provided further that the operating charges shall be leviable for a minimum period of one month, a fraction of a month being rounded off to a full month.
4. The annual fee shall be determined by the Commission after taking into account the required capital investment for setting up the Centre. The fee will be revised only on the basis of a filing made to the Commission by SLDC to cover any investments for upgradation and/or modernization of SLDC that may be required.
5. The basis for determination of the annual fee shall be the Capital Cost to cover the repayment of principal and payment of interest on investments in a year, plus any residual capital cost of past investments.

The annual fee shall be calculated as follows:

$$\text{Annual SLDC Fee (Rs/MW/p.a)} = \frac{\text{Capital Cost (CC) (in Rs.)}}{\text{Total Generation Capacity (MW)}}$$

Capital Cost (CC) for a given year shall be computed as follows:

$$CC \text{ (in Rs)} = \text{Investment} \times \frac{r}{1 - \frac{1}{(1+r)^t}}$$

Where,

Investment = Actual investment made in year plus any residual value of previous investment (s).

r = Actual rate of interest on borrowed capital or 150% of the Bank Rate, whichever is the lower.

t = Number of years in which the investment is proposed to be recovered, for software, it would be 5 years and 10 years for other investments.

Operating Charges shall be fixed for a year on the basis of the filing of the SLDC and will cover:

- a) Employee cost;
- b) Administration and general charges;
- c) Repairs and Maintenance expenses; and
- d) Any other relevant costs and expenses deemed appropriate by the Commission.

6.1.4.5 Employee Cost: The employee cost to be considered for the year shall be as per the approved staffing plan or the actual employee cost, whichever is lower. As a first step, SLDC shall file the staffing plan within three months from the date of notification of this Regulation. The Commission will approve the staffing plan after examining the details thereof. The approval shall be for the purpose of cost recovery through operating charges alone and for no other purpose whatsoever.

6.1.4.6 Administration and General Expenses & Repairs & Maintenance Expenses:

These expenses for the first Control Period will be fixed on the basis of the Information filed by SLDC and accepted by the Commission. Thereafter, these, will be fixed as per the norms to be determined by the Commission.

6.1.4.7 Other expenses:

All other expenses, not covered by Capital cost, Employee cost, Administration and General Expenses or Repairs & Maintenance expenses shall be furnished along with the details of such expenses, if any, at the time of filing for the purpose of fixation of charges.

The monthly operating charges per MW shall be computed as per the following formula

$$\text{Operating Charges (Rs/MW/pm)} = \frac{\text{Annual Operating Charges}}{\text{Total Generation Capacity (MW)} \times 12}$$

Variations in recovery of capital cost and operating charges over the fee and charges fixed for a year on account of variations in SLDC usage shall be adjusted in subsequent control period, in case the variations are considered to be significant by the Commission warranting

adjustment thereof before the commencement of the subsequent control period, with financing cost at the average rate(s) of borrowing during the year(s) to which the variations relate.

6.1.5 IMPLEMENTATION OF OPEN ACCESS (OA) AND TRADING

The Electricity Act, 2003 which has come into force from 10th June, 2003 repeals the Indian Electricity Act, 1910; Electricity (Supply) Act 1948; and Electricity Regulatory Commissions Act, 1998. In view of a variety of factors, financial performance of the state Electricity Boards has deteriorated. The cross subsidies have reached unsustainable levels. The Act provides for, amongst others, newer concepts, like Power Trading and Open Access.

Open Access on Transmission and Distribution on payment of charges to the Utility will enable number of players utilizing these capacities and transmit power from generation to the load centre. This will permit utilization of existing infrastructure to ease power shortage. Trading, now a licensed activity and regulated will also help in innovative pricing which will lead to competition resulting in lowering of tariffs.

Definition: Open Access is the non-discriminatory provision for the use of transmission lines or distribution system or associated facilities with such lines or system by any licensee or consumer or a person engaged in generation in accordance with the regulations specified by the Appropriate Commission"

APERC issued Regulation No.2 of 2005, regarding terms and conditions of Open Access to Intra State transmission and Distribution networks with effect from 01-07-2005, covering the following:

- Agreements for long term and short term open access between Transco – Discoms – Open Access Users
- Bulk power transmission Agreement between Transco and Discoms
- Providing special energy meters capable of measuring active energy, reactive energy, average frequency, and demand integration in a 15 minute time blocks, with built-in calendar and clock conforming to relevant standards at all entry and exit points.

APERC issued Regulation No.2 of 2006, regarding Interim Balancing and Settlement Code for open access transactions with effect from 01-12-2006, covering the following:

- Balancing and settlement of energy and demand for OA users,
- Ways and means for implementation of state level ABT and provision of special energy meters compatible to ABT for OA users,
- Scope of work for SLDC, EBC and AP Discoms for finalizing balancing and settlement accounts

ISSUES:

- a) Freedom to buy/sell, and access to market
- b) Adequacy of intervening transmission
- c) Transmission/wheeling charges
- d) Treatment of transmission losses
- e) Energy accounting, scheduling, metering and UI Settlement.

6.1.5.1 Criteria for allowing Open Access

- 1) The long-term open access shall be allowed in accordance with the transmission planning criteria and distribution planning code stipulated in the State Grid Code.
- 2) The short-term open access shall be allowed, if the request can be accommodated, by utilizing
 - a. Inherent design margins
 - b. Margins available due to variation in power flows and
 - c. Margins available due to in-built spare transmission system capacity and distribution system capacity created to cater to future load growth.

6.1.5.2 Types of Open Access: Interstate Open Access; Intrastate Open Access

Inter State Open Access: Regulations 2008 (amended in 2009), and Regulations 2009 provide for Open Access in inter-State Transmission, Grant of Connectivity, Long-term Access and Medium-term Open Access in inter- State Transmission and related matters

Types of Short Term Open Access

- Advance
- First cum First Served
- Day ahead
- Contingency

Nodal agency:

- The nodal agency for bilateral transactions shall be the Regional Load Despatch Centre of the region where point of drawl of electricity is situated.
- In case of the collective transactions, the nodal agency shall be the National Load Despatch Centre

Application Fee:

- There is non-refundable application fee of RS.5000/- for each bilateral or collective transaction.
- The application must be processed within three working days of submission of the application for existing applicants and seven working days for new users.

Transmission Charges:

In case of bilateral transactions, at the point of injection (Rs. /MWh) as on July 2010:

• (a) Intra-regional	-	80
• (b) Between adjacent regions	-	160
• (c) Wheeling through one or more intervening regions	-	240

Operating Charges

- Rs. 2,000/- per day or part of the day for each bilateral transaction for each of the RLDC involved and at the rate of RS.2,000 /- per day or part of the day for each SLDC involved shall be payable by the applicant.
- In case of the collective transaction, operating charges shall be payable by the power exchange @ RS.5000/- per day to the NLDC for each State involved and Rs.2,000 /- per day for the State Load Despatch Centre involved for each point of transaction

Example: Suppose a company from Maharashtra wants to sell 100 MW to Discom-A in Andhra Pradesh.

Following steps need to be taken:

- a) The company and Discom-A to agree on terms and conditions of sale
- b) The company to get the consent of MSEB and "no-objection" of MSERC
- c) Discom-A to get the consent of APTransco and "no-objection" of APSERC.
- d) MSLDC and APSLDC to ascertain transmission adequacy, and agree to arrange necessary metering, scheduling, energy accounting and UI settlement.
- e) WRLDC and SRLDC to ascertain transmission adequacy in their regional transmission systems.
- f) All concerned to have a common understanding about treatment/sharing of transmission losses, and levy of transmission/ wheeling charges for the use of intra-State and inter-State systems

6.1.5.3 INTRA STATE OPEN ACCESS

Intra State Regulations

Regulation NO.2 of 2006 • Interim Balancing and Settlement Code for Open Access Transactions

Regulation NO.2 of 2005 • Interim Balancing and Settlement Code for Open Access Transactions

Procedure for applying for Intra State Open Access

- 1) An application for open access shall be filed to the respective Nodal Agency by the intending open access customer, with a copy marked to the distribution licensee of the area.
- 2) The application shall contain such details as capacity needed, point of injection, point of drawl, voltage level, phase arrangement, duration of availing open access, peak load/time, average load and any other additional information that may be specified by the nodal agency.
- 3) The application shall be accompanied by a non-refundable processing fee of Rs.5,000/- for long-term customers and Rs 1000/- for short-term customers for Intra State.

- 4) The nodal agency, based on the system studies by the concerned licensee or otherwise assess the capacity available and communicate the same to the applicant within the time schedule indicated below.
 - a) Short term open access - Within 7 days from the date of receipt of application
 - b) Long term open access - within 30 days from the date of receipt of application.
- 5) Where the nodal agency is of the opinion that open access cannot be allowed without system strengthening, it shall identify the scope of work for system strengthening and the probable date from which the open access can be allowed and the applicant shall be informed accordingly within 30 days.
- 6) An open access customer shall enter into commercial agreements with transmission and distribution licensees, generators, traders, consumers and others, as applicable to him. Such agreements shall include a clause pertaining to payment security mechanism.
- 7) After agreements have been entered into and copies furnished to the nodal agency, the nodal agency shall inform the open access customer the date from which open access will be available,

6.1.5.4 Granting permission to Intra State short-term open access by SLDC:

- 1) Availability of ABT meters at the Entry Point /Exit point should be ensured.
- 2) The company has to enter into short-term open access agreement with APTRANSCO and Discoms, in the APERC approved format before commencement of open access
- 3) The company has to submit an undertaking on a RS.100/- stamp paper as per "Annexure 1 &2" immediately before commencement of open access.
- 4) The company has to contact FA & CCA (R&A), APTRANSCO, respective CGM/Commercial of Discoms for payment of security deposit amount and opening of LC after receiving the approval from APSLDC respectively.
- 5) Settlement for energy and demand is as per Regulation 2 of 2006 and shall be done by Energy Billing Center/APTRANSCO which will be certified by the ad hoc committee until the committee consisting of representatives of all classes of generators is approved by APERC.
- 6) Wheeling schedule on day ahead basis is to be furnished by the generator at 15 minutes integration at both entry and exit points from the day before commencement of Open access to SLDC and EBC.
- 7) Meter reading need to be recorded at 00:00 hours on the day of commencement of open access by DE/Operation concerned in the presence of open access users.

- 8) The role of DISCOMs in respect to HT billing shall be for both energy and MD drawn from DISCOMs after settlement calculation, to be done as per regulation and DISCOMs tariff orders prevailing.
- 9) The computed consumption shall be taken for substitution in case of partial/non-availability of MRI data as approved by APPCC (flat curve basis).
- 10) Verification by EBC of sample MRI data after rectification of observations made on the meters at both entry and exit point is to be completed.
- 11) During the entire period of OPEN ACCESS utilizing any power from other sources. (Furnish the details of own generation if any and all probable sources of supply)
- 12) The company has to undertake to abide by the decisions of APTRANSCO/AP Discoms in matters arising out of commercial metering issues, UI fluctuations and methodology for settlement including UI etc on the proposed Open Access transactions

6.1.5.5 Extracts from Regulation No.2 of 2005 and Regulation No.2 of 2006 issued by APERC are given below:

Regulation No. 2 of 2005:

Terms and Conditions of Open Access to Intra-State Transmission and Distribution Networks

Introduction:

Subsection (2) of Section 42 of the Electricity Act, 2003, mandates the introduction of open access in such phases and subject to such conditions as may be specified by the State Commission considering the relevant factors including operational constraints. The Commission formulated and finalized Regulation on the terms and conditions for allowing open access for supply of electricity to consumers

Clause 2: Definitions:

- a) “Act” means the Electricity Act, 2003 (36 of 2003);
- b) “Applicant” means a person who makes an application to the Nodal Agency for open access and includes any person engaged in generation, a licensee or any consumer eligible for open access under this Regulation;
- c) “Available capacity” means the capability in megawatts (MW) or kilowatts (kW) of a transmission or distribution network to transfer power from one point to the other, after deducting the power requirements of already committed users;
- d) “Commission” means the Andhra Pradesh Electricity Regulatory Commission;
- e) “Contracted capacity” in the context of open access for supply to consumers means the capacity contracted in megawatts (MW) or kilowatts (kW) for transmission and /or wheeling to a consumer under open access ;

- f) “Open access agreement” means an agreement entered into between a licensee and the applicant to avail open access to the licensee’s network for transmission and / or wheeling of electricity;
- g) “Entry point” means a point at which electricity is injected into the electricity Transmission network or the electricity distribution network;
- g) “Exit point” means a point at which electricity is drawn from the electricity transmission network or the electricity distribution network ;
- h) “Nodal Agency” means the entities referred to in clause 5 of this Regulation;
- i) “User” or “Open access user” means a person using or intending to use the transmission system and / or the distribution system of the licensees in the state for receiving supply of electricity from a person other than the distribution licensee of his area of supply, and the expression includes a generating company and licensee.

Clause 3: Extent of application:

This Regulation shall apply to open access to intra-state transmission and distribution systems of licensees in the State, including when such systems are used in conjunction with inter-state transmission system(s).

Clause 4 : Categorization of open access users

The open access users of the transmission and/or distribution system(s) shall be classified as follows:

- a) **Long-Term Open Access User:** Any user of the transmission and/or distribution system(s) entering into an open access agreement with the concerned licensee(s) for a period of two years or more shall be categorised as a Long-Term Open Access User.
- b) **Short-Term Open Access User:** Any user other than a long term user of the transmission and/or distribution system(s) entering into an open access agreement with the concerned licensee(s) shall be treated as Short-term open access user, but open access shall not be allowed at a time for a period of more than one year.

Clause 5: Nodal Agency

- 5.1 For all long-term open access transactions, the Nodal Agency for receiving and processing applications shall be the State Transmission Utility (STU).
- 5.2 For short-term open access transactions, the Nodal Agency for receiving and processing applications shall be the State Load Dispatch Centre (SLDC). The SLDC shall, however, allow short-term open access transactions only after consulting the concerned transmission and/or distribution licensee(s) whose network(s) would be used for such transactions:

Provided that for short-term transactions with duration of less than one week, the SLDC may not consult the concerned licensees for permitting such transactions. The SLDC and Licensees shall devise procedures for coordination among themselves for allowing such short-term transactions.

Clause 6: Criteria for allowing open access to transmission and/or distribution systems:

- 6.1 The long-term open access shall be allowed in accordance with the transmission planning criterion and distribution planning criterion stipulated in the State Grid Code and/or the Distribution Code and / or Indian Electricity Rules as the case may be.
- 6.2 The short-term open access shall be allowed, if the request can be accommodated by utilizing:
- a) Inherent design margins;
 - b) Margins available due to variations in power flows and unutilised capacity, if any; and
 - c) Margins available due to in-built spare capacity in transmission and/or distribution system(s) created to cater to future load growth

Clause 7: Provision for existing users:

- 7.1 **Existing distribution licensees:** The existing distribution licensee (s) shall be deemed to be the long-term open access user (s) of the Intra-State transmission system (s) and / or the distribution system (s) for the term specified in / under the existing agreement (s) or arrangement (s) and shall make payment of transmission charges, wheeling charges and other charges, as applicable, and as may be determined by the Commission from time to time.

The existing distribution licensee (s) shall, within 60 days of coming into force of this Regulation, furnish details of their use of intra-state transmission system (s) and/or distribution system (s) to the STU, SLDC and the Commission.

- 7.2 **Existing users other than the distribution licensees:** The existing user (s) other than the existing distribution licensees may continue to avail themselves of the wheeling facility as per the existing agreements for the period(s) specified in those agreement(s), to the extent they are not inconsistent with the Act and this Regulation:

Provided that such existing user (s) shall pay the transmission charges, wheeling charges and other charges as may be determined by the Commission from time to time:

Provided also that any additional capacity sought by such existing user (s) in addition to the capacity already contracted, shall be treated as new application for open access to the extent of additional capacity sought.

Clause 8: Phasing of Open Access

- 8.1** Where open access to the Transmission and/or Distribution systems is sought by any user, the Nodal Agency shall permit such open access strictly in accordance with the following phases:

	Eligibility criteria	Commencement date
1.	Consumers availing of power from NCE developers irrespective of the quantum of contracted capacity	September, 2005
2.	Contracted capacity being greater than 5 MW	September, 2005
3.	Contracted capacity being greater than 2 MW	September, 2006
4.	Contracted capacity being greater than 1 MW	April, 2008

Provided that the Commission shall allow open access to consumers with contracted capacity of 1 MW or less in due course at such time and in such phases as it may consider feasible having due regard to operational constraints and other factors:

Provided further that the Commission may revise the above schedule for the subsequent phases of open access, as considered necessary, not being inconsistent with the provisions of the Act:

Provided also that the Commission may exempt any consumer or a class of consumers from this phasing scheme if it considers necessary or expedient in the public interest:

Provided also that only the consumers availing of supply from the existing users covered under clause 7.2 from a date prior to coming into force of this Regulation shall not be affected by the above phasing.

- 8.2** The licensees shall make all reasonable attempts to ensure that operational constraints in the Transmission and / or Distribution systems as the case may be, including metering, communication systems, capacity determination, etc. are removed as per the phasing plan indicated above so that, as far as possible, no eligible consumer is denied open access on the grounds of operational constraints in the system.

Clause 9. Criteria for allotment/reservation of capacity

- 9.1** A distribution licensee, due to its obligation to supply on request under section 43 of the Act, shall have the highest priority in allotment of capacity, long-term as well as short-term.
- 9.2** As regards the other applicants for allotment of capacity of transmission and/or distribution systems, the persons applying for Long-Term open access shall have priority over the persons applying for Short-Term open access. However, within a category, an applicant requesting transmission and/or distribution access for longer duration shall have priority over the person(s) seeking access for shorter duration.

9.3 Allotment of capacity in case of insufficient spare capacity/ congestion

9.3.1 For Long-Term applicants: In the event of insufficient spare capacity in distribution system/congestion in the transmission system hindering accommodation of all long-term open access applications, the Nodal Agency shall inform the applicants of the same and shall advise the concerned Licensee(s) to carry out an assessment of works required to create additional capacity by strengthening of the system to accommodate such applicant(s). After completion of such works, the Nodal Agency shall allot the capacity to such applicant(s). As regards capital expenditure incurred by the licensee(s) for system-strengthening, the licensee(s) can require a capital contribution from the applicant(s) subject to the provisions of clause 17.1 (v) of this Regulation.

9.3.2 For Short-Term applicants: In case of applicants for short-term open access with transactions required to be accommodated through congested corridors of the network, the Nodal Agency shall invite bids by Fax/e-mail with floor price equal to the un-congested price for the short-term users. The bidders shall quote percentage points above the floor price. The allotment of capacity shall be done in decreasing order of the price quoted. In case of quotes involving equal prices, the allotment of capacity shall be done, if required, *pro rata* to the capacity sought. The user getting allotment of capacity less than the capacity sought by him shall pay charges as per the price quoted by him. All other applicants getting capacity allotment equal to the capacity sought by them shall pay charges as per the price quoted by the last applicant getting full allotment of the capacity sought.

Explanation 1: For the purpose of clauses 9.3.1, and 9.3.2, “congestion” in the context of allotment of capacity for transmission of electricity shall be construed to have occurred when a transmission system cannot accommodate all transactions that would normally occur among users due to physical or engineering limitation.

Explanation 2 : For the purpose of clause 9.3.2, the term “un-congested price” means the transmission and / or wheeling charges required to be paid by the short-term users as per the rates approved by the Commission and published by the Nodal Agency from time to time.

Clause 10. Procedure of application for Long Term open access

10.1 The Nodal Agency (STU) shall make available the format of application for open access requiring broadly the details as set out in Annexure-1 to this Regulation, to the general public in physical form at its offices and in electronic printable form at its website.

10.2 An application for long-term open access shall be filed with the STU by the applicant, with a copy to the concerned transmission / distribution licensee(s). The application shall be accompanied by a non-refundable processing fee as prescribed by the Commission in the Tariff Orders, or otherwise, from time to time:

Provided that till such time the processing fee is so prescribed by the Commission, it shall be Rs.10,000.

10.3 The Nodal Agency shall acknowledge the receipt of an application made under clause 10.2 above within 24 hours of the receipt of the application.

10.4 If after submission of the open access application, the applicant becomes aware of any material alteration in the information contained in the application, the applicant shall promptly notify the Nodal Agency of the same:

Provided that in case the Nodal Agency is made aware of the material alteration in the information contained in the application already submitted under clause 10.2 above, the Nodal Agency shall treat the application as if the same was received on the date the applicant notifies it of the said alteration.

10.5 All applications received within a calendar month e.g. during 1st April to 30th April, shall be considered to have been filed simultaneously. This window of a calendar month shall keep rolling over i.e. after the expiry of a monthly window, another window of the duration of the next calendar month shall commence.

10.6 Based on system studies conducted in consultation with other agencies involved including other Licensees, if it is determined that Long-Term open access sought can be allowed without further system-strengthening, the Nodal Agency shall, within 30 days of closure of a window, intimate the applicant(s) of the same.

10.7 If, on the basis of the results of system studies, the Nodal Agency is of the opinion that the Long-Term open access sought cannot be allowed without further system-strengthening, the Nodal Agency shall notify the applicant of the same within 30 days of closure of a window. Thereafter, at the request of the applicant, which shall be made within 15 days of such notification by the Nodal Agency, the Nodal Agency shall carry out further studies, if required, to identify the scope of works involved and intimate the same to applicant within 30 days of receipt of such request from the applicant. The Nodal Agency shall also inform the applicant of the probable time frame for execution of the works involved after consultation with the concerned licensee(s).

Provided that in such cases, the applicant shall fully reimburse the Nodal Agency for actual expenditure incurred to carry out such system studies to identify the scope of works involved in system-strengthening. The fee, as prescribed in clause 10.2, paid by the applicant shall be adjusted against the actual expenditure to be reimbursed by the applicant:

Provided further that while identifying the scope of works for such system-strengthening, the Nodal Agency shall follow the standards required under the Grid Code and / or Distribution Code and / or Indian Electricity Rules, as the case may be.

Clause 11.Procedure of application for Short-Term open access

11.1 The SLDC shall make available the format of application similar to the one referred to the clause 10.1 above, to the general public in physical form at its office and in electronic printable form at its website.

- 11.2** The application for short-term open access to Transmission and/or Distribution system(s) shall be filed with, the SLDC with copies to concerned licensees. The application shall be accompanied by a non-refundable processing fee as prescribed by the Commission in the Tariff Orders, or otherwise, from time to time: Provided that till such time the processing fee is so prescribed by the Commission, it shall be Rs.1,000.
- 11.3** The SLDC shall process the applications for Short-Term open access within the following time limits:

Duration for which open access is required	Maximum processing time
Up to one day	12 hours
Up to one week	Two days
Up to one month	Seven days
Up to one year	Thirty days

Clause 12. Open Access Agreement

- 12.1** Based on the intimation by the Nodal Agency to the open access applicant, the applicant shall execute an open access agreement with the concerned Licensee(s), which shall broadly set out the information as given in Annexure-2 to this Regulation. The Licensees shall draft a standard open access agreement format and get the same approved by the Commission within 30 days of coming into effect of this Regulation.
- 12.2** The open access agreement referred to in clause 12.1 shall be bipartite, tripartite or multi-partite involving the applicant, the concerned Distribution Licensee in whose area of supply the applicant's exit point is located and the concerned Transmission Licensee or Licensees. The Open Access Agreement shall clearly bring out the rights and obligations of all parties which are broadly set out in Annexure – 3 with respect to exit points on transmission and distribution systems separately:

Provided that in cases where the open access applicant's point(s) of entry as well as the point(s) of exit are located within the distribution system of the same Distribution Licensee (at voltages 33KV and below), the applicant shall be required to execute an open access agreement only with such Distribution Licensee.

- 12.3** Subject to the capacity being available, the Licensee(s) shall, after the applicant for long-term open access has completed all the pre-requisite formalities, including the execution of open access agreement, make arrangements to provide access to the applicant within the time period specified in the Andhra Pradesh Electricity Regulatory Commission (Licensees' Duty for Supply of Electricity on Request) Regulation, 2004 (No. 3 of 2004):

Provided that in the case of short-term users, the open access shall be allowed as early as possible notwithstanding the time frame specified in the aforementioned Regulation.

- 12.4** **Minimum term and renewal of the Open Access Agreement:** The minimum term of an open access agreement is such term as the parties may agree and set out in the agreement subject to the provisions of clause 4 above. A long-term open access

agreement between a long-term user and the licensee may be renewed for a further term of two years or more without the requirement of a fresh open access application, on receipt of at least three (3) months' notice from the concerned long-term user to the concerned licensee(s) and the Nodal Agency, before the expiry of the Agreement. In case, no notice is provided by the Long-Term user, the Long-Term user shall forgo his right over the allotted capacity.

In case of short-term users, however, no extension of the original open access agreement shall be allowed, and a user wanting extension shall have to apply afresh to the Nodal Agency for open access.

Clause 13. Metering

13.1 All Long-Term and Short-Term open access users shall provide special energy meters capable of measuring active energy, reactive energy, average frequency and Demand integration in each 15-minute time block, with a built-in calendar and clock and conforming to BIS/CBIP Technical Report / IEC standards at all entry and exit points. This shall however be subject to the regulations to be made by the Central Electricity Authority under section 55 of the Act.

13.2 The users covered under clause 7 of this regulation shall have to provide the required metering at their premises within a period of 3 months from the date of coming into force of the Regulation failing which the Licensees shall no longer be obliged to wheel the energy to them. In such an event, all energy recorded at the premises of the user shall be deemed to have been supplied by the Distribution Licensee of that area of supply and shall be billed for by such Licensee accordingly at the appropriate tariff:

Provided that in the case of distribution licensees, the Commission may, considering the large number of meters required to be installed by them, extend this 3-month time limit, as considered appropriate, on receipt of requests to this effect duly supported by valid reasons.

Clause-14: Procedure for determining the available capacity of transmission and distribution (T&D) networks

14.1 The licensees shall carry out load flow studies, system impact studies, etc. taking into account the existing capacity commitments and future projections of capacity requirements for open access users, load growth as projected by distribution licensees, growth of generation, network topology and consumption pattern, network investments, Repairs and Maintenance programs, etc. to determine the capacity available to accommodate open access transactions. While so determining the capacity available for open access transactions, capacity commitments to all existing users of the network and the system reliability margin shall be deducted.

14.2 The Licensees shall keep updating the data on available capacity, taking into account the contracts with open access users, the impact of such transactions on the capacity of system elements, the increase/decrease in native load, changes in consumption pattern, network strengthening programs actually carried out and those projected, etc.

- 14.3** In order to decide the availability of sufficient spare capacity in the T&D networks so as to permit an open access transaction applied for, the Nodal Agency may also carry out load flow studies to simulate the impact of power flows associated with such open access transaction on the network and thus determine whether capacity is available to permit such open access transaction (in conformity with technical standards according to Grid Code and / or Distribution Code and / or Indian Electricity Rules , as the case may be) or there is a need to carry out system-strengthening works to ensure availability of sufficient capacity. The Nodal Agency may have to carry out this exercise on a case-to-case basis as and when an open access application is received.
- 14.4** The licensees shall carry out information exchange among themselves and keep one another and the Nodal Agency informed of the transactions on their respective networks.
- 14.5** The Nodal Agencies and Transmission / Distribution Licensees shall post details of available capacity on their respective websites, including the details of open access transactions permitted on different Licensees' networks with their respective entry and exit points, etc. on a daily basis

Clause 15. Underutilization

- 15.1** In the event a user expects to underutilize the capacity contracted under open access, the user may surrender a part of the capacity subject, however, to an advance notice as set out in the terms of the open access agreement, along with an explanation for such underutilization.
- 15.2** In the event of underutilization of the capacity contracted by the open access user, which, if made available, could be used to meet requirements of other applicant(s), the concerned licensee may file an application with the Nodal Agency to reduce or cancel the capacity allocated to the open access user :

Provided that the Licensee shall not so approach the Nodal Agency without first issuing a notice to the concerned user as set out in the open access agreement:

Provided, further that the Nodal Agency shall not reduce or cancel the capacity allotted without giving a notice of at least 15 days, in advance, to enable the concerned open access user to file his objections if any in writing.

- 15.3** In the event of user's surrender of whole or part of contracted capacity as per clause 15.1, or reduction/cancellation of the capacity allotted to the user as per clause 15.2, the user shall pay compensatory charges to the licensees concerned as follows:
- a) An amount equivalent to 50% of current application fee for Long-Term or Short-Term users, as the case may be, if all the capacity surrendered or reduced/cancelled is fully re-allotted to other applicants within the notice period so given by the user or the licensee, as the case may be.
 - b) If the capacity surrendered or reduced/cancelled could not be fully re-allotted to other applicants within the notice period, then

- i) In case of Long-Term users, the user shall, as a one-time exit fee, pay 25% of the transmission charges and / or wheeling charges as the case may be, and the scheduling and system operation charges in force at that point in time, applied on the capacity that could not be re-allotted for the remaining term of the agreement; and
- ii) In case of Short-Term users, the user shall bear the full transmission charges and / or wheeling charges, as the case may be, and the scheduling and system operation charges in force at that point of time, applied on the capacity that could not be re-allotted for the remaining term of the agreement.

Clause 16. Flexibility to change entry and exit points

- 16.1** The Long-Term users shall have the flexibility to change entry and/or exit points twice a year subject to the results of system impact studies to be carried out by the concerned Licensees at the behest of such users. All expenses incurred by the Licensees to carry out such studies shall be reimbursed in full by such users.
- 16.2** A Short-Term user availing of open access for one full year may also change entry and/or exit points twice, subject to feasibility.

Clause 17. Open Access charges

17.1 The charges for the use of the transmission and / or distribution system by an open access user shall be regulated as under:

- i) Open Access users connected to the transmission/distribution system shall pay the transmission charges and / or wheeling charges and any other applicable charges as determined by the Commission from time to time, and notified in the relevant Tariff Order or otherwise, and as per the conditions stipulated therein: Provided that the wheeling charges so payable shall be subject to a minimum level, as fixed by the Commission in the relevant Tariff Order or otherwise.
- (ii) In case of utilization of inter-state transmission system in addition to the intra-state transmission system and/or distribution system by an open access user, the transmission charges and / or wheeling charges shall be payable for the use of intra-state system in addition to the charges for utilization of the inter-state transmission system
- (iii) The Open access users of the Transmission and / or Distribution System where such open access is for delivery of electricity to the consumer's premises in the area of supply of a distribution licensee, shall pay to the distribution licensee the (cross-subsidy) surcharge as determined by the Commission from time to time under Section 42 (2) of the Act : Provided that no (cross-subsidy) surcharge shall be payable if the open access is provided to a person who has established a captive generating plant for carrying the electricity to the destination of his own use.

- (iv) The Open Access user shall also be liable to pay additional surcharge on charges of wheeling as may be specified by the Commission from time to time under section 42(4) of the Act, in case open access is sought for receiving supply from a person other than the distribution licensee of such consumer's area of supply, to meet the fixed cost of the distribution licensee arising out of his obligation to supply.
- (v) Where an electrical plant or electrical line is to be constructed by the Licensee in order to extend power supply to an open access user, the Licensee may recover such expenditure as per the Andhra Pradesh Electricity Regulatory Commission (Licensee's Duty for Supply of Electricity on Request) Regulation, 2004(Regulation No.3 of 2004)
- (vi) If network augmentation is required for providing access to an applicant, the Licensee shall carry out such augmentation only if (a) the Licensee can recover within a reasonable time the costs, the capital investment and a reasonable rate of return on the capital investment in respect of the augmentation, and (b) the Licensee has the ability to raise funds to finance such capital expenditure: Provided that the Licensee may require the open access user to make a capital contribution towards such network augmentation.
- (vii) Scheduling and system operation charges shall be payable by all open access users under scheduling by SLDC. Such charges shall be governed by the relevant Regulations issued by the Commission.

Clause-18: Payment terms and conditions

- 18.1** In case of Long-Term users, the concerned Distribution Licensee may invoice a user in respect of the open access charges as set out in clause 17 of this Regulation and the open access user must pay those charges, in accordance with the procedures set out in the open access agreement between the Licensees and the user: Provided that the Distribution Licensee shall have appropriate back-to-back arrangements in place with the Transmission Licensee(s) in order to pass on the transmission charges so collected from the user to the concerned Transmission Licensee.
- 18.2** In case of short-term users, the Distribution Licensee(s) may invoice the user and the user shall pay the charges to the concerned Licensee(s) directly. The SLDC shall assist / advise the Distribution Licensee in the matter of energy accounting and allocation.
- 18.3** All open access users shall pay the charges payable under the open access agreement from the date of commencement of open access specified in the open access agreement, regardless of whether or not such open access is used on and from that date, except if the failure to use such open access is due to the default of the concerned licensee(s) whose networks are being used.
- 18.4** In case of underutilization leading to surrender or cancellation of contracted capacity, the user shall pay such charges and in such manner as set out in clause 15 above.

- 18.5** Meter readings and Billing in respect of open access for supply to consumers: The Distribution Licensee in whose area the consumer is located shall take the meter readings at the exit point. The billing shall be done by the respective Licensees as per the open access agreement under clause 12 read with the provisions of clauses 17 and 20 of this Regulation.
- 18.6** For the purpose of clause 18.5 above, a consumer using the Transmission and /or Distribution systems for his total power requirements without any contracted maximum demand(CMD) from the Distribution licensee shall be deemed to be a consumer of the distribution licensee in whose area the consumer is located.

Clause 19. Other matters

- 19.1. Coordination among licensees and SLDC:** For the success of open access implementation, the licensees and the State Load Dispatch Centre shall carry out information exchange among themselves on a daily basis to determine the level of open access transactions in their respective areas of supply, energy flows, loading of transmission and distribution lines and equipment to determine system stability, available capacity, congestions in the networks, etc.
- 19.2. Information requirements:** The licensees and the State Load Dispatch Centre shall maintain the following information on their websites in order to ensure transparency and carry out information exchange among themselves required to process open access applications:
- i) Transmission and / or wheeling charges, as the case may be, for open access users located within the State; and
 - ii) A status report on the current long-term users indicating name of user, period of the access granted (start date and end date), point(s) of injection and point(s) of drawl, capacity contracted and applicable charges. This report shall be updated as and when the status changes; and
 - iii) Information regarding usage of the inter-regional links as well as interface between the Central Transmission Utility and State systems and inter-state links indicating time of updating, name of the link, total transmission capacity of the link, scheduled capacity use and current capacity of the link in use. This information shall be updated at least on hourly basis and wherever feasible on 15-minute basis.
- 19.3 Quality of supply:** The licensee(s) shall ensure compliance with Grid Code wherever applicable. The Distribution Licensees shall also comply with the quality of supply standards as prescribed under the Andhra Pradesh Electricity Regulatory Commission (Licensees' Standards of Performance) Regulation, 2004 (Regulation No.7 of 2004) in respect of all open access users of its network.
- 19.4 Energy and Demand Balancing:** All open access users, and the users covered under clause 7.2, shall make reasonable endeavor to ensure that their actual demand or actual sent-out capacity, as the case may be, at an inter-connection does not exceed the Contracted Maximum Demand or allocated sent-out capacity for that inter-

connection: Provided that for carrying out balancing and settlement of energy and demand at all entry and exit points relating to open access agreements, the licensee shall strictly adhere to the Balancing and Settlement Code to be approved by the Commission, from time to time.

19.5 Curtailment due to constraints: The licensee, based on directions from SLDC, may curtail power to any open access user or users, whether long-term or short-term, in an event of emergency threatening grid security and stability. As far as practicable, the priority in curtailment shall be as prescribed hereunder:

- a) Short-term open access users of the network shall be curtailed in the first step, followed by
- b) All other consumers including long-term access users, but excluding distribution licensees, in ascending order of contract period, followed by
- c) Distribution licensees.

Clause 20. General Terms and Conditions of Supply

With regard to matters not contained herein, including but not limited to the following, and wherever the context so requires, the conditions set forth in the General Terms and Conditions of Supply shall generally be applicable:

- (a) Voltage of supply vis-à-vis total Contracted Demand;
- (b) Security Deposit;
- (c) Disconnection for non-payment of charges;
- (d) Title Transfer to successor entity; and
- (e) Levy and collection of Customer Charges

Clause 21. Dispute resolution

All disputes and complaint shall be referred to the Nodal Agency for Resolution:

Provided that when the Nodal Agency is itself a party to the dispute, the dispute shall be referred for resolution to the Forum for Redressal of Consumer grievances set up under Regulation No.1 of 2004 :

Provided further that in case of wheeling of power from the captive generating plants, any disputes regarding the availability of transmission facility shall be adjudicated upon by the Commission.

Clause 22. Force Majeure

22.1 Events such as war, mutiny, civil commotion, riot, flood, cyclone, lightning, earthquake or other force and strike, lockout, fire affecting the premises, installations and activities of any of the parties having an open access agreement shall constitute force majeure events for the purpose of this Regulation.

22.2 If any person being party to an open access agreement is unable to, wholly or in part, perform on time and as required, any obligation under such open access agreement or this Regulation because of the occurrence of a force majeure event, then, subject to

this Regulation, that obligation shall be treated as suspended to the extent and for so long as the affected person's ability to perform such obligation remains affected by that force majeure event.

Clause 23. Issue of orders and practice directions

Subject to the provisions of the Electricity Act, 2003, the A.P. Electricity Reform Act, 1998, and this Regulation, the Commission may, from time to time, issue orders and practice directions in regard to the implementation of this Regulation, the procedure to be followed and other matters, which the Commission has been empowered by this Regulation to specify or direct.

Clause 24. Power to remove difficulties

- 24.1** In case of any difficulty in giving effect to any of the provisions of this Regulation, the Commission may by general or special order, direct the Open Access users, generators and the licensees to take suitable action, not being inconsistent with the provisions of the Act, which appears to the Commission to be necessary or expedient for the purpose of removing the difficulty.
- 24.2** The Open Access users, generators and the licensees may make an application to the Commission and seek suitable orders to remove any difficulties that may arise in implementation of this Regulation.

Annexure-1:

Suggested contents of Open Access Application

Name and address of the applicant
Details of applicant's installation

Nature of wheeling i.e., whether it is for captive use or third party sale

Name and address of consumers to whom the power is to be wheeled

- a) Type of open access required, whether long-term, or short-term
- b) Capacity in KW or MW required for open access in respect of consume
- c) Point(s) of Entry
- d) Point(s) of Exit
- e) Period for which open access is required
- f) Details of metering arrangements at the entry points and exit points as required under the Metering Code (part of the Grid Code or the Distribution Code, as the case may be) as amended from time to time
- g) Information whether the recipients of power are already consumers of Distribution licensee of their area. If so, furnish the Contracted Maximum Demand (CMD) of each of them with the Distribution Licensee concerned

Any other information reasonably required by the licensee/ Nodal Agency

Annexure-2

Suggested essential features of Open Access Agreement

- a) The Entry and Exit points
- b) Allotted capacity (in kW or MW) for open access in the Transmission and / or Distribution system
- c) The rates and charges for providing various access services, such as:
 - i) Transmission and/or Wheeling charges as the case may be;
 - ii) Transmission losses and / or wheeling losses to be deducted;
 - iii) Cross-subsidy Surcharge ;
 - iv) Additional surcharge ;
 - v) SLDC charges;
 - vi) Reactive energy charges, if applicable; and
 - vii) Any other charges
- d) A requirement that the applicant's equipment / installations at all times for the entire duration of the contract complies with the provisions of the Grid Code and/or the Distribution Code, as the case may be
- e) The date of commencement of Open Access
- f) The manner of accounting of energy and demand balancing procedures, as per the Balancing and Settlement Code to be approved by the Commission, from time to time
- g) The billing cycle and the payment terms and conditions;
- h) The Agreement period and its termination / deration conditions
- i) Other terms and conditions including powers of the Nodal Agency on surrender of capacity, premature termination of open access agreement, penalty for under-utilization of allotted capacity, etc.
- j) Provision for renewal of open access Agreement in applicable cases

Any other information as considered reasonable by the Licensee.

Annexure – 3

Duties, rights and obligations of parties, inter-alia, in case of Tripartite Open Access Agreements referred to in clause 12.2 of the Regulation

Exit Points location on 132 KV and above (Transmission System):

- a) Concerned Transmission Licensee's obligation to provide transmission capacity – User's right on transmission capacity contracted
- b) Duties of Distribution Licensee of that area of supply where such exit point is located for meter reading and billing (for transmission charges, surcharges, out-of-balance payments, etc.);
- c) User's duty to pay the charges, as billed for ; and
- d) Distribution Licensee's obligation to pass on the transmission charges so collected from the user to the concerned Transmission Licensee.

Exit Points location on 33 KV and below (Distribution System):

- a) Concerned Transmission Licensee's obligation to provide Transmission capacity – User's right on Transmission capacity contracted;
- b) Concerned Distribution Licensee's obligation to provide Distribution System capacity –User's right on Distribution capacity contracted;
- c) Distribution Licensee's duties for meter reading and billing (for Transmission charges, Wheeling charges, applicable surcharges, out-of-balance payments, etc.) ;
- d) User's duty to pay for charges as billed for ; and
- e) Distribution Licensee's obligation to pass on the transmission charges collected from the user to the concerned Transmission Licensee

REGULATION NO.2 OF 2006

INTERIM BALANCING AND SETTLEMENT CODE FOR OPEN ACCESS TRANSACTIONS

1. Introduction: Clause 19.4 of APERC Regulation No.2 of 2005 provides that the balancing and settlement of energy and demand shall be done in accordance with the Balancing and Settlement Code to be approved by the Commission. The Commission has also been expressing its keenness to introduce the ABT regime at the State level. Pending finalization of a comprehensive settlement system for the State pool under ABT, the Commission considered it appropriate to specify an Interim Balancing and Settlement Code, envisaging a day-ahead wheeling schedule of energy on the basis of 15-minute time blocks, and monthly settlement of deviations. The Commission accordingly issued Regulation NO. 2 of 2006, on Interim Balancing and Settlement Code for Open Access Transactions. This Regulation came into force on 01.12.2006.

2. Definitions of certain terms:

- a) “Billing month” means the period between any two successive meter reading dates, as provided in open access agreement;
- b) “Distribution Licensee” or “DISCOM” means a licensee authorized to operate and maintain a distribution system for supplying electricity to the consumers in his area of supply
- c) “Losses” means the energy losses in percentage for an EHT system as a single system and for all other voltage levels, the losses in percentage as provided in the applicable Tariff Order of the Commission, or the actual levels of energy losses as provided in this Regulation.

Explanation:

(i) If the wheeling of electricity is through the distribution system of more than one distribution licensee or if the Entry/Exit point is connected to EHT system, the losses would include transmission loss and the distribution loss up to the voltage level of the distribution licensee in whose area of supply such exit/entry point (whichever is lower) is located.

(ii) If the entry and exit points are located within the distribution system (33 kV and below) of the same distribution licensee, the losses would include only the distribution loss of the distribution licensee up to the voltage level at the relevant exit or the entry point(s), whichever is lower.

- d) “Scheduled Consumer” means a consumer who has a supply agreement with the distribution licensee in whose area of supply the consumer is located and also has a supply agreement with a person other than the distribution licensee under the Open Access Regulation and includes a consumer of a distribution licensee who also avails of wheeling facility for carrying the electricity from his captive generating plant to the destination of his own use.

- e) “Time Block” means each block of fifteen (15) minutes for which the energy meters record specified electrical parameters and quantities, with the first time block for a day starting at 00:00 hours.
- f) “Open Access Agreement” means an agreement entered into between the Transmission and / or Distribution Licensees and the persons availing Open Access facility under clause 12 of the Open Access Regulation.
- g) “Open Access Consumer” or “OA Consumer” means a consumer not having a supply agreement with the distribution licensee in whose area of supply the consumer is located, but availing or intending to avail supply of energy from a person other than that distribution licensee under the Open Access Regulation and includes a consumer availing wheeling facility for carrying the electricity from his captive generating plant to the destination of his own use without having a supply agreement with the distribution licensee of the area in which the consumer’s premises is located.
- h) “Open Access Generator” means a generating company using or intending to use the transmission system and / or the distribution system of the licensees in the State of Andhra Pradesh for supply of electricity to a Scheduled Consumer or OA Consumer under the Open Access Regulation.
- i) “Wheeling Schedule” means the schedule for a fifteen (15) minute block provided by the scheduled consumer, an OA consumer or an OA generator to the SLDC, pursuant to clause 4 of this regulation, read with clause 6

3. Extent of Application

The Interim Balancing & Settlement Code set out in this Regulation shall apply to Open Access Generators, Scheduled Consumers and OA Consumers.

4. Scheduling

- 4.1 Each Open Access Generator, Scheduled Consumer and OA Consumer shall provide a Wheeling Schedule in the format as at Appendix–1(a), to the SLDC/DISCOM for each fifteen (15) minute time block for a day, on a day-ahead basis by 10:00 a.m. on the day preceding the commencement of the first time block for which the wheeling of energy is scheduled, with a copy each to the State Transmission Utility (APTRANSCO) and the concerned DISCOM:

Provided that an Open Access Generator, Scheduled Consumer and OA Consumer requiring to wheel electricity from more than one generating station with the interface points located at different locations (with separate metering at each entry point) shall provide separate wheeling schedule for the entry point(s) of each generating station:

Provided also that the Wind-based or Mini-Hydel Open Access Generators shall not be required to provide a day-ahead wheeling schedule and the actual electricity injected by them shall be deemed to be the scheduled energy.

- 4.2 The OA generators scheduling their supply to more than one scheduled/OA consumer or the scheduled/OA consumer receiving supply from more than one OA generator shall communicate to the SLDC/DISCOM (along with the day-ahead schedule) the inter-se order of allocation of the actual generation among the Schedule/OA consumers or the inter-se order of allocation of the actual consumption among the OA

generators as the case may be. Such communication of inter-se order of allocation/consumption to the SLDC/DISCOM shall be deemed to have been done with prior consent of all the parties involved and binding on all the OA generators, Scheduled consumers and OA consumers.

- 4.3 In the event of failure to submit the wheeling schedule in accordance with clause 4.1, the latest wheeling schedule available with the SLDC/DISCOM shall be treated as the effective wheeling schedule.
- 4.4 SLDC shall communicate the final day-ahead schedule to the respective parties along with inter-se order of allocation of consumption/generation capacities wherever applicable as per the time-frame setout in the State Grid Code and the same shall be binding on all parties.

5. Allocation of Capacity by OA Generators

- 5.1 The sum total of the capacity allocations by an OA Generator for any time block to all the Scheduled Consumers and OA Consumers shall not exceed the available capacity from his generating plant being not higher than the installed capacity or contracted Open Access capacity, whichever is lower.
- 5.2 The OA Generator shall also indicate the allocated capacity in kW at the exit point(s) for each consumer in the Format at Appendix - 1 (a) using the loss levels as specified in the applicable Tariff Order of the Commission. The energy account of the billing month shall be finalized based on the transmission and distribution losses specified by the Commission in the applicable Tariff Order.
- 5.3 The SLDC/DISCOM shall verify the capacity allocated at the Exit point(s) and correct it in case of discrepancy, if any. The computations of SLDC shall be final and binding on all.

6. REVISION OF WHEELING SCHEDULE

In case of any system constraint, the SLDC/DISCOM may modify the schedules of Open Access Generators, Scheduled Consumers and/or the OA Consumers, as the case may be, at any time in accordance with the Grid Code and the Open Access Regulation, which shall be conveyed to them. Compliance with the instructions of SLDC shall not be reckoned as a deviation by the concerned Generator/Consumer from the schedule. The Open Access Generator, Scheduled Consumer or OA Consumer, shall not, however, be entitled to revise a wheeling schedule during the course of a day.

7. Meter Reading, Energy Accounting and Settlement

- 7.1 SLDC shall undertake the accounting of energy for each time block on monthly basis with the assistance of the Energy Billing Centre (EBC) of the State Transmission Utility (STU) in respect of the Open Access Generators, Scheduled Consumers and the OA Consumers who are connected to the transmission system, In respect of the Open Access Generators, Scheduled Consumers and the OA Consumers who are connected to the distribution system, it is the EBC that shall be responsible for energy accounting and settlement in co-ordination with the DISCOMs.

7.2 Such Account shall be examined and signed by a Committee comprising the STU, DISCOMs and Generators:

Provided that in the case of Generators, only one representative, as approved by the Commission, from each class of Generators mentioned below shall be represented on the Committee:

- Central Generating Stations (CGS)
- APGENCO
- Independent Power Producers (IPPs)
- Non-conventional Energy (NCE) Developers (Biomass, Mini-hydel, Hydro, Wind etc)
- Captive Power Plants (CPPs)

7.3 The monthly meter readings shall be taken by the respective DISCOM at all the entry points at 33 kV and below and at all the exit point(s) of the Open Access Generators located in its licensed area, as identified in the wheeling schedules. Where, however, the entry point is connected to the Transmission system, such monthly readings shall be taken by the Transmission Licensee: provided that the readings for each time block shall be retrieved through a Meter Reading Instrument (MRI) or otherwise by the respective licensees mentioned above once in a week and shall be transmitted to the SLDC. The meter readings as and when taken shall also be made available to the Open Access Generator/Consumer in whose premises the readings are taken, or to his representative, if available.

In case of failure of metering equipment or non-availability of MRI data, a suitable methodology as approved by the Commission may be employed for finalising the energy account. The Licensees may submit proposed data- substitution methodology for Commission's approval within one month of issue of this Regulation.

7.4 The SLDC shall finalize the energy account of the Open Access transactions of a billing month with the assistance of EBC and arrive at the deviations for each time block and the consequent adjustments integrated over the month in respect of all Open Access Generators, Scheduled Consumers and the OA Consumers in accordance with the procedure specified herein.

8. Settlement of Energy/Demand at exit point in respect of Scheduled consumer:

8.1 The Scheduled energy (in kWh) at exit point shall be calculated for each time block from the scheduled capacity (kW) at the Exit point, as provided in the wheeling schedule, by multiplying it with the period of time block in hours.

8.2 The Scheduled demand at exit point shall be calculated by dividing the scheduled capacity (kW) at exit point by the power factor for the time block, for which purpose the Power factor shall be equal to the recorded kWh divided by kVAh.

8.3 The Scheduled energy of a Scheduled Consumer from an OA Generator for each time-block shall be deducted from the recorded energy (in the inter-se order of such Generators, as and if intimated by the consumer, in case the consumer is availing of energy from more than one Generator) as a first charge. The balance energy shall be

deemed to have been supplied by the DISCOM and shall have to be paid for as per the terms of the supply agreement with the DISCOM:

Provided that where there is a deviation between the scheduled capacity and actual capacity being injected at an Entry point in a time block, the shortfall, if any, in the capacity allocated to the Scheduled Consumer shall be deemed to have been drawn by the Scheduled Consumer from the DISCOM and the energy corresponding to such shortfall shall be paid for by the party which has contracted for the Open Access capacity with the Licensee to the DISCOM as per the energy tariff applicable for the same consumer category of DISCOM under which the Scheduled Consumer would normally fall.

- 8.4 The Scheduled demand at Exit point or the actual demand made available to a consumer from each OA Generator at that Exit point in a time-block whichever is less, shall be deducted from the recorded demand (in the inter-se order of such Generators, as confirmed by the SLDC while finalising the day-ahead schedule, in case the consumer is availing of energy from more than one Generator). The balance demand for each time-block shall be deemed to have been consumed from the DISCOM and shall be paid for as per the terms of the supply agreement with the DISCOM.

9. Settlement of Energy at Exit point in respect of OA Consumers:

- 9.1 The Scheduled Energy at Exit point of an OA Consumer shall be calculated from the Scheduled capacity from an OA Generator at the Exit point for each time block as provided in clause 8.1 above.
- 9.2 In case the Open Access Consumer is receiving supply from more than one Open Access generator, the total energy and demand recorded shall be deemed to have been consumed from the respective Open Access Generators in the inter-se order of Generators as confirmed by the SLDC while finalizing the day-ahead schedule.
- 9.3 The excess energy recorded, if any, at the exit point for any time block with reference to scheduled energy or the actual energy available at that Exit point, whichever is less, shall be deemed to have been consumed by the Generator or the OA consumer whoever has contracted for the Open Access capacity with the Licensee, from the DISCOM and shall be paid for by the Open Access Generator/Consumer at the energy tariff applicable for the same consumer category of DISCOM to which the OA Consumer would normally belong. Such excess consumption shall also attract all penal provisions provided in the applicable Tariff Order like those in respect of Low Power Factor, voltage surcharge, etc and wherever applicable, the relevant charges shall also be paid for by the OA generator/OA consumer.
- 9.4 The Scheduled demand at Exit point or the actual demand made available to a consumer from each OA Generator at that Exit point in a time-block whichever is less, shall be deducted from the recorded demand (in the inter-se order of such Generators, as confirmed by the SLDC while finalizing the day-ahead schedule, in case the consumer is availing of energy from more than one Generator). The balance demand for each time-block shall be deemed to have been consumed from the

DISCOM and shall be paid at twice the demand charges applicable for the same consumer category of DISCOM to which the OA Consumer would normally belong.

10. Settlement for OA Generators at Entry point:

- 10.1 Excess draws of energy and demand by Scheduled Consumers on account of under-generation by the Generator for each time block shall be deemed to have been drawn from the DISCOM. The energy and demand charges for such excess draws shall be paid for by the Scheduled Consumer in accordance with the proviso to clause 8.3 and as per clause 8.4 respectively.
- 10.2 Excess drawl of energy and demand by an OA Consumer on account of under-generation by the Generator for each time block shall be deemed to have been drawn by the Generator (or Open Access Consumer whoever has contracted for Open Access Capacity) and shall be paid for by the Generator/Consumer as per the normal energy tariff and twice the demand charges applicable for the same consumer category to which the OA Consumer would normally belong.
- 10.3 The under-drawls by Scheduled Consumers and/or OA Consumers shall have impact on the Generator and on the DISCOM in whose area of supply the Exit point is located. Such under-drawls at Exit point shall be treated as inadvertent energy supplied by the Generator to the DISCOM(s) and shall not be paid for by the DISCOM.
- 10.4 Injection of energy by an OA Generator over and above the scheduled capacity at an Entry point shall not be accounted for. In such cases, only the scheduled capacity at exit point shall be accounted for as having been supplied by the Generator to the Scheduled Consumer or the OA Consumer, as the case may be.
- 10.5 In case of wind and mini-hydel OA generators the actual generation during the month shall be deemed as scheduled energy. For the purpose of settlement in respect of scheduled/OA consumer availing supply from these OA generators, the actual generation during the month will be apportioned for each time block of the month and deviations reckoned accordingly.

11. Levy of Surcharge and Additional Surcharge:

Each Open Access Generator, Scheduled Consumer and OA Consumer shall, in addition to the tariff and other charges mentioned in the preceding clauses, also be required to pay, wherever applicable, the surcharge in accordance with the provisions of the Open Access Regulation as also the applicable additional surcharge, if any, under Section 42 (4) of the Act.

12. Banking:

- 12.1 No generators other than the Wind and Mini Hydel power generators shall be allowed the facility of banking the electricity generated by them:

Provided, however, that in the case of generators whose cases are pending appeals in the Hon'ble High Court of Andhra Pradesh and/or the Hon'ble Supreme Court, this provision shall be applicable subject to the final decision of the High Court and / or the Supreme Court, as the case may be.

- 12.2 The banking facility to the Wind and Mini Hydel power generators shall be subject to the conditions specified in Appendix – 3.

13. Dispute Resolution :

All disputes and complaints shall be referred to the SLDC for resolution, which shall not decide a matter without first affording an opportunity to the concerned parties to represent their respective points of view. The decisions of the SLDC shall be binding on all parties.

14. Issue of Orders and practice Directions:

Subject to the provisions of the Act, the A.P Electricity Reform Act, 1998, and this Regulation, the Commission may, from time to time, issue orders and practice directions in regard to the implementation of this Regulation, the procedure to be followed and other matters, which the Commission has been empowered by this Regulation to specify or direct.

15. Power to remove Difficulties:

In case of any difficulty in giving effect to any of the provisions of this Regulation, the Commission may by general or special order, issue appropriate directions to Open Access Generators, Scheduled Consumers, OA Consumers, Transmission Licensee(s), Distribution licensee(s) etc., to take suitable action, not being inconsistent with the provisions of the Act, which appear to the Commission to be necessary or expedient for the purpose of removing the difficulty.

APPENDIX – 1 (a)

Format for the Day-ahead Wheeling schedule for each 15 minute time block of the day

Date:

Declared capacity for the day

Name of the Generator:

Time Block

Address of the Generating Station:

Available Capacity

Entry Point Voltage:

DISCOM	Name of the consumer	Voltage level of Exit point	Time Blocks	Allocated capacity at Entry point (KW)	Net Capacity at Exit point (KW)

Any other information to be provided:

**Signature of the OA Generator /
Scheduled Consumer/OA Consumer**

Note: An example each for computation of Net capacity at Exit point is given in Appendix – 1(b) and examples for Settlement are given in Appendix - 2

APPENDIX – 1 (b)

Computation of Net capacity at the Exit Point

Date:

Declared capacity for the day

Name of the generator: Z in SPDCL

Time Block Available Capacity

Entry Point Voltage: 132 kV

DISCOM	Name of the consumer	Voltage Level at Exit point	Time Block	Allocated Capacity At Entry Point (KW)	Net Capacity at Exit point (KW)
SPDCL	1. Sch. Consr	11kV	1to96	1000	830.8
	2.sch. Consr	132kV	1to96	2000	1900.0
	3.OA. Consr	33kV	1to96	1000	893.4
Total for SPDCL					
CPDCL	1.Sch. Consr	11kV	1to96	1000	827.2
	2.Sch. Consr	33kV	1to96	3000	2676.6
	3.OA. Consr	132kV	1to96	5000	4750.0
Total for CPDCL					
NPDCL	1.Sch. Consr	11kV	1to96	1000	821.0
	2.OA.Consr	33kV	1to96	2000	1778.6
Total for NPDCL					
EPDCL	1.Sch. consr	11kV	1to96	1000	818.9
	2.OA. Consr	33kV	1to96	3000	2636.7
Total for EPDCL					
Grand Total				20,000	17938.2

Note: In the Table above, the following loss levels have been taken into consideration, sourced from the Commission's Tariff Order for FY 2005-06. The loss levels of corresponding FY as per the Tariff Order of the Commission for the relevant year should be taken for computation of the net capacity at exit point:

Transmission losses = 5%

Distribution losses up to the Voltage level of exit point (Percentage)

Voltage	SPDCL	CPDCL	NPDCL	EPDCL
33kV	5.66	5.78	6.07	7.11
11kV	11.92	12.28	12.9	13.11
LT	20.44	20.5	23.05	21.3

Example for calculation of Losses: OA Consumer 3 of SPDCL

→ 132 kV + Losses up to 33 kV → (5+5.66=10.66%) → 1000 X 10.66/100 = 106.60 kW

APPENDIX – 2

(A). Where Generator is Generating at the level of Scheduled Capacity: (kW)

DISCOM	Consumer	Sch.Cap.at Exit point	Recorded Consumption	Accountable to generator	Accountable to Discom	Deviation
SPDCL	1.Sch.Consr	830.8	1000	830.8	169.2	Nil
	2.Sch.Consr	1900.0	2000	1900.0	100	Nil
	3.OA.consr	893.4	1200	893.4	306.6	306.6
CPDCL	4.Sch,Consr	827.2	600	600	0.0	(-)227.7
	5.Sch.Consr	2676.6	3000	2676.6	323.4	Nil
	6.OA.Consr	4750.0	4000	4000.0	0.0	(-)750.0
NPDCL	7.Sch.Consr	821	1100	821.0	279.0	Nil
	8.OA.Consr	1778.6	1900	1778.6	121.4	Nil
EPDCL	9.Sch.consr	818.9	1200	818.9	381.1	Nil
	10.OA.consr	2636.7	2500	2500.0	0.0	(-)163.3

(B) Where Generator is under generating w.r.t. Scheduled Capacity

Consumer	Sch.Cap. At Entry Point	Sch. cap at Exit Point	Act. Cap. At Entry Point	Act.cap. At Exit point	Recorded consumption	Deviation
1.Sch.consr	1000	830.8	900	747.72	1000	83.08
2.Sch.Constr	2000	1900.0	1800	1710.0	2000	190.0
3.OA.Constr	1000	893.4	900	804.06	1200	395.94
4.Sch.consr	1000	827.2	900	744.48	600	(-)144.48
5.Sch.consr	3000	2676.6	2700	2408.94	3000	267.66
6.OA.Constr	5000	4750.0	4500	4275.0	4000	(-)275
7.Sch.Constr	1000	821.0	900	738.9	1100	82.1
8.OA.Constr	2000	1778.6	1800	1600.74	1900	299.26
9.Sch.consr	1000	818.9	900	737.01	1200	81.89
10.OA.Constr	3000	2636.7	2700	2373.03	2500	126.97

APPENDIX – 3**Terms and Conditions for banking facility allowed to Wind power and Mini-hydel Power Generators**

- 1) Banking allowed during all the 12 months.
- 2) Drawls are subject to the following:
 - a) The banking year shall be from January to December.
 - b) The banking charges shall be in kind @ 2% of the energy delivered at the point of Injection.
 - c) Drawls shall be permitted only during the 6-month period, from July to December. The banked energy remaining unutilized as on 31st December shall be treated as lapsed.
 - d) Drawl of banked energy during the peak hours i.e. 06:00 to 09:00 hours and 18:00 hours to 21:00 hours shall not be permitted.

6.1.6 Overview of APPCC Power Procurement Process:

Andhra Pradesh Power Coordination Committee (APPCC) is an apex committee constituted under GO Ms. No. 59 dt.07-06-2005 regulation. APPCC consists of CMDs of Discoms, Director (Finance&Revenue) and JMD (HRD&Distribution) APTRANSCO as members and the CMD (APTRANSCO) as Chair person. CE (Commercial) is the convener. APPCC has a primary role in power procurement of the four Discoms.

On behalf of four Discoms, APPCC will procure the additional power as and when needed by the Discoms to meet their demand when there is shortage of power available from the approved sources.

Quantity of energy required and the period shall be estimated and provided by the SLDC after consideration of various factors such as weather conditions, generators availability discoms' demand etc.,.

Once the requirement is finalized by the SLDC, the power procurement indent will be communicated to CE/APPCC for initiating procurement process.

6.1.6.1 Types of Power Procurements available are:

- Power purchases from private Generators within State.
- Power purchases through Short Term Open Access through traders
- Power purchases from Power Exchanges
- Power purchases through UI (by means of Over drawl from CGS)

Depending on the merits and de-merits of various factors, such as transmission corridor availability, landing cost and power requirement, the APPCC purchases power from various sources after obtaining concurrence from the APPCC members.

It is important to note that the CE/Commercial/APPCC will submit proposals on every transaction of power procurement to the Board and after the approval, will take up the procurement process. The Power purchase activity will be reviewed by the APPCC members and approved.

6.2 LOAD DESPATCH OPERATIONS

6.2.1 ROLE OF STATE, REGIONAL AND NATIONAL GRIDS

A high degree of reliability is expected for electric power system in order to meet continuity of supply with reasonable level. Reliability is, and always has been, one of the major factors in planning, design, operation, and maintenance of electric power systems.

Modern power system is complex, highly integrated and very large.

In olden days a satisfactory degree of reliability was achieved through empirical methods and policies. As systems grew larger and more complex, however, the need for vigorous analysis became increasingly evident and in recent years, the formal concepts and methods of

reliability theory have been applied to almost every aspect of power system reliability evaluations.

The major parts of an electric power system are generation, transmission, and distribution systems. In order to achieve the overall system reliability at the customer level, each sub system must provide higher degree of reliability.

Networking with neighboring power systems is highly utilized in order to assure supply continuity and to achieve economic system operation. Transmission systems are highly interconnected and modern utilities purchase economic energy from sources outside their own systems. Transmission systems often traverse a long distance to transport the energy over various networks to load centers. Parallel redundancy of transmission lines is a common way of improving the reliability of power supply. Multiple transmission line outages can significantly alter the transmission system operating configuration and possibly result in supply interruptions to a large number of customers. One of the major causes of transmission line outages is extreme adverse weather conditions.

Experience indicates that disturbances on the bulk system are rare but have a great impact when they do occur. The reliability of an electric supply system has been defined as the probability of providing the users with continuous service of satisfactory quality. The quality aspect refers to the requirement that the frequency and voltage of power supply should remain within prescribed tolerances.

Balancing generation and demand within the state and across the nation by supplying power from surplus areas to deficit regions is required for maintaining reliability. Electricity Act 2003 provides for formation of State, Regional and National level grids defining role and responsibility of these grids. Relevant clauses of the act are indicated below.

6.2.1.1 NATIONAL LOAD DESPATCH CENTRE

According to notification dated 2nd March 2005, by the Ministry of Power, Government of India, under Section 26(2) of the Act, NLDC shall be the apex body to ensure integrated operation of the National Power system and shall discharge the following functions. This would also include such other functions assigned by the Government of India through resolutions issued from time to time:

- a) Supervision over the Regional Load Despatch Centers.
- b) Scheduling and despatch of electricity over inter-regional links in accordance with Grid Standards specified by the Authority and Grid Code specified by Central Commission in coordination with Regional Load Despatch Centers.
- c) Coordination with Regional Load Despatch Centers for achieving maximum economy and efficiency in the operation of National Grid.
- d) Monitoring of operations and grid security of the National Grid.
- e) Supervision and control over the inter-regional links as shall be required for ensuring stability of the power system under its control.
- f) Coordination with Regional Power Committees for regional outage schedule in the national perspective to ensure optimal utilization of power resources.
- g) Coordination with Regional Load Despatch Centers for the energy accounting of inter-regional exchange of power.

- h) Coordination for restoration of synchronous operation of national grid with Regional Load Despatch Centers.
- i) Coordination for trans-national exchange of power.
- j) Providing operational feedback for national grid planning to the Authority and the Central Transmission Utility.
- k) Levy and collection of such fee and charges from the generating companies or licensees involved in the power system, as shall be specified by the Central Commission.
- l) Dissemination of information relating to operations of transmission system in accordance with directions or regulations issued by Central Electricity Regulatory Commission and the Central Government from time to time.

NLDC shall also carry out the following functions

- i) NLDC shall be the nodal agency for collective transactions.
- ii) NLDC would act as the Central control room in case of natural & man made emergency/disaster where it affects the power system operation.
- iii) Any other function as may be assigned by the Commission by order or regulations from time to time.

6.2.1.2 REGIONAL LOAD DESPATCH CENTRE

According to sections 28 and 29 of Electricity Act, 2003, the functions of RLDCs are as follows:

- 1) The Regional Load Despatch Centre shall be the apex body to ensure integrated operation of the power system in the concerned region.
- 2) The Regional Load Despatch Centre shall comply with such principles, guidelines and methodologies in respect of wheeling and optimum scheduling and despatch of electricity as may be specified in the Grid Code.
- 3) The Regional Load Despatch Centre shall-
 - Be responsible for optimum scheduling and despatch of electricity within the region, in accordance with the contracts entered into with the licensees or the generating companies operating in the region;
 - Monitor grid operations;
 - Keep accounts of quantity of electricity transmitted through the regional grid;
 - Exercise supervision and control over the Inter-State transmission system ; and
 - Be responsible for carrying out real time operations for grid control and despatch of electricity within the region through secure and economic operation of the regional grid in accordance with the Grid Standards and the Grid Code.
- 4) The Regional Load Despatch Centre may give such directions and exercise such operations as supervision and control as may be required for ensuring stability of grid operations and for achieving the maximum economy and efficiency in the operation of the power system in the region under its control.

- 5) Every licensee, generating company, generating station, substation and any other person connected with the operation of the power system shall comply with the directions issued by the Regional Load Despatch Centers.
- 6) All directions issued by the Regional Load Despatch Centers to any transmission licensee of State transmission lines or any other licensee of the State or generating company (other than those connected to inter-State transmission system) or substation in the State shall be issued through the State Load Despatch Centre and the State Load Despatch Centers shall ensure that such directions are duly complied with by the licensee or generating company or sub-station.
- 7) If any dispute arises with reference to the quality of electricity or safe, secure and integrated operation of the regional grid or in relation to any direction given by the Regional Load Despatch Centre, it shall be referred to Central Commission for decision. However, pending the decision of the Central Commission, the directions of the Regional Load Despatch Centre shall be complied with by the State Load Despatch Centre or the licensee or the generating company, as the case may be.

The following are contemplated as exclusive functions of RLDCs

- System operation and control including inter-state transfer of power, covering contingency analysis and operational planning on real time basis;
- Scheduling / re-scheduling of generation;
- System restoration following grid disturbances;
- Metering and data collection;
- Compiling and furnishing data pertaining to system operation;
- Operation of regional UI pool account, regional reactive energy account and Congestion Charge Account, provided that such functions will be undertaken by any entity(ies) other than RLDCs if the Commission so directs.
- Operation of ancillary services

In cases of Short-term Open access, bilateral transaction in Inter-state Transmission, the Regional Load Despatch Centre of the region where point of drawl of electricity is situated, shall be the nodal agency for the short-term open access. The procedure and modalities in regard to short-term Open Access shall be in accordance with the Central Electricity Regulatory Commission (Open Access in Inter-state Transmission) Regulations, 2008, as amended from time to time.

6.2.1.3 REGIONAL POWER COMMITTEES (RPC)

In accordance with the Electricity Act, 2003, RPCs have been constituted by the Central Government for the specified Region(s) for facilitating the integrated operation of the power system in the Region. The Secretariat of the RPC is headed by the Member Secretary, who is appointed by the Central Electricity Authority (CEA), together with the other staff for the RPC Secretariat. Under section 29(4) of the Electricity Act, 2003, the Regional Power Committee in the region may, from time to time, agree on matters concerning the stability and smooth operation of the integrated grid and economy and efficiency in the operation of the power system in that region.

Functions of RPCs:

- a) To undertake Regional Level operation analysis for improving grid performance.
- b) To facilitate inter-state/inter-regional transfer of power.
- c) To facilitate all functions of planning relating to inter-state/ intrastate transmission system with CTU/STU.
- d) To coordinate planning of maintenance of generating machines of various generating companies of the region including those of interstate generating companies supplying electricity to the Region on annual basis and also to undertake review of maintenance programmed on monthly basis.
- e) To undertake planning of outage of transmission system on annual / monthly basis.
- f) To undertake operational planning studies including protection studies for stable operation of the grid.
- g) To undertake planning for maintaining proper voltages through review of reactive compensation requirement through system study committee and monitoring of installed capacitors.
- h) To evolve consensus on all issues relating to economy and efficiency in the operation of power system in the region.

The decisions of RPC, arrived at by consensus regarding operation of the regional grid and scheduling and despatch of electricity, if not inconsistent with the provisions of IEGC / CERC Regulations, shall be followed by the concerned RLDC/SLDC/CTU/STU and Users, subject to directions of the Central Commission, if any.

Member Secretary, RPC shall certify transmission system availability factor for regional AC and HVDC transmission systems separately for the purpose of payment of transmission charges:

RPC Secretariat or any other person as notified by the Commission from time to time, shall prepare monthly Regional Energy Account (REA), weekly unscheduled interchange account, reactive energy account ,and congestion charge account, based on data provided by RLDC and renewable regulatory charge account based on data provided by SLDC/RLDC of the State/Region in which the wind generator is located and any other charges specified by the Commission for the purpose of billing and payments of various charges .

6.2.1.4 CENTRAL TRANSMISSION UTILITY

In accordance with the section 38 of Electricity Act, 2003, the functions of the Central Transmission Utility (CTU) shall be –

(1)

- a) To undertake transmission of electricity through inter-State transmission system;
- b) To discharge all functions of planning and co-ordination relating to inter-State Transmission system with
 - State Transmission Utilities
 - Central Government;
 - State Governments;

- Generating companies;
 - Regional Power Committees;
 - Authority;
 - Licensees;
 - Any other person notified by the Central Government in this behalf;
- a) to ensure development of an efficient, co-ordinated and economical system of inter-State transmission lines for smooth flow of electricity from generating stations to the load centers;
 - b) to provide non-discriminatory open access to its transmission system for use by any licensee or generating company on payment of the transmission charges; or any consumer and when such open access is provided by the State Commission under sub-section (2) of section 42 of the Act, on payment of the transmission charges and a surcharge thereon, as may be specified by the Central Commission.
- (2) Until a Government company or authority or corporation is notified by the Central Government, the Central Transmission Utility shall operate the Regional Load Despatch Centre.

CTU shall not engage in the business of generation of electricity or trading in electricity.

In case of Inter-state Transmission System, Central Transmission Utility shall be the nodal agency for the connectivity, long-term access and medium-term open access. The procedure formulated by CTU and approved by CERC and modalities in regard to connectivity, long-term access and medium-term open access shall be in accordance with the Central Electricity Regulatory Commission (Grant of Connectivity, Long-term Access and Medium-term Open Access in inter-State Transmission and related matters) Regulations, 2009, as amended from time to time.

6.2.1.5 CENTRAL ELECTRICITY AUTHORITY:

According to the section 73 of Electricity Act, 2003, the functions of CEA as relevant to IEGC are as under:

- (1)
 - i) CEA shall formulate short-term and perspective plans for development of the electricity system and co-ordinate the activities of the planning agencies for the optimal utilization of resources to sub-serve the interests of the national economy and to provide reliable and affordable electricity to all consumers.
 - ii) to specify the technical standards for construction of electrical plants, electric lines and connectivity to the grid ;
 - iii) to specify the safety requirements for construction, operation and maintenance of electrical plants and electric lines;
 - iv) to specify the Grid Standards for operation and maintenance of transmission lines;
 - v) to specify the conditions for installation of meters for transmission and supply of electricity.
 - vi) to promote and assist in the timely completion of schemes and projects for improving and augmenting the electricity system;

- vii) to collect and record the data concerning the generation, transmission, trading, distribution and utilization of electricity and carry out studies relating to cost, efficiency, competitiveness and such like matters;
 - viii) to carry out, or cause to be carried out, any Investigation for the purposes of generating or transmitting or distributing electricity.
- (2) CEA shall prepare a National Electricity Plan in accordance with the National Electricity Policy published by the Central Government under the provisions of section 3(1) of Electricity Act, 2003. The CEA shall notify the National Electricity Plan once in five years.

6.2.1.6 STATE LOAD DESPATCH CENTRE

In accordance with section 32 of Electricity Act, 2003, the State Load Despatch Centre (SLDC) shall have following functions:

- 1) The State Load Despatch Centre shall be the apex body to ensure integrated operation of the power system in a State.
- 2) The State Load Despatch Centre shall:
 - a) be responsible for optimum scheduling and despatch of electricity within a State, in accordance with the contracts entered into with the licensees or the generating companies operating in that State;
 - b) monitor grid operations;
 - c) keep accounts of the quantity of electricity transmitted through the State grid;
 - d) exercise supervision and control over the intra-State transmission system;
 - e) be responsible for carrying out real time operations for grid control and despatch of electricity within the State through secure and economic operation of the State grid in accordance with the Grid Standards and the State Grid Code.

In accordance with section 33 of the Electricity Act, 2003, the State Load Despatch Centre may give such directions and exercise such supervision and control as may be required for ensuring the integrated grid operations and for achieving the maximum economy and efficiency in the operation of power system in that State. Every licensee, generating company, generating station, sub-station and any other person connected with the operation of the power system shall comply with the directions issued by the State Load Despatch Centre under subsection (1) of Section 33 of the Electricity Act, 2003.

The State Load Despatch Centre shall comply with the directions of the Regional Load Despatch Centre. .

In case of inter-state bilateral and collective short-term open access transactions having a state utility or an intra-state entity as a buyer or a seller, SLDC shall accord concurrence or no objection or a prior standing clearance, as the case may be, in accordance with the Central Electricity Regulatory Commission (Open Access in inter-state Transmission) Regulations, 2008, amended from time to time.

6.2.1.7 STATE TRANSMISSION UTILITY

Section 39 of the Electricity Act, 2003, outlines that the functions of the State Transmission Utility (STU) shall be:

(1)

- a) to undertake transmission of electricity through intra-State transmission system;
- b) to discharge all functions of planning and co-ordination relating to intra-state transmission system with
 - i) Central Transmission Utility;
 - ii) State Government;
 - iii) Generating companies;
 - iv) Regional Power Committees;
 - v) Authority;
 - vi) Licensees;
 - vii) any other person notified by the State in this behalf;
- c) to ensure development of an efficient, coordinated and economical system of intra-State transmission lines for smooth flow of electricity from a generating station to the load centers;
- d) to provide non-discriminatory open access to its transmission system for use by any licensee or generating company on payment of the transmission charges; or any consumer as and when such open access is provided by the State Commission under sub-section (2) of section 42 of the Act, on payment of the transmission charges and a surcharge thereon, as may be specified by the State Commission.

(2) Until a Government company or any authority or corporation is notified by the State Government, the State Transmission Utility shall operate the State Load Despatch Centre.

6.2.2 AVAILABILITY BASED TARIFF (ABT)

Prior to 2002, operation of regional grids in India was in a deplorable state, with frequency fluctuations from below 48.0 Hz to above 52.0 Hz, voltages going down to 80% even at 400 kV level, due to large deviations from schedules by the utilities, and perpetual operational & commercial disputes.

6.2.2.1 The main reasons were:

- i) shortage and poor availability of generating capacity, which necessitated extensive load curtailment particularly during peak-load hours,
- ii) reluctance to back down generating stations during off-peak hours, due to faulty bulk power tariff structure which encouraged the utilities to go on generating,
- iii) inadequate reactive power compensation,
- iv) blocked governors on most generating units,
- v) gaps in understanding of the subject, and

- vi) lack of consensus on how to tackle the problems.

6.2.2.2 During 2002-03, a new system of tariff called Availability Based Tariff (ABT) was introduced at the regional level. The Availability Based Tariff is a combination of frequency based Tariff (Drawls (Vs) frequency) and Reactive power based Tariff(Reactive Power (Vs) Voltage). The components are given as follows

(A) Three parts of active power of ABT are

- Capacity charge for payment of fixed cost, linked to plant availability and shared by the States in proportion to their percentage allocation in the Central station,
- Energy charge, for payment of the variable cost, basically the fuel cost for supply of scheduled energy, and
- Unscheduled Interchange (UI) to account for deviations from schedule. The third part (UI) has frequency linked pricing, with the UI rate varying from zero at a frequency of 50.5 Hz and above, to a ceiling at a frequency of 49.0 Hz and below. The rates of UI will be varied according to prevailing grid system conditions and as fixed by CERC.

(B) The reactive power part of ABT is

- Payable/receivable for reactive power draws/injections at the rate of 5 paise per KVARh for voltages below 97 % (at the 400kV interconnectivity point).
- Receivable/payable for reactive power draws/ injections at the Rate of 4 paise per KVARh for voltages above 103 % (at the 400kV interconnectivity point).
- Similarly the rates of reactive power will be varied according to prevailing grid System conditions and as fixed by CERC.

6.2.2.3 Un-scheduled Interchange:

Para 21(ii) of CERC's Open access regulation No. L- 7/25(4)- 2003 dt.30-01-04, stipulates That "A separate bill for UI charges shall be issued to the direct customers and in case of embedded customers, a composite UI bill for the State as a whole shall be issued, the segregation for which shall be done at the State level."

Further CERC's Open access regulation issued subsequently on Inter-State transmission vide No. L-105(121)/2007- CERC dt.25-1-08 provides the following in respect of UI charges (vide para-20)

(1) All transactions of State utilities and for intra-state entities scheduled by the Nodal Agency under these regulations, shall be accounted for and included in the respective day ahead net interchange schedules of the concerned regional entity issued by the Regional Load Despatch Center.

(2) Based on net metering on the periphery of each regional entity, composite UI accounts shall be issued for each regional entity on a weekly cycle and transaction wise UI accounting for intra-state entities shall not be carried out at the regional level.

(3) The State utility designated for the purpose of collection/disbursement of UI charges from/to intra-state entities, shall be responsible for timely payment of the State's composite dues to the regional UI pool account.

(4) Any mis-match between the scheduled and actual drawl at drawl points and scheduled and actual injection at injection points for the intra-state entities shall be determined by the concerned state load dispatch center and covered in the intra-state UI accounting scheme.

(5) Unless specified otherwise by the concerned State Commission, UI rate for intra-state entity shall be 105% (for over-drawls or under generation) and 95% (for under-drawls or over-generation) of UI rate at the periphery of regional entity.

In view of the above, the designated state utility (Transco/APPCC/SLDC) , as authorized by APERC need to calculate and levy UI charges for any mis-match between scheduled and actual injection at injection points of embedded generators within the state who are supplying to other states as per inter-state open access regulations.

In case of Generators having multiple transactions, i.e. part of generation supplied to APPCC as per PPA, part supplied to intra-state consumers (scheduled consumers of AP Discoms) and also supplying to other STUs through traders as well as through power exchanges as per inter-state open access regulations; APTransco being a STU has to calculate and levy UI charges on the Generator for any mis-match between scheduled and actual generation at injection points for all inter-state transactions.

6.2.3 UI Charges Calculation methodologies

6.2.3. (1) OA Generators

Let

Actual generation = A

Total schedule of all inter-state OA transactions (E sch.) = (Inter-state OA through traders + through power exchanges)

Scheduled power to APPCC = X sch.

Third party consumer allocation in 15 minutes block T = (X% of A) where A is actual generation

Balance actual generation B = (Actual generation A – T)

Schedule of intra-state OA consumers = I sch.

Case A: An in-state generator connected to APTransco/Discoms Network and having inter-state OA transactions to State A, State B and power exchange and also supply power to APPCC

UI of the generator = Actual generation A – (X sch + E sch)

Generator must give the Schedules and Actuals of APPCC power to SLDC in 15 minutes block wise. UI rates applicable for calculation of UI charges at the prevailing frequency shall be 105% (under generation) or 95% (over generation) of the UI rate.

Case B: An in-state generator connected to APTransco/Discoms Network having inter-state OA transactions and power exchange and also third party wheeling to a consumer in the state (within certain percentage of actual generation from the generator)

UI of Generator for inter-state transactions = [Actual generation A – (T+ E sch.)]

Generator must give the Schedules and Actuals of APPCC power to SLDC in 15 minutes block wise. UI rates applicable for calculation of UI charges at the prevailing frequency shall be 105% (under generation) or 95% (over generation) of the UI rate.

Note: If the generation becomes nil, then third party consumer allocation becomes zero and UI need to be calculated for entire loss of generation. Discoms supply power to third party consumer by drawing power at UI rates from the grid.

Case C: An in-state generator connected to APTransco/Discoms Network having inter-state OA transactions, intra-state OA transactions, power exchange and also third party wheeling to a consumer in the state (with certain percentage of actual generation from the generator)

UI of Generator for inter-state transactions = [Balance generation B – (I sch + E sch)]

Generator should give the Schedules and Actuals of wheeling power and Schedules and Actuals of APPCC power to SLDC in 15 minutes block wise. UI rates applicable for calculation of UI charges at the prevailing frequency to be at 105% (under generation) or 95% (over generation) of the UI rate.

Note: If the generation becomes nil, then third party consumer allocation becomes zero and UI for inter-state intra-state transaction is (Zero – E sch.) with 105% of corresponding rates at prevailing frequency.

Case D: An in-state generator connected to APTransco having PPA for a certain percentage of plant capacity with APPCC and wishes to trade the balance capacity to inter-state / intra-state OA customers and also to power exchanges.

Actual generation = A

Generation allocation to APPCC as per PPA, in each 15 minutes block P = (X% of A)

Balance actual generation B = (Actual generation A - P)

UI of generator for inter-state = [Balance generation B – (I sch + E sch)]

Generator should submit Schedules and Actual of PPA/wheeling power and Schedules and Actuals of APPCC power to SLDC in 15 minute block wise. UI rates applicable for calculation of UI charges at the prevailing frequency to be 105% (under generation) or 95% (over generation of the UI rate.)

Note: If the generation becomes nil, then third party consumer allocation becomes zero and UI for inter-state transaction is (Zero – E sch) with 105% of corresponding rates at prevailing frequency.

6.2.3.(2) OA Consumers

AP Discom Scheduled Consumer: Drawing power under inter-state open access and draws power from Discom on a regular basis through a service connection and also have some allocation from a generator within the State simultaneously

Actual drawl by the consumer = A

Actual energy allocation from third party generator = T

Inter-state transaction = I sch

Case A: When Discom does not impose power holiday/restrictions

Drawls from Discom = [Actual drawl A – (T + I sch)]

Note (i): Since the consumer is a scheduled consumer of Discom and is also having long term contract with third party state generator, energy allocation from the third party generator is taken as first charge and the energy allocated from inter-state transaction is treated as second charge.

Open access energy and excess energy drawn from Discom will be calculated by EBC and communicated to the HT billing units of concerned Discoms to raise energy and demand charges as per Discom tariff order.

Note (ii): State generator shall have ABT compatible meter.

Note (iii): Merchant plant operates at inter-state level and will not be confined to intra-state operations alone.

Case B: When Discom impose power holiday/restrictions

UI energy drawl = {Actual drawl A – (T + I sch)}

Note (i): since OA consumer is having long term contract with third party state generator, the energy allocation from third party generator is taken as first charge. The UI fluctuations are to be worked out under inter-state short-term open access transactions at UI rates for any mismatch between scheduled and actual drawl at drawl points.

Note (ii): In this case state third party generator /consumer should have ABT compatible meter.

Note (iii): Third party generator has to submit Schedules and actuals of PPA/Wheeling power to SLDC in 15minutes block wise.

6.2.3.3 General principles of UI charges applicable for OA users availing inter-state open access as per CERC regulations:

- i. All the UI calculations are done on 15 minute basis

ii. In case of missing MRI data for certain periods, average computed value is considered. (arrived from field data)

iii. Any generation up to 105% of the declared capacity in a time block and averaging up to 101% of the average declared capacity over a day shall not be considered as gaming.

iv. The UI charges and additional charges for inter/intra-state entities shall be as per prevailing CERC regulations and shall change from time to time

v. The open access generator requires to give details of all transactions/arrangements for sale of its power to EBC.

The results of ABT introduction (along with certain other measures) have been most dramatic. The frequency of the regional grids now remains in the range of 49.0 - 50.5 Hz for most of the time. Many other benefits have also come about, such as

- Generation being maximized during peak-load hours: more consumer load being met.
- Generation being backed down during off-peak hours and according to merit-order.
- Over-drawls being curtailed by utilities, on their own.
- Voltages improved; Transmission losses reduced; Transmission capacity increased
- Automatic under-frequency load shedding restored : grid security improved
- Power plants performance improved, trippings and long-term damage reduced
- Commercial and operational disputes resolved
- Autonomy to utilities (within the frame-work).
- Shares/allocations now have a meaning
- Framework for bilateral trading established at Inter-State level.
- Formal scheduling process in place.
- Optimized use of hydro resources, including pumped storage.
- Common pricing signal through frequency: true free-market in electricity established
- IPPs being scheduled according to their tariff

6.2.4 INTER-STATE TRANSMISSION NETWORK -SHARING OF TRANSMISSION CHARGES & LOSSES

Since 1992, Transmission charges for Interstate system have been paid by the beneficiaries on a fixed basis. Annual charges for each transmission system are computed by apportioning the charges among the beneficiaries in proportion to their respective aggregate MW allocation in Central generating station. This concept of sharing of the charges is not sensitive to distance, direction and location of load or generation. Thus the concept proved to be illogical.

Central Electricity Regulatory Commission (CERC) has taken up the task of determining the tariff for interstate transmission of electricity to facilitate cost effective transmission of power

across the region. Thus CERC vide ref. No. L-1/44/2010-CERC, dt.15th June 2010 notified CERC (Sharing of Inter-State transmission Charges and Losses) Regulations 2010.

Within this regulation, the tariff mechanism would be sensitive to distance, direction and quantum of power. Transmission charges under this frame work can be determined on MW per circuit Kilometer basis to get the transmission system users to share the total transmission cost in proportion to their respective utilization of the transmission system. This generates reasonable revenue to the transmission system owners to enable repayment of loans, payment of interest, returns on equity, reimbursement of O&M cost, contingencies etc. This will also induce the transmission system owner to enhance the availability of the system by minimizing the outages to keep it ready for utilization by beneficiaries to maximize its revenue.

These regulations will apply to all designated ISTS customers, Inter State Transmission Licensees, NLDC, RLDCs, SLDCs and RPCs. These regulations will come into force from 1st January 2011 and will remain in force for a period of 5 years unless modified by the Commission.

Definitions:

Application Period means the period of application of the charges determined as per these regulations and shall ordinarily be 12 (twelve) months coinciding with the Financial Year, which shall be further divided into multiple blocks of months representing the seasonal conditions and peak and other than peak conditions;

Approved Injection means the injection in MW vetted by Implementing Agency (IA) for the Designated ISTS Customer for each representative block of months, peak and other than peak scenarios at the ex-bus of the generator or any other injection point of the Designated ISTS Customer into the ISTS, and determined based on the generation data submitted by the Designated ISTS Customers incorporating total injection into the grid, considering the long term and medium term contracts;

Approved Additional Medium Term Injection means the additional injection, as per the Medium Term Open Access approved by CTU after submission of data to NLDC by the Designated ISTS Customer over and above the Approved Injection for the Designated ISTS Customer for each representative block of months, peak and off-peak scenarios at the ex-bus of the generator or any other injection point of the Designated ISTS Customer into the ISTS;

Approved Short Term Injection means the injection, as per the Short Term Open Access approved by RLDC / NLDC such injection including all injections cleared on the power exchange;

Approved Withdrawal means the simultaneous withdrawal in MW vetted by Implementing Agency for any Designated ISTS Customer in a control area aggregated from all nodes of ISTS to which Designated ISTS Customer is connected for each representative block of months, peak and other than peak scenarios at the interface point with ISTS, and where the Approved Withdrawal shall be determined based on the demand data submitted by the Designated ISTS Customers, incorporating long term and medium term transactions;

Approved Additional Medium Term Withdrawal means additional withdrawal, as per the Medium Term Open Access approved by CTU after submission of data to NLDC by the Designated ISTS Customer over and above Approved Withdrawal for Designated ISTS Customer s aggregated from all nodes of ISTS for each representative block of months, peak and other than peak scenarios at the interface point with the ISTS;

Basic Network shall mean the power system of the country at voltage levels 132 kV and above and 110 kV where generators are connected, HVDC transmission network and all Generator and loads connected to it;

Designated ISTS Customers ('DIC's) means the users of any segments/elements of the ISTS and shall include all generators, state transmission utilities, SEBs or load serving entities directly connected to the ISTS including Bulk Consumer and any other entity/person;

Hybrid Methodology shall mean the hybrid of the Marginal Participation Method and the Average Participation method detailed in Chapter-3 of the regulations and in Annexure - I

Implementing Agency (IA) shall mean the agency designated by the Commission to undertake the estimation of allocation of transmission charges and transmission losses at various nodes/zones for the Application Period along with other functions as per [Chapter-4, Chapter-5, Chapter-6, Chapter-7 and Chapter-8] of the regulations;

Loss Allocation Factor of a bus measures the losses attributed to that node.

Point of Connection (PoC) Charging Method shall mean the methodology of computation of sharing of ISTS charges and losses amongst Designated ISTS Customers, which depends on the location of the node.

Point of Connection (PoC) transmission charges are the nodal / zonal charges determined using the Point of Connection charging method.

Yearly Transmission Charge (YTC) means the Annual Transmission Charges for existing lines determined by the Commission in accordance with the Terms and Conditions of Tariff Regulations or adopted in the case of tariff based competitive bidding in accordance with the Transmission License Regulations as specified by the Commission and as in force from time to time and for new lines based on benchmarked capital costs.

6.2.4.1 The transmission tariff design thus has two distinct aspects as follows:

- a) Determining the total charges that the transmission system owner would get.
- b) How the total transmission charges are to be shared by the customers/beneficiaries of the transmission system.

Determining the total transmission charges of a system:

Aspects considered are:

- 1) Irrationality of following fixed charge method irrespective of quantum of power flow.
- 2) Providing incentive to the owner of the system for minimizing the outages thus keeping the annual availability of the system above the specified norms.
- 3) Total charges payable to the transmission owners are independent of power flows and system owner is assured of the returns and are determined according to the norms of CERC both interstate system and for future addition/augmentation

Sharing of transmission charges for regional system by beneficiaries/customers:

To arrive at Transmission charges sharing the following are considered

- a) Present system of levy of transmission charges on pro-rata basis to MW allocation to CGS is continued for the existing ISTS.
- b) 400 KV line of ISTS are beneficial to all the beneficiaries
- c) The Step down transformers on downstream system would serve the local beneficiary except where ISTS substation (220 KV) supplying power to different beneficiaries.
- d) Sharing of transmission charges for future additions/augmentation.
- e) Sharing of transmission charges for inter regional lines.

6.2.4.2 Transmission loss allocation:

Transmission losses are unavoidable over a given transmission system and keep varying with time depending on power flows, voltage profile, reactive flows etc. Reduction of transmission loss by the transmission system owner can be accomplished by enhancing the availability of transmission elements and by reducing their outages. The beneficiaries/users of the transmission system can contribute to reduction of transmission losses by reducing drawl of reactive power, thereby reducing reactive flows and improving the voltage profile. This is induced in the scheme by introduction of reactive charges.

The tariff policy stipulates loss allocation on the basis of average losses arrived at appropriately considering the distance and directional sensitivity.

Principle of sharing of ISTS charges and losses:

- i) Based on the yearly transmission charges (YTC) of ISTS transmission licensees and transmission losses in the ISTS network, the implementation agency shall compute the point of connection charges and loss allocation factor for all the Designated Inter State Customers (DICs)
 - a) Using load flow based methods and
 - b) Based on the point of connection charging method

- ii) Sharing the ISTS charges and losses amongst the designated ISTS customers is accomplished by applying hybrid methodology.

Hybrid methodology is the combination of average participation and marginal participation methods.

Utilization of the network is generally determined in terms of either average utilization or marginal utilization of the transmission assets. Pricing of transmission services based on average or marginal utilization of the network branches is known as Average Participation or Marginal Participation method respectively.

MARGINAL PARTICIPATION METHOD

Any usage based methodology tries to identify how much of the power that flows through each of the lines in the system is due to the existence of a certain network user, in order to charge it according to the adopted measure of utilization. To do so, the marginal participation method analyzes how the flows in the grid are modified when minor changes are introduced in the production or consumption of agent i . For each of the considered scenarios (for each season) the procedure can be considered as follows:

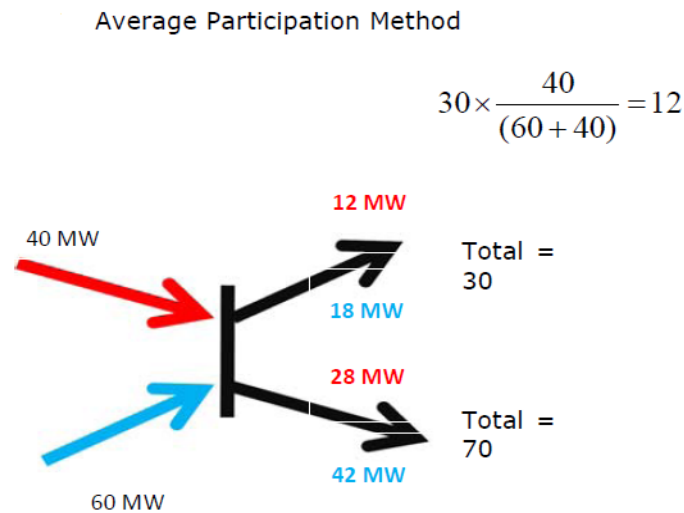
- a) Marginal Participation sensitivities A_{ij} are obtained that represent how the flow in line j changes when the injection in bus i is increased by 1 MW. The increase in 1 MW has to be compensated by a corresponding increase in load or generation at some other bus or buses – called the slack bus (es).
- b) Total participations for each agent are calculated as a product of its net injection by its marginal participation. If net injection is considered positive for generators and negative for demands, the total participation of any agent i in line j is $A_{ij}(\text{generation}_i - \text{demand}_i)$.
- c) The cost of each line is allocated pro-rata to the different agents according to their total participation in the corresponding line.

AVERAGE PARTICIPATION (AP) METHOD

The method of average participation works as follows:

1. For every individual generator i , a number of physical paths are constructed, starting at the node where the producer injects the power into the grid, following through the lines, as the power moves through the network, and finally reaching several of the loads in the system.
2. Similar calculations are also performed for the demands, tracing upstream the energy consumed by a certain user, from the demand bus until some generators are reached. One such physical path is constructed for every producer and for every demand.
3. In order to create such physical paths, a basic criterion is adopted: A rule allocates responsibility for the costs of actual flows on various lines from sources to sinks according to a simple allocation rule, in which inflows are distributed proportionally between the outflows. The main attractions of tracing are that the rule has some theoretical backing based and does not require the choice of a slack node. The drawbacks of tracing are first that aggregation of users can lead to counterintuitive results: if generation and load or different nodes are aggregated, then they are

exposed to different tariffs. Second, the choice of the allocation rule is decisive but apparently arbitrary.



The average participation method calculates the participation of agent i by tracking the influence in the network of a transit between node i and several ending nodes that result from the rules that conform the algorithm. In the example above, based on flow in the outgoing lines, the injection of 40MW (through the red line) is allocated to the outgoing lines in the proportion of the transfers from the two outgoing lines. Thus the outgoing line that transfers 30 MW (i.e, 30% of the total transfer out of the bus) is allocated 30% of the 40 MW injection from the red line, i.e., 12 MW. Similar allocations are made for the other flows as well.

6.2.4.3 REASONS FOR ADOPTION OF THE HYBRID METHOD

The Marginal Participation method (with slight modifications to the above generic framework) has been implemented in various countries including United Kingdom, Norway (for transmission losses), Brazil, Columbia etc. There is however little international experience in the use of the Average Participation Method. Further in the Indian context the Hybrid Method – where the slack buses are selected by using the Average Participation Method and the burden of transmission charges or losses on each node computed using the Marginal Participation Method was found appropriate because:

The nodal transmission access charges in the AP method have a higher variance compared to the range of transmission access charges in the Hybrid method (Rs 2.98 – 17.75 lakh / MW), the range in the AP method (Rs. 2.79 – 53.61 lakh / MW) is much higher.

Further, since Hybrid method takes into account all the incidental flows – which is the reality of interconnected transmission networks – the Hybrid Method captures network utilization much better than the AP method, which simply traces the path of power from the origin to the sink(s) or vice-versa. Because of the ability of the Hybrid method to consider incidental flows, the method captures network ‘utilization’ better than AP method – which is one of the objectives of the NEP.

6.2.4.4 Mechanisms for sharing ISTS transmission charges.

The sharing of ISTS transmission charges between designated ISTS customers shall be computed for an application period (normally financial year) and shall be determined in advance and shall be subjected to periodic true up such that the yearly transmission charges of the ISTS licensees are fully and exactly recovered.

The Point of Connection transmission charges shall be computed in terms of Rupees per Megawatt per month. The amount to be recovered from any Designated ISTS Customer towards ISTS charges shall be computed on a monthly basis as per these regulations. The Point of Connection transmission charges for short term open access transactions shall be in terms of Rupees per MegaWatt per hour and shall be applicable for the duration of short term open access approved by the RLDC/NLDC.

6.2.4.5 Mechanism of sharing of ISTS losses:

- 1) The schedule of electricity of designated ISTS customers shall be adjusted to account for energy losses in the transmission system as estimated by the RLDC and SLDC concerned. The losses shall be apportioned based on the loss allocation factors determined using the hybrid methodology.
- 2) The applicable transmission losses for the ISTS shall be declared in advance and shall not be revised retrospectively

Process for sharing of transmission charges and losses:

The process to determine the allocation of transmission charges and losses shall be as below:

- i) The implementing agency shall collect the basic network data pertaining to the network elements and the generation and load at the various network nodes from all concerned entities including designated ISTS customers, transmission licensees, NLDC, RLDCs, SLDCs, RPCs.
- ii) Approved basic network, nodal generation and nodal demand data shall form the base for computation of marginal participation factors and loss allocation factors
- iii) The loss allocation factors shall be computed for each season using the hybrid method. The loss allocation factors shall be applied to the total losses computed as per the procedures developed by the NLDC under this regulation to attribute to each designated ISTS customer.

6.2.4.6 Determination of specific transmission charges applicable for a Designated ISTS Customer:

- 1) Based on the Yearly Transmission Charges determined by the Commission, the Implementing Agency shall determine the charges applicable to each Designated ISTS Customer for use of the ISTS to the extent of the Approved Withdrawal or Approved Injection in the ISTS. Each Designated ISTS Customer shall ensure that the forecast data of demand and injection for each season is furnished to the Implementing Agency as per the timelines described in these regulations for both peak and other than peak conditions as specified in Chapter 7 of these regulations;

- 2) In the event of a Designated ISTS Customer failing to provide its requisition for demand or injection for an Application Period, the last demand or injection forecast supplied by the Designated ISTS Customer and as adjusted by the Implementing Agency for Load Flow Analysis shall be deemed to be Approved Withdrawal or Approved Injection, as the case may be, for the Application Period;
- 3) The transmission charges for any month shall be determined as per Regulation 11 of these Regulations; Sharing of Inter State Transmission Charges and Losses Regulations, 2010
- 4) In case the metered MWs (ex-bus) of a power station or the aggregate demand of a Designated ISTS Customer exceeds, in any time block,
 - a) **In case of generators:** The Approved Injection + Approved Additional Medium Term Injection + Approved Short Term Injection or;
 - b) **In case of demand customers:** The Approved Withdrawal + Approved Additional Medium Term Withdrawal + Approved Short Term Demand,

Then for first 20% deviation in any time block, the Designated ISTS Customer shall be required to pay transmission charges for excess generation or demand at the same rate and beyond this limit, the Designated ISTS Customer shall be required to pay additional transmission charges which shall be 25% above the zonal Point of Connection charges determined for zone where the Designated ISTS Customer is physically located. Such additional charges shall not be charged to the generators in case of rescheduling of the planned maintenance program which is beyond the control of the generator and certified to be so by the appropriate RPC. Further, any payment on account of additional charges for deviation by the generator shall not be charged to its long term customer and shall be payable by the generator;

5) In the case of the Approved Withdrawal or Approved Injection not materializing either partly or fully for any reason whatsoever, the Designated ISTS Customer shall be obliged to pay the transmission charges allocated.

6) For Long Term customers availing supplies from inter-state generating stations, the charges payable by such generators for such Long Term supply shall be billed directly to the respective Long Term customers based on their share of capacity in such generating stations. Such mechanism shall be effective only after “commercial operation” of the generator. Till then, it shall be the responsibility of generator to pay these charges.

6.2.5 METERING CODE

In exercise of the powers conferred by sub-section (1) of section 55 and clause (e) of section 73 read with sub-section (2) of section 177 of Electricity Act, 2003, the Central Electricity Authority published a notification in the Govt. of India, Gazette dt.17th March 2006, communicating the regulations on installation and operation of meters called Central Electricity Authority (installation and Operation of Meters) Regulations, 2006 coming into force with effect from 17-3 2006.

Clause 2: Definitions of certain important terms in the regulations:

- Act means the Electricity Act, 2003;
- Accredited Test Laboratory means a test laboratory accredited by National Accreditation Board for Testing and Calibration Laboratories (NABL);
- Main Meter' means a meter, which would primarily be used for accounting and billing of electricity; and Check Meter means a meter, which shall be connected to the same core of the Current Transformer (CT) and Voltage Transformer (VT) to which main meter is connected and shall be used for accounting and billing of electricity in case of failure of main meter;
- Consumer Meter means a meter used for accounting and billing of electricity supplied to the consumer but excluding those consumers covered under Interface Meters;
- Energy Accounting and Audit Meters means meters used for accounting of the electricity to various segments of electrical system so as to carry out further analysis to determine the consumption and loss of energy therein over a specified time period;
- Interface Meter means a meter used for accounting and billing of electricity, connected at the point of interconnection between electrical systems of generating company, licensee and consumers, directly connected to the Inter-State Transmission System or Intra-State Transmission System who have to be covered under ABT and have been permitted open access by the Appropriate Commission;
- Standby Meter means a meter connected to CT and VT, other than those used for main meter and check meter and shall be used for accounting and billing of electricity in case of failure of both main meter and check meter;
- Time of the Day (TOD) Meter means a meter suitable for recording and indicating consumption of electricity during specified time periods of the day.

Clause 3: Applicability of regulations

- 1) These Regulations shall be applicable to meters installed and to be installed by all the generating companies and licensees who are engaged in the business of generation, transmission, trading, distribution, supply of electricity and to all categories of consumers.
- 2) After coming into force of these regulations, the provisions of the Indian Electricity Rules, 1956 relating to installation and operation of meters in this regard shall not be applicable.
- 3) These regulations provide for type, standards, ownership, location, accuracy class, installation, operation, testing and maintenance, access, sealing, safety, meter reading and recording, meter failure or discrepancies, anti tampering features, quality assurance, calibration and periodical testing of meters, additional meters and adoption of new technologies in respect of following meters for correct accounting, billing and audit of electricity:
 - i) Interface meter
 - ii) Consumer meter
 - iii) Energy accounting and audit Meter

Clause 4: Type of meters: All interface meters, consumer meters and energy accounting and audit meters shall be of static type. The meters not complying with these regulations shall be replaced by the licensee on his own or on request of the consumer. The meters may also be

replaced as per the regulations or directions of the Appropriate Commission or pursuant to the reforms programme of the Appropriate Government.

Clause 5: Standards: All meters, shall comply with the relevant standards of Bureau of Indian Standards (BIS), the relevant British Standards (BS), International Electro-technical Commission (IEC) Standards, or any other equivalent Standard: The meters shall conform to the standards on 'Installation and Operation of Meters' as specified in Schedule annexed to these regulations and as amended from time to time.

Clause 6: Ownership of meters

(1) Interface meters

- a) All interface meters installed at the points of interconnection with Inter-State Transmission System (ISTS) for the purpose of electricity accounting and billing shall be owned by Central Transmission Utility (CTU).
- b) All interface meters installed at the points of interconnection with Intra-State Transmission System excluding the system covered under sub-clause (a) above for the purpose of electricity accounting and billing shall be owned by State Transmission Utility (STU).
- c) All interface meters installed at the points of inter connection between the two licensees excluding those covered under sub-clauses (a) and (b) above for the purpose of electricity accounting and billing shall be owned by respective licensee of each end.
- d) All interface meters installed at the points of inter connection for the purpose of electricity accounting and billing not covered under sub-clauses (a), (b) and (c) above shall be owned by supplier of electricity.

(2) Consumer meters

- a) Consumer meters shall generally be owned by the licensee.
- b) If any consumer elects to purchase a meter, the same may be purchased by him. Meter purchased by the consumer shall be tested, installed and sealed by the licensee. The consumer shall claim the meter purchased by him as his asset, only after it is permanently removed from the system of the licensee.
- c) All consumer meters shall bear BIS mark, meet the requirements of these regulations and have additional features as approved by the Appropriate Commission or pursuant to the reforms programme of the Appropriate Government. To facilitate this, the licensee shall provide a list of makes and models of the meters.

(3) Energy accounting and audit meters

Energy accounting and audit meters shall be owned by the generating company or licensee, as the case may be.

Clause 7: Locations of meters:

The location of interface meters, consumer meters and energy accounting and audit meters shall be as per the Table given below:

Provided that the generating companies or licensees may install meters at additional locations in their systems depending upon the requirement.

Sl. No.	Stages	Main meter	Check meter	Standby meter
A	Generating Station	On all outgoing	On all outgoing	(i) High voltage (HV) side of generator transformers (ii) High voltage side of all station auxiliary transformers

Explanation: Location of main, check and standby meters installed at the existing generating stations shall not be changed unless permitted by the authority

B	Transmission and Distribution System	At one end of the line between the substations of the same licensee, and at both ends of the line between substations of two different licensees. Meters at both ends shall be considered as main meters for respective licensees	–	There shall be no separate standby meter. Meter installed at the other end of the line in case of two different licensees shall work as standby meter.
C	Inter connecting Transformer (ICT)	High Voltage (HV) side ICT	–	Low Voltage (LV) side of ICT
D	Consumer directly connected to the Interstate transmission system or intra state transmission who have to be covered under ABT and have been permitted open access by the appropriate commission or any other system not covered above	As decided by the Appropriate Commission		

(a) Interface Meters

- i) Consumers who have interconnection with the Inter-State Transmission System or Intra-State Transmission System and have been permitted open access by the Appropriate Commission shall be provided with interface meters.
- ii) For consumers connected to distribution system and permitted open access, provision of interface meters may be made as per the regulations or directions of the Appropriate Commission.

- iii) The scheme for location of interface meters shall be submitted to the CTU or the STU or the licensee by owner of the meter in advance, before the installation of the scheme.

(b) Consumer meters

- i) The consumer meter shall be installed by the licensee either at consumer premises or outside the consumer premises:

Provided that where the licensee installs the meter outside the premises of the consumer, then the licensee shall provide real time display unit at the consumer premises for his information to indicate the electricity consumed by the consumer:

Provided further that for the billing purpose, reading of consumer meter and not the display unit shall be taken into account.

- ii) In the event the Appropriate Commission allows supply of electricity directly from a generating company to consumer on a dedicated transmission system, the location of the meter will be as per their mutual agreement.

(c) Energy accounting and audit meters

Energy accounting and audit meters shall be installed at such locations so as to facilitate to account for the energy generated, transmitted, distributed and consumed in the various segments of the power system and the energy loss. The location of these meters shall be as under:

i) Generating Stations

- 1) at the stator terminal of the generator;
- 2) on HV and LV sides of the station and the unit auxiliary transformers;
- 3) on feeders to various auxiliaries.

ii) Transmission System

All incoming and out going feeders (If the interface meters do not exist).

iii) Distribution System

- 1) all incoming feeders (11 kV and above);
- 2) all outgoing feeders (11 kV and above);
- 3) Sub-Station Transformer including Distribution Transformer – Licensee may provide the meter on primary or secondary side or both sides depending upon the requirement for energy accounting and audit.

Clause 8: Accuracy Class of meters. Every meter shall meet the requirement of accuracy class as specified in the standards given in the Schedule.

Clause 9: Installation of meters

- 1) Generating company or licensee, as the case may be, shall examine, test and regulate all meters before installation and only correct meters shall be installed.
- 2) The meter shall be installed at locations, which are easily accessible for installation, testing, commissioning, reading, recording and maintenance. The place of installation of meter shall be such that minimum inconvenience and disruptions are caused to the site owners and the concerned organizations.
- 3) In case of single phase meters, the consumer shall ensure that there is no common neutral or phase or looping of neutral or phase of two or more consumers on consumers' side wiring. If such common neutral or phase or looping of neutral or phase comes to the notice of the licensee, it shall suitably inform the consumer through installation report or regular electricity bills or meter test report as applicable.
- 4) Consumer shall install the Earth Leakage Protective Device (ELPD) in accordance with the provisions of the rules or regulations in this regard.
- 5) If the earth leakage indication is displayed in the meter the licensees shall suitably inform the consumer through installation report or regular electricity bills or meter test report as applicable.
- 6) In case CTs and VTs form part of the meters, the meter shall be installed as near the instrument transformers as possible to reduce the potential drop in the secondary leads.

Clause 10: Operation, Testing and Maintenance of meters: The operation, testing and maintenance of all types of meters shall be carried out by the generating company or the licensee, as the case may be.

Clause 11: Access to meter: The owner of the premises where, the meter is installed shall provide access to the authorized representative(s) of the licensee for installation, testing, commissioning, reading and recording and maintenance of meters.

Clause 12: Sealing of meters

(1) Sealing Arrangements

- a) All meters shall be sealed by the manufacturer at its works. In addition to the seal provided by the manufacturer at its works, the sealing of all meters shall be done as follows at various sealing points as per the standards given in the Schedule:
 - Sealing of interface meters, shall also be done by both the supplier and the buyer
 - Sealing of consumer meters shall be done by the licensee.
 - Sealing of energy accounting and audit meters shall be done by the licensee or generating company as the case may be.
- b) A tracking and recording software for all new seals shall be provided by the manufacturer of the meter so as to track total movement of seals starting from

manufacturing, procurement, storage, record keeping, installation, series of inspections, removal and disposal.

- c) Seal shall be unique for each utility and name or logo of the utility shall be clearly visible on the seals.
- d) Only the patented seals (seal from the manufacturer who has official right to manufacture the seal) shall be used.
- e) Polycarbonate or acrylic seals or plastic seals or holographic seals or any other superior seal shall be used.
- f) Lead seals shall not be used in the new meters. Old lead seals shall be replaced by new seals in a phased manner and the time frame of the same shall be submitted by the licensee to the Appropriate Commission for approval.

(2) Removal of seals from meters

- a) Interface meters: Whenever seals of the interface meters have to be removed for any reason, advance notice shall be given to other party for witnessing the removal of seals and resealing of the interface meter. The breaking and re-sealing of the meters shall be recorded by the party, who carried out the work, in the meter register, mentioning the date of removal and resealing, serial numbers of the broken and new seals and the reason for removal of seals.
- b) Consumer meters: Seal of the consumer meter shall be removed only by the licensee. No consumer shall tamper with, break or remove the seal under any circumstances. Any tampering, breaking or removing the seal from the meter shall be dealt with as per relevant provisions of the Electricity Act 2003.
- c) Energy accounting and audit meters: Seal of the energy accounting and audit meter shall be removed only by the generating company or the licensee who owns the meter.

Clause 13: Safety of meters:

- 1) The supplier or buyer in whose premises the interface meters are installed shall be responsible for their safety.
- 2) The consumer shall, as far as circumstances permit, take precautions for the safety of the consumer meter installed in his premises belonging to the licensee.
- 3) Licensee shall be responsible for the safety of the consumer meter located outside the premises of the consumer and the consumer shall be responsible for the safety of the real time display unit installed by the licensee in consumer premises.
- 4) The generating company or the licensee who owns the energy accounting and audit meters shall be responsible for its safety.

Clause 14: Meter reading and recording:

- 1) Interface meters: It shall be the responsibility of the Appropriate Transmission Utility or the licensee to take down the meter reading and record the metered data, maintain database of all the information associated with the interface meters and verify the correctness of metered data and furnish the same to various agencies as per the procedure laid down by the Appropriate Commission.
- 2) Consumer meters:

- a) It shall be the responsibility of the licensee to record the metered data, maintain database of all the information associated with the consumer meters and verify the correctness of metered data.
 - b) The licensee shall maintain accounts for the electricity consumption and other electrical quantities of its consumers.
 - c) Brief history, date of installation and details of testing, calibration and replacement of meters shall be maintained by the licensee.
- 3) Energy accounting and audit meters: It shall be the responsibility of the generating company or licensee to record the metered data, maintain database of all the information associated with the energy accounting and audit meters and verify the correctness of metered data. Each generating company or licensee shall prepare quarterly, half-yearly and yearly energy account for its system for taking appropriate action for efficient operation and system development.

Clause 15: Meter failure or discrepancies.

(1) Interface meters

- (a) Whenever difference between the readings of the Main meter and the Check meter for any month is more than 0.5%, the following steps shall be taken:
 - i) checking of CT and VT connections;
 - ii) testing of accuracy of interface meter at site with reference standard meter of accuracy class higher than the meter under test.

If the difference exists even after such checking or testing, then the defective meter shall be replaced with a correct meter.

- (b) In case of conspicuous failures like burning of meter and erratic display of metered parameters and when the error found in testing of meter is beyond the permissible limit of error provided in the relevant standard, the meter shall be immediately replaced with a correct meter.
- (c) In case where both the Main meter and Check meter fail, at least one of the meters shall be immediately replaced by a correct meter.
- (d) Billing for the Failure period:
 - The billing for the failure period of the meter shall be done as per the procedure laid down by the Appropriate Commission.
 - Readings recorded by Main, Check and Standby meters for every time slot shall be analyzed, crosschecked and validated by the Appropriate Load Despatch Centre (LDC). The discrepancies, if any, noticed in the readings shall be informed by the LDC in writing to the energy accounting agency for proper accounting of energy. LDC shall also intimate the discrepancies to the Appropriate Transmission Utility or the licensee, who shall take further necessary action regarding testing, calibration or replacement of the faulty meters in accordance with the provisions laid down.

(e) The defective meter shall be immediately tested and calibrated

(2) Consumer meters: In case the consumer reports to the licensee about consumer meter readings not commensurate with his consumption of electricity, stoppage of meter, damage to the seal, burning or damage of the meter, the licensee shall take necessary steps as per the procedures given in the Electricity Supply Code of the Appropriate Commission read with the notified conditions of supply of electricity.

(3) Energy accounting and audit meters: Energy accounting and audit meters shall be rectified or replaced by the generating company or licensee immediately after notice of any of the following abnormalities:

- a) the errors in the meter readings are outside the limits prescribed for the specified Accuracy Class;
- b) meter readings are not in accordance with the normal pattern of the load demand;
- c) meter tampering, or erratic display or damage.

Clause 16: Anti-tampering features of meters: The meters shall be provided with such anti-tampering features as per the Standards on Installation and Operation of Meters given in the Schedule.

Clause 17: Quality assurance of meters:

- 1) The distribution licensee shall put in place a system of quality assurance and testing of meters with the approval of Appropriate Commission.
- 2) The licensee shall set up appropriate number of accredited testing laboratories or utilize the services of other accredited testing laboratories. The licensee shall take immediate action to get the accreditations of their existing meter testing laboratories from NABL, if not already done.
- 3) The generating company or licensee shall ensure that all type, routine and acceptance tests are carried out by the manufacturer complying with the requirement of the relevant IS or BS or IEC as the case may be.

Clause 18: Calibration and periodical testing of meters

(1) Interface meter

- a) At the time of commissioning, each interface meter shall be tested by the owner at site for accuracy using standard reference meter of better accuracy class than the meter under test.
- b) (b)All interface meters shall be tested at least once in five years. These meters shall also be tested whenever the energy and other quantities recorded by the meter are abnormal or inconsistent with electrically adjacent meters. Whenever there is unreasonable difference between the quantity recorded by interface meter and the corresponding value monitored at the billing center via communication network, the communication system and terminal equipment

shall be tested and rectified. The meters may be tested using NABL accredited mobile laboratory or at any accredited laboratory and recalibrated if required at manufacturer's works.

- c) Testing and calibration of interface meters may be carried out in the presence of the representatives of the supplier and buyer. The owner of the meter shall send advance notice to the other party regarding the date of testing.
- (2) Consumer meters: The testing of consumer meters shall be done at site at least once in five years. The licensee may instead of testing the meter at site can remove the meter and replace the same by a tested meter duly tested in an accredited test laboratory. In addition, meters installed in the circuit shall be tested if study of consumption pattern changes drastically from the similar months or season of the previous years or if there is consumer's complaint pertaining to a meter. The standard reference meter of better accuracy class than the meter under test shall be used for site testing of consumer meters up to 650 volts. The testing for consumers meters above 650 volts should cover the entire metering system including CTs, VTs. Testing may be carried out through NABL accredited mobile laboratory using secondary injection kit, measuring unit and phantom loading or at any accredited test laboratory and recalibrated if required at manufacturer's works.
- (3) Energy accounting and audit meters: Energy accounting and audit meters shall be tested at site at least once in five years or whenever the accuracy is suspected or whenever the readings are inconsistent with the readings of other meters, e.g., check meters, standby meters. The testing must be carried out without removing the CTs and VTs connection. Testing may be carried out through NABL accredited mobile laboratory using secondary injection kit, measuring unit and phantom loading or at any accredited test laboratory and recalibrated if required at manufacturer's works.

Clause 19: Additional meters: In addition to any meter which may be placed for recording the electricity consumed by the consumer, the licensee may connect additional meters, maximum demand indicator or other apparatus as he may think fit for the purposes of ascertaining or regulating either the quantity of electricity supplied to the consumer, or the number of hours during which the supply is given, or the rate per unit of time at which energy is supplied to the consumer, or any other quantity or time connected with the supply to consumer:

Provided that the meter, indicator or apparatus shall not, in the absence of an agreement to the contrary, be placed otherwise than between the distributing mains of the licensee and any meter:

Provided further that, where the charges for the supply of energy depend wholly or partly upon the reading or indication of any such meter, indicator or apparatus as aforesaid, the licensee shall, in the absence of an agreement to the contrary, keep the meter, indicator or apparatus correct.

Clause 20: Adoption of new technologies: The distribution licensee shall make out a plan for introduction and adoption of new technologies such as pre-paid meters, time of the day meters (TOD), automatic remote meter reading system through appropriate communication system with the approval of the Appropriate Commission or as per the regulations or

directions of the Appropriate Commission or pursuant to the reforms programme of the Appropriate Government.

SCHEDULE

(See regulations 2, 5,8,12 and 16)

Standards on Installation and Operation of Meters

Part I Standards Common to All Type of Meters

- 1) These standards provide for specification of meters, immunity to external factors, sealing points and functional requirements that are required from regulatory perspective. Detailed technical specification shall be prepared by the purchaser of the meter.
- 2) Specifications of Meters: Standard reference voltage, voltage range, standard frequency, standard basic current, starting current and maximum current, power factor range, power factor withstand voltage, impulse voltage withstand test for 1.2/50 micro seconds and power consumption by the meter shall be as per IS.

(Current range of customer meter shall be so chosen as to record the load current corresponding to sanctioned load)

Accuracy Class - Meters shall meet the following requirement of accuracy class:

Inter face meters: 0.2S

Consumer meters: up to 650 volts – 1.0S or better

Above 650 volts and up to 33kV – 0.5S or better

Above 33kV – 0.2S

Energy accounting and audit meters: Accuracy class of meters in generation and transmission systems shall not be inferior to that of 0.2S class and in distribution systems shall not be inferior to that of 0.5S class.

- 3) Meter shall have downloading facilities of metered data through Meter Reading Instrument (MRI).
- 4) Immunity to External Factors: The meter shall be immune to external influences like magnetic induction, vibration, electrostatic discharge, switching transients, surge voltages, oblique suspension and harmonics and necessary tests shall be carried out in accordance with relevant standard.
- 5) Sealing Points: Sealing shall be done at the following points (as applicable):
 - a) Meter body or cover
 - b) Meter terminal cover
 - c) Meter test terminal block
 - d) Meter cabinet
- 6) The accuracy class of Current transformers (CTs) and Voltage transformers (VTs) shall not be inferior to that of associated meters. The existing CTs and VTs not complying with these regulations shall be replaced by new CTs and VTs, if found defective, non-functional or as per the directions of the Appropriate Commission. In case the CTs and VTs of the same Accuracy Class as that of meters can not be

accommodated in the metering cubicle or panel due to space constraints, the CTs and VTs of the next lower Accuracy Class can be installed.

- 7) The Voltage Transformers shall be electromagnetic VT or Capacitive Voltage Transformer (CVT).

Part II - Standards for interface meters

(1) Functional Requirements:

- a) The Interface meters suitable for ABT shall be static type, composite meters, as self-contained devices for measurement of active and reactive energy, and certain other parameters as described in the following paragraphs. The meters shall be suitable for being connected directly to voltage transformers (VTs) having a rated secondary line-to-line voltage of 110 V, and to current transformers (CTs) having a rated secondary current of 1A (Model-A: 3 element 4 wire or Model C: 2 element, 3 wire) or 5A (model-B: 3 element , 4 wire or Model D: 2 element 3 wire). The reference frequency shall be 50Hz.
- b) The meters shall have a non-volatile memory in which the following shall be automatically stored:
 - Average frequency for each successive 15-minute block, as a two digit code (00 to 99 for frequency from 49.0 to 51.0Hz).
 - Net Wh transmittal during each successive 15-minute block, up to second decimal, with plus/minus sign.
 - Cumulative Wh transmittal at each midnight, in six digits including one decimal.
 - Cumulative VArh transmittal for voltage high condition, at each midnight, in six digits including one decimal.
 - Cumulative VArh transmittal for voltage low condition, at each midnight, in six digits including one decimal.
 - Date and time blocks of failure of VT supply on any phase, as a star(*) mark.
- c) The meters shall store all the above listed data in their memories for a period of at least ten days. The data older than ten days shall get erased automatically. Each meter shall have an optical port on its front for tapping all data stored in its memory using a hand held data collection device. The meter shall be suitable for transmitting the data to remote location using appropriate communication medium.
- d) The active energy (Wh) measurement shall be carried out on 3-phase, 4-wire principle, with an accuracy as per class 0.2 S of IEC-687/IEC-62053-22. In model-A and C, the energy shall be computed directly in CT and VT secondary quantities, and indicated in watt-hours. In model-B and Model D, the energy display and recording shall be one fifth of the Wh computed in CT and VT secondary quantities.
- e) The Var and reactive energy measurement shall also be on 3-phase, 4-wire principle, with an accuracy as per class 2 of IEC-62053-23 or better. In model-A

or Model C, the Var and VARh computation shall be directly in CT and VT secondary quantities. In model-B or Model D, the above quantities shall be displayed and recorded as one-fifth of those computed in CT and VT secondary quantities. There shall be two reactive energy registers, one for the period when average RMS voltage is above 103% and the other for the period the voltage is below 97%.

- f) The 15-minute Wh shall have a +ve sign when there is a net Wh export from substation busbars, and a –ve sign when there is a net Wh import. The integrating (cumulative) registers for Wh and Varh shall move forward when there is Wh/Varh export from substation busbars, and backward when there is an import.
- g) The meters shall also display (on demand), by turn, the following parameters:
 - i) Unique identification number of the meter
 - ii) Date
 - iii) Time
 - iv) Cumulative Wh register reading
 - v) Average frequency of the previous 15-minute block
 - vi) Net Wh transmittal in the previous 15-minute block, with +/-sign
 - vii) Average percentage voltage
 - viii) Reactive power with +/- sign
 - ix) Voltage-high VARh register reading
 - x) Voltage-low VARh register reading.
- h) The three line-to-neutral voltages shall be continuously monitored, and in case any of these falls below 70%, the condition shall be suitably indicated and recorded. The meters shall operate with the power drawn from the VT secondary circuits, without the need for any auxiliary power supply. Each meter shall have a built-in calendar and clock, having an accuracy of 30 seconds per month or better.
- i) The meters shall be totally sealed and tamper-proof, with no possibility of any adjustment at site, except for a restricted clock correction. The harmonics shall be filtered out while measuring Wh, Var and VARh, and only fundamental frequency quantities shall be measured/computed.
- j) The Main meter and the Check meter shall be connected to same core of CTs and VTs.

Part III - Standards for consumers meters

(1) Measuring Parameters

- a) The consumer meter shall be suitable for measurement of cumulative active energy utilized by the consumer.
- b) The consumer meter may have the facilities to measure, record and display one or more of the following parameters depending upon the tariff requirement for various categories of consumers. All parameters excluding instantaneous electrical parameters shall also be stored in memory.

- i) Cumulative reactive energy
 - ii) Average power factor
 - iii) Time of use of energy
 - iv) Apparent power
 - v) Maximum demand
 - vi) Phase voltage and line currents
- (2) All the three phase meters shall have data storage capacity for at least 35 days in a non-volatile memory.
- (3) Anti-Tampering Features
 - The meter shall not get damaged or rendered non-functional even if any phase and neutral are interchanged.
 - The meter shall register energy even when the return path of the load current is not terminated back at the meter and in such a case the circuit shall be completed through the earth. In case of metallic bodies, the earth terminal shall be brought out and provided on the outside of the case.
 - The meter shall work correctly irrespective of the phase sequence of supply (only for poly phase).
 - In the case of 3 phase, 3 wire meter even if reference Y phase is removed, the meter shall continue to work. In the case of 3 phase, 4 wire system, the meter shall keep working even in the presence of any two wires i.e., even in the absence of neutral and any one phase or any two phases.
 - In case of whole current meters and LV CT operated meter, the meter shall be capable of recording energy correctly even if input and output terminals are interchanged.
 - The registration must occur whether input phase or neutral wires are connected properly or they are interchanged at the input terminals.
 - The meter shall be factory calibrated and shall be sealed suitably before dispatch.
 - The meter shall be capable of recording occurrences of a missing potential (only for VT operated meters) and its restoration with date and time of first such occurrence and last restoration along with total number and duration of such occurrences during the above period for all phases.
 - Additional anti-tampering features including logging of tampers such as current circuit reversal, current circuit short or open and presence of abnormal magnetic field may be provided as per the regulations or directions of the Appropriate Commission or pursuant to the reforms programme of the Appropriate Government.

Part IV - Standards for energy accounting and audit meters

- (1) The energy accounting and audit meters shall be suitable for measurement, recording and display of cumulative active energy with date and time.
- (2) The energy accounting and audit meters may also have the facility to measure, record and display one or more of the following parameters depending upon the energy

accounting and audit requirement. All parameters excluding instantaneous electrical parameters shall also be stored in memory.

- a) Apparent power
 - b) Phase wise kilowatt at peak KVA
 - c) Phase wise KVA(reactive) at peak KVA
 - d) Phase wise voltage at peak KVA
 - e) Power down time
 - f) Average power factor
 - g) Line currents
 - h) Phase voltages
 - i) Date and time
 - j) Tamper events
- (3) The energy accounting and audit meter shall have data storage capacity for at least 35 days in a non-volatile memory.
- (4) Energy accounting and audit meters shall have facility to download the parameters through meter reading instruments as well as remote transmission of data over communication network.

6.2.6 STATAE LOAD DESPATCH CENTRE OPERATIONS

Bulk sources of power generations are thermal power plants (coal as fuel), gas plants (gas as fuel), nuclear power plants (uranium as fuel) and hydro power plants. These machines generally rotate at 3000 revolutions per minute to produce power.

The hydro power stations produce power in bulk but operate during certain months in the year to produce power. Other power stations produce electricity, all the 24 hours in day and operate continuously.

Though various types of machines run at different speeds, the power generated will have a common feature called frequency as these machines get electrically locked together. This means either all machines run together or stop together, if there is frequency problem. Frequency indicates the speed at which the machines run.

Power utilization fluctuates during the 24-hour cycle of a day, like maximum utilization during evening peak times and reduced utilization during nights. Therefore during nights the machines run faster as demand is less and become slow when demand is higher. Also the machines run faster when hydro power is more during monsoon months.

High frequency may cause damage to the turbines that drive the generators to produce power and low frequency causes damage to the consumer motors and causes low lighting. Thus there is need to control the running speed of the machines on instant to instant basis continuously i.e., the frequency of the power system is to be within safe operating limits

The state load dispatch center takes care of this aspect while the regional load dispatch centers and national load dispatch center look after the entire power system of the country. They monitor the system, round the clock all-through the year.

State meets the power requirements of its consumers, from the state owned generating company APGENCO, Allocated power from central generating stations and central transmission lines (NTPC & Power Grid) and from private power plants.

This means there are two conditions to be honored by any state in the country

- i) To keep the frequency in safe limits and
- ii) Draw power from center as per quota. Deviation of the two conditions causes instability and consequent failure of grid.

Frequency is maintained within stipulated limits by dynamically balancing the Generation and Load on a continuous basis as the power system frequency has a bearing on the grid security.

In India, the lower limit of the operating frequency limit is enhanced from 49.00 Hz to 49.20 (49.22) Hz by the Central Electricity Regulatory Commission to ensure grid security as some of the states in the country are drawing excess power beyond the quota allotted from the Central Generating Stations. If the power drawn by the states is more than the capacity of the machines, all machines slow down and at a certain stage all generators stop producing power as these machines are locked together. This is called grid failure. Therefore it is essential that grid frequency is maintained at safe level.

With power requirements growing day by day, and adequate generation capacity not built up by installing additional generating plants, the states are utilizing more than their quota of power from center. This is resulting in frequency coming below 49.22 HZ. This is signal / warning to the states to build additional power plants adequately and immediately. Till then the states have to limit their usage of power to the capacity available to them. If the States fail to adhere to the capacity available to them, total grid failures occur frequently.

Sustained over draws from center prove financially very costly in addition to causing power failure in several other states, because all states are inter-connected. In the event of grid failure, restoration of power supply will take long time necessitating drawl of more hydro power and exhausting the same, thus losing the reserve. This is apart from public suffering and public unrest.

6.2.6.1 Role of State Load Despatch Center as envisaged in Electricity Act 2003

Clause 29 (3): All directions issued by the Regional Load Despatch Centers to any transmission licensee of State transmission lines or any other licensee of the State or generating company (other than those connected to inter State transmission system) or sub-station in the State shall be issued through the State Load Despatch Centre and the State Load Despatch Centers shall ensure that such directions are duly complied by the licensee or generating company or sub-station.

Clause 29 (5): If any dispute arises with reference to the quality of electricity or safe, secure and integrated operation of the regional grid or in relation to any direction given under subsection (1), it shall be referred to the Central Commission for decision: Provided that pending the decision of the Central Commission, the directions of the Regional load Despatch Centre shall be complied with, by the State Load Despatch Centre or the licensee or the generating company, as the case may be.

Clause 31 (1): The State Government shall establish a Centre to be known as the State Load Despatch Centre for the purposes of exercising the powers and discharging the functions under this act.

Clause 31 (2) : The State Load Despatch Centre shall be operated by a Government company or any authority or corporation established or constituted by or under any company or any authority or corporation established or constituted by or under any State Act, as may be notified by the State Government. Provided that until a Government company or any authority or corporation is notified by the State Government, the State Transmission Utility shall operate the State load Despatch Centre: Provided further that no State load Despatch Centre shall engage in the business of trading in electricity.

Clause 31 (1): The State Load Despatch Centre shall be the apex body to ensure integrated Operation of the power system in a State. The State Load Despatch Centre shall:

- a) be responsible for optimum scheduling and despatch of electricity within a State, in accordance with the contracts entered into with the licensees or the generating companies operating in that State;
- b) monitor grid operations:
- c) keep accounts of the quantity of electricity transmitted through the State and;
- d) exercise supervision and control over the intra-state transmission system; and
- e) be responsible for carrying out real time operations for grid control and despatch of electricity within the State through secure and economic operation of the State grid in accordance with the Grid Standards and the State Grid Code.
- f) The State Load Despatch Centre may levy and collect such fee and charges from the generating companies and licensees engaged in intra-State transmission of electricity as may be specified by the State Commission.

Clause 33 (1): The State Load Despatch Centre in a State may give such directions and exercise such supervision and control as may be required for ensuring the integrated grid operations and for achieving the maximum economy and efficiency in the operation of power system in that State.

Clause 33 (2): Every licensee, generating company, generating station, sub- station and any other person connected with the operation of the power system shall comply with the direction issued by the State Load Despatch Centre under sub-section (1).

Clause 33 (3): The State Load Despatch Centre shall comply with the directions of the Regional Load Despatch Centre.

Clause 33 (4): If any dispute arises with reference to the quality of electricity or safe, secure and integrated operation of the State grid or in relation to any direction given under sub-section (1), it shall be referred to the State Commission for decision: Provided that pending the decision of the State Commission, the direction of the State Load Despatch Centre shall be complied with by the licensee or generating company.

Clause 33 (5): If any licensee, generating company or any other person fails to comply with the directions Issued under sub-section(I), he shall be liable to penalty not exceeding rupees five lakhs.

Clause 37: Charges for intervening transmission facilities: The Appropriate Government may issue directions to the Regional Load Despatch Centers or State Load Despatch Centers, as the case may be; to take such measures as may be necessary for maintaining smooth and stable transmission and supply of electricity to any region or State.

Clause 40: It shall be the duty of a transmission licensee:

- a) to build, maintain and operate an efficient, coordinated and economical inter-State transmission system or intra-State transmission system, as the case may be;
- b) to comply with the directions of the Regional Load Despatch Centre and the State Load Despatch Centre as the case may be;
- c) to provide non-discriminatory open access to its transmission system for use by any licensee or generating company on payment of the transmission charges; or
- d) any consumer as and when such open access is provided by the State Commission under sub-section (2) of section 42, on payment of the transmission charges and a surcharge thereon, as may be specified by the State Commission:

Provided that such surcharge shall be utilized for the purpose of meeting the requirement of current level cross-subsidy.

Provided further that such surcharge and cross subsidies shall be progressively reduced and eliminated in the manner as may be specified by the Appropriate Commission: Provided also that such surcharge may be levied till such time the cross subsidies are not eliminated.

Provided also that the manner of payment and utilization of the surcharge shall be specified by the Appropriate Commission:

Provided also that such surcharge shall not be leviable in case open access is provided to a person who has established a captive generating plant for carrying the electricity to the destination of his own use.

Inter State Open Access as per CERC order dt: 25-01-2008.

Definition(h): "Intra-State entity" means a person whose metering and energy accounting is done by the State Load Despatch Centre or by any other authorized State utility;

Clause 8: Concurrence of State Load Despatch Centre for bilateral and collective Transactions

- i) Wherever the proposed bilateral transaction has a State utility or an intra-State entity as a buyer or a seller, concurrence of the State Load Despatch Centre shall be obtained in advance and submitted along with the application to the nodal agency. The concurrence of the State Load Despatch Centre shall be in such form as may be provided in the detailed procedure.
- ii) When a State utility or an intra-State entity proposes to participate in trading through a power exchange, it shall obtain a "no objection" or a prior standing clearance from the State Load Despatch Centre in such form as may be

- prescribed in the detailed procedure, specifying the MW up to which the entity may submit a buy or sell bid in a power exchange.
- iii) In case the infrastructure required for energy metering and time block wise accounting already exists, and required transmission capacity in the State network is available, the State Load Despatch Centre shall accord its concurrence or 'no objection' or standing clearance, as the case may be, within three (3) working days of receipt of the application:
 - iv) In case SLDC decides not to give concurrence or "no objection" or standing clearance as the case may be, the same shall be communicated to the applicant in writing, giving the reason for refusal within the above stipulated period of 3 days.
 - v) Unless specified otherwise by the State Commission concerned, the State Load Despatch Centre may charge a fee of Rupee five thousand (Rs 5000/-) for processing applications for concurrence or "no objection" or prior standing clearance.

Clause 17: Operating Charges:

- i) Operating charges at the rate of Rs. 2,000 per day or part of the day for each bilateral transaction for each of the Regional Load Despatch Centre involved and at the rate of RS.2000 per day or part of the day for each State Load Despatch Centre involved shall be payable by the applicant.
- ii) In case of the collective transaction, operating charges shall be payable by the power exchange @ Rs.5000/- per day to the National Load Despatch Centre for each State involved and RS.2,000 per day for the State Load Despatch Centre involved for each point of transaction.
- iii) National Load Despatch Centre shall share the operating charges with the Regional Load Despatch Centres in such manner as may be decided by the Central Transmission Utility.
- iv) All buyers within a State shall be clubbed together and all sellers within a State shall be clubbed together by the power exchange (with necessary coordination with the State Load Despatch Centre) and each of the groups shall be counted as a single entity by National Load Despatch Centre for levy of operating charges and for scheduling; Provided that for levy of operating charges for State Load Despatch Centre and levy of the intra-State transmission charges, each point of injection or drawl in the State network shall be counted separately.

Clause 20: UI charges:

- i) All transactions for State utilities and for intra-State entities scheduled by the nodal agency under these regulations shall be accounted for and included in the respective day-ahead net interchange schedules of the concerned regional entity issued by the Regional Load Despatch Centre.
- ii) Based on net metering on the periphery of each regional entity, composite UI accounts shall be issued for each regional entity on a weekly cycle and transaction-wise UI accounting, and UI accounting for intra-State entities shall not be carried out at the regional level.

- iii) The State utility designated for the purpose of collection/disbursement of UI charges from/to intra-State entities shall be responsible for timely payment of the State's composite dues to the regional UI pool account.
- iv) Any mismatch between the scheduled and the actual drawl at drawl points and scheduled and the actual injection at injection points for the intra- State entities shall be determined by the concerned State Load Despatch Centre and covered in the intra-State UI accounting scheme.
- v) Unless specified otherwise by the concerned State Commission, UI rate for intra-State entity shall be 105% (for over-drawls or under generation) and 95% (for under-drawls or over generation) of UI rate at the periphery of regional entity
- vi) In an interconnection (integrated AC. grid), since MW deviations from schedule of an entity are met from the entire grid, and the local utility is not solely responsible for absorbing these deviations, restrictions regarding magnitude of deviations (except on account of over-stressing of concerned transmission or distribution system), and charges other than those applicable in accordance with these regulation (such as standby charges, grid support charges, parallel operation charges) shall not be imposed by the State Utilities on the customers of inter-State open access.

Clause 25 (5): In case a State utility is the open access customer, the operating charges and the transmission charges to be collected by the nodal agency shall not include the charges for the State network and operating charges for the State Load Despatch Centre.

Clause 26: Redressal Mechanism: Unless the dispute involves the State Load Despatch Centre and the intra-State entities of the concerned State and falls within the jurisdiction of the State Commission, all disputes arising under these regulations shall be decided by the Commission based on an application made by the person aggrieved.

6.2.7 SCHEDULING AND DESPATCH CODE

6.2.7.1 Introduction: This Part sets out the

- a) Demarcation of responsibilities between various regional entities, SLDC, RLDC and NLDC in scheduling and despatch
- b) Procedure for scheduling and despatch
- c) Reactive power and voltage control mechanism
- d) Complementary commercial mechanisms (in the Annexure–1)

6.2.7.2 Objective: This code deals with the procedures to be adopted for scheduling of the net injection / drawls of concerned regional entities on a day ahead basis with the modality of the flow of information between the NLDC / RLDCs / SLDCs/Power Exchange and regional entities. The procedure for submission of capability declaration by each ISGS and submission of requisition / drawl schedule by other regional entities is intended to enable RLDCs to prepare the dispatch schedule for each ISGS and drawl schedule for each regional entity. It also provides methodology of issuing real time despatch/drawl instructions and rescheduling, if required, to regional entities along with the commercial arrangement for the deviations from schedules, as well as, mechanism for reactive power pricing. This code also provides the methodology for rescheduling of wind and solar energy on three (3) hourly basis and the methodology of compensating the wind and solar energy rich State for dealing with the

variable generation through a Renewable Regulatory charge. For this, appropriate meters and Data Acquisition System facility shall be provided for accounting of UI charges and transfer of information to concerned SLDC and RLDC.

The provisions contained in this Part are without prejudice to the powers conferred on RLDC under sections 28 and 29 of the Electricity Act, 2003

Scope: This code will be applicable to NLDC, RLDC/SLDCs, ISGS, Distribution licensees/SEBs/STUs/ regional entities, Power Exchanges, wind and solar generating stations and other concerned persons in the National and Regional grid.

The scheduling and despatch procedure for the generating stations of Bhakra Beas Management Board (BBMB) shall be as per the procedure formulated by the BBMB in consultation with NRLDC.

Similarly, the scheduling and despatch procedure for the generating stations of Sardar Sarovar Project (SSP) shall be as per the procedure formulated by the Western Regional Load Despatch Centre (WRLDC) in consultation with Narmada Control Authority (NCA).

6.2.7.3 Demarcation of responsibilities:

- 1) The national interconnected grid is divided into control areas like Regional ISTS, States, DVC, etc. where the load dispatch centre or system operator of the respective control area controls its generation and/or load to maintain its interchange schedule with other control areas whenever required to do so and contributes to frequency regulation of the synchronously operating system. The Load Despatch Centre of a control area therefore is responsible for coordinating the scheduling of a generating station, within the control area, real-time monitoring of the station's operation, checking that there is no gaming (gaming is an intentional mis-declaration of a parameter related to commercial mechanism in vogue, in order to make an undue commercial gain) in its availability declaration, or in any other way revision of availability declaration and injection schedule, switching instructions, metering and energy accounting, issuance of UI accounts within the control area, collections/disbursement of UI payments, outage planning, etc.
- 2) The following generating stations shall come under the respective Regional ISTS control area and hence the respective RLDC shall coordinate the scheduling of the following generating stations:
 - a) Central Generating Stations (excluding stations where full Share is allocated to host state),
 - b) Ultra-Mega power projects
 - c) In other cases, the control area shall be decided on the following criteria:
 - i) If a generating station is connected only to the ISTS, RLDC shall coordinate the scheduling, except for Central Generating Stations where full Share is allocated to one State.

- ii) If a generating station is connected only to the State transmission network, the SLDC shall coordinate scheduling, except for the case as at (a) above.
 - iii) If a generating station is connected both to ISTS and the State network, scheduling and other functions performed by the system operator of a control area will be done by SLDC, only if the state has more than 50% Share of power. The role of concerned RLDC, in such a case, shall be limited to consideration of the schedule for inter state exchange of power on account of this ISGS while determining the net drawl schedules of the respective states. If the State has a Share of 50% or less, the scheduling and other functions shall be performed by RLDC.
 - iv) In case commissioning of a plant is done in stages the decision regarding scheduling and other functions performed by the system operator of a control area would be taken on the basis of above criteria depending on generating capacity put into commercial operation at that point of time. Therefore it could happen that the plant may be in one control area (i.e. SLDC) at one point of time and another control area (i.e. RLDC) at another point of time. The switch over of control area would be done expeditiously after the change, with effect from the next billing period.
- 3) There may be exceptions with respect to above provisions, for reasons of operational expediency, subject to approval of CERC. Irrespective of the control area jurisdiction, if a generating station is connected both to the ISTS and the STU, the load dispatch centre of the control area under whose jurisdiction the generating station falls, shall take into account grid security implication in the control area of the other load dispatch centre.
- 4) For those generating stations supplying power to any state other than host state and whose scheduling is not coordinated by RLDC, the role of the concerned RLDC shall be limited to consideration of the schedule for inter-State exchange of power on account of this generating station while determining the net drawl schedules of the respective control area.
- 5) The Regional grids shall be operated as power pools with decentralized scheduling and despatch, in which the States shall have operational autonomy, and SLDCs shall have the total responsibility for
 - i) Scheduling/despatching their own generation (including generation of their embedded licensees),
 - ii) Regulating the demand of its control area,
 - iii) Scheduling their drawl from the ISGS (within their share in the respective plant's expected capability),
 - iv) Permitting long term access, medium term and short term open access transactions for embedded generators/consumers, in accordance with the contracts and

- v) Regulating the net drawl of their control area from the regional grid in accordance with the respective regulations of the CERC.
- 6) The system of each regional entity shall be treated and operated as a notional control area. The algebraic summation of scheduled drawl from ISGS and from contracts through a long-term access, medium-term and short-term open access arrangements shall provide the drawl schedule of each regional entity, and this shall be determined in advance on day-ahead basis. The regional entities shall regulate their generation and/or consumers' load so as to maintain their actual drawl from the regional grid close to the above schedule. If regional entities deviate from the drawl schedule, within the limit specified by the CERC in UI Regulations as long as such deviations do not cause system parameters to deteriorate beyond permissible limits and/or do not lead to unacceptable line loading, such deviations from net drawl schedule shall be priced through the Unscheduled Interchange (UI) mechanism.
- 7) The SLDC, SEB/distribution licensee shall always endeavour to restrict the net drawl of the state from the grid to within the drawl schedules, whenever the system frequency is below 49.7 Hz. The concerned SEB/distribution licensee User, SLDC shall ensure that their automatic demand management scheme mentioned in clause 5.4.2 acts to ensure that there is no over drawl when frequency is 49.5 Hz or below. If the automatic demand management scheme has not yet been commissioned, then action has to be taken as per manual demand management scheme to ensure zero overdrawl when frequency is 49.5 Hz. or below.
- 8) The SLDCs/STUs/Distribution Licensees shall regularly carry out the necessary exercises regarding short-term demand estimation for their respective States/area, to enable them to plan in advance as to how they would meet their consumers' load without overdrawing from the grid.
- 9) The ISGS, other generating stations and sellers shall be responsible for power generation/power injection generally according to the daily schedules advised to them by the RLDC/SLDC on the basis of the contracts/ requisitions received from the SLDCs/buyers/Power Exchanges.
- 10) The ISGS would normally be expected to generate power according to the daily schedules advised to them. The ISGS may also deviate from the given schedules within the limits specified in the UI Regulations of CERC, depending on the plant and system conditions. In particular, they may be allowed to generate beyond the given schedule under deficit conditions as long as such deviations do not cause system parameters to deteriorate beyond permissible limits and/or do not lead to unacceptable line loading. Deviations, if any, from the ex-power plant generation schedules shall be appropriately priced in accordance with UI Regulations. In addition, deviations, from schedules causing congestion, shall also be priced in accordance with the Congestion Charge Regulations of CERC
- 11) Provided that when the frequency is higher than 50.2 Hz, the actual net injection shall not exceed the scheduled despatch for that time block. Also, while the frequency is above 50.2 Hz, the ISGS may (at their discretion) back down without waiting for an advice from RLDC to restrict the frequency rise. When the frequency falls below 49.7 Hz, the generation at all ISGS (except those on peaking duty) shall be maximized, at

least up to the level which can be sustained, without waiting for an advice from RLDC subject to the condition that such increase does not lead to unacceptable line loading or system parameters to deteriorate beyond permissible limit .

- 12) However, notwithstanding the above, the RLDC may direct the SLDCs/ISGS/other regional entities to increase/decrease their drawl/generation in case of contingencies e.g. overloading of lines/transformers, abnormal voltages, threat to system security. Such directions shall immediately be acted upon. In case the situation does not call for very urgent action, and RLDC has some time for analysis, it shall be checked whether the situation has arisen due to deviations from schedules, pursuant to short-term open access. These shall be got terminated first, before an action, that would affect the scheduled supplies to the long term and medium term customers is initiated in accordance with Central Electricity Regulatory Commission (Grant of Connectivity, Long-term Access and Medium-term Open Access in inter-state Transmission and related matters) Regulations,2009.
- 13) For all outages of generation and transmission system, which may have an effect on the regional grid, all Regional entities shall cooperate with each other and coordinate their actions through Operational Coordination Committee (OCC) for outages foreseen sufficiently in advance and through RLDC (in all other cases), as per procedures finalized separately by OCC. In particular, outages requiring restriction of ISGS generation and/or restriction of ISGS Share which a beneficiary can receive and curtailment of other long term transactions shall be planned carefully to achieve the best optimization.
- 14) The regional entities shall enter into separate joint/bilateral agreement(s) to identify the beneficiary's Shares in ISGS (based on the allocations by the Govt. of India, where applicable), scheduled drawl pattern, tariffs, payment terms etc. All such agreements shall be filed with the concerned RLDC(s) and RPC, Secretariat, for being considered in scheduling and regional energy accounting. Any bilateral agreements between buyer and seller for scheduled interchanges on long-term, medium-term basis shall also specify the interchange schedule, which shall be duly filed with CTU and CTU shall inform RLDC and SLDC, as the case may be about these agreements in accordance with Central Electricity Regulatory Commission (Grant of Connectivity, Long-term Access and Medium-term Open Access in inter-state Transmission and related matters) Regulations,2009 .
- 15) All other regional entities should abide by the concept of frequency-linked load despatch and pricing of deviations from schedule, i.e., unscheduled interchanges. All regional entities should normally be operated according to the standing frequency-linked load despatch guidelines issued by the RLDC, to the extent possible, unless otherwise advised by the RLDC/SLDC.
- 16) The ISGS shall make an advance declaration of ex-power plant MW and MWh capabilities foreseen for the next day, i.e., from 0000 hrs to 2400 hrs. During fuel shortage condition, in case of thermal stations, they may specify minimum MW, maximum MW, MWh capability and declaration of fuel shortage. The generating stations shall also declare the possible ramping up / ramping down in a block. In case of a gas generating station or a combined cycle generating station, the generating

station shall declare the capacity for units and modules on APM gas, RLNG and liquid fuel separately, and these shall be scheduled separately.

- 17) While making or revising its declaration of capability, except in case of Run off the River (with up to three hour pondage) hydro stations, the ISGS shall ensure that the declared capability during peak hours is not less than that during other hours. However, exception to this rule shall be allowed in case of tripping/re-synchronization of units as a result of forced outage of units.
- 18) It shall be incumbent upon the ISGS to declare the plant capabilities faithfully, i.e., according to their best assessment. In case, it is suspected that they have deliberately over/under declared the plant capability contemplating to deviate from the schedules given on the basis of their capability declarations (and thus make money either as undue capacity charge or as the charge for deviations from schedule), the RLDC may ask the ISGS to explain the situation with necessary backup data.
- 19) The ISGS shall be required to demonstrate the declared capability of its generating station as and when asked by the Regional Load Despatch Centre of the region in which the ISGS is situated. In the event of the ISGS failing to demonstrate the declared capability, the capacity charges due to the generator shall be reduced as a measure of penalty.
- 20) The quantum of penalty for the first mis-declaration for any duration/block in a day shall be the charges corresponding to two days fixed charges. For the second mis-declaration the penalty shall be equivalent to fixed charges for four days and for subsequent mis-declarations, the penalty shall be multiplied in the geometrical progression over a period of a month
- 21) The CTU shall install special energy meters on all inter connections between the regional entities and other identified points for recording of actual net MWh interchanges and MVARh draws. The installation, operation and maintenance of special energy meters shall be in accordance with Central Electricity Authority (Installation and Operation of Meters) Regulations, 2006. All concerned entities (in whose premises the special energy meters are installed) shall take weekly meter readings and transmit them to the RLDC by Tuesday noon. The SLDC must ensure that the meter data from all installations within their control area are transmitted to the RLDC within the above schedule.
- 22) The RLDC shall be responsible for computation of actual net injection / drawl of concerned regional entities, 15 minute-wise, based on the above meter readings. The above data along with the processed data of meters shall be forwarded by the RLDC to the RPC secretariat on a weekly basis by each Thursday noon for the seven day period ending on the previous Sunday mid-night, to enable the latter to prepare and issue the Unscheduled inter-change (UI) account in accordance with the CERC (Unscheduled Interchange charges and related matters) Regulations, 2010, as amended from time to time. All computations carried out by RLDC shall be open to all regional entities for checking/verifications for a period of 15 days. In case any mistake/omission is detected, the RLDC shall forthwith make a complete check and rectify the same.

- 23) The operating log books of the generating station shall be available for review by the Regional Power Committee. These books shall keep record of machine operation and maintenance.
- 24) Hydro generating stations are expected to respond to grid frequency changes and inflow fluctuations. The hydro generating stations shall be free to deviate from the given schedule without causing grid constraint and a compensation for difference between the actual net energy supply by the hydro generating station and the scheduled energy (ex-bus) over day shall be made by the concerned Regional Load Despatch Centre in the day ahead schedule for the 4th day (day plus 3).
- 25) RLDC shall periodically review the actual deviation from the dispatch and net drawl schedules being issued, to check whether any of the regional entities are indulging in unfair gaming or collusion. In case any such practice is detected, the matter shall be reported to the Member Secretary, RPC for further investigation/action.
- 26) NLDC shall be responsible for scheduling and despatch of electricity over inter-regional links in accordance with the grid code specified by Central Commission in coordination with Regional Load Despatch Centers.

NLDC shall be responsible for coordination with Regional Load Despatch Centers for the energy accounting of inter-regional exchange of power. NLDC shall also be responsible for coordination for trans-national exchange of power.
- 27) NLDC shall develop a procedure for scheduling of collective transaction through Power Exchanges, scheduling of inter-regional power exchanges including HVDC setting responsibility and power exchanges of the country with other countries

6.2.7.4 Scheduling and Despatch procedure for long-term access, Medium-term and short-term open access (to be read with provisions of Open Access Regulations 2008 as amended from time to time. The scheduling procedure for medium-term open access transactions shall be similar to the scheduling procedure for long-term access transactions and is as given below, except where it is specifically mentioned for collective transactions):

1. All inter-State generating stations (ISGS) shall be duly listed on the respective RLDC and SLDC web-sites. The station capacities and allocated/contracted Shares of different beneficiaries shall also be listed out.
2. Each State shall be entitled to a MW despatch up to (foreseen ex power plant MW capability for the day) x (State's Share in the station's capacity) for all such stations. In case of hydro-electric stations, there would also be a limit on daily MWh despatch equal to (MWh generation capacity for the day) X (State's Share in the station's capacity).
3. By 8 AM every day, the ISGS shall advise the concerned RLDC, the station-wise ex-power plant MW and MWh capabilities foreseen for the next day, i.e., from 0000 hrs to 2400 hrs of the following day.
4. The above information of the foreseen capabilities of the ISGS and the corresponding MW and MWh entitlements of each State, shall be compiled by the RLDC every day

for the next day, and advised to all beneficiaries by 10 AM. The SLDCs shall review it vis-à-vis their foreseen load pattern and their own generating capability including bilateral exchanges, if any, and advise the RLDC by 3 PM their drawl schedule for each of the ISGS in which they have Shares, long-term and medium-term bilateral interchanges, approved short term bilateral interchanges.

5. Scheduling of collective transaction:

- NLDC shall indicate to Power Exchange(s), the list of interfaces/control areas/regional transmission systems on which unconstrained flows are required to be advised by the Power Exchange(s) to the NLDC. Power Exchange(s) shall furnish the interchange on various interfaces/control areas/regional transmission systems as intimated by NLDC. Power Exchange(s) shall also furnish the information of total drawl and injection in each of the regions. Based on the information furnished by the Power Exchanges, NLDC shall check for congestion. In case of congestion, NLDC shall inform the Exchanges about the period of congestion and the available limit for scheduling of collective transaction on respective interface/control area/transmission systems during the period of congestion for Scheduling of Collective Transaction through the respective Power Exchange. The limit for scheduling of collective transaction for respective Power Exchange shall be worked out in accordance with CERC directives.
- Based on the application for scheduling of Collective Transaction submitted by the Power Exchange(s), NLDC shall send the details (Scheduling Request of Collective Transaction) to different RLDCs for final checking and incorporating them in their schedules. After getting confirmation from RLDCs, NLDC shall convey the acceptance of scheduling of collective transaction to Power Exchange(s). RLDCs shall schedule the Collective Transaction at the respective periphery of the Regional Entities.
- The individual transactions for State Utilities/intra-State Entities shall be scheduled by the respective SLDCs. Power Exchange(s) shall send the detailed break up of each point of injection and each point of drawl within the State to respective SLDCs after receipt of acceptance from NLDC. Power Exchange(s) shall ensure necessary coordination with SLDCs for scheduling of the transactions.
- Timeline for above activities will be as per detailed procedure for Scheduling of Collective Transaction issued in accordance with CERC (Open access in inter-state transmission) Regulations, 2008 and as amended from time to time.

6. The SLDCs may also give standing instructions to the RLDC such that the RLDC itself may decide the best drawl schedules for the States.

7. By 6 PM each day, the RLDC shall convey:

- The ex-power plant “despatch schedule” to each of the ISGS, in MW for different time block, for the next day. The summation of the ex-power plant drawl schedules advised by all beneficiaries shall constitute the ex-power plant station-wise despatch schedule.
- The “net drawl schedule” to each regional entity, in MW for different time block, for the next day. The summation of the station-wise ex-power plant drawl schedules from all ISGS and drawl from /injection to regional grid consequent to

other long term access, medium term and short-term open access transactions, after deducting the transmission losses (estimated), shall constitute the regional entity-wise drawl schedule.

8. The SLDCs/ISGS shall inform any modifications/changes to be made in drawl schedule/foreseen capabilities, if any, to RLDC by 10 PM or preferably earlier.
9. The hydro electric generation stations are expected to respond to grid frequency changes and inflow fluctuations. They would, therefore, be free to deviate from the given schedule as long as they do not cause a grid constraint.

As a result, the actual net energy supply by a hydro generating station over a day may differ from schedule energy (ex-bus) for that day. Compensation shall then be made by the concerned load despatch centre in the day ahead schedule for the 4th day (day plus 3).

10. The declaration of the generating capability by hydro ISGS should include limitation on generation during specific time periods, if any, on account of restriction(s) on water use due to irrigation, drinking water, industrial, environmental considerations etc. The concerned Load Despatch Centre shall periodically check that the generating station is declaring the capacity and energy sincerely, and is not manipulating the declaration with the intent of making undue money through UI.
11. Since variation of generation in run-of-river power stations shall lead to spillage, these shall be treated as must run stations. All renewable energy power plants, except for biomass power plants, and non-fossil fuel based cogeneration plants whose tariff is determined by the CERC shall be treated as 'MUST RUN' power plants and shall not be subjected to 'merit order despatch' principles.
12. Run-of-river power station with pondage and storage type power stations are designed to operate during peak hours to meet system peak demand. Maximum capacity of the station declared for the day shall be equal to the installed capacity including overload capability, if any, minus auxiliary consumption, corrected for the reservoir level. The Regional Load Despatch Centers shall ensure that generation schedules of such type of stations are prepared and the stations despatched for optimum utilization of available hydro energy except in the event of specific system requirements/constraints.
13. The schedule finalized by the concerned load despatch centre for hydro generating station, shall normally be such that the scheduled energy for a day equals the total energy (ex-bus) expected to be available on that day, as declared by the generating station, based on foreseen/planned water availability/release. It is also expected that the total net energy actually supplied by the generating station on that day would equal the declared total energy, in order that the water release requirement is met. While the 15- minute wise, deviations from schedule would be accounted for as Unscheduled Interchange (UI), the net energy deviation for the whole day, if any, shall be additionally accounted for as shown in the illustration.

Illustration

Suppose the foreseen/expected total energy (ex-bus) for Day-1 is $E1$, the scheduled energy is $S1$, actual net energy (metered) is $A1$, all in ex-bus MWh. Suppose the expected energy availability for Day 4, as declared by the generator, is $E4$. Then, the schedule for day4 shall be drawn up such that the scheduled energy for Day 4, shall be $S4=E4+(A1-E1)$. Similarly, $S5= E5+(A2-E2)$, $S6=E6+(A3-E3)$, $S7=E7+(A4- E4)$, and so on.

14. While finalizing the above daily despatch schedules for the ISGS, RLDC shall ensure that the same are operationally reasonable, particularly in terms of ramping-up/ramping-down rates and the ratio between minimum and maximum generation levels. A ramping rate of up to 200 MW per hour should generally be acceptable for an ISGS and for a regional entity (50 MW in NER), except for hydro-electric generating stations which may be able to ramp up/ramp down at a faster rate.
15. While finalizing the drawl and despatch schedules as above, the RLDC shall also check that the resulting power flows do not give rise to any transmission constraints. In case any impermissible constraints are foreseen, the RLDC shall moderate the schedules to the required extent, under intimation to the concerned regional entities. Any changes in the scheduled quantum of power which are too fast or involve unacceptably large steps may be converted into suitable ramps by the RLDC.
16. In the event of bottleneck in evacuation of power due to any constraint, outage, failure or limitation in the transmission system, associated switchyard and substations owned by the Central Transmission Utility or any other transmission licensee involved in inter-state transmission (as certified by the RLDC) necessitating reduction in generation, the RLDC shall revise the schedules which shall become effective from the 4th time block, counting the time block in which the bottleneck in evacuation of power has taken place to be the first one. Also, during the first, second and third time blocks of such an event, the scheduled generation of the ISGS shall be deemed to have been revised to be equal to actual generation, and the scheduled drawls of the beneficiaries shall be deemed to have been revised accordingly.
17. In case of any grid disturbance, scheduled generation of all the ISGS and scheduled drawl of all the beneficiaries shall be deemed to have been revised to be equal to their actual generation/drawl for all the time blocks affected by the grid disturbance. Certification of grid disturbance and its duration shall be done by the RLDC.
18. Revision of declared capability by the ISGS(s) having two part tariff with capacity charge and energy charge (except hydro stations) and requisition by beneficiary (ies) for the remaining period of the day shall also be permitted with advance notice. Revised schedules/declared capability in such cases shall become effective from the 6th time block, counting the time block in which the request for revision has been received in the RLDC to be the first one. Provided that RLDC may allow revision, of the DC at 6 hourly intervals effective from 0000,0600,1200 and 1800 hours in case of Run of the River (ROR) and pondage based hydro generating stations, if there is large variation of expected energy (MWh) for the day compared to previous declaration.
19. Notwithstanding anything contained in Regulation (18), in case of forced outage of a unit for a Short Term bilateral transaction, where a generator of capacity of 100 MW and above is seller, the generator shall immediately intimate the same along with the

requisition for revision of schedule and estimated time of restoration of the unit, to SLDC/RLDC as the case may be. With the objective of not affecting the existing contracts, the revision of schedule shall be with the consent of the buyer till 31.07.2010.

Thereafter, consent of the buyer shall not be a pre-requisite for such revision of schedule. The schedule of the generator and the buyer shall be revised, accordingly. The revised schedules shall become effective from the 4th time block, counting the time block in which the forced outage is declared to be the first one. The RLDC shall inform the revised schedule to the seller and the buyer. The original schedule shall become effective from the estimated time of restoration of the unit. However the transmission charges as per original schedule shall continue to be paid for two days.

20. If, at any point of time, the RLDC observes that there is need for revision of the schedules in the interest of better system operation, it may do so on its own, and in such cases, the revised schedules shall become effective from the 4th time block, counting the time block in which the revised schedule is issued by the RLDC to be the first one.
21. To discourage frivolous revisions, RLDC may, at its sole discretion, refuse to accept schedule/capability changes of less than two (2) percent of previous schedule/capability. The schedule of thermal generating stations indicating fuel shortage while intimating the Declared Capacity to the RLDC shall not be revised except in case of forced outage of generating unit.

Provided that in case of gas based ISGS, for optimum utilization of gas, this shall be permitted, i.e. in case of tripping of a unit, this gas may be diverted to another unit using the same gas.

22. The Regional Load Despatch Centre shall also formulate the procedure for meeting contingencies both in the long run and in the short run (Daily scheduling).
23. Special dispensation for scheduling of wind and solar generation
 - i) With effect from 1.1.2011 Scheduling of wind power generation plants would have to be done for the purpose of UI where the sum of generation capacity of such plants connected at the connection point to the transmission or distribution system is 10 MW and above and connection point is 33 KV and above, and where PPA has not yet been signed. For capacity and voltage level below this, as well as for old wind farms (A wind farm is collection of wind turbine generators that are connected to a common connection point) it could be mutually decided between the Wind Generator and the transmission or distribution utility, as the case may be, if there is no existing contractual agreement to the contrary. The schedule by wind power generating stations may be revised by giving advance notice to SLDC/RLDC, as the case may be.
 - ii) Such revisions by wind power generating stations shall be effective from 6th time-block, the first being the time-block in which notice was given. There may be a maximum of 8 revisions for each 3 hour time slot starting from 00:00 hours during the day.

- iii) The schedule of solar generation shall be given by the generator based on availability of the generator, weather forecasting, solar insolation, season and normal solar generation curve and shall be vetted by the RLDC in which the generator is located and incorporated in the inter-state schedule. If RLDC is of the opinion that the schedule is not realistic, it may ask the solar generator to modify the schedule.
 - iv) Concerned RLDC and SLDC shall maintain the record of schedule from renewable power generating stations based on type of renewable energy sources i.e. wind or solar from the point of view of grid security. While scheduling generating stations in a region, system operator shall aim at utilizing available wind and solar energy fully.
24. Generation schedules and drawl schedules issued/revised by the Regional Load Despatch Centre shall become effective from designated time block irrespective of communication success.
 25. For any revision of scheduled generation, including post facto deemed revision, there shall be a corresponding revision of scheduled drawls of the beneficiaries.
 26. A procedure for recording the communication regarding changes to schedules duly taking into account the time factor shall be evolved by the Central Transmission Utility.
 27. When for the reason of transmission constraints e.g. congestion or in the interest of grid security, it becomes necessary to curtail power flow on a transmission corridor, the transactions already scheduled may be curtailed by the Regional Load Despatch Centre.
 28. The short-term customer shall be curtailed first followed by the medium-term customers, which shall be followed by the long-term customers and amongst the customers of a particular category, curtailment shall be carried out on *pro rata* basis.
 29. After the operating day is over at 2400 hours, the schedule finally implemented during the day (taking into account all before-the-fact changes in despatch schedule of generating stations and drawl schedule of the States) shall be issued by RLDC. These schedules shall be the datum for commercial accounting. The average ex-bus capability for each ISGS shall also be worked out based on all before-the-fact advice to RLDC.
 30. Collective Transaction through Power Exchange(s) would normally be curtailed subsequent to the Short Term Bilateral Transaction(s).
 31. RLDCs would curtail a Transaction at the periphery of the Regional Entities. SLDC(s) shall further incorporate the inter-se curtailment of intra- State Entities to implement the curtailment.
 32. RLDC shall properly document all above information i.e. station-wise foreseen ex-power plant capabilities advised by the generating stations, the drawl schedules advised by regional entities, all schedules issued by the RLDC, and all revisions/updating of the above.

33. The procedure for scheduling and the final schedules issued by RLDC, shall be open to all regional entities and other regional open access customers entities for any checking/verification, for a period of 5 days. In case any mistake/omission is detected, the RLDC shall forthwith make a complete check and rectify the same.
34. While availability declaration by ISGS shall have a resolution of one (1) MW and one (1) MWh, all entitlements, requisitions and schedules shall be rounded off to the nearest two decimal at each control area boundary for each of the transaction, to have a resolution of 0.01 MW and 0.01 MWh.”

6.2.7.5 WEB BASED SCHEDULING: Scheduling of power is being carried out through a web based program. Its application includes the following features:

- Creation of Declaration capacities (Form A) by ISGS
- Creation of Entitlements (Form B) by SRLDC
- Creation of Requisition (Form C) by constituents
- Creation of Bilaterals by Constituents
- Creation of Drawl Schedule (Form D) by SRLDC

The web based scheduling program reduces the time required for scheduling by reducing manual feeding.

6.2.8 MERIT ORDER DESPATCH OF GENERATORS:

Fixed charges are payable to a generator as per the agreement. These are committed charges. Economy in Power Purchases can be achieved only in variable charges payable to the generators. Energy cost expressed in Rupees/MW varies greatly between base load and peaking stations. Energy from peaking stations is most expensive, as these stations are underused on average. Efforts should, therefore be made in managing the loads such that peak demand is cut down.

Fixed costs of generator consist of depreciation, interest on capital Borrowed, O&M costs, return on equity, interest on working capital and income tax. These are the committed costs and are liable to be paid by utilities.

Variable costs consist of fuel cost, auxiliary consumption, station heat rate, gross calorific value of relevant fuel.

SLDC shall exercise control on variable costs in dispatching generators in conformity with PPA in their daily operation.

Load Despatch shall obtain generation availability to drawl schedule on a day a head basis from the generators. These are matched on hourly/15 minutes time slots and communicated to generators/Discoms.

While monitoring on line operation of the system, the LD should obtain actual generation and actual draws for every 15 minute time block. During the periods when the frequency is tending to increase or during sustained high frequency period, SLDC shall request generators to reduce the generation. While reducing generation merit order despatch procedure shall be

followed by SLDC duly following the back down limits of generators and the conditions stipulated in PPAs. Backing down instructions from Central Generating Stations (CGS) shall be issued before six time blocks in line with IEGC regulations. Generators whose cost is higher than UI rates, their generation will be reduced and the required power drawn at cheaper UI rates.

During on line operation, SLDC should document all outages/restoration of generators apart from CTU/STU elements, as they have commercial importance. Similarly, SLDC has to document every backing down instruction issued to generators.

To implement merit order dispatch variable cost data shall be obtained from Commercial wing on a month ahead basis and arranged in descending order of variable cost of generator.

Load Despatch will dispatch generators following economics and reduce generation from generator in terms of PPA, when cheaper power is available in the grid.

Example: In case of a load crash in a state, frequency will be high in the region and there is scope for remaining states to get low cost power and these states can back down their costly sources.

If there is shortage in a state, remaining states may dispatch all their generators and have advantage of differential pricing. Such operations will be plenty, during on line operation and the states can have the advantage.

Variable charges of all the generators will be tabulated by the SLDC and the frequency will be monitored at SLDC Vis-à-vis the UI rates. Variable charges have to be worked out every month and merit order list is updated periodically. Incentives payable to a generator should not be added to the variable costs of the generator till the qualifying plant load Factor (PLF) is achieved. Once this threshold PLF is achieved, the position of generators change in merit order list and therefore merit list should be revised. Backing down instructions issued, are to be in conformity with the provisions.

Whenever any generator does not comply back down instructions from LD, LD centre should report the Electricity Regulatory commission about the non-compliance.

Failure of generators to follow SLDC instructions constitutes violation of code of technical interface(Grid Code) 2001, IEGC and will entail penalties as per section 33 (4) of Elec. Act 2003.

6.2.9 GRID MANAGEMENT:

Objective of grid management is to maintain power supply ensuring quality, reliability and security of the grid.

6.2.9.1 There are five regional grids operating in the country

Northern Region: covering Delhi, Uttar Pradesh, Uttarakhand, Rajasthan, Punjab, Haryana, Himachal Pradesh, Jammu & Kashmir States.

Western Region: Covering Gujarat, Maharashtra, Madhya Pradesh, Chhattisgarh, Goa.

Southern Region: Covering Andhra Pradesh, Tamilnadu, Karnataka, Kerala and Pondicherry

Eastern Region: Covering Orissa, Bihar, Jharkhand, West Bengal & Sikkim

North Eastern Region: Covering all North Eastern States.

Inter Regional lines will be AC Transmission back to back facility (AC - DC - AC) and/or DC transmission, to provide transfer of bulk power from one region to the other and also avoid cascade tripping in one region due to disturbance in the other region.

Load despatch operators shall mainly concentrate on the following:

- i) Daily scheduling of load for 96 time blocks of 15 minutes each for next day (Day ahead schedule)
- ii) Indenting of power each source wise as per merit order despatch.
- iii) Reschedule in case of sudden unit outages or transmission constraints
- iv) Maintain load generation balance (frequency control)
- v) Maintain voltages at buses (Control reactive power)
- vi) Ensuring system security etc.

To ensure that load incident on the grid matches with the generation for maintaining 50 Hz frequency, Grid operators should work continuously for the units to be brought or backed down or loads to be interrupted. Every effort shall be made to maintain frequency above 49 Hz and below 50.5 Hz. Main parameters to be monitored continuously are frequency, voltage, power flows (active and reactive) through all lines and equipment. Grid Operators shall be authorized to enforce grid discipline, through remote control of identified elements in the Power System, in order to restore system security, whenever it is under threat.

6.2.9.2 Causes of grid Collapse: A grid collapse or a total blackout of a region may occur due to

- i) Sudden loss of generation due to tripping of a major generating station. Tripping of a major generating station cause a sudden dip in system frequency and voltage. If both fall below the permissible operating limits, cascade tripping of generators take place causing a total grid collapse.
- ii) Upset in load generation balance: sudden large scale incidence/throw off of existing load causes, wide fluctuations in frequency and tripping of lines on account of power swings or over voltages or generators experiencing low/high frequency or low/high voltage. This may lead to cascade tripping of lines as well as generators causing separation of state grids, resulting in partial or total grid collapse.

As per IEGC, addition or deletion of loads of more than 100 MW should be done with prior intimation to RLDC except in cases of emergencies arising out of all need to protect equipment

- i) Tripping at Grid Sub-stations isolating them from the system.
- ii) When all the lines connected to an important grid Sub-station trip due to a bus fault or on operation of LBB, the other lines in the system get over loaded and trip. This may lead to power swings and trigger a grid collapse.
- iii) Sudden occurrence of Transmission constraints.
- iv) Tripping of one or more heavily loaded, critical transmission lines on fault, may cause over loading of parallel lines and if they are lines inter connecting two power stations, large power swings occur resulting in separation of systems or even a grid collapse.
- v) Low voltages: Low voltages occur in certain locations in the system due to high reactive nature of loads without adequate capacitive compensation. This may cause over loading of lines beyond surge impedance levels. Extremely low voltages at any node in the system will cause power swings on transmission lines and when tripping of critical lines takes place, it may lead to grid collapse.
- vi) Delayed clearance of faulty in the system: If system faults persist due to mal operation or nonoperation of protective relays, severe voltage dips occur which may cause tripping of lines for pull out of generators, leading to grid collapse.

6.2.9.3 Steps for preventing grid collapse:

Maintaining grid frequency: System frequency should be maintained within + or - 3% of rated frequency. For proper security of the grid, it is desirable that the frequency is maintained above 49 Hz.

AS per IEGC, each generating unit shall be capable of instantaneously increasing its output by 5% and maintain for a minimum of 5 minutes when the frequency falls and when operating at any loading up to 105% maximum continuous rating (MCR).

All generating units shall have their automatic voltage regulators in operation with appropriate settings for maintaining voltage profile.

Step-I: Implementation of automatic under frequency load shedding schemes and islanding schemes

Sudden loss of a 500MW unit and a sudden loss of total generation at a generating station due to bus fault etc would cause dip in system frequency. When there is huge loss of generation, the system frequency will dip to below safe limits and can cause cascade tripping of other generations if the frequency falls below 47.5Hz. There will be no time for manual intervention to take rectification action and it may lead to total blackout .

To safeguard the system from low frequency conditions when there is huge loss of generation, the following automatic load shedding schemes are implemented by all the states of Southern Regional grid.

Automatic 3-Stage instantaneous under frequency load shedding scheme:

Under frequency relays connected to various feeders and power transformers in all the substations across the state will disconnect the identified loads (of approximately 10% of the grid demand for each stage) for the respective fall in frequencies as given below instantly thus improving the grid frequency. The quantum of loads connected in A.P. at various stages is as follows.

Stage-I	:	48.8 Hz	-	620MW
Stage-II	:	48.5 Hz	-	1000MW
Stage-III	:	48.2 Hz	-	1940MW

Automatic Instantaneous Rate of fall of Frequency (df/dt) Load Shedding Scheme:

When there is huge generation loss, there will be drastic fall in the grid frequency which may pose severe problem to the security of the Grid. To arrest drastic fall in grid frequency automatic instantaneous rate of fall of frequency (df/dt) relays are installed to shed the identified loads with the following settings.

Under frequency Condition setting	=	49.0Hz
Rate of Fall of frequency	=	0.3 Hz/Sec.

Both the above conditions should be satisfied for relay operation to trip the breaker. In AP System 30nos. df/dt relays are installed throughout the state to give a load relief of about 1770 MW.

Step-II: Distress mechanism:

500kV HVDC Talcher-Kolar Inter-trip Load Shedding Scheme:

500kV Bi-polar HVDC transmission system is installed to import 2500MW from Talcher (Orissa) to Kolar (Karnataka) in which all the constituent states of Southern Region have specified shares. On tripping of HVDC Single Pole there will be 50% reduction in import and there will be 100% loss on tripping of both the HVDC poles or tripping of HVDC transmission line.

Due to loss of import on the above system, the Southern Region grid frequency will fall and a special inter-trip load shedding scheme is implemented in Southern Region to safeguard the Grid.

Inter-trip signals will be generated at Kolar in 3-stages depending on quantum of loss of import and gets transmitted to the constituent states and the signal is utilized to trip the identified loads.

In AP Transco, the quantum loads connected for relief in each stage is as follows:

Stage-I	:	150 MW
Stage-II	:	250 MW
Stage-III	:	125 MW

The other constituent states of Southern Region had also implemented the above schemes giving load relief according to their state's grid demands. These schemes are to be reviewed periodically and necessary modifications done, according to the grid conditions.

6.2.9.4 Islanding scheme:

When there is total blackout of the State grid /Regional grid, it takes a long time for revival of the system causing lot of public inconvenience and heavy revenue loss to the Power utilities. To avoid total blackout of the grid during grid emergency condition, Islanding scheme is devised and implemented so that grid normalcy can be restored quickly if this Island survives.

In AP System, islanding scheme is implemented consisting of generation at Ramagundam STPS, load of Ramagundam area and city loads of Hyderabad.

From Ramagundam STPS, a load of about 500 to 600MW in Ramagundam area is fed by 5Nos. ICTs at Ramagundam and about 1000 to 1100MW of Hyderabad city loads are fed by 4Nos. 400kV Ramagundam –Hyderabad (Ghanapur) lines and 315MVA ICTs at Ghanapur & Mamidipally Substations.

Island is conceived with an expected load of about 1500 to 1700MW against total generation of 2600MW at Ramagundam STPS keeping in view of generation availability at the instant of Islanding. Generators will reject load to an extent of about 500MW on experiencing over frequency.

Islanding will take place on operation of under frequency relays set at 47.6Hz. with a time delay of 2.0Sec. installed at Ramagundam and other Hyderabad city Substations. Necessary modifications of the Island have to be done based on experience and network modifications.

Islanding of major thermal stations may be resorted to as a last step to save the thermal generators so that system can be restored to normalcy in the shortest possible time. Availability based tariff is a commercial mechanism through which demand of power by constituent starts from the central generating stations as per entitlements is done. In this system, energy charges are fixed on frequency and reactive power changes based on voltages. This ensures grid discipline, thereby maintaining frequency and voltages in limits constraints in Transmission system.

Augmentation of transmission system is required to maintain satisfactory voltages while meeting the growth in demand. Power systems planning group shall design an optimal transmission system based on the load forecast and generation addition plan to meet the load growth. The system expansion proposed shall be based on Techno economic studies i.e., Investment Vs loss reduction and voltage improvement and cost benefit ratio. Also timely completion of the planned projects is necessary to maintain satisfactory system parameters and to improve system stability. It shall be the project construction unit's endeavor to achieve this.

Grid Managers have to develop commercial skills, besides the technical skills required to operate the power system to ensure maximum economy in power purchase, with due consideration to the consumers interests.

Grid operators/managers need to be trained for techno-economic evaluation with commercial outlook.

6.2.9.5 In respect of Nuclear Power Plants (NPPs) following Grid Stability and safety issues shall be addressed:

Safety issues: Rejection of load/loss of external load when NPPS are connected to grid. Load rejection results in sudden decrease in electrical and reactor demand; causing increase in turbine/generator shaft speed. When reactor controls are inadequate or too large imbalance persists the reactor/turbine may trip causing loss of supply to remaining load.

Degraded Voltage: Drop in grid voltage to below permissible level may cause over current and trip the auxiliary motors. NPPs are provided with logic to sense degraded voltage condition and trip reactor. To ensure safety the standby/backup power sources shall have correct voltage and frequency for long term delay heat removal.

Degraded Frequency: Reduced grid frequency, reduces coolant flow. NPPs are provided with logic to sense severe load frequency, trip electrical buses, thus tripping reactor.

If a Nuclear Power Plant carrying a disproportionate amount of system load suddenly trips, collapse of the grid is likely.

In case of loss of offsite power in a NPP numerous reactor protective trips (turbine) generator trip, low coolant flow, loss of feed water flow etc. could occur.

The implant loads must then be temporarily powered by backup power sources, which operate instantly at correct voltage and frequency.

Offsite electric power supplies, including the batteries and on site electric distribution system shall have sufficient independence, redundancy and testability to perform their safety functions.

Grid interface: NPPs are considered to be based load units. They shall be able to draw power from the grid for their startup. There shall not be large drop in voltage/frequency, due to transients, while starting largest pump motors or else they may trip.

NPPs do not normally load any faster than 5% per minute within limited range, due to nuclear fuel metallurgical limits. Increased generation during grid emergency cannot be supplied by NPPs like hydel/gas generators.

NPPs are assumed to unload at 5 to 10% per minute without tripping.

NPP designs are capable of controlled runback (without trip) following 40% load rejection via fast turbine control valving, steam by pass and Automatic Reactor Control rod insertion. When load reject capability is exceeded, NPPs trip and cannot be returned to service for many hours.

6.2.9.6 Control of reactive power to maintain voltage profile:

Integrated operation of Power Systems is necessary for handling large quantum of Power. Integrated Operation has the advantages of improving the Power System stability and resources for effective operation and control of the Power System can be utilized optimally. Handling of large Power System increases complexity of operations due to more dynamics and multi dimensional control problems like system performance during disturbance etc. Advancement in technology helps in handling the tasks in a more efficient way through computers/communication based measures.

Generators in synchronism are electrically locked. Torque angle in a generator increases with increase of load on the machine. If this angle exceeds a value corresponding to maximum driving force, the magnetic forces will no longer be able to hold the rotor in synchronization and the generator will fall out of synchronism. Transmission lines have properties of capacitance as well as inductance. A line can be viewed as comprising number of distributed inductors and shunt capacitors. Power flowing on a line causes a phase angle shift between sending and receiving end voltages. This shift increases with increase of load on the line. The amount of power flowing on a transmission line is determined by length of line, size of conductor and spacing. As the power flow increases up to maximum the system will be stable. Further increase beyond this limit causes the angle to increase into unstable region and an out of step condition of generators will follow.

For a short line, heating of the conductor due to line losses sets a thermal limit. If large current is drawn, conductor sag increases and the clearance to ground may reduce. Conductor and equipment may be damaged due to over heating. For medium length lines (of the order of about 100 km) the limit is set by voltage drop on the line. For longer AC lines system stability sets the limit for power flow.

6.2.9.7 Surge impedance loading:

When a line is idle charged (no load), the line generates/produces reactive power at $1/2 CV^2$ (C is the shunt capacitance of the line and V is the voltage at which the line is charged). When a load is put on the line, the line absorbs reactive power at $1/2 LI^2$ (L is the series inductance and I is the current flow on the line). Maximum Power can flow on the line when reactive power absorbed by the line is equal to the reactive power generated by the line. The load at which this occurs, is called the surge impedance load.

$$1/2 CV^2 = 1/2 LI^2$$

$$\text{Surge impedance (SI)} = V/I = \sqrt{L/C}$$

$$\text{Surge impedance Loading (SIL) (Power)} = V^2/S.I.$$

When a line is loaded above SIL, it acts like a shunt reactor, absorbing MVAR from the system and when a line is loaded below SIL, it acts like a shunt capacitor supplying MVAR to the system.

6.2.9.8 Condition to be fulfilled for synchronizing a generator to a power system:

- a) Frequency and phase sequence of generator and power system shall be same.
- b) Voltages shall be same both in magnitude and phase. (can be adjusted by operator at generating station)

- c) Generator inertia is much lesser than system.

Condition for synchronization of two power systems:

- a) Speed and voltage magnitudes are to be matched closely.
- b) Phase angle should be matched. Larger angular displacements may cause unwanted relay operation causing system break ups/damage to equipment.

6.2.9.9 Active power does useful work, such as running of motors, heating, illumination etc. Reactive Power is used to provide voltage levels necessary for active power to do useful work. Reactive Power is essential to move active power through the transmission and distribution systems, to the consumer.

Transformers and motors require reactive power. Transformers and transmission lines have series inductance as well as resistance. Electric motors need reactive power to produce magnetic fields for their operation. Reactive Power results from energy storage elements in the power grid (Inductors & Capacitors). Reactive power must balance in the grid to prevent voltage problems.

Inadequate reactive power support results in voltage drop. Reduced voltage causes reduction in reactive power generation by capacitors and line charging; which further reduces the support resulting in greater voltage drops and ultimately tripping of generators and voltage collapse. Reactive power levels thus have an effect on voltage collapse. To ensure system stability both under normal operating conditions and post disturbance, voltages must be maintained within acceptable levels. Transmission lines generate reactive power at light loads and absorb at heavy loads. Voltage is controlled by managing production and absorption of reactive power.

Voltage are controlled by controlling suitable reactive power devices such as shunt capacitors, shunt reactors, dynamic compensation and maintaining proper voltage schedule of generation. Type of reactive compensation required is based on the time needed for voltage recovery. Static compensation can be opted where response required is in seconds/minutes and Dynamic compensation is suitable for instantaneous responses. A proper balance of static and dynamic voltage support is needed to maintain voltage levels within an acceptable range.

The reactive power sources must be coordinated to maintain voltages at every bus in the interconnected system, under all possible system conditions. Maintaining acceptable voltages involves coordination of reactive power sources and sinks which include:

Plant voltage schedules, Transformer tap setting
Reactive device setting, Load shedding schemes

Series Capacitors: Series capacitor connected on the line reduces net transmission line inductive reactance. Increases power transfer capacity of the line and improves transient stability. Reactive power generation increases with the increase in load, with the current squared (generating reactive power when it is most needed). However at light loads series capacitors have little effect.

Shunt Capacitors: connected at sub-stations or near loads, keep the voltage within limits. But reactive power output drops with voltage squared. Hence adequate support is not

available when needed. Over voltages in the system may cause damage to shunt capacitors due to over loading and heating.

Shunt Reactors: are mainly required to keep the voltage down. They absorb reactive power in the case of light load and load rejection. They compensate the capacitive load of transmission lines.

Voltage Schedules: Generators typically operate in the middle of its reactive capability range during normal conditions and at the high-end of its reactive capability range during contingencies. Under extreme light load conditions, generators shall operate in under excited condition, when they absorb reactive power.

Power Transformer taps must be coordinated with each other and with near by generating station voltage schedules. Transformer taps should be selected so that secondary voltages remain below equipment limits during light load condition.

6.2.9.10 Load shedding Schemes: Load shedding schemes must be implemented as a last resort to maintain acceptable voltage levels.

6.2.10 POWER TRANSFER CAPABILITY – CONGESTION MANAGEMENT

Indian Electricity Grid Code defines ‘Transfer Capability’ of a transmission network as the ability to transfer electric power when operated as part of the interconnected power system that may be limited by the physical and electrical characteristics of the system considering security aspects of the grid.

Total transfer capability means the amount of electric power that can be transferred reliably over the inter-control area transmission system under a given set of operating conditions considering the effect of occurrence of the worst contingency.

6.2.10.1 Provisions in Electricity Act 2003

28(3) (a): The Regional Load Despatch Centre shall be responsible for optimum scheduling and despatch of electricity within the region, in accordance with the contracts entered into with the licensees or generating companies operating in the region:

40(c): It shall be the duty of a transmission licensee to provide non-discriminatory open access to its transmission system

5. Criteria for allowing transmission access:

ii) The short term access shall be allowed, if request can be accommodated by utilizing:

- (a) Inherent design margins
- (b) Margins available due to variation in power flows
- (c) Margins available due to in-built spare transmission capacity created to cater to future load growth

For successful implementation of OA, the assessment of available transfer capability (ATC) is very important. A pessimistic approach in assessing the ATC will lead to under utilization

of the transmission system. Similarly, over assessment of ATC will place the grid security in danger.

Central transmission Utility shall be responsible for declaration of TTC for power requirements of Long-term Access & Medium term Open Access as per CERC (Grant of Connectivity, Long term Access and Medium term Open Access in inter State Transmission related matters) Regulations, 2009.

In respect of Short-term Open Access NLDC shall be responsible for inter regional corridors and RLDC for individual control areas within the region as per CERC (Measures to relieve congestion in real time operation), regulations 2009.

Transmission Capacity Vis-à-vis Transfer Capability

	Transmission Capacity	Transfer Capability
1	Declared by designer/ manufacturer	Declared by the Grid Operator
2	Is a physical property in isolation	Is a collective behaviour of a system
3	Depends on design only	Depends on design, topology, system conditions, accuracy of assumptions
4	Deterministic	Probabilistic
5	Constant under a set of conditions	Always varying
6	Time independent	Time dependent
7	Non-directional (Scalar)	Directional (Vector)
8	Determined directly by design	Estimated indirectly using simulation models
9	Independent of Parallel flow	Dependent on flow on the parallel path

Transfer capability is generally less than transmission capacity because Power flowing on a transmission line is determined by location of injection, drawl and the impedance between them. Transfer Capability depends on Network topology, location of generator and its dispatch, point of connection of the customer and the quantum of demand, other transactions through the area and parallel flow in the network.

Transmission Capacity is independent of all of the above.

When electric power is transferred between two areas, the entire network responds to the transaction.

Transfer capability computations must consider time variant conditions, simultaneous transfers, parallel flows and the extent of dependence on points of injection/ drawl. Transfer Capability Calculations must conform to reliability criteria and accommodate reasonable uncertainties in system conditions and provide flexibility. Some cushion (margin) should be made in the total transfer capability to ensure that the interconnected transmission network is

secure under a reasonable range of uncertainties in system conditions. This margin is called “Transmission reliability Margin” (TRM).

TRM is a security margin that copes with uncertainties on the computed TTC values arising from unintended deviations of physical flows during operation due to physical functioning of load-frequency regulation, emergency exchanges between Transmission systems to meet the unexpected unbalanced situations in real time and inaccuracies in data collections and measurements. TRM is time dependent.

TRM supplements in meeting unintended load frequency regulation deviations and provides for common reserves and emergency exchanges.

6.2.10.2 Factors to be considered for assessment of TRM

- Uncertainties related to load forecasting
- Change in transmission network loading due to change in frequency
- Size of largest generating unit
- Single largest anticipated infeed

Available or Net Transfer Capacity (NTC) is therefore the difference of total transfer capability and transmission reliability margin. $NTC = TTC - TRM$

CERC Regulation on measures to relieve congestion in real time operation defines TRM as the amount of margin kept in the total transfer capability necessary to ensure that the interconnected transmission network is secure under a reasonable range of uncertainties in system conditions. Available Transfer Capability (ATC) is the transfer capability of the inter control area transmission system available for scheduling commercial transactions (through long term access, medium term open access and short term open access) in a specific direction, taking into account the network security.

Transfer capability can be increased by improving reliability of protection system, by Strengthening the safety net (introducing df/dt and under voltage load shedding schemes, System Protection schemes) and by improving system observability and deployment synchrophasor technology.

The following system strengthening and upkeep measures also aid in improving the transfer capability:

Capacity augmentation

- Augmentation of transmission system as planned in the given time without any delay.
- Generation at load centre
- Installation of shunt capacitors in pockets with high reactive drawl & low voltage

Improving availability of transmission/generation elements

- Enforcing system availability norms

- Improving O&M practices- Condition monitoring
- Minimizing outage of existing system for facilitating construction of new lines

6.2.10.3 Congestion

Congestion in a transmission system occurs when the demand exceeds the capability, when voltage levels in a corridor are beyond prescribed limits and when power flow in real time exceeds TTC. This indicates the growth of power system and occurs in deregulated markets. A congested system faces security threat.

In real time congestion may be due to inadequate system conditions or temporary outage of transmission line / Generator / Load. Congestion can be the result of more transactions by a far end consumer or seasonal skew in generation / load balance

Congestion Management:

CERC framed congestion regulations w.e.f. 11-06-2010. Under these regulations congestion charge shall be applied as a commercial measure. The congestion charge will be payable by a Regional entity or entities causing congestion in the inter-regional link or intra-regional link and receivable by a Regional entity or entities relieving congestion. Congestion charges are leviable in addition to the Unscheduled Interchange charges

Congestion mitigation measures:

Cost free methods (Physical)

- Generation/ Load Control
- Network Reconfiguration (Parallel Paths, Loops)
- Reactive power control (FACTS/ FSC etc.)
- Voltage improvement

Non-cost free methods (Commercial)

- Rescheduling of transactions
- Curtailment
- Imposition of Congestions charge
- Ancillary Services

ATC shall be declared by NLDC/ RLDCs for Inter Regional/ Intra regional and each control area. Congestion charges are imposed only when there are deviations from schedules. Rate of congestion charge is Rs.5.45/u.

Entity causing congestion would receive notice of 2 time blocks for imposing and 1 time block for lifting congestion charge.

At frequency below 50 Hz, congestion charge would be levied for over drawl or under-injection. NLDC/ RLDC shall display the TTC, ATC, Actual flow on the congested corridor on common SCADA display.

No congestion charges would be levied if congestion is due to outage of a transmission line in the corridor, but schedules are maintained.

Real time congestion management:

In case of transmission constraint or threat to grid security, the scheduled transactions may be curtailed in the manner as decided by the NLDC /RLDCs / SLDCs to relieve the transmission constraint/ to improve grid security.

CERC Regulations stipulate that information regarding TTC, ATC, TRM along with details of basis of calculations including assumptions if any and specific constraints indicated by the study should be displayed on web site.

Collective Transaction through Power Exchange(s) would normally be curtailed subsequent to the Short-Term Bilateral Transaction(s). RLDCs would curtail a Transaction at the periphery of the Regional Entities. SLDC(s) shall further incorporate the inter-se curtailment of intra-State Entities to implement the curtailment.

In case of curtailment of a Transaction caused by transmission constraints/ threat to grid security, the Transmission Charges in respect of such transaction shall be payable on pro-rata basis in accordance with the finally implemented Schedules. Operating Charges shall not be revised in case of curtailment.

Power Exchange (s) shall be responsible for the settlement on account of curtailment, directly with its participants. NLDC/RLDCs/SLDCs shall interact only with the respective Power Exchange(s), for the same.

6.2.11 GRID RESTORATION PROCEDURES:

Introduction: In an integrated power system, disturbances of major / minor nature can occur under various contingencies. Such disturbances can result in collapse of a part of the system or sometimes entire system, requiring restoration of the affected system in the minimum possible time. In order to achieve the same, it is necessary to have a well laid down restoration procedure under various conditions of partial black out and /or total black out of the system.

In the event of a black out, the initial moments are extremely precious and it requires the right decision to be taken at first instance for speedy restoration of the system. Any lapse or delay in taking the right initial decision may prove to be very costly. Hence, it is of paramount importance that all the operating personnel of Load Despatch Centres and the officials involved in grid operation should be thoroughly conversant with the restoration procedure so as to minimize the time taken in restoration of the system after partial /total black out. Further during the Restoration process the system operators, Power station and Substation personnel must act in consonance to normalize the grid.

Restoration procedures need to be revised commensurate with the expansion in grid from time to time. As per clause 5.8 (a & b) of IEGC, the procedure will be reviewed, confirmed and / or revised once every year and Mock trial runs of the procedure for different sub-systems shall be carried out by the constituents at least once every six months under intimation to the RLDC.

In the 44th Operation Coordination committee meeting held on 11-02-2010 the “Restoration Procedure in SR” was reviewed and updated and approved by the SRPC forum.

6.2.11.1 BLACK START FACILITIES

List of generating stations having self start facilities in AP is given in the annexure.

Survival/Auxiliary power requirement: Survival power can be defined as the minimum power required for avoiding the damage to the equipment in case of supply failure and keep the equipment fit for reuse immediately. Under black start failure the survival / auxiliary power would consist of the following:

- Turbine emergency oil pump
- Jacking oil pumps
- Barring gear of the turbine
- Lubricating oil pumps
- Compressors for breaker operation
- Emergency lighting
- Battery chargers communication & telemetry system.

As a general rule, the survival power requirement would be around 0.25-0.30% of the unit capacity.

Sl.No.	Unit Capacity	Survival power required
1	120 MW Unit	250-350 KW
2	210 MW unit	350-500 KW
3	500 MW Unit	1250-1500 KW

Start up power requirement: The start up power is the power required for the auxiliaries while the generating unit is restored. The requirement of start up power by various units is as follows:

Nuclear & Thermal	:	7 to 8% of the unit capacity
Hydro	:	0.5 to 1% of the unit capacity
Gas	:	1.5 to 2% of the unit capacity

The start up power requirement for starting the thermal units is considerably high as the major auxiliaries like BFP, ID Fan, FD fan, CW pumps etc. are of bigger size and the starting torque is large. However, in case of hydro units, the requirement of start-up power is comparatively much lower because of relatively very few auxiliaries. Details of the DG Set installed in the generating stations for providing start up power are furnished in the annexure.

Synchronizing facilities at Power Stations / Major sub-stations: In order to build up the system, the synchronizing facilities play a very important role. All generating stations and major 220/220KV sub-stations should have synchronizing facilities. All 400kV Stations in the Region have Synchronizing facility

Railway Traction Supply: During the time of System Restoration (Black Start) due importance should be given to the traction load and the supply to the grid points feeding the Railway Traction Station is to be extended on priority.

ANNEXURE

LIST OF POWER STATIONS WITH BLACK START FACILITY IN AP:

POWER STATION	INSTALLED CAPACITY	UNIT TYPE	STARTUP FACILITY		SYNCHRONIZING FACILITY (YES/NO)
			SOURCE	CAPACITY	
N'SAGAR	1*110 + 7*100	HYDRO	DG SET	250KVA	YES
SRISAILAM	7*110	HYDRO	DGSET	800KVA	YES
LOWER SILERU	4*115	HYDRO	DGSET	250KVA	YES
MACHKUND	70% (3*23+3*17)	HYDRO	DGSET	250KVA	YES
TBDAM	80% (4*9+4*9)	HYDRO	HOUSE SET	350KVA	YES
UPPER SILERU	4*60	HYDRO	DG SET	250KVA	YES
SRISAILM LB	6*150	HYDRO	DG SET	2*1000KVA	YES

6.2.11.2 SYSTEM RESTORATION APPROACH

While Restoring the System the following specific points must be given due importance:

(a) Systems with a fair dispersal of generating stations with Black Start facilities: Those generating stations where black start facility are available should be started up and stable islands should be formed around these generating stations by connecting essential loads.

These islands should be gradually interconnected at the earliest opportunity keeping into consideration the total load-generation balance. Care should be taken to add loads in steps keeping in view the load characteristics i.e. variation of load with respect to voltage & frequency.

(b) Systems with limited and /or distant Black Start facility: Providing start up power for systems which have few generating stations with black start facilities or where the start up power is to be imported from neighboring regions at one or two points is a challenging job. This is mainly due to the distance between the source of startup power and the generators and while extending the startup power care should be taken to control the voltages at various intermediate points. This can be achieved by providing loads and adjusting the taps of the transformers at the intermediate stations. Special attention has to be given for MVAR management and line loadings to prevent secondary collapse during restoration which will extend the restoration time.

(c) Reactive Power Control: During initial stages of restoration process, it is of utmost importance to keep the system voltages within the allowable limit. This can be accomplished by

- Charging the shorter line first
- Switching off capacitor bank
- Taking bus reactors into service
- Charging transformers and taking Bus reactors into service wherever available.
- Converting line reactors into Bus reactors wherever feasible.
- Operating generators at minimum voltage levels
- Changing transformer taps
- Energization of fewer high voltage lines.

(d) Load & Generation Balance:

- Achieving load generation balance by restoring commensurate and essential loads only.
- Restoring load in small steps keeping in view the load characteristics.
- Paying special attention while restoring traction and other fluctuating loads.
- If considered essential, then by by-passing the U/F relays initially, until sufficient loads are connected & frequency stabilizes.
- Maintaining frequency close to 50 Hz.
- Keeping Generating units on Free governor Mode Operation

(e) Priorities:

- Provide back up survival/start up power to nuclear units.
- Restore start up power supply to generating stations, critical sub-stations and load dispatch centres
- Formation of self sustaining Islands around the generating stations for which procedures should be laid down in advance.
- Avoid paralleling islands through weak ties.

(f) Communication & Co-ordination:

- Ensuring reliable communication between LDCs, generating stations and major sub-stations.
- Agreed back up procedures & delegation of control in the event of failure of communication facilities.

(g) Actions to be taken at Generating Stations and Substations: Each Substation/Generating Station should draw its own detailed procedure for the action to be taken in their stations during restoration

- To avoid delay in restoration, ensure proper functioning of bus couplers, synchronizing facility etc at regular intervals
- Ensure proper gas/air pressure in breakers and attend to minor leaks in time.
- Do not attempt charging the suspected element.
- Controlling high voltage during restoration to avoid damage to equipments
- In case of low battery condition during restoration (due to weak battery/long duration outage of power supply), to avoid excessive power drain, only the essential load/communication channels to be kept in service. Detail procedure for such actions has to be prepared and kept handy by the concerned substation/generating station

6.2.11.3 Power Supply arrangements at SLDC: Uninterrupted power supply should be maintained at SLDC to carry out operations smoothly. For this purpose the following should be made available:

- AC incoming supply from two independent sources

- Standby supply through 2nos. DG sets to feed 2nos. UPS systems being operated in parallel mode with one battery bank. Back up system should be capable of extending supply for about 6hours.

One UPS will be in service and the second one acts as standby. Standby UPS will takeover the loads automatically in case the first UPS trips.

Ratings of back up standby supplies shall be adequate to cater to SLDC requirement with enough margin to take care of additional load due to expansion.

Survival Power: Ensuring availability of backup power supplies such as batteries, battery chargers, diesel sets to ensure supply to essential loads like air compressor for operation of circuit breakers, DC system for communication systems etc.

6.2.11.4 General Guidelines: While each disturbance would be different and may require a different plan, nevertheless it would be useful to formulate general guidelines for the benefit of the load despatchers. These are described below:

- a) The operator at generating stations and sub-stations should have the knowledge of pre-identified synchronizing locations and pre laid down synchronizing procedures.
- b) Switching procedure should be clearly laid down and periodically reviewed.
- c) The transformer taps should be checked for desired setting to minimize voltage difference.
- d) The sub-stations operators and load despatchers should make a check of the capacitor banks and reactors in service & accordingly should carry out the switching operations for voltage control.
- e) Energizing of high voltage lines and cables should be avoided until enough generating capacity is available.
- f) Provision of islanding schemes area-wise, power station wise, and Unit wise would enhance the ability to restore faster. These should be fully exploited.
- g) Start up power to nuclear plants should be extended fast as poisoning of the reactors would delay restoration of nuclear units.
- h) Guidelines for decision making should be clear and should be delegated to all the major sub-stations and generating stations under varied conditions.
- i) Imparting training & providing necessary documentation to the load despatchers

AP has been divided into three subsystems geographical area wise, on the basis of natural separation taking place during disturbances. Source for providing start up power both from within the Subsystem and from outside are identified.

The details of subsystems are:

Sub System - 1: The sub-system 1 comprises of major thermal stations viz. VTPS & RYTPS and the important load centers like Hyderabad, Vijayawada, Kurnool & Nellore along with Black Start facilities at Srisailem & N'Sagar Hydro stations

Sub System - 2: The sub-system 2 comprises of Ramagundam Thermal power station and the important load centers like Ramagundam loads & Western Region with No Black Start facilities in the Sub system.

Sub System - 3: The sub-system 3 comprises of major thermal stations viz. KTPS, Simhadri & Gas Stations viz Jegrupadu, VGTS-2, Spectrum and BSES and the important load centers like Vizag, Machilipatnam, Kakinada along with Black Start facilities at U'Sileru, L'Sileru Hydro stations, Vijjeswaram stage1 gas Station.

Procedure Details: Source of start up power in case of Total Blackout of the Region, Blackout of the entire state system and Blackout of the Subsystem alone.

- Identifying the loads for each Subsystem.
- Points of synchronization with other Subsystems.
- Actions to be taken by various Generating Stations and Substations.

Note: The procedures indicated above are general in nature and provide a guideline for the Restoration team depending on the availability of Transmission Elements, Generators and the Type and the extent of Blackout. Restoration Team, on Real Time basis, should adopt the best procedure suited for the situation.

The SLDC should prepare Station wise detailed switching instructions so that the Operators will have clarity to ensure faster restoration.

General Pre Restoration Requirements: When ever there is a total Blackout in a state / region, to facilitate early building up of the stable subsystems, the constituents should keep the UFRs & FGMO in by-passed condition during the restoration process. Also all the filter banks / capacitor banks should be in switched off condition during the restoration process.

The three sub systems in AP, can be brought up independently and synchronized subsequently once the system develops in to larger sustainable islands

6.2.11.5 IMPORTANT CONNECTIONS OF AP SYSTEM WITH OTHER REGION

Western Region: HVDC Back to Back Station at Chandrapur (Bhadravathi) with A/C by-pass arrangement and 400kV Chandrapur – Ramagundam D/C

Eastern Region: HVDC Back to Back Station at Gajuwaka with A/C by-pass arrangement and 400kV Jeypore – Gajuwaka D/C

220kV Barasur – Lower Sileru and 220kV Balimela – Upper Sileru lines are not in use and can be used for black start as and when made available for operation.

WITHIN THE REGION

Karnataka:

400kV S/C Gooty – Hoody

400kV S/C Gooty – Neelamangala

400kV D/C Gooty – Raichur
400kV S/C Mehaboobnagar – Raichur
400kV S/C Kadapa – Kolar
220kV S/C Gooty – Alipur (Bellary)
220kV S/C Tandur – Sedam

Tamil Nadu

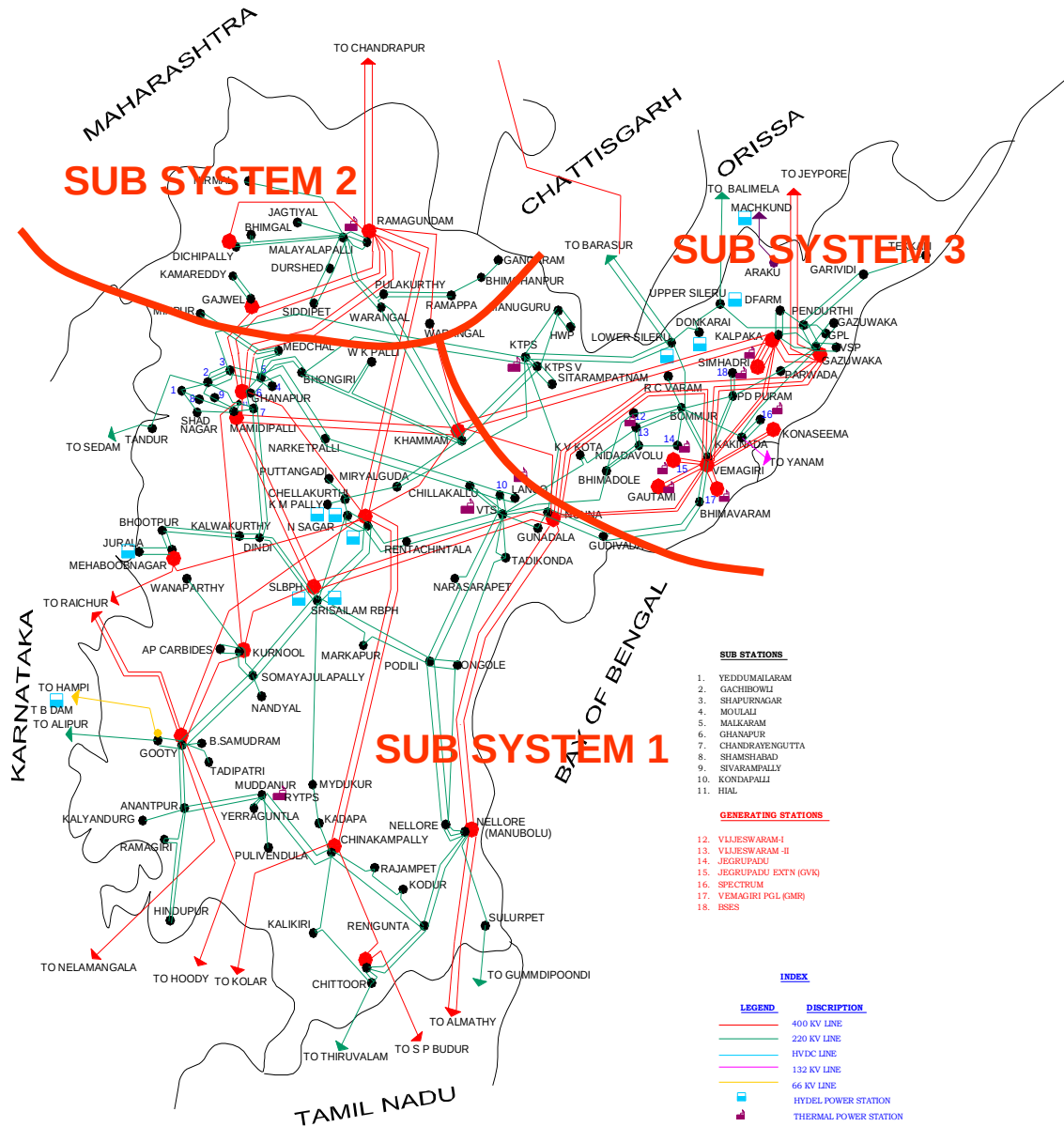
400kV S/C Chittoor – Sriperumpudur
400kV D/C Nellore – Alamathy
220kV S/C Sulurpet – Gummidipoondi
220kV S/C Chittoor - Thiruvallam

6.2.11.6 Synchronisation of Sub Systems: Once the individual subsystems are built to a stable level, the systems are synchronized with each other. The synchronization of subsystems will be done at the generating stations, preferably.

CRITICAL LOADS IN A.P

- a) Heavy Water Plant at Manuguru, KTS 220kV.
- b) Vizag Naval Wharf, Gazuwaka(AP) 220kV.
- c) Vizag steel plant, Gazuwaka(PSG) 220kV.
- d) DGNP, Vizag(Naval Wharf 132 kV)
- e) Ports at Kakinada, Kakinada 220kV.
- f) Nuclear Fuel Complex Maulali 220kV.
- g) Sriharikota, Sulurpet 220Kv
- h) Shamshabad Airport, Mamidapally 220kV
- i) Gangavaram Port, Gazuwaka (AP) 220kV
- j) Ports at Machilipatnam, Gundala 220kV

POWER MAP OF ANDHRA PRADESH



NOT TO SCALE

SRLDC, BANGALORE
FEBRUARY 2010

6.2.12 SUPERVISORY CONTROL AND DATA ACQUISITION (SCADA):

6.2.12.1 Introduction:

SCADA is a combination of various equipments that provides operator at remote location with real time information on analog and discrete measurands in addition to provision for controlling the loads and voltages of the controlled substation from remote location.

Analog parameters are continuous electrical signals which include current, voltage, frequency, active & reactive power and energy etc.

Discrete parameters are switching signals [High (1) or Low (0) signals which include status of circuit breakers, isolators, transformer taps, alarms, relay indications etc.

6.2.12.2 SCADA Architecture:

Master station is typically a collection of computers, peripherals and appropriate Input/Output subsystems that enable the dispatchers to monitor the state of power system and control it. 100% standby equipment should be made available (total redundancy at every stage including in modems). Local RTU with filters, analog to digital converters(ADC), multiplexers, Modems(modulators/demodulators) etc. form components at master station.

Field station (remote location) comprises different transducers, analog and digital cards and control cards, ADCs, RTUs, Modems etc.

Communication between master and remote stations: For transfer of speech, data and controls between master and field stations different communication systems are available which include Power line carrier communication (PLCC), Optic fibre cable (OFC), Micro wave radio systems (V SAT), PSTN etc.

Time synchronization: of master and remote stations is essential for the accuracy in computation/analysis of the data from various stations as any mismatch in time will introduce errors. GPS time reference unit enables synchronizing the sampling time in different substations, time tagged phasors of AC voltages and currents up to 50/60 times per second are acquired.

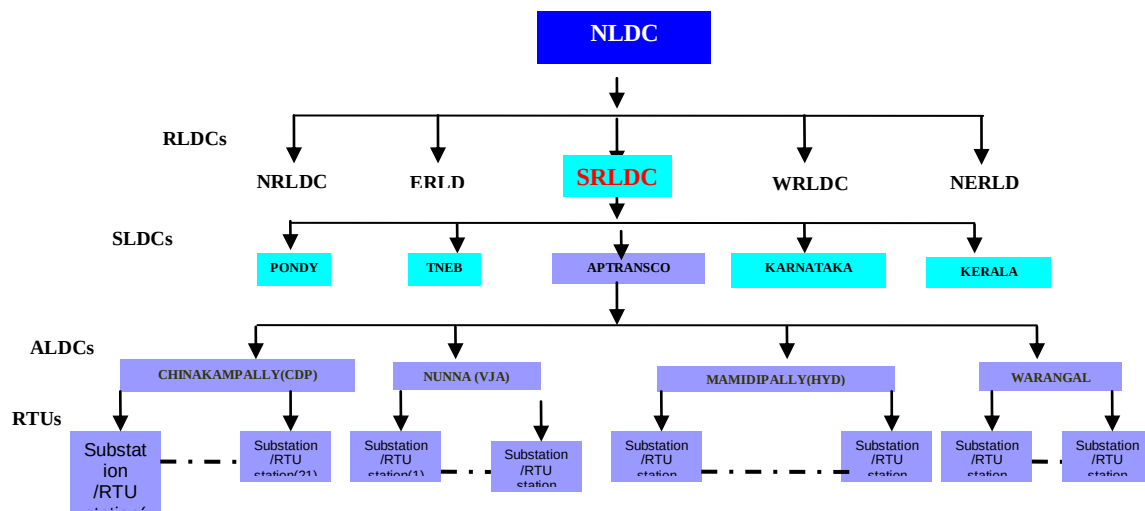
6.2.12.3 Working of SCADA:

AC parameters like voltage, current, power (active and reactive), energy, frequency etc from the designated lines and transformers in each controlled station are fed into respective transducers which convert these into DC milli-amp current signal and connect to ADCs through analog cards. The ADCs are connected to RTU which scans the data from external devices. RTU has analog and digital and control cards. Present system in APTRANSCO scans every 10 seconds. RTUs follow IEC-870-5-101 protocol. RTU will respond to controls sent from the Master. Modems are data communication devices that convert digital signals to analog signals and vice versa. Modems allow digital transmission over analog communication. They are used for long distance data transmission.

At the Master station the processor (FEP), captures the data from RTU. The Processor has RCC and SCC cards. It sends the requests to all RTUs with 10 seconds period for Data. It processes the data and pushes on to the SCADA Server for viewing by the operator. The whole system can be operated and visualized by the operator from the workstation which is the end user computer.

Unified Load Despatch: To carry out grid related operations effectively and maintain quality and reliability of power supply online monitoring of the system at various levels is necessary. With this objective concept of Unified Load dispatch scheme has been developed in each region covering the regional LDC, LDCs of constituent states with each state having area load dispatch centres covering different areas in the state for ease in handling. A typical SCADA system of the LDCs in the country is given below.

Supervisory Control and Data Acquisition System (SCADA)-INDIA



SCADA at the regional and State level LDCS is implemented. SCADA facilitates these LDCs in carrying out the following functions:

Load forecasting (Long and Short Term): The load pattern can be predicted for hourly, daily, weekly basis, based on the compilation of historical data. Long term forecasting can be done for a few years in advance, using historical data, growth rates, anticipated bulk loads etc.

Inflow forecasting: Inflow pattern for the reservoir for a week period on hourly basis based on the previous year's pattern can be predicted.

Hydro-Thermal Coordination: The hydro-thermal coordination can be achieved by minimizing the thermal cost along with optimizing usage of hydro potential.

Unit commitment: Hourly forecasted demand can be met with least cost by proper unit commitment on hourly basis, duly considering factors such as cost of generation at different

thermal stations, pre-planned depletion of hydel reservoirs, judicious and cost effective power purchases from various available sources etc.

Energy Management System (EMS): Basic functions like Generation dispatch and control and power network applications can be implemented. EMS functions include acquisition of data, effecting necessary controls, alarm processing, automatic generation control, economic dispatch, inter change and scheduling, contingency analysis, optimal power flow etc. Pre dispatch facility such as operation planning, real time system operation (current dispatch facility) and review of system operation (post dispatch facility) can be monitored effectively with SCADA.

SLDC's SCADA system covers data from all generating Stations & EHV Sub-stations in Andhra Pradesh. Total 91 RTUs cover the entire Andhra Pradesh System electrical net work. There is one local RTU at state Load Despatch Centre. About 2731 analog points and 5242 status points are handled by SLDC.

Data from entire Andhra Pradesh net work is received at SLDC; through 4 ALDCs and local RTUs.