

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

VOLUME - I



TRANSMISSION CORPORATION OF ANDHRA PRADESH LIMITED



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FOREWORD

In the year 2000, APTRANSCO brought out a “Technical Reference Book”. With the introduction of reforms in power sector in Andhra Pradesh in 1999, the erstwhile APSEB was unbundled into separate entities for Generation, Transmission and Distribution. Number of technological advancements, commercial and Regulatory procedures were introduced in APTRANSCO in the last decade, with a view to improve Transmission system and improve quality and security of power supply. Thrust was given on improving the efficiency and commercial viability. Number of measures were initiated to reduce transmission losses, increase the transmission system availability and optimal operation of the grid.

Growth in power sector has been phenomenal in the last decade after the reforms were introduced. Strength of transmission network rose from 229 nos. EHV Substation and 19826 km lines to 404 nos. substations and 31634 km lines. It is felt necessary to bring out a Reference Manual for Transmission duly updating the relevant topics in the earlier Reference Book and include various measures introduced in the last ten years. An attempt has therefore been made to bring out a Reference Manual covering the topics in Transmission Planning and Design, Construction and Maintenance practices relating to EHV substations and lines and Commercial and Load Despatch operations, in one or two volumes which would serve as a guide to the practicing Engineers of APTRANSCO.

Sri M.Gopal Rao, Former Director, APTRANSCO who has been requested to prepare a Reference Manual on the above lines, has a rich and varied experience of over 40 years in the fields of MRT, O&M of hydro generating stations, O&M of EHV substations & lines, commercial operations, planning, tendering and execution of Transmission projects. He had been a member of the expert committee of CBIP in the preparation and publication of Manuals on maintenance of EHV substations equipment and EHV Substations Design & Layout published in 2006. He has introduced Auto transformers without tertiary windings in 220 kV, 100 MVA capacity to minimize the failures and introduced 30 KVAR shunt capacitor banks at 132 kV level to improve transmission efficiency in AP. He was instrumental in the implementation of condition based maintenance with the help of diagnostic equipment such as Tan δ test equipment; off-line electronic fault locators etc.

A comprehensive Manual covering most of the technical functions in Transmission including various new technological measures and procedures introduced in the last ten years has been prepared by Sri M.Gopal Rao in two volumes. He has availed assistance from a team of Engineers drawn from different technical wings in the preparation of the Manual.

I appreciate the work done by Sri M.Gopal Rao and his team, and complement them for the best efforts they have put in. I am confident that this Manual (containing two volumes) will be very useful to all practicing Engineers of APTRANSCO. APTRANSCO would strive to update the Manual depending on the need and relevance from time to time.

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ACKNOWLEDGEMENTS

I worked in erstwhile APSEB and later in APTRANSCO for 37 years in various cadres from Assistant Engineer to Executive Director and retired in 2006. Then I served APTRANSCO as Director (Transmission) for two years and later as Advisor & Head (Power & Energy Division), Engineering Staff College of India, Hyderabad.

In the last 40 years, I have seen many technological developments such as SCADA, HVDC, GIS, Compact transmission line structures viz. Narrow based , multi circuit, Mono poles; Shunt Capacitor Banks and Underground cables at EHV level, Composite Insulators, New generation conductors to name a few.

After detailed discussions held by Sri.K.Vijayanand, then JMD(HRD) (presently MD, APGENCO), Sri P.SriRama Rao, Director (Grid Operation) and myself on the need for a Manual on Transmission for the guidance of technical staff, it was proposed to bring out a Reference Manual covering technical functions and duties of various technical wings. APTRANSCO during June 2009 issued an order requesting me to prepare Reference Manuals on construction and operational practices relating to EHV substations and lines and Commercial and Load Despatch operations. A final version of the Manual was prepared in December 2010. The Manual has been brought out in two volumes.

At the outset I express my sincere thanks to CMD and Board of APTRANSCO in having reposed confidence in me and entrusted the task of preparation of Manual to me.

During the preparation of Manual, reference has been made to relevant articles from various CBIP publications. I thank the CBIP for permitting me to extract useful information from these Manuals.

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In the last decade of post reforms, we have witnessed several technological and commercial developments in Power sector for improving the efficiency. Therefore there is a need to take stock of the developments periodically and update the Manual accordingly.

(M.GOPAL RAO)

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MANUAL ON TRANSMISSION PLANNING

1. MANUAL ON TRANSMISSION PLANNING

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 socio-economic 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 programmes, 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.

1.4.3.5 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:

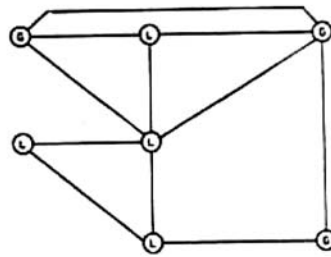
1. Focuses on identification of correlation between demand for electricity and explanatory variables.
2. Provide insights into causes of past growth and variation in growth
3. To produce a forecast, projections of independent variables are needed
4. Combines economic theory and statistical techniques
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.

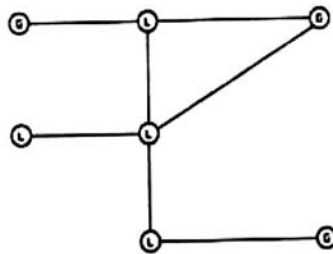
1.5 Planning Norms and Guidelines:

- 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 economical 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.



INTEGRATED SYSTEM



NON-INTEGRATED SYSTEM

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, one S/C line and one 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 unity 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	

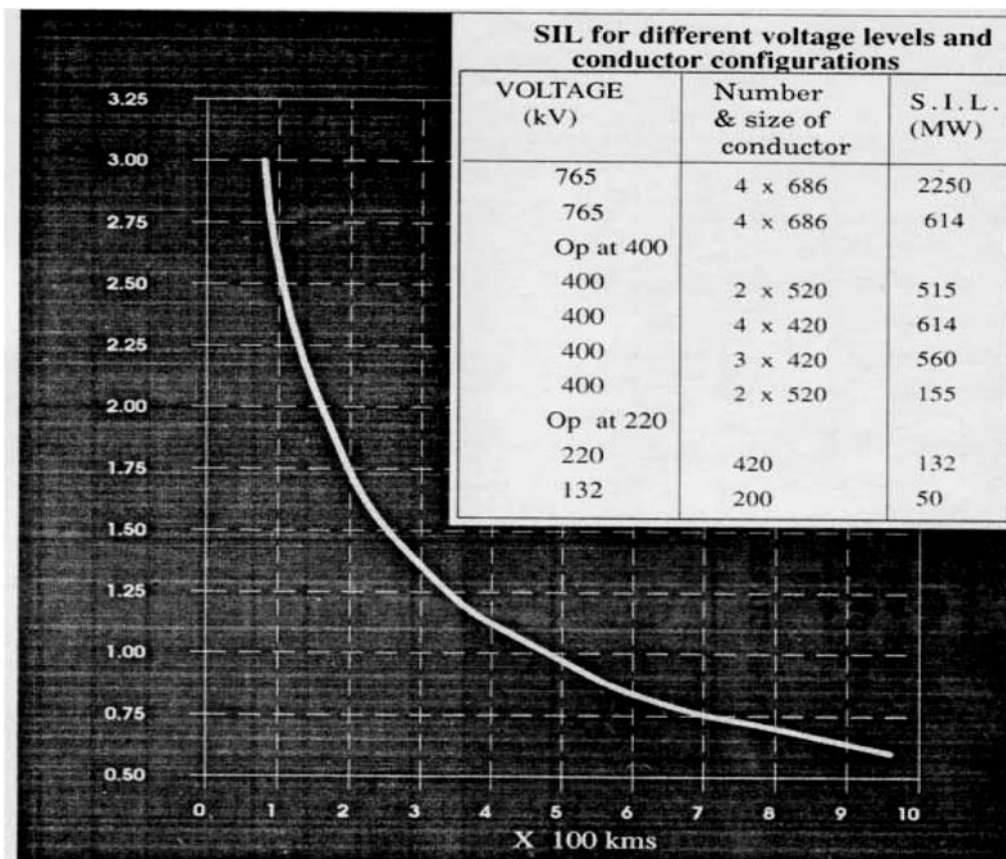
AAAC 420 Sq. mm	40			762
	45			701
	48			661
	50			632
AAAC 520 Sq. mm	40			843
	45			773
	48			726
	50			694
AAAC 560 Sq. mm	40			882
	45			808
	48			759
	50			725

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

Absorption coefficient = 0.8, Emissivity coefficient = 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.

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

$$r = \text{Discount rate (\%)/100}$$

$$n = \text{number of years from the reference year}$$

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 Power System 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, $Z_s = X \div B$

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 75° Cond. Temp Amp/MVA at100%kV	45° C ambient 75° Cond. Temp Amp/MVAat100%kV	40° C ambient 100° Cond. Temp Amp/MVAat100%kV
400k VTwin Moose ACSR	1368 / 948	1190 / 825	1800 /1247
220kV Zebra ACSR Moose ACSR	622 / 237 684 / 261	546 / 208 595 / 227	795 / 303 900 / 343
132kV Panther ACSR-	413 / 9	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).

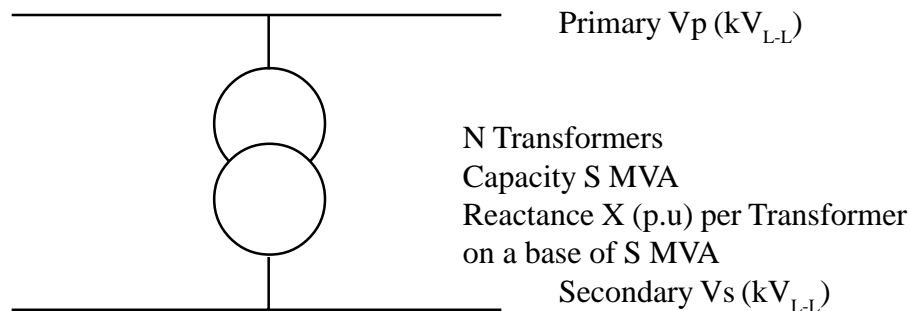
1.10.2 Selection of a particular type of arrangement should be based on existing substations and the importance of the new substation within the system. For major stations (400kV, 220kV), the most common arrangements are main and transfer bus, double-bus, double bus with transfer bus, ring bus, and breaker-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

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

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; a fixed 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 in 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 necessitate 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 submitted 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

- 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
- 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
- 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
- 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
- Forecast of standby or backup support in terms of energy and demand
- 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
- Technical and commercial losses for each voltage and category of consumers in the distribution system and Transmission losses
- Developing scenarios to show the impact of Government policies
- 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.

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 APTRANSCO's existing or planned transmission capacity arising from projected transmission transactions as submitted in the load forecast, including the transport of power through APTRANSCO's 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 plant 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 consumer's 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 consumer 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 TRANSCO 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.
- 1.14.5.2 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 (Kilometres 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.

**MANUAL ON DESIGN, ENGINEERING,
TECHNICAL SPECIFICATIONS,
TENDERING AND AWARD**

2. MANUAL ON DESIGN, ENGINEERING, TECHNICAL SPECIFICATIONS, TENDERING AND AWARD

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 Quarters.

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 sub-station, 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, reconnaissance/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 in case 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 previous 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 have sufficient power rating 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 maintenance 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 voltages switching over voltages are considered the governing factor.

Recommended Clearances

Highest system voltage (kV)	Lightning impulse voltage (kV)	Lightning impulse voltage (kV)	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 the table refer to an altitude not exceeding 1000 m and take into consideration 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 co-ordination, 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 voltages. 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 (U_m) 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.

SUBSTATION LAYOUT

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)	Nominal Diameter	
	External(mm)	Internal (mm)
72.5	42	35
145	60	52
	60	49.25
245	89	78
	89	74
	101.6	90.1
	101.6	85.4
	114.3	102.3
	114.3	97.2
	114.3	102.3
400	114.3	102.3
	114.3	97.2
	127	114.5
	127	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 (A1/St) Dia (mm)	Diameter of Complete Conductor (mm)
72.5 17.65	ACSR AAC	30/7/2.79 19/-/3.53	19.53 17.65
145	ACSR AAC	30/7/3.53 19/-/4.22	21.00 21.10
245	ACSR AAC	54/7/3.18 30/7/4.27 54/7/3.35 19/-/5.36 37/-/5.23	28.62 29.89 30.15 26.80 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

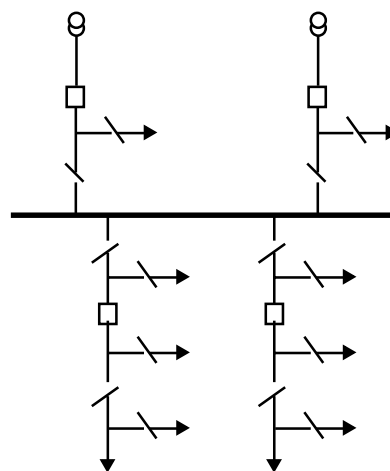
2.3.3.1 Selection of bus-bar scheme:

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 here under. 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.

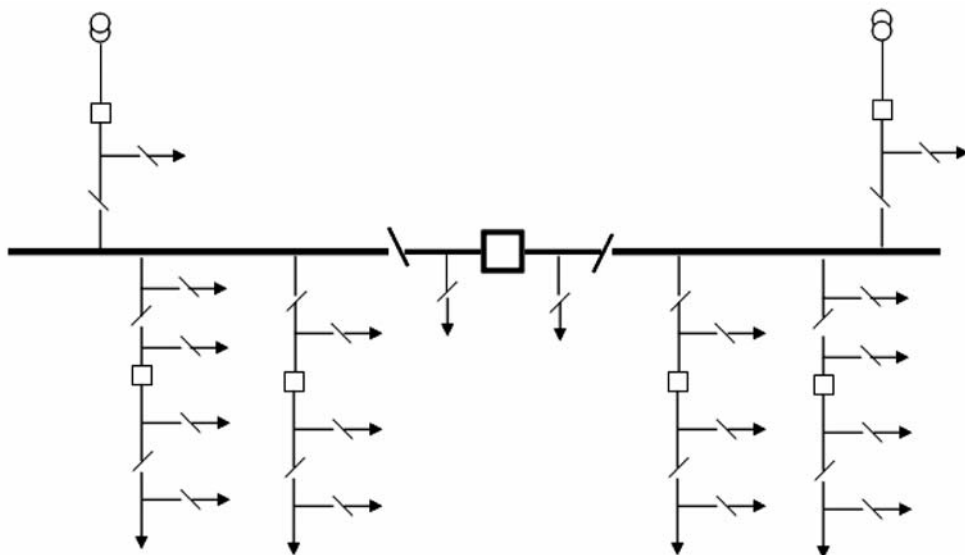
2.3.3.2 Single Bus-Bar Scheme: This is the simplest scheme, in which each circuit is provided with one circuit breaker [Fig.(A)]. This arrangement offers little security against bus bar isolator maintenance. The entire substation is lost in case of a fault on the bus bar or any bus-bar isolator and also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

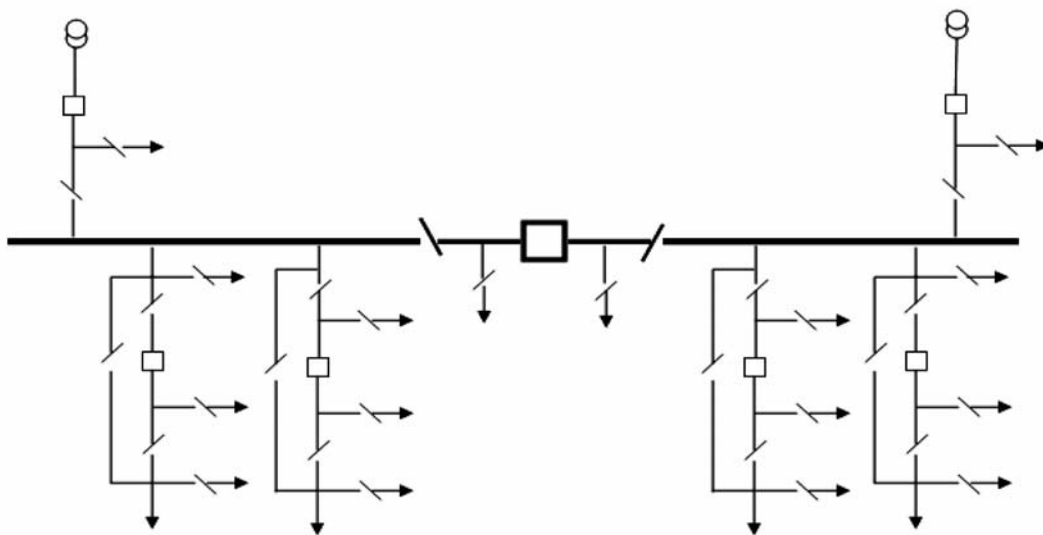
Different bus schemes shown below include two earth switches one on bus side and the other on feeder side for feeder breakers and one earth switch on bus side of transformer breaker. These earth switches are intended to discharge the concerned breakers before carrying out any works on these breakers.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



(A) Single Bus-bar Scheme



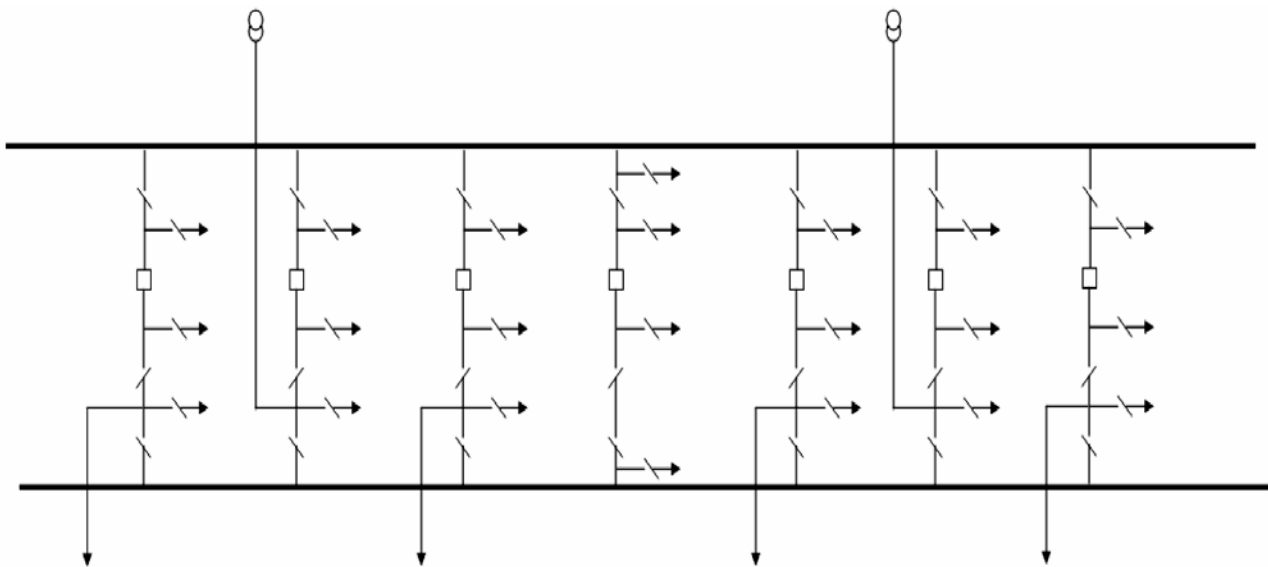
(B) Single Sectionalized Bus bar



(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.

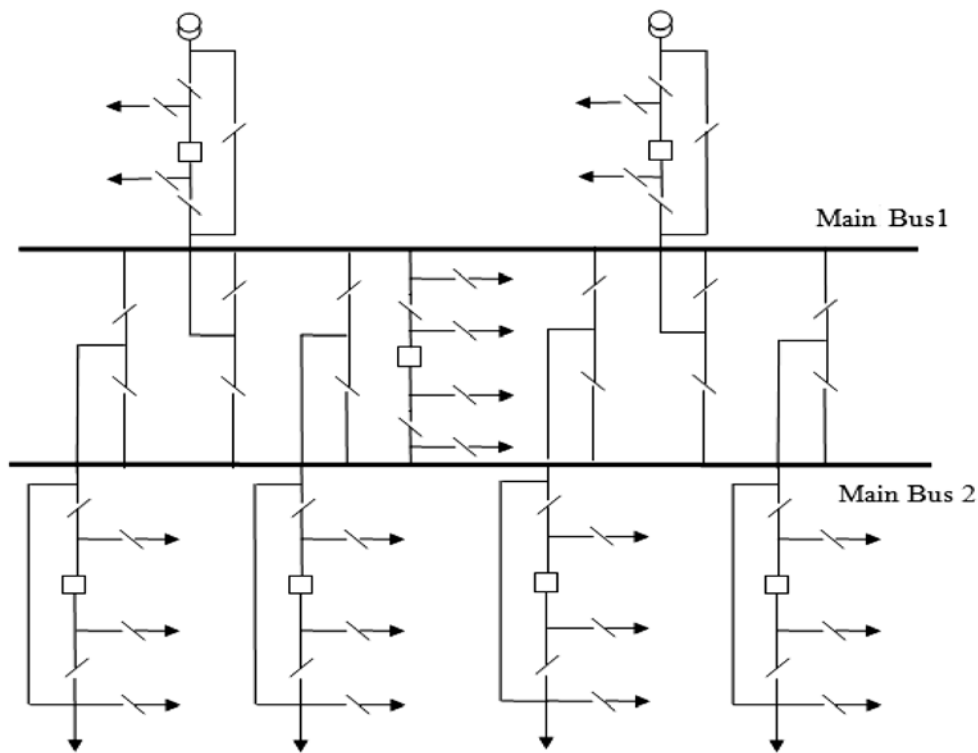
As in the case of single bus arrangement, this scheme also suffers from the disadvantage that in the event of a fault on the main bus bar or the associated isolator, there is a complete shutdown of the substation. Complete shut down can be avoided through sectionalizing the main bus with the provision 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.



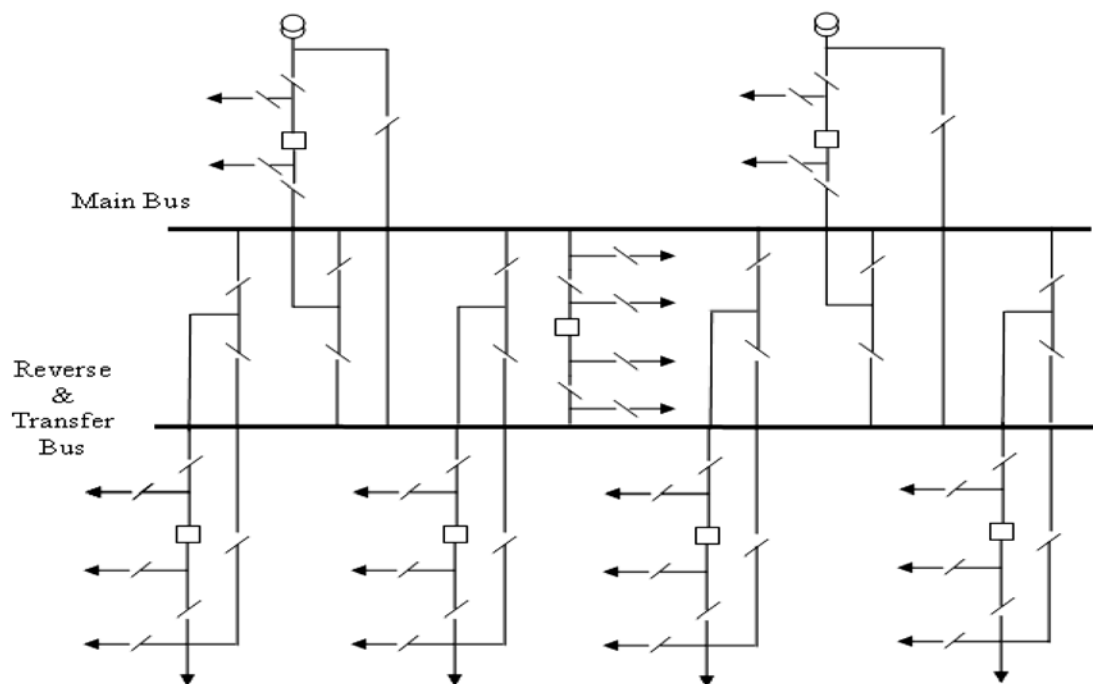
(D) Main and Transfer Bus Scheme

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.



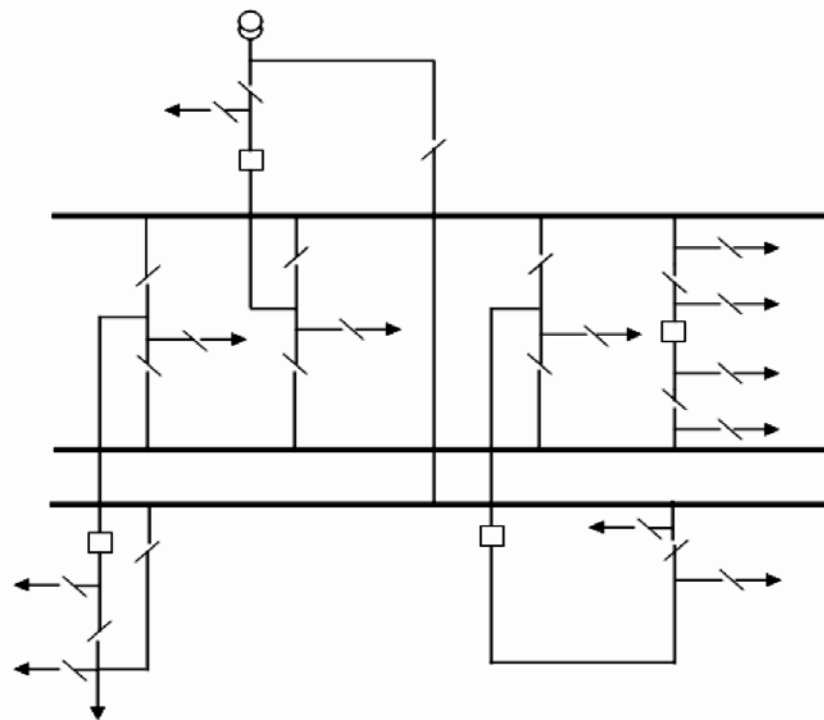
(E) Double Bus-bar System with By-pass insulators



(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.

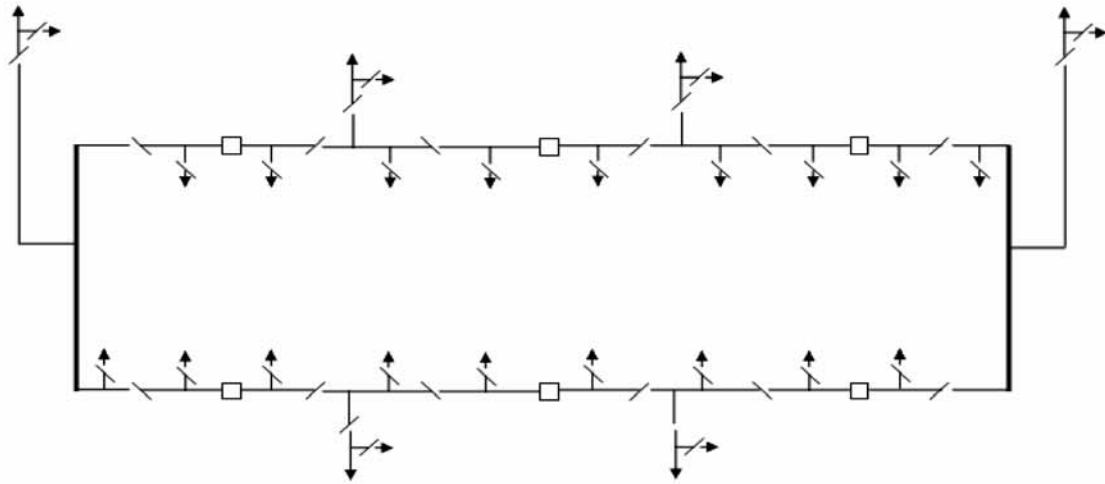


(G) Double main and transfer Bus-bar scheme

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.

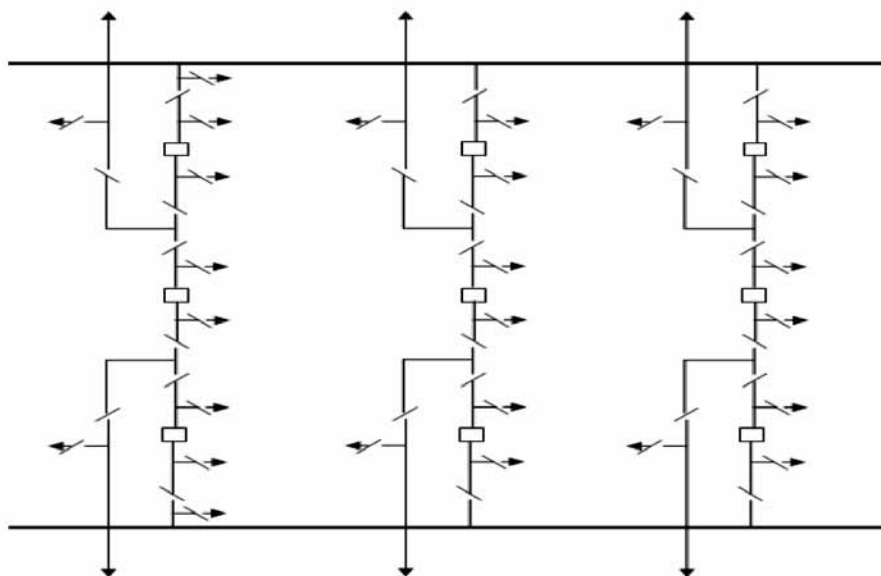
The mesh scheme is very suitable where the number of circuits is comparatively small and chances of future expansion are less such as substations associated with generating plants and also step-down substations operating at extra high voltages. This scheme has been used on many of our early installations. 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.



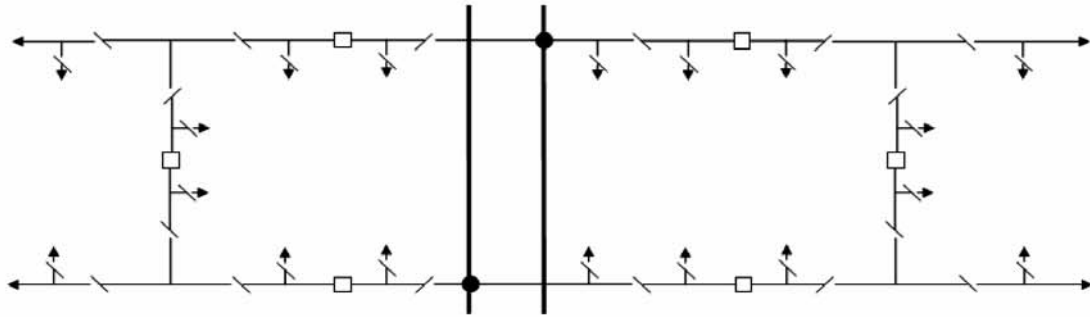
(H) Mesh Bus-bar System

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.

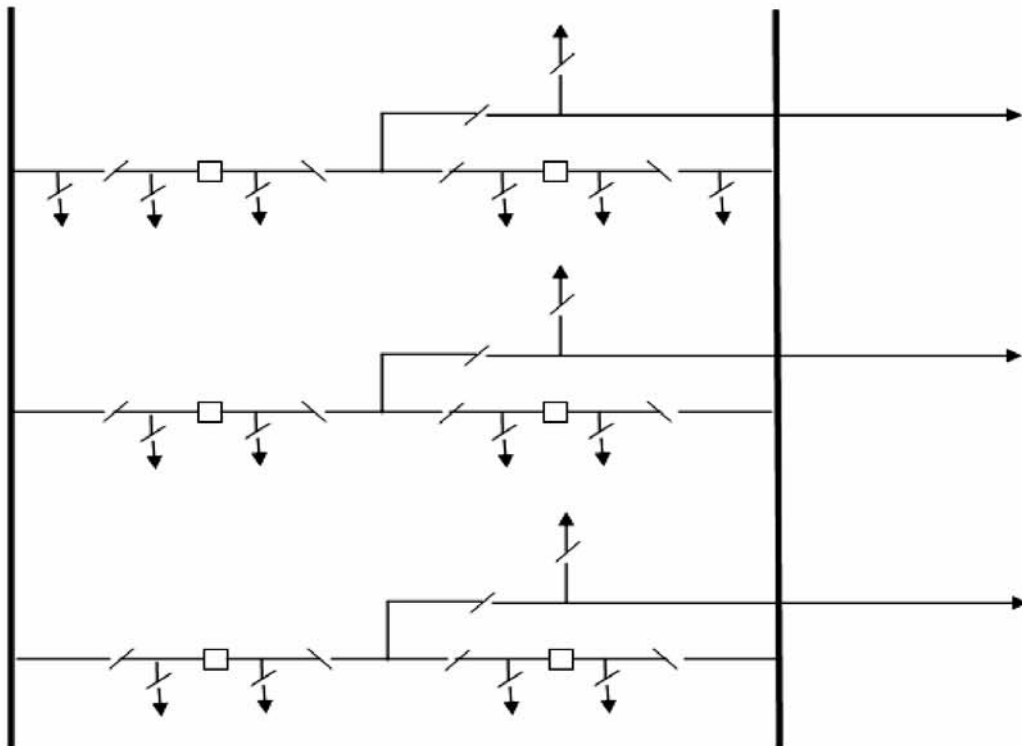


(I) One and half breaker Scheme



(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 a 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. SUBSTATION MAIN EQUIPMENT

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 400/220kV 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 BIL 170kV 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 increased 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 MVA	Voltage ratio kV	Desired CT HV side	Ratio (Amps) 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	400/1II	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, SF6
145 kV	:	Minimum oil, Bulk oil, Air Blast, SF6
245 kV	:	Minimum oil, Bulk oil, Air Blast, SF6
420 kV	:	Minimum oil, Bulk oil, Air Blast, SF6

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)					
		1250	1600	2000	2500	3150	4000
36	25 31,5	1250	1600		2500		
145	31.5 40	1250	1600 1600	2000 2000		3150	
245	31.5 40 50	1250	1600 1600	2000 2000 2000		3150 3150	4000
420	40 50 63		1600	2000 2000		3150 3150 3150	4000 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: 1 No. numerical distance protection schemes and a separate backup directioned Over Current/ Earth Fault scheme is used for 132kV lines.

Relay settings for Distance Protection:

Zone-1: Set to cover 80% the protected 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 protected line + 50% adjacent shortest line or 120% of protected 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 protected 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% Un 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% Un 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:

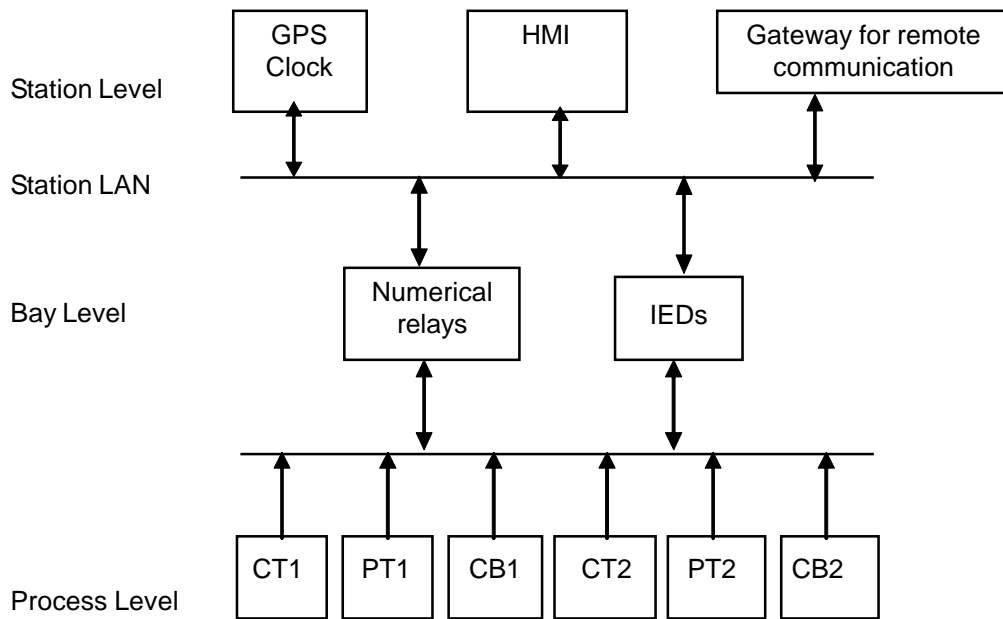
During 70s protection was through electromechanical relays and the control of the CBs, isolators, and transformer tap changers were done manually. The real time status was available through analog meters mounted on the C&R panels. The reports and logs were prepared manually.

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.



Up arrow indicates data flow

Down arrow indicates control

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 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 time synchronized 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(isolate 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	Class 5	Class 3	Class3	Class3	Class 3	Class 3
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 connected 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 in turn 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, Sand 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 (CONDUCRETE/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 GlareIndex
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 co-efficient 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 number pump of 96 m³/hr capacity with a pressure of 5.6 kg/cm² (gauge)
- b. For the total number of hydrants exceeding twenty upto fifty five, one no. pump of 137 m³/hr capacity with a pressure of 7.0 kg/cm² (gauge)
- c. For the total number of hydrants exceeding fifty five, upto hundred, one no. pump of 171 m³/hr with a pressure of 7.0 kg/cm² (gauge)

As per TAC guidelines, the jockey pump should have a capacity of 10.8 m³/hr. and the hydro-pneumatic tank should have a capacity of 18 m³. The effective capacity of the Fire Water Tank should be not less than one hour of aggregate pumping capacity, with a minimum of 135 m³.

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 maximum when the rate of burning of the flammable liquid is 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 tanks should be equal to the sum of the following:

One-hour pumping capacity of Hydrant System or 135 m³ whichever 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 out going circuits for closing and tripping, alarm and indication for control and relay panels. A separate circuit is provided for the emergency load normally fed cm 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-1 - 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. Basic 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	32°C	32°C	32°C
	b) Maximum temperature for conductor (ACSR)	75°C	75°C	75°C
	c) Maximum temperature for ground wire	53°C	53°C	53°C
	d) Minimum temperature	10°C	10°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 from the tower body			
	a) Suspension insulator string when deflected			
	0 deg	1.530 Mtr.	2.130 Mtr.	3.050 Mtr (for deflection up to 22 deg)
	15 deg	1.530 Mtr.	1.980 Mtr.	
	30 deg	1.370 Mtr.	1.830 Mtr.	
	45 deg	1.220 Mtr.	1.675 Mtr.	
	60 deg	1.070 Mtr.	---	
	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	Broken wire conditions: 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, inside 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 PRELIMINARY 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 Metro politan 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 Ethelene 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 of single wires or additionally segmented in order to 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 line failure (potentially several weeks), it is reasonable to maintain two full redundant circuits for 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

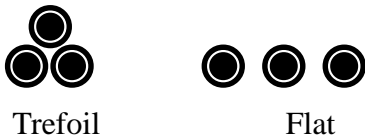
- Variation in number of cables (maximum 12 in number)
- Variation in depth of water table
- Variation in loading of cables (80% to 100%)
- Soil thermal resistance of the ground

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.



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 (°C)	Factor	Ground Temperature (°C)	Factor	Soil Thermal Resistivity (°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:

Cross-sectional Area (mm²) Direct buried	Direct buried	Pipe Duct	In Air	
			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

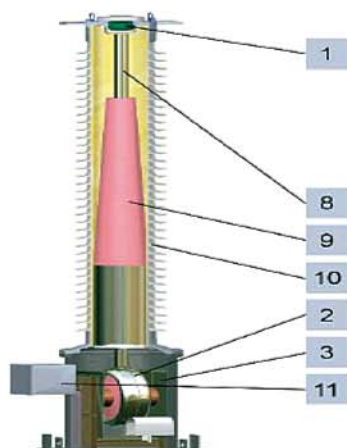
Creepage distance requirement is less compared to porcelain insulators

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.

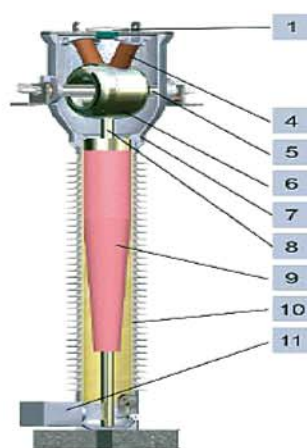
Gas filled units with composite insulators are available for voltage transformers, current transformers and combined voltage and current transformers. Diagrams showing these varieties are given below.

Voltage Transformer Type SVS



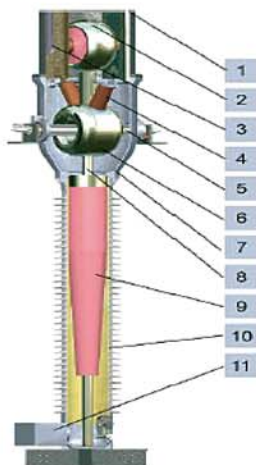
- Available from 72.5 to 800 kV
- Single high voltage coil design upto 800 kV ensures measurement accuracy
- Wide Ferro resonance-free design without use of an external damping device
- Suitable for line-discharging
- Ideal for power plants for tariff metering as accuracy does not depend on the system 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 di-electric 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-conducting 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-conducting 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 (1/3rd 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 current 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 comers.

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	Windings (kV)	Bushings
a) 1.2/50 μ s wave shape impulse withstand (kVp)	400 220 132 33 11	1450 950 550 70 25	1550 1050 650
b) Power frequency Voltage withstand (kV rms)	400 220 132 33 11	630 460 275 70 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/OFAP. 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, tapchangers 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
- b) The conservator shall be fitted with magnetic oil level gauge with low level electrically insulated alarm contact.
- c) Conservator shall be provided in such a position as not to obstruct the electrical connections to the transformer.
- d) 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 gasketted 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.	Characteristic	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 (tanδ) 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) Tan δ 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 atleast 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 with stand 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
	Synthetic, Air	120	70
6.	Any part of metal or of insulating material in contact with oil except contacts	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 ground 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 lightning impulse withstand voltage (kvp)	1424	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 creepage distance of porcelain housing (mm)	10500	6125	3625
15	Rated short time withstand current for 1 Sec. duration (kArms)	40	40	31.5

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:

S1 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		
		400 KV	220 KV	132 KV
1.	Type of installation	Single Phase, Oil Filled, Hermetically sealed and 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) Secondary voltage (volts) i. Winding i (metering) ii. Winding ii (protection) iii. Winding iii (protection)	400/ $\sqrt{3}$ 110/ $\sqrt{3}$ 110/ $\sqrt{3}$ 110-110/ $\sqrt{3}$	220/ $\sqrt{3}$ 110/ $\sqrt{3}$ 110/ $\sqrt{3}$ 110-110/ $\sqrt{3}$	132/ $\sqrt{3}$ 110/ $\sqrt{3}$ 110/ $\sqrt{3}$ 110-110/ $\sqrt{3}$
6	a) Simultaneous output of secondary winding (VA) Winding-i Winding-ii Winding-iii b) Rated total thermal burden(simultaneous) VA	50 200 50 300	50 200 50 300	50 200 50 300
7	Accuracy class Winding-I Winding-ii Winding-iii	0.2 0.5 3P	0.2 0.5 3P	0.2 0.5 3P
8	Method of earthing system	Effectively earthed		
9	1.2/50 μ s lightning impulse withstand voltage (kVp)	1400	1050	650
10	1minute 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 Metering 0.2 ±0.2 Protection 0.5 ±0.5 Protection 3P ±3	Phase displacement ±10 ±20 ±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°C	As pr 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)	<div>I</div> <div>110 – 110/$\sqrt{3}$</div> <div>0.2</div> <div>150</div>		<div>II</div> <div>110 – 110/$\sqrt{3}$</div> <div>3P</div> <div>50</div>

2.8.3 Surge Arrestors (Lightning Arrestors):

Principal parameters:

Sl.No	Particulars	400kV	220kV	132kV	33kV
1	Nominalsystem 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 currentfor I 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		
6	System frequency (Hz)	50 ± 2.5			
7	Neutral grounding	Effectively earthed			
Technical requirements of metal oxide d(Dgapless) arrestors					
1	Rated arrestor 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 connectors suitable 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) b) 120% rated current (minutes)	5 30	5 30	5 30	5 30
6.	Rated voltage (kVrms)/highest system voltage (kVrms)	400 420	220 245	132 145	33 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)	1425	1050	650	170
	b) Across isolating distance (one terminal subject to lightning impulse (kVp) and opposite terminal subjected to power frequency (kvrms) voltage (as per IS)	1425	1200	750	195
	ii) Rated 1 minute power frequency withstand voltage (kvrms)				
	a) Across isolating distance (kvrms)	610	530	315	95
	To Earth and between poles (kvrms)	520	460	275	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	2500	2500	2500	2500
	b) live part to ground	6400	4900	3800	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	12 Secs 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	1000micro 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 operated 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 pr 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 Load 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 \pm 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.

		<p>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.</p>
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	<ul style="list-style-type: none"> 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	<ul style="list-style-type: none"> 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	<p>For local communication one (1) optically isolated communication port (IR port)</p> <p>For remote communications – one (1) RS485 port</p>
xix)	Display	Alpha – Numeric LCD with bright backlight. Automatic back light time out after 1 minute.
xx)	Software	<p>The supply, software installation and testing of the following software is to be considered.</p> <ul style="list-style-type: none"> 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 in the panel shall be with 1100 V grade, single 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 minimum 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 nos. 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 within 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 interposing 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 fault 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 by pass 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
 - o have two sets of relays and each set shall be able to monitor the three phase voltage.
 - o have one set connected to the line CVTs with a fixed setting of 20% of rated voltage
 - o have one set connected to the bus VTs with a fixed setting of 60% of rated voltage
 - o 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
1	Normal System Voltage kV	400	220	132	33
2	Maximum System Voltage kV	420	245	145	35
3	Continuous current rating (A) rms	2500	2500	1600	1600
		(only indicative to be speicified 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	10 A at 220V DC	10 A at 220V DC	10 A at 220V DC	10 A at 220V DC
	ii) No. of auxiliary contacts	10NO and 10NC as spare	10 NO and 10 NC as spare	10 NO and 10 NC as spare	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 Hexafluoride (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/Sq.mm 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 in tact 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 reclosing 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 7/3.18mm Steel	54/3.53 mm Aluminum 7/3.53 mm steel
b.	Number of stands i) Central steel wire ii) 1 st steel layer iii) 1 st Aluminum layer iv) 2 nd Aluminum layer v) 3 rd Aluminum layer	1 6 12 18 --	1 6 12 18 24	1 6 12 18 24
c.	Sectional area of Aluminum mb(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°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°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 butt 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	11.5x10 ⁻⁶ per deg C	11.5x10 ⁻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:

Dual Window Single Mode(DWSM) Optical Fibre Characteristics

Mode Field diameter	8.6 to 9.5 μm ($\pm 0.6\mu\text{m}$)
Cladding Diameter	125.0 $\mu\text{m} \pm 1 \mu\text{m}$
Mode Field concentricity error	$\leq 0.6 \mu\text{m}$
Cladding non-circularity	$\leq 1\%$
Cable cut-off wavelength λ_{cc}	$\leq 1260 \text{ nm}$
1550 nm loss performance	As per G.652D
Proof Test level	$\geq 0.69 \text{ Gpa}$
Attenuation Coefficient	@ 1310 nm $\leq 0.35 \text{ dB/km}$ @ 1550 nm $\leq 0.21 \text{ dB/km}$
Chromatic Dispersion; Maximum:	18 ps/ (nm \times km) @ 1550 nm 3.5 ps/ (nm \times km) 1288 –1339 nm 5.3 ps/ (nm \times km) 1271 – 1360 nm
Zero dispersion Wavelength:	1300 to 1324 nm
Zero dispersion Slope:	0.092 ps/ (nm ² \times km) maximum

Polarization Mode dispersion coefficient	$\leq 0.2 \text{ ps/ km}^{\text{ns}}$
Temperature dependence:	Induced attenuation $\leq 0.05 \text{ dB}(-60^{\circ}\text{C}- +85^{\circ}\text{C})$
Bend Performance:	@1310 nm ($75 \pm 2\text{mm}$ dia mandrel), 100 turns; Attenuation Rise $\leq 0.05 \text{ dB}$ @ 1550 nm ($30 \pm 1\text{mm}$ radius Mandrel), 100 turns; attenuation Rise $\leq 0.05\text{dB}$ @ 1550 nm ($32 \pm 0.5\text{mm}$ dia mandrel), 1 turn; attenuation Rise $\leq 0.50\text{dB}$

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	$\leq 3.5 \text{ PS/ nm x km}$

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 (SiO_2) 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-hygroscopic, 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			
		70 KN B & S Type normal Dise Insulators	120 KN B&S Type normal Dise Insulators	70 KN B & S Type Anit-fog Dise Insulators	120 KN B&S TypeAnti-fog Dise 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 / Sperodical 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 + / - (ii) Spacing + / -	(0.04d + 1.5) mm where ‘d’ is the dia of shell (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 frequency withstand voltage (kV) Wet	45	45	45	45
15	Flashover power frequency voltage (kV) Dry Wet	80 45	80 45	85 50	85 50
16	Visible discharge voltage (kV)	9	18	9	18
17	Puncture voltage (kV)	120	120	140	140
18	Impulse flashover voltage (kV) Positive Negative	125 130	125 130	125 130	125 130
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 220 kV	9 13	10 14	9 13	10 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 SUS-PENSION STRING	SINGLE SUS-PENSION 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 Insulator Disc (mm)	460	460	460	470	470

NOTE: MAJOR CROSSINGS

Supension Towers : 120 kN 2X24 Discs.

Angle Towers : 160 kN 2X24 Discs.

STRING CHARACTERISTICS:

The Characteristics of complete porcelain string shall be as follows:

Sl. 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.

S. 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 string insulator	11,500 Kgs.	11,500 Kgs.	16,500 Kgs.
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 (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.

Die 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
(I) Diameter of Sleeves (mm)		
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
(Outer Diameter)		
i) Aluminum	54 + or – 1	38 or – 0.5
ii) Steel	24 + or – 0.5	18 + or – 0.5

b) After Compression (Corner to Corner) i) Aluminum ii) Steel (face to Surface) i) Aluminum ii) Steel	$53 + \text{or} - 0.5$ $23.4 + \text{or} - 0.5$ $46 + \text{or} - 0.5$ $20.2 + \text{or} - 0.5$	$37 + \text{or} - 0.5$ $17.4 + \text{or} - 0.5$ $32 + \text{or} - 0.5$ $15.1 = \text{or} - 0.5$
(II) Length of Sleeve (mm) a) Before Compression i) Aluminum ii) Steel b) After Compression i) Aluminum ii) Steel	 $735 + \text{or} - 5$ $305 + \text{or} - 5$ $785 + \text{or} - 5$ $330 + \text{or} - 5$	 $610 + \text{or} - 5$ $203 + \text{or} - 5$ $650 + \text{or} - 5$ $225 + \text{or} - 5$

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)		
a) Before Compression Outer Diameter	$54 + \text{or} - 1$	$38 + \text{or} - 1$
b) After Compression		
i) Corner to Corner	$53 + \text{or} - 0.5$	$37 + \text{or} - 0.5$
ii) Surface to Surface	$46 + \text{or} - 0.5$	$32 + \text{or} - 0.5$
a) Before Compression	$305 + \text{or} - 5$	$241 + \text{or} - 5$
b) After Compression	$330 + \text{or} - 5$	$271 + \text{or} - 5$

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° C
b) Maximum ambient air temperature (under sun)	50° C
c) Minimum ambient air temperature	7.5° C
d) Maximum daily average ambient air temperature	35° C
e) Maximum yearly average ambient air temperature	30° 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 NT, 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 load 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 – 1IS 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 assemblies	IEC 439
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:3618IS: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:5578IS: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	Transmission Tower Bolts	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:6745BS:443
102	Method of chemical Analysis of slab zinc	IS:406
103	Aluminum conductors steel reinforced for over head 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, 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	IEC-794- Part-1., E1, E3, 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 (FOTPS)	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 Auvehoegvaj -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, Pentonvilla Road, N-19-ND-UK.

MANUAL ON COMMERCIAL AND LOAD DESPATCH OPERATIONS

3. MANUAL ON COMMERCIAL AND LOAD DESPATCH OPERATIONS

3.1.1 INTERFACE METERS GENERATION–TRANSMISSION–DISTRIBUTION

3.1.1.1 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, Nanna (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 stakeholders 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.

3.1.1.2 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.

3.1.1.3 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	:	97
b) PGCIL/CGS	:	41*
c) NTPC	:	04
d) Other Inter-state	:	02
e) IPPs	:	19
f) CPPs	:	19
g) APGPCL	:	06
h) 132kV EHT PDs	:	13

* Inclusive of inter-state lines

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.

3.1.1.4 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 recorded by staff with reasons in the control sheets.

3.1.1.5 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.

3.1.1.6 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.

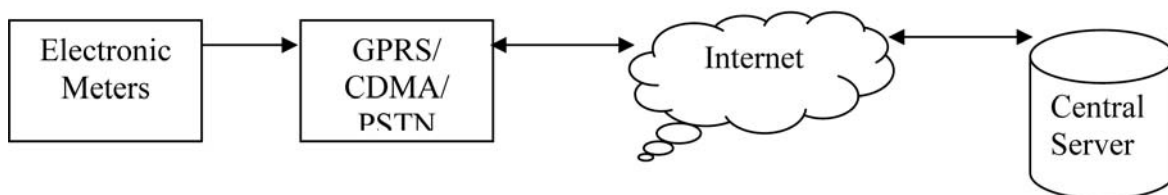
The EBC staff will prepare the DSM metering points and the list will be communicated to the concerned SEs/DEs (TL&SS) for taking necessary action to avoid repetition of the same in future.

3.1.2 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:



3.1.2.1 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.

3.1.2.2 The usage of AMR data for various applications is 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.

3.1.3 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 (Kadapa), 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.]

$$E_o = \{E_{\text{LVs(E)}} + E_{\text{EHT}} + E_{\text{EHT PDs(E)}} + E_{\text{GENCO-SLBPH(I)}}\}$$

Where,

$E_{\text{LVs(E)}}$ = 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)

$E_{\text{EHT PDs(E)}}$ = 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 $E_{\text{EHT PDs(E)}}$ 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.

$E_{\text{GENCO-SLBPH(I)}}$ = 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.

3.1.4 Procedure for Determination of Transmission Charges

3.1.4.1 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 issued Regulation vide APERC Regulation No. 5 of 2005.

3.1.4.2 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.

3.1.4.3 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 APERC Regulations.

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, the 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	5
2009-10	788.13	13744	47.79	4.16%
2010-11	948.50	15542	50.86	4.13%
2011-12	1215.75	15963	63.47	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.

3.1.4.4 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&5 of APERC Regulation No. 1 of 2006, the Annual fee and monthly Operating charges calculation procedures are as follows:

1. SLDC charges (Annual fee & Operating charges) shall be payable by Generating companies (including captive generating plants), Distribution licensees and Trading Licensees using Inter-State Transmission network under any agreement or arrangement with Transmission Licensee in proportion to the capacity contracted.

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

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.

2. 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.
3. 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.

4. 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:

$$\text{CC (in Rs)} = \text{Investment} \times \frac{r}{1 - \frac{1}{(1+r)^t}}$$

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 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.

5. 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. An amount equivalent to two months' operating charges shall have to be deposited in advance as security against default in payment of operating charges.

3.1.4.5 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.

3.1.4.6 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.

3.1.4.7 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.

3.1.4.8 The monthly operating charges per MW shall be computed as per the following formula

$$\text{Operating Charges (Rs/MW/pm)} = \frac{\text{Annual Operating Charges}}{\text{Total Generation Capacity (MW)} \times 12}$$

3.1.4.9 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 or earlier, 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.

3.1.5 IMPLEMENTATION OF OPEN ACCESS (OA) AND TRADING

The Electricity Act, 2003 has come into force from 10th June, 2003 repealing the Indian Electricity Act, 1910; Electricity (Supply) Act 1948; and Electricity Regulatory Commissions Act, 1998. to improve performance of power sector. 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”

ISSUES IN OPEN ACCESS:

- a) Freedom to buy/sell, and access to market
- b) Adequacy of intervening transmission capacity
- c) Transmission/wheeling charges
- d) Treatment of transmission losses
- e) Energy accounting, scheduling, metering and UI Settlement.

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:

- Procedures for Long-term and Short-term open access approvals
- Agreements for long term and short term open access between Transco – Discoms – Open Access Users
- Long-term 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 and regulations made by CEA under section-5 of the act 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

3.1.5.1 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.

3.1.5.2 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 MSLDC
- c) Discom-A to get the consent of APTransco and “no-objection” of APSLDC.
- 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

3.1.5.3 INTRA STATE OPEN ACCESS

Intra State Regulations

Regulation No.2 of 2005 • APERC (Terms&Conditions of open access) Regulations, 2005

RegulationNo.2of2006 • 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, and point of drawl, voltage level, 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.10,000/- 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 user shall enter into OA agreements with transmission and distribution licensees, as applicable after issue of OA approval by Nodal agency. Such agreements shall include a clause pertaining to payment security mechanism.
- 7) Date of commencement of OA shall be as agreed in the agreement.

3.1.5.4 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 of 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

3.1.5.5 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:

S. No.	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 them 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 consumers
- 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 set out 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 Exist Point	Time Block	Allocated Capacity at Entry point (KW)	Net capacity at Exit point (KW)
SPDCL	1. Sch. Consr	11 kK	1 to 96	1000	830.8
	2. Sch. Consr	132 kV	1 to 96	2000	1900.0
	3. Sch. Consr	33 kV	1 to 96	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%) → $1000 \times 10.66/100 = 106.60 \text{ kW}$

APPENDIX – 2

(A). Where Generator is Generating at the level of Scheduled Capacity: (kW)

DISCOM	Consumer consumer	Sch. Cap.at Exit Point	Recorded Consumption	Accountable to genertor	Accountable to Discom	Deviation
SPDCL	1.Sch. Consr	830.8	1000	830.8	169.2	Nil
	2.Sch.Constr	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.Constr	2676.6	3000	2676.6	323.4	Nil
	6.OA.Constr	4750.0	4000	4000.0	0.0	(-)750.0
NPDCL	7.Sch.Constr	821	1100	821.0	279.0	Nil
	8.OA.Constr	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.]Consr	2000	1900.0	1800	1710.0	2000	190.0
3.OA.Consr	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.Consr	5000	4750.0	4500	4275.0	4000	(-)275
7.Sch.Consr	1000	821.0	900	738.9	1100	82.1
8.OA.Consr	2000	1778.6	1800	1600.74	1900	299.26
9.Sch.consr	1000	818.9	900	737.01	1200	81.89
10.OA.Consr	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.

3.1.6 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.

3.1.6.1 Types of Power Procurement\ 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.

3.2 LOAD DESPATCH OPERATIONS

3.2.1 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.

3.2.1.1 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.

3.2.1.2 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.

3.2.1.3 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 .

3.2.1.4 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.

3.2.1.5 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.

3.2.1.6 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.

3.2.1.7 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.

3.2.2 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.

3.2.2.1 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.

3.2.2.2 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 drawls/injections at the rate of 5 paise per KVARh for voltages below 97 % (at the 400kV interconnectivity point).
- Receivable/payable for reactive power drawls/ 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.

3.2.2.3 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.

3.2.3 UI Charges Calculation methodologies

3.2.3. (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 $P = (X\% \text{ of } A)$

Balance actual generation $B = (\text{Actual generation } A - P)$

UI of generator for inter-state = $[\text{Balance generation } B - (\text{I sch} + \text{E sch})]$

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.

3.2.3.(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 = $[\text{Actual drawl } A - (T + \text{I sch})]$

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 imposes power holiday/restrictions

$$\text{UI energy drawl} = \{ \text{Actual drawl } A - (T + I \text{ sch}) \}$$

- 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 mis-match 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.

3.2.3.3 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 giving 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

3.2.4 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.

3.2.4.1 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.

3.2.4.2 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:

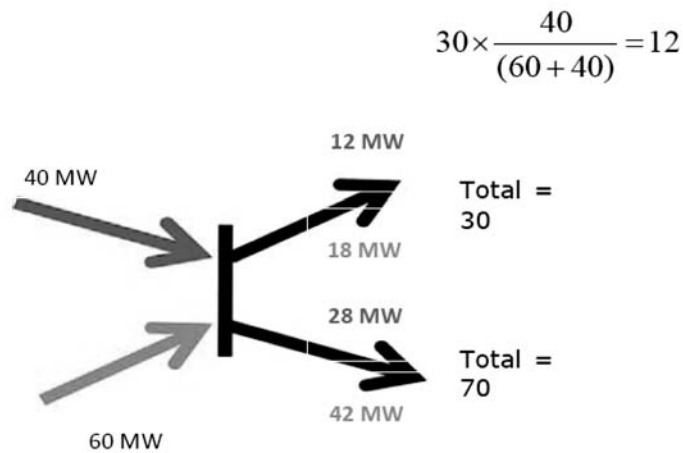
- a) Marginal Participation sensitivities A_{ij} are obtained that represent how the flow in line j changes when the injection in bus i is increased by 1 MW. The increase in 1 MW has to be compensated by a corresponding increase in load or generation at some other bus or buses – called the slack bus (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.

Average Participation Method



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.

3.2.4.3 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 the entire 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.

3.2.4.4 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.

3.2.4.5 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.

3.2.4.6 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.

3.2.5 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, and 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	Standby Meter
A station	Generating Station	On all outgoing	On all outgoing	(i) High voltage (HV) side of generator transformers (ii) High voltage side of all 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 sub-stations 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 outgoing 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, and 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.
- 2) 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) 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) 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 frequency

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 cannot 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 bus bars, 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 bus bars, 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 meters 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.

3.2.6 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 49.22 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 loosing the reserve. This is apart from public suffering and public unrest.

3.2.6.1 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 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 32 (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) 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.

3.2.7 SCHEDULING AND DESPATCH CODE

3.2.7.1 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)

3.2.7.2 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).

3.2.7.3 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 interstate 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/despaching 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 00-00 hrs to 24-00 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

3.2.7.4 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 E_1 , the scheduled energy is S_1 , actual net energy (metered) is A_1 , all in ex-bus MWh. Suppose the expected energy availability for Day 4, as declared by the generator, is E_4 . Then, the schedule for day4 shall be drawn up such that the scheduled energy for Day 4, shall be $S_4 = E_4 + (A_1 - E_1)$. Similarly, $S_5 = E_5 + (A_2 - E_2)$, $S_6 = E_6 + (A_3 - E_3)$, $S_7 = E_7 + (A_4 - E_4)$, 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 draws 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 form 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 out, 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.”

3.2.7.5 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.

3.2.8 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 ahead 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 drawls 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.

3.2.9 GRID MANAGEMENT:

Objective of grid management is to maintain power supply ensuring quality, reliability and security of the grid.

3.2.9.1 There are five regional grids operating in the country

Northern Region: covering Delhi, Uttar Pradesh, Uttaranchal, 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.

3.2.9.2 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 faults in the system: If system faults persist due to mal operation or non-operation of protective relays, severe voltage dips occur which may cause tripping of lines for pull out of generators, leading to grid collapse.

3.2.9.3 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.

3.2.9.4 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 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, there by 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. Project construction units shall 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.

3.2.9.5 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 with in 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.

3.2.9.6 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 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 overheating. 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.

3.2.9.7 Surge impedance loading:

When a line is idle charged (no load), the line generates/produces reactive power at $\frac{1}{2} CV^2$ (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 $\frac{1}{2} LI^2$ (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.

$$1/2CV^2 = 1/2LI^2$$

$$\text{Surge impedance (SI)} = V/I = \sqrt{L/C}$$

$$\text{Surge impedance Loading (SIL) (Power)} = V^2/S.I.$$

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.

3.2.9.8 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.

3.2.9.9 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 nearby generating station voltage schedules. Transformer taps should be selected so that secondary voltages remain below equipment limits during light load condition.

3.2.9.10 Load shedding Schemes: Load shedding schemes must be implemented as a last resort to maintain acceptable voltage levels.

3.2.10 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.

3.2.10.1 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.

3.2.10.2 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 in feed

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 of 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

3.2.10.3 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 Congestion 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 and 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.

3.2.11 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.

3.2.11.1 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 startup 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 startup 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
SRISAILMLB	6*150	HYDRO	DG SET	2*1000KVA	YES

3.2.11.2 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 backup 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:8

- 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. Detailed procedure for such actions has to be prepared and kept handy by the concerned substation/generating station

3.2.11.3 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. Backup 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 take over 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 margins 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 compressors for operation of circuit breakers, DC system for communication systems etc.

3.2.11.4 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 Jegurupadu, VGTS-2, Spectrum and BSES and the important load centers like Vizag, Machilipatnam, and Kakinada along with Black Start facilities at U'Sileru, L'Sileru Hydro stations, Vijjeswaram stage1 gas Station.

Procedure Details: Source of startup 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: Whenever 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

3.2.11.5 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

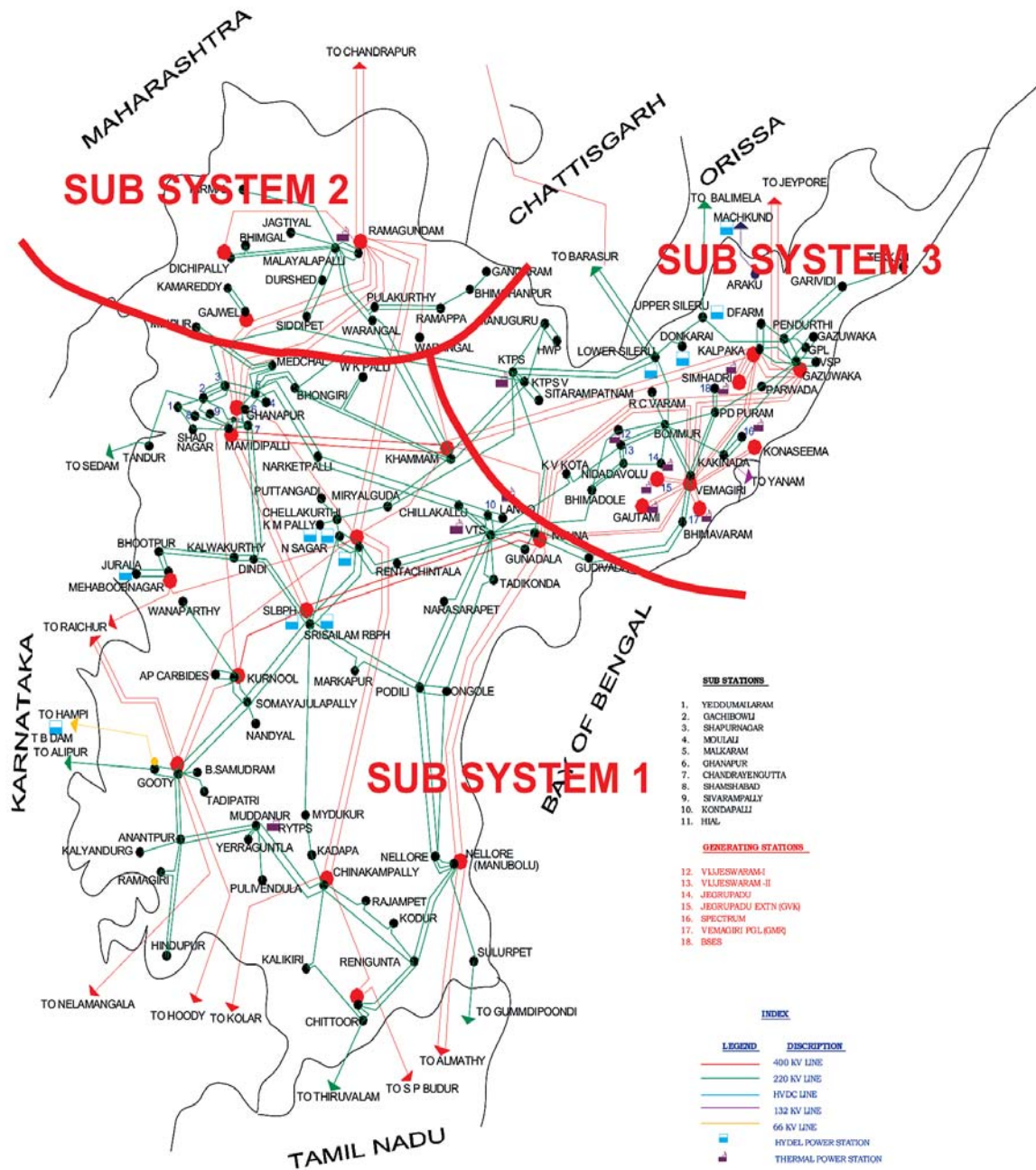
220kV S/C Chittoor - Thiruvalem

3.2.11.6 Synchronization 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

SRLCD, BANGALORE
FEBRUARY 2010

3.2.12 SUPERVISORY CONTROL AND DATA ACQUISITION (SCADA):

3.2.12.1 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.

3.2.12.2 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), 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.

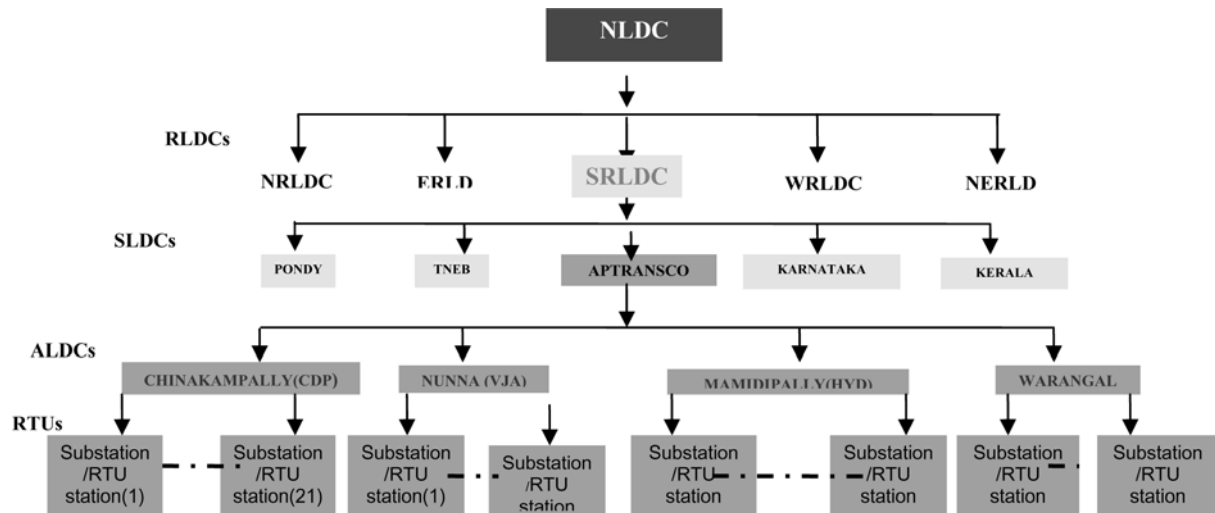
3.2.12.3 Working of SCADA:

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 Dispatch: 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 forecast 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 129 RTUs cover the entire Andhra Pradesh System electrical net work. There is one local RTU at state Load Dispatch Centre. About 3500 analog points and 7200 status points are handled by SLDC.

Data from entire Andhra Pradesh net work is received at SLDC; through 4 ALDCs and local RTUs.



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

- BY M. GOPAL RAO