



सत्यमेव जयते

ELECTRICITY DISTRIBUTION NETWORK PLANNING CRITERIA



**CENTRAL ELECTRICITY AUTHORITY
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INTRODUCTION

The availability of 24x7 uninterrupted power supply to all the consumers along with transparency in the operation, consumer participation & empowerment is utmost important in today's power scenario. As per Section-42 of Electricity Act 2003, it is the responsibility of the respective DISCOM to develop and maintain an efficient, coordinated and economical distribution system in its area of supply, hence, DISCOMs are required to install adequate electrical infrastructure to meet the load growth and operational requirement for providing 24x7 reliable and quality power supply to all consumers.

Central Government launches various schemes from time to time to provide financial assistance to the States/discoms for providing funding for creation/augmentation of distribution infrastructure in the country. For development of distribution sector, Government of India has launched various scheme in recent past like Deendayal Upadhyaya Gram Jyoti Yojana (DDUGJY), Integrated Power Development Scheme (IPDS), SAUBHAGAYA and recently Revamped Distribution Sector Scheme(RDSS) to provide funding to discoms for creation/augmentation of distribution infrastructure along with IT intervention to help the discoms to reduce the losses and providing reliable & quality power to the consumers. However, successful implementation of the schemes rests with the DISCOMs/Power Departments, hence, they have to plan their distribution system adequately and optimally to meet the Standard of Performance (SOP) notified by the respective SERCs.

Since the enactment of the Electricity Act 2003, Indian Power Sector has come a long way in accomplishing the goal of providing 24x7 reliable power with optimal utilization of resources. However, still distribution sector stands out as the weakest link in the entire value chain of the Electricity sector due to various reasons such as :

- Weak & inadequate distribution network with very low penetration of Information Technology (IT)
- Obsolete/ageing infrastructure at sub transmission and distribution level which is not compatible to the automation and Intelligent Electronic Devices (IEDs).
- Poor Metering, Billing and Collection efficiency resulting in high AT&C losses.
- Delay in adoption of New technologies including Smart meters & Information & Communication Technologies(ICT) in Distribution sector
- Poor forecasting and inadequate power procurement planning
- Capacity and capability constraints of the existing workforce including technology embracing barrier.

It is very crucial to overcome the above challenges and endeavor to become smarter distribution utility by showcasing the best performance in terms of reliability and accountability. Thus, there is a need for adopting new technologies, introduction of IT and automation in operation of distribution utilities to overcome the present challenges along with better planning of the distribution system.

For any power distribution utility, planning of adequate distribution system to cater existing as well as future load growth requirement is of utmost importance to provide 24x7 reliable power to all the consumers. The driving factors for planning of the system generally are consumer growth, consumption growth, change in consumption pattern of the consumers, dynamic price of electricity, energy efficient measures etc. The Discoms need to work out energy/peak load requirement, trajectory of AT&C losses, optimal design of the distribution system, Impact of IT intervention including smart metering /DSM etc. and this planning may be done now a day by use of software tools available for distribution planning.

In order to provide a uniform framework and guidelines to distribution utilities/DISCOMs and to evolve integrated approach for strengthening of Distribution System in the country, a document on “Electricity Distribution Network Planning Criteria” has been prepared by Central Electricity Authority under guidance of Ministry of Power. This document has been prepared after detailed consultation with DISCOMs and is based on the inputs provided by the Distribution Companies considering the existing status of distribution system in their area of operation. This document will help various planning agencies in distribution sector to design the efficient distribution system by utilizing the resources optimally.

CHAPTER-1

SUMMARY OF DISTRIBUTION PLANNING CRITERIA

1.1 OBJECTIVE FOR PLANNING

The main objectives of Distribution Network Planning is to design and develop an efficient and economical distribution network to provide safe, reliable and quality power supply to all consumers without any overloading or inefficient operation. Further, the following objectives of Distribution Planning are envisaged:

- Providing 24x7 reliable, quality & economical power to all consumers
- Making the power system more agile, resilient & smart with environmental sustainability.
- Optimum utilization of existing assets with minimum Technical & Commercial Losses
- Minimum addition of new network elements to meet the performance standards set by the respective Regulatory Commissions
- Phase the system expansion to match the growing power demands in the time horizon

The planning methodology includes the analysis of existing system and planning of optimal & efficient future requirement of Sub-transmission and Distribution system to meet the expected demand in the operational areas. The methodology would also include the requirement of adequate communication system and IT infrastructure like SCADA, DMS, OMS, AMI, etc. for enhancing the reliability & quality of the power supply and better consumer satisfaction.

1.2 APPROACH FOR PLANNING

The approach for planning of distribution system should be based on the following parameters: -

- Ensuring an adequate network for existing as well as future needs with N-1 redundancy in the network as per the site conditions / feasibility of network, to provide 24x7 reliable power supply.
- Optimization of loading of Feeders and Transformers (Power and Distribution transformers)
- Reducing technical & commercial losses below 10% by optimizing the network
- Ensuring power quality parameters like voltage regulation, harmonics, reactive power compensation etc. in line with the applicable Standards.

- Adoption of Information & Communication Technology like AMI, SCADA/ DMS for metering, data acquisition, data analysis and control for better managing & planning the system
- Consumer satisfaction /Faster disposal of the Consumer Grievances
- Meeting the Standard of Performance(SOP) notified by the respective SERCs

The Distribution system should be planned with the primary objective of meeting existing and future load growth efficiently & optimally and maintaining the desired redundancy level in the system to meet current & future supply requirements for reliable power supply. The approach for Integrated system planning of distribution network with upstream sub-transmission network may be adopted to facilitate the analysis considering various contingency conditions with a view to identify loading pattern of various elements in the distribution network along with constraints in upstream network for taking appropriate improvement measures. Feeder wise /Area wise loss level is also assessed as per the existing & future loading conditions along with measures to match with future technical & commercial loss reduction trajectory.

With the use of system studies software, the distribution system can be studied against the existing and future projected load conditions and a short term & Mid/long term program for new development/addition/augmentation of the system (Transformers/ Feeders/ grid stations/ Substations etc.) may be prepared based on the system study results. The other various works related to upgrading IT tools/software to meet various business requirements, availability of compatible hardware & software and communication system for better connectivity between various offices, control centers & substations etc. are also to be planned for introducing automation in the system.

1.3 PLANNING ATTRIBUTES

To meet the objectives, the distribution system planning must have the following attributes:

- 1) Analysis of the existing distribution network and its operational situation.
- 2) Load Forecasting: Compilation of data of existing loading on the network and loads that will be incident in the future (2-5 years time span). Estimating load projection for the time duration for which planning is done.
- 3) Identification of inadequacies in the network considering future load projections and designing of optimal future network for future load projections
- 4) Examining the options available to address the inadequacy in the system in a cost effective manner, like enhancement of existing transformer / feeder capacity or reconfiguration of existing network or setting up a new substation etc.
- 5) Planning for replacing existing meters with Smart Pre-paid meters as per notification of MOP/SERC

- 6) Conformance to safety requirements by adhering to appropriate design standards.
- 7) Identification of works to improve system performance to increase reliability & quality of supply and to reduce technical & non-technical losses.
- 8) Adopting technically feasible solution for network inadequacy in such a way that system should operate at minimum overall cost, comprising both capital and running cost. i.e. the proposals for expansion should comply with the set standards and should be the least-cost optimal solution which was selected among technically-feasible alternatives.
- 9) To adopt regular safety and reliability audits of all major equipment of the network
- 10) Efficient Integration of Distributed Energy Resources(DER).and Electric Vehicles (EVs) with the distribution grid
- 11) To install Reactive Power Compensation at appropriate places as per requirement for correcting voltage profile and reduce technical losses
- 12) Matching of sub-transmission and distribution planning with transmission sector planning.
- 13) Adoption of ICT tools like SCADA, DMS, OMS etc. for system data acquisition, analyzing the network and control for increasing the reliability of the system.
- 14) Selection of network equipment based on merits of overall service life of electrical devices factoring both CAPEX & OPEX to ensure optimization of cost and highest system reliability

1.4 SUMMARY OF DISTRIBUTION NETWORK PLANNING CRITERIA

To achieve the objectives set out, the following criteria may be adopted for planning the Sub-Transmission and Distribution system:

1. Generally, each 33/11 kV, 33/22 kV, 22/11 kV Sub-stations, subject to space constraints, should have two or more transformers and two or more incoming feeders from two different sources for meeting N-1 contingency for reliability considerations.
2. In case of two Power Transformers at one Sub-stations, both power transformers should have sufficient cyclic loading capacity to supply the sub-station maximum demand in the event of outage of single largest capacity transformer. As the load increases on the sub-station restricting the above condition, an additional transformer may be provided to meet the N-1 condition at the sub-station. The additional power transformer should also have sufficient cyclic loading capacity to

supply the maximum demand in the event of outage of single largest capacity transformer.

Additionally, N-1 condition for 11 KV critical feeders may also be explored by 11 kV network interconnection from nearby Sub-station for shifting of load during any contingency like outage of any transformer or S/S feeding line, if additional transformer /line is not available to meet N-1 condition.

3. After study of existing system, in case, the loading of 33/11 kV, 33/22 kV, 22/11 kV power transformer reached beyond 70% of its capacity, some of the load may be shifted to other lightly loaded Power Transformer in the same S/S . If not possible within the sub-station, the reduction in loading may be explored by shifting some of the load on the nearby under loaded Sub-station. In case, no nearby Sub-station with spare capacity is available, then the augmentation of Sub-station should be planned by installing additional transformer at the Sub-station after taking load growth for at least 5 years and 70% loading.
4. In case, the space is not available in the sub-station for installation of additional transformer, the existing transformer may be replaced with higher capacity transformer after ensuring the alternate power supply to consumers during augmentation period. It should also be ensured that the incoming feeding lines of Sub-station have sufficient capacity to cater the additional load of Sub-station after proposed augmentation before taking up the augmentation work.
5. In case, augmentation of sub-station is also not possible due to some reasons like non-availability of space, Sub-station capacity restriction or inadequacy of incoming feeding lines etc, then a new Sub-station at the appropriate load center may be planned.
6. The location of Sub-stations should be near to the load center as far as possible. Adequate power supply at normal voltage should be available at grid sub-stations to meet the system demand. The transformation capacity and feeding line capacity at the grid Sub-stations shall be such that the system demand shall be met even with the outage of one of the feeder or outage of largest capacity transformer (N-1 condition).
7. In urban areas where it is difficult to get sufficient land for establishment of new Grid Sub-station near load area, a Unitized sub-stations with one power transformers (33/11 kV or 22/11kV) may be planned near load center without conventional control room with provisions of Ring Main Units (RMUs) at incomer and outgoing feeders without compromising N-1 condition. The RMUs should be remotely controlled if SCADA is available. Each Unitized sub-station may get the power supply through RMU which may get in-feed supply from two separate Grid Sub-stations having 100% back up capacity for reliability purpose. The capacity of 11 KV feeders may also be designed such as to get full back up through RMUs from nearby feeders in case of any fault or emergency.

8. The each incoming circuit should be designed to take up the full load of the S/S to meet N-1 contingency. If both the incoming feeders at a S/S emanate from the same source (Grid sub-station), then each feeders should supply independent sections of the 33/11 kV or 33/22 kV or 22/11 kV Sub-station and the two sections being isolated from each other by bus coupler or isolators. This results in increased reliability. However, if one of the 33 kV feeders has much longer route, the shorter feeder may normally feed the 33/11 kV s/s and the other one may be used as stand by feeder to supply in emergency.
9. The grid sub-station may be indoor, outdoor or underground type depending on the site requirement. The Sub-station may be Air Insulated (AIS), Gas Insulated (GIS) or Hybrid as per the requirement, however, only GIS Sub-stations should be planned in coastal areas /disaster prove areas. GIS / Hybrid sub-stations may also be adopted in urban areas where the sufficient land is not available for AIS.
10. On load tap changing device may be provided on HT windings of 33/11 kV or 22/11 kV power transformers of 3.15 MVA and higher rating for better voltage control by manual and automatic means.
11. The installed capacity of 33/11 kV, 33/22 kV, 22/11 kV grid sub-station should be on the basis of spatial load forecast, demographic factors, space availability, right of way considerations, existing network configuration and N-1 redundancy etc. and should have the adequate capacity to cater to load growth for at least 5 year. However, the feeding lines should be planned for meeting the load of the sub-station upto 15 years due to ROW issues.

The maximum capacity of 33/11 kV, 33/22 kV and 22/11 kV Sub-stations shall be as per CEA Regulations as amended upto date. As per latest CEA (Technical Standards for Construction of Electrical Plants & Electric Lines) Regulations 2022, the maximum capacity of 33/11 kV, 33/22 kV and 22/11 kV Sub-stations shall be as 100 MVA, 75 MVA and 75 MVA respectively.
12. While deciding the capacity of the transformers, the de-rating due to increase in altitude and for cables, due to depth of burial in the ground, thermal resistivity and laying configuration should be considered.
13. Before deciding the ratings of the equipment in a grid sub-station, it is necessary to prepare a schematic/lay out diagram of the substation. There are a number of arrangements dependent upon system voltage, position of the sub-station in the system, flexibility, reliability of supply and cost etc. The factors to be considered while deciding the layout are:
 - All electrical safety requirements, clearances , fire detection & extinguishing system, earthing & ventilation etc should be as per Central Electricity Authority (Measures relating to Safety and Electric Supply) Regulations, 2023 or any successor or subsequent Regulations in this regard. It shall also be ensured in the layout to carry out equipment maintenance without interrupting the entire supply.

- As far as possible, there should be alternate arrangements in the event of outage of any one important item of equipment/line.
- The layout should be economical and should not hinder future expansion.
- The lay out of the sub-stations shall be such that the fire, in case of any emergency, shall not spread from one to other equipment and areas as far as possible.
- The sub-station shall have independent circuit breaker control of 33 kV and 22 kV incoming feeders and 22 kV or 11 kV outgoing feeders. The incoming feeders should also have independent circuit breakers at source end.

14. Single Bus bar, Single Bus bar with Bus sectionalizer, main and transfer Bus, Double bus or mesh scheme are various types of layouts being adopted in the Sub-stations. A layout which is most economical and satisfies technical requirements as per actual site conditions may be adopted. Generally, a 33/11 kV sub-station with single bus bar with a sectionalizer on the 33 kV as well as 11 kV sides may be adopted in rural areas, while double bus system / main & transfer bus system may be adopted in towns /cities.

15. Bus-bar shall be able to carry the expected maximum load current continuously without exceeding the temperature rise limit as per relevant IS. The capacity of a bus-bar shall also be checked for maximum temperature rise of the conductor under short circuit conditions.

16. The incoming & outgoing feeder in new Sub-stations may be planned on multi ckt towers or on Uni-poles to minimize ROW requirement in future. In urban /congested areas, underground cables may be used for incoming & outgoing feeder. In case of Electric lines of 33 kV and below passing through the protected areas (National Parks, Wildlife Sanctuaries, Conservation Reserves, Community Reserves), Eco-sensitive zones around the protected areas and Wildlife Corridors, only underground cable shall be used.

17. The voltage regulation in 33 kV, 22 kV, 11 kV and LT feeders should not exceed the following limits at the farthest end under peak load conditions and normal system operation regime.

11 kV, 22 kV & 33 kV	(-) 9.0% to (+) 6.0%
Low Voltage	(-) 6.0% to (+) 6.0%

The action should be initiated if the voltage regulation reaches (-) 8% or (+) 5% for 11 KV, 22 kV and 33 kV and (-) 5% or (+) 5% for LT level to bring the voltage variation within limits.

The load bifurcation on nearby line / DT, augmentation of lines, use of High Voltage Distribution System (HVDS), use of energy efficient Distribution Transformers & use of automatic switched capacitors at 33 kV Sub-stations or at Distribution Transformers level may be adopted to enhance the voltage profile at the farthest

end. The installation of Automatic Power Factor Controller (APFC) panels at LT level may also be explored as per requirement.

18. The adequate capacity of Shunt capacitors should be connected on secondary side of 33/11 kV, 33/22 kV or 22/11kV transformers, if found necessary, based on network studies conducted. Where the sub-station is feeding loads which have high harmonic levels, suitable harmonic filters shall also be installed. In cases of sub-stations loaded with highly fluctuating loads like arc furnaces etc., flickers and voltage regulation problems may be overcome by installation of static var compensators (SVCs) or STATCOM. In mainly urban areas, where high voltage, beyond the specified limits, may occur during off-peak period and less voltage during peak load period, the automatic reactive compensation (capacitor + reactors) may be adopted. The power quality should be maintained as per IS 17036 (Distribution System Supply Voltage Quality).
19. The Distribution transformers to be installed in the field should have standard rating as per relevant Indian Standards (IS-1180) and should follow other rules and regulations in force like Quality Control Order, Star rating criteria etc. The higher capacity DTs (i.e. larger than 250 kVA) may be used for concentrated loads or area with high load density and lower capacity DTs (less than 250 kVA) may be used for Rural areas based on the requirement. 33/0.415 kV distribution transformers of appropriate rating, may also be used based on techno-economic considerations and actual field conditions.
20. It is a good practice that the Utility may Standardize the ratings of Distribution Transformers, switchgears etc to be used within the utility as per the load conditions in the utility areas, as standardization of ratings would help in achieving reduction in inventory for purposes of Procurement & Maintenance and reduction in price on account of bulk purchase.
21. The distribution transformers in urban areas may operate at an average loading of about 65%-75% of their rated capacity and would have to be augmented when the maximum demand on the transformer reaches above 80% of capacity (sustained peak). In case of Rural areas, a slightly higher loading based on the time horizon of peak load and assessment of load growth may be considered for augmentation adoption. In urban areas, the use of BESS (Battery Energy Storage System) at DT level may also be explored, based on economic consideration, to reduce the peak loading of distribution transformers.
22. Standard conductor sizes should be adopted for 33 kV, 22 kV, 11 kV and LT lines to meet the expected load up to next 15 years time period. ACSR, AAAC, HTLS conductors, covered conductor/ABC for overhead lines and XLPE cables for U/G system may be adopted. Most power utilities use ACSR conductors on account of price considerations although AAAC conductors are lighter in weight and have a longer life on account of higher resistance to corrosion. The characteristics of conductors/cables being used in distribution systems are detailed in respective chapters. As a guideline, the some of suggested sizes of conductors/cables are indicated below :

<u>System voltage</u>	<u>Suggested Conductor Type</u>
33kV/22kV	ACSR Wolf, Dog, Racoon, Rabbit or equivalent AAAC, covered conductors, 3 core XLPE cables of sizes 150, 185, 240, 300 and 400 sq.mm. etc.
11 kV	ACSR Dog, Racoon, Rabbit, Weasel or equivalent AAAC. Equivalent Aerial Bunched Cables (ABC)/ covered conductors, 3-core XLPE cables of sizes 120, 150, 185, 240 , 300 & 400 Sq.mm. etc.
LT	ACSR , Racoon, Rabbit, Weasel, Squirrel , Wasp, Ant or equivalent AAC/ AAAC or equivalent Aerial Bunched Cables (ABC)/covered conductor or 3 ½ core or 4-core XLPE / cables of 95, 120, 150, 185, 240, 300 & 400 sq.mm. etc.

Table 1.1 Sizes of conductors/Cables

In the choice of conductor size, the parameters to be considered are thermal limit of conductors to meet the expected loads, voltage regulation and economic loading of the lines along with related spare requirement. The choice of OH line or UG cable may be made based on the actual field conditions/ requirement of regulations and finances available etc. Preferably, the distribution system should be designed to provide alternate path in the system for increasing the reliability of the system at all levels.

23. Overhead lines are generally preferred for their ease of operation & maintenance, easy identification of faults, less time for rectification of faults, and much less initial cost as compared to underground cable system. The ABC cable/ covered conductor or UG cables may be laid in theft prone areas.
24. The UG cables in Distribution network are more preferred in urban areas/densely populated areas including tourist & religious places, reserve forest areas due to safety reasons and to improve the aesthetic look of the areas in spite of higher cost. U/G cables should also be used in disaster prone areas. However, UG cables take more time in case of locating & repairing of any fault in the cable. Hence, it is essential that the UG cabling system should be designed such as to provide the alternate path for feeding the loads through Ring Main units (RMUs) with the additional cable from nearby circuits. As per CEA Regulations, in case of Electric lines of 33 kV and below passing through the protected areas (National Parks, Wildlife Sanctuaries, Conservation Reserves, Community Reserves), Eco-sensitive zones around the protected areas and Wildlife Corridors, only underground cable shall be used.

25. It would be desirable to limit the length of feeders to a minimum to have better voltage regulation and reduced technical losses. The maximum length of the feeders would depend upon the conductor used and max load on the feeder keeping the voltage regulation at farthest end within limits. The voltage levels wise feeder size and length should be decided based on system studies considering various load conditions to meet voltage regulation at farthest end with least technical losses.
26. In case the size of the line conductor is inadequate or the voltage drop exceeds the prescribed limits, load on the feeder may be reduced by transferring some load on new feeders/ nearby under loaded existing feeder or the line may be augmented by replacing the existing conductor by higher size conductor. Most of the power utilities use 0.4 kV, 11 kV, 22 kV and 33 kV as distribution voltages depending upon contract demand and location of loads. The higher the voltage, more expensive is the system in terms of investment cost, however, the technical losses reduce as voltage level increases. The most economic voltage level in the system may be determined through techno-economic studies taking into account the voltage regulation considerations, load to be supplied, loading limits of conductor, cost of losses and investment cost considerations etc.
27. The system configuration may be radial, ring or combination of both as per requirement, however, the radial configuration may be minimized to improve reliability in the system. In urban areas, in densely populated areas and for essential services etc, the ring configuration should be adopted.
28. Generally, the criteria for releasing the various loads at various voltage levels are prescribed in the Supply Codes notified by respective SERCs and utilities should follow the release of loads on various voltage levels as per the Notifications/ Regulations/Code of respective SERCs.

However, separate dedicated feeders may be laid for major industrial consumers and critical loads like VIP loads, Airport, Hospitals, and Water Works etc. Provision of alternate feed for Hospitals , Airports , water works etc and (N-1-1) redundancy for feeding the Critical loads /important areas may also be adopted.

As agriculture consumer do not require 24x7 power supply whole of the year, hence , for regulating the power supply of Agriculture loads in rural areas, separate feeders for Agriculture loads and Non–agriculture loads (domestic, Industrial, commercial etc.) may be provided. This will also help in proper accounting of agriculture consumption. Further, the virtual separation of agriculture loads on a mixed feeder (through RMUs or separately controlled dedicated DTs for Agriculture loads) may also be adopted as per field requirement.

29. For big industrial consumers, high value and critical loads consumers, it may be appropriate to provide an alternative source of supply by using an open ring circuit for 33 kV and 11 KV consumers with the least possible restoration time. In case

of important low voltage consumers, alternate source of supply from adjacent distribution transformer may also be provided, so as not to lose the revenue from these consumers. However, enhanced power reliability options for all consumers should be as per Rules and Regulations of SERCs.

30. The power factor of the system would preferably be not less than 0.95 at 11 kV and above level. In case of low/high power factor, adequate capacity of reactive power compensator shall be installed for pf correction.

31. The system may be designed that three phase fault levels may not exceed the following values except where the system is nearer to the generating source. The actual short circuit value may be used to decide switchgear specifications:

- i) 33 kV systems 25 KA
- ii) 11 kV system 25 KA (Urban area)
17.5 KA (Rural area)

32. Keeping in view the existing Indian Distribution system in India, the system should be designed /planned to target levels and maximum tolerable loss levels for Sub-Transmission and Distribution voltage level at the 33 KV & below system as shown below: -

PROPOSED TARGETS FOR TECHNICAL LOSS LEVELS
Sub- Transmission & Distribution System

<u>System component</u>		<u>Levels for peak power losses</u>	
		Target level (%)	Maximum Tolerable Limit (%)
(i)	Sub-transmission system(33 KV) and step-down to primary distribution level.(11 KV)	1.5%	2.0%
(ii)	Primary distribution system (11 kV) Including Distribution Transformers	1.5 %	2.5%
(iii)	Distribution LT lines and Service connections	2.5%	3.5%
Total Distribution System Technical losses		5.50%	8.00%

Table 1.2 Target Levels And Maximum Tolerable Loss Levels For Sub-Transmission And Distribution Voltage Level At The 33 KV & Below System

It is seen today that many distribution utilities, which are operating in a limited areas, have achieved technical losses less than the above suggested limits due to concentration of loads, optimal design and availability of less 11 KV and LT

lines etc. Hence, the achievement of technical losses less than above suggestion is possible based on the better design and more investment.

33. Harmonic distortion is caused principally by non-linear loads such as LED, Computers, TV, rectifiers and arc furnaces etc. and can affect the operation of a supply system. It may cause overloading of equipment or even resonance with the system leading to overstressing (excessive voltage & current). Other effects may be interference with telephone circuits and broadcasting, metering errors, overheating of rotating machines due to increased iron losses (eddy current effects), overheating of winding of transformer due to excessive third harmonics or excessive exciting current etc.

Utilities should install sufficient number of harmonic measuring instruments for carrying out measurements at regular intervals near the source of harmonics generation and shall use requisite filters/ correction devices at appropriate places to regulate the harmonics within the prescribed limits.

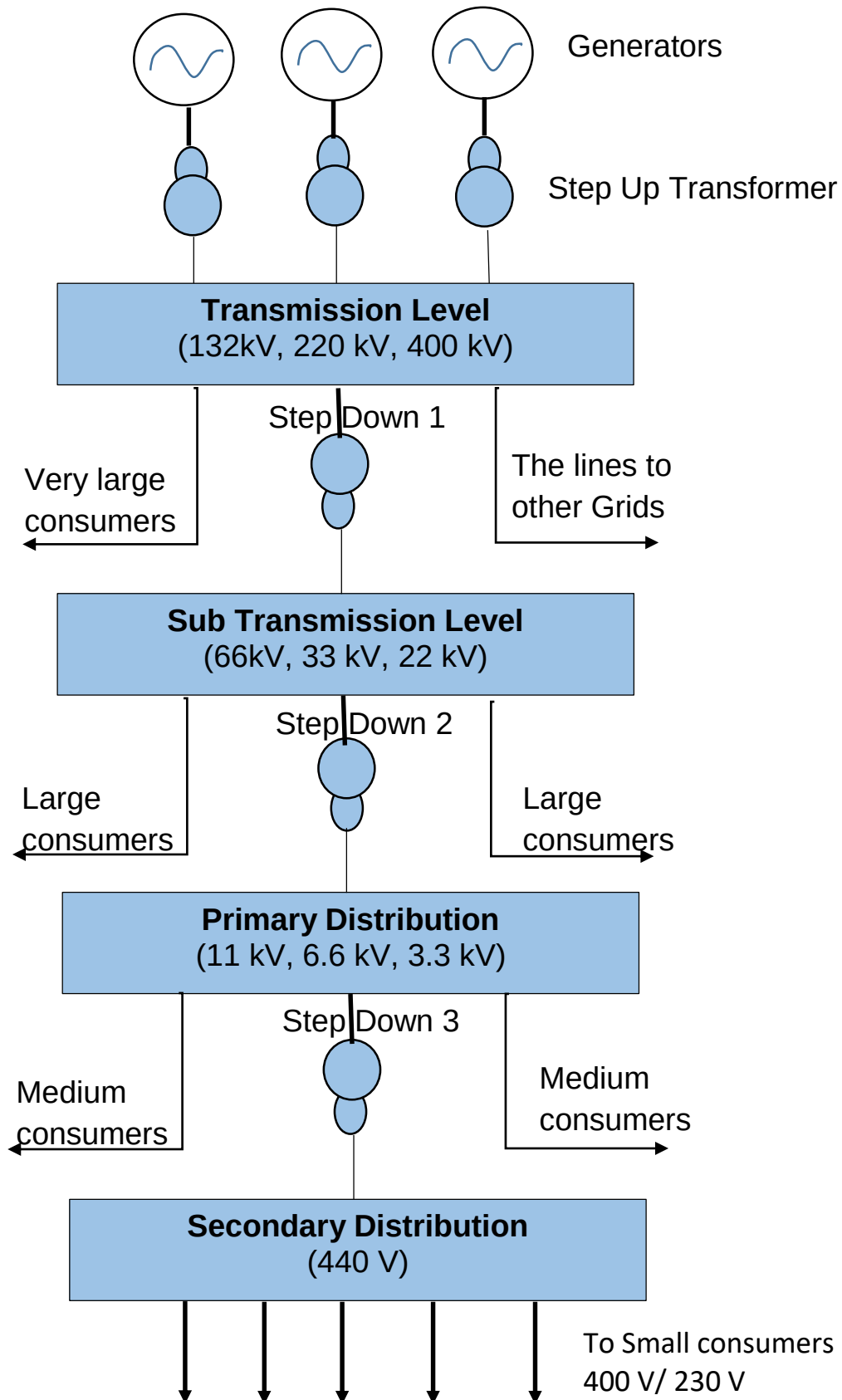
The suggested total harmonic voltage distortion and individual harmonic voltage distortion at point of common coupling shall be in accordance with the CEA Regulations, as amended from time to time, which stipulates individual harmonic voltage distortion in accordance with IEEE 519 -2014 standards.

34. The use of automation and smart metering can play a pivotal role in bringing the positive transformation in the distribution sector. To improve the operational flexibility, to minimize restoration time of power supply and to prevent overloading of lines and transformers in real time mode, modern technologies such as SCADA, RTDAS, Distribution Automation, Automatic sectionalizer, Fault Passage Indicators (FPI), RMUs, completely self-protected Transformers (CSPs) etc. may be incorporated in the Sub-stations and field. Adequate cyber security measures should also be ensured in the IT/OT system.
35. The installation of Smart Pre-paid Meters /simple pre-paid meters and communicable system meters on all Feeders and Distribution Transformers may be taken up as per CEA Regulations. Geographical Information system (GIS) with Asset mapping & consumer indexing and ERP may also be taken up along with smart meters for more visibility of the system.
36. As a dedicated and reliable telecommunication system is the heart of all automation, a suitable communication system should also be adopted by utilities as per availability & requirement complying the relevant Regulations.
37. A mobile substation could be used as back up of distribution substation in the event of a transformer failure. Where a mobile substation can not be provided to feed the total normal load of the failed transformer, tie line of adequate capacity may be provided to serve the remainder of the load from other sources.

38. Adequate number of accredited testing laboratory /testing infrastructure for in-house testing of major items like Distribution Transformers, Power Transformers, Instrument transformers, meters, conductors, etc. should be available with the discoms. A well trained staff for testing of various distribution equipment should also be maintained by the Discoms.
39. The overall planned system subject to meeting the technical requirement for supplying quality and reliable power supply to the consumers should be the least cost system.

[NOTE: The Voltage levels of 33 kV, 22 kV ,11 kV and 230V/400 V , which are more prevalent in the country, are being taken in this document As other voltage levels like 6.6 kV , 3.3 kV etc are also in use at many distribution utilities , hence, the planning of these voltage levels may be considered by Utilities appropriately under the respective chapters. The planning of 66 KV voltage level has been included under Transmission Planning criteria of CEA]

Single Line Diagram of Electrical Power system from Generation to Distribution



CHAPTER-2

STAGES INVOLVED IN SYSTEM PLANNING

2.1 SHORT-TERM PLANNING

To plan their distribution system efficiently and optimally, the Discoms should adopt the short term and long term planning of their system. A short term plan shall cover the measures required for immediate distribution network improvement for enhancing the reliability of the system and reduction of losses with focus on utilizing the existing system with best possible options. The key activities identified under short term plan may have an execution time frame upto 2 years.

The key activities which may be undertaken under short term plan may be as under:

- Immediate measures to reduce commercial losses to the minimum possible
- Network reconfiguration and converting radial system into ring main system
- Installation of Capacitor at various locations for voltage Correction
- Load Balancing
- Re-conductoring of overloaded lines/shifting of loads to nearby under loaded feeders
- Augmentation of overloaded Distribution Transformers (DTs) / shifting of LT load on nearby under loaded DT
- Improvement of joints in the network like by using jointing sleeves and twisting wrenches or by compressed joints and jumper connections
- Replacement of bare conductor LT lines with ABC/ covered conductors in theft prone areas
- Shifting distribution transformers to load centers
- Refurbishment /replacement of Old /obsolete equipment
- Replacing of existing meters of High Valued /Industrial consumers with Smart Meters /AMR meters
- To take up the installation of consumer Smart pre-paid meters/simple pre-paid meters & communicable system meters in consultation with respective SERCs as per CEA Regulations.

2.2 MEDIUM /LONG-TERM PLANNING

The medium/ long term planning is oriented more on optimizing technical losses in the system with nil commercial losses, enhancing the reliability of power supply in future load scenarios catering to increase in load demand as per the projection and measures for introduction of IT in distribution system for more visibility & reliability. Some of the key activities which may be undertaken under medium/long term plan having execution time frame beyond 2 years time period may be :-

- Construction of new Sub-Stations (S/S) at new load centers or augmentation of exiting S/S to cater the new projected loads as per the actual field conditions
- Upgrading, strengthening and improvement of the existing sub transmission and distribution lines to cater the new projected loads
- Rearranging/ reconfiguration of the feeders by using higher size conductor
- Replacement of bare conductor lines with ABC/ covered conductor/ UG cable in theft prone areas/ densely populated areas/ electrical accident prone area/disaster prone areas etc.
- Provision for additional feeders & power/ distribution transformers to reconfigure the sub transmission network to achieve N-1 contingency
- Augmentation of the existing transformation capacity to cater the new projected loads
- Major emphasis on use of ICT and automation in the distribution system. Adoption of modern technologies like RMUs, FPI, Compact DTs, SCADA GIS mapping, consumer indexing, Asset Mapping, etc
- Adopting HVDS in theft prone /high loss areas.
- Conversion of LT lines to HT lines to increase HT/LT ration to reduce losses (ideally , it should be 1)
- To adopt appropriate Reactive power compensation at suitable places
- Use of Energy efficient distribution transformers , Installation of Completely self-protected transformers (CSP), Package S/Ss, dry type transformers at appropriate places as per regulations
- Use of AI/ML software to analyze data generated through IT/OT devices including System Meters & consumer Smart meters to prepare actionable MIS from system generated energy accounting reports every month so as to enable the DISCOMs to take informed decisions on loss reduction, demand forecasting, asset management, Time of Day (ToD) tariff, Renewable Energy (RE) Integration and for other predictive analysis.
- Analysis of impacts of EV / Solar Roof Top generation on network and taking necessary actions
- Adoption of Demand Side Management (DSM) measures
- Adoption of Management Information Systems, Customer Relationship Management System, Outage Management System linked with GIS, ERP etc
- Use of underground cable & GIS substations in disaster prone areas.
- Adoption of Roof top solar on vacant land of S/Ss
- Use of Battery storage system for peak load management, if feasible, etc

2.3 STAGES INVOLVED IN NETWORK PLANNING:

Mainly the following stages are involved in the network planning of distribution system:

- ❖ Capturing the status of the existing distribution network and analysis of its operational parameters (loading , losses etc) for inadequacies in the system
- ❖ Make Action Plan /identify works to be carried out immediately under short term plan
- ❖ Load Forecasting: Carry out load forecasting based on loads that will be incident in the near future. Estimating load projection should be for the time duration for which planning is done.
- ❖ Analysis of the network under proposed network conditions considering load projections and identification of inadequacies in the network.
- ❖ Examining the options available to address the inadequacy in the system in a cost effective manner, like enhancement of existing transformer / feeder capacity or reconfiguration of existing network or setting up a new substation/ transformer/ feeder etc
- ❖ Examining the measures needed for reduction of technical & commercial losses like erection of ABC cables, covered conductor, UG cables etc
- ❖ Feasibility check of site location and new substation design.
- ❖ Preparation of CAPEX & OPEX for execution of proposed plans along with benefits and payback period, if possible.
- ❖ Approval of DPR within organization and further submission of DPRs to the regulatory commission for approval along with benefits and payback period
- ❖ Execution of proposals as per the plan within specified time period
- ❖ The Planning system studies may be carried out every year for noting any deviation in short term and Long term plan and the reasons for any deviation may also be highlighted.

(i) DATA COLLECTION/COMPILATION OF EXISTING SYSTEM DATA FOR SHORT TERM & LONG TERM PLAN

To prepare a short term / long term plan of the distribution system, several parameters need to be ascertained so that the analysis of the system can be performed accurately. The parameters are described as below:

- Category wise number of consumers and connected load
- Load Peak demand MW/MVAR- simultaneous and non-simultaneous –feeder wise/division wise/circle wise/utility wise
- Annual energy consumption
- Geographical map of the area depicting ST&D system (GIS Mapping)
- Details of Sub-transmission system-length, type of conductor used, loading
- Details of Distribution system- length, type of conductor used, loading
- Operational parameters
- Electrical network details along with equipment parameter data
- System load factor and Loss load factor (LF&LLF)
- Data validation

(ii) ANALYSIS OF EXISTING SUB-TRANSMISSION AND DISTRIBUTION SYSTEMS

For an accurate distribution system planning, it is essential to determine the current status and network conditions of sub-transmission and distribution system. A complete overview of the same helps in establishing the base case scenario and identifying priority areas for action. Following are various parameters which are evaluated for establishing current status of sub-transmission and distribution system.

a. Voltage Variation

- Voltage at each node/bus section
- Percentage voltage variation w.r.t rated input voltage
- Whether Voltage variation is within permissible limit

b. Peak power loss/Energy loss of each system element for arriving at total technical losses in the circle

c. Computation of AT&C Losses and then commercial losses by deducting technical losses from AT&C losses

- d. Assessment of inadequacies of the existing Sub-transmission & distribution system along with the identification of the following:
- Overloading of transformers
 - Overloading of lines
 - Requirement of reactive compensation
 - Requirement of harmonics compensation
- e. Inadequacy of the back-up sub-transmission system
- f. Security, sustainability, and reliability of power supply
- g. Need for introduction of Automation at various levels
- h. Need for various measures for redressal of consumer complains/ grievances etc.

(iii) FUTURE NET WORK PLANNING & ANALYSIS:

a) Load Forecasting

One of the most important steps in the planning procedure is an accurate and consistent Load Forecasting. As the Distribution System planning Involves the erection/establishment of new feeders/ substations and many other decisions relating to both locations and capacity additions in the system which are cost intensive, therefore, the load forecast of the distribution system should be as accurate as possible keeping in view the quantum of future load growth and impact of EV/Solar Roof tops/BESS/DSM etc on the demand.

b) Network Extension Planning

This involves Proactive Network Analysis conducted on an annual basis and Planning of new network and extension/ reconfiguration of existing network to meet the load considering future growth in an optimal way. It also involves preparation of Capital Expenditure for proposed network augmentation plans.

- ❖ Annual CAPEX & OPEX study using GIS updated network and analyzing peak load data (from SCADA/system meters) using specialized software tools for 33 kV, 11 kV, Distribution Transformers, LT Network.
- ❖ Annual Capex and Opex Plan for modernization , automation and use of ICT in distribution system for more visibility and control
- ❖ Approval of DPR within organization and further submission to the Regulatory Commission for Budget approval.

- c) Technical Feasibility Study for “providing new connections & load enhancement” for all segments of consumers. The new connections are given to the Consumers based on the timelines defined by the Supply code notified by the Regulatory commission after critically analysis the existing and proposed scenario.
- d) Assessment of Technical & Commercial losses and providing mitigation plans for “Reduction of Technical & Commercial losses” upto an optimal level for the entire network in licensed area.
- e) IT based tracking & “Monitoring of Project Execution” to ensure that the network extension plans are executed on time to meet the projected load growth.
- f) Technical feasibility of providing Roof Top Photo Voltaic (PV)/ Electrical Vehicle (EV) connection as per the guidelines defined by the Regulator & considering the system parameters such as voltage & harmonics limits etc.

g) SYSTEM IMPROVEMENT PROPOSALS IN ORDER OF PRIORITY

- ❖ Optimizing the technical loss reduction with least cost methodology
- ❖ Improving the Power factor of the system by providing optimal capacity of capacitors at suitable places in the Network as per load flow simulation results (For optimal selection of position & capacity of reactive compensation in the system, the reactive compensation studies to be conducted)
- ❖ Reconfiguration of lines to make ring main with RMUs for providing alternate path to increase reliability
- ❖ Identification of Feeder segments loaded beyond break even loading limits and identification of measures for reducing the loading within capacity
- ❖ Re-conductoring the specified portion as per the load flow analysis or providing the additional feeder as per load flow analysis. The shifting of some load on nearby under loaded feeder may also be taken up if feasible as per site conditions.
- ❖ Augmentation of overloaded distribution transformers or if feasible, to shift the LT load to nearby under loaded DT

(iv) LOAD FLOW ANALYSIS :

Load Flow Analysis is one of the most common computational methods for analyzing the system network as per existing and future load conditions including contingency scenarios.

- The major Data / particulars required for load flow study is:
 - ❖ The system configuration, like Voltage , length, conductor size etc.
 - ❖ Loads at each bus / line / DT.
 - ❖ The power generation available at each bus/ each generator or source.
 - ❖ Other data/ parameters as per requirement of Load flow software
- The primary parameters considered in a load flow are:
 - P - Active power into the network
 - Q - Reactive power into the network
 - |V| - Magnitude of bus voltage
 - R, X, & Z - Line parameters
- The system is analyzed based on the existing and future load conditions along with possible contingency conditions ensuring that the sub-transmission and distribution system is designed to satisfy its performance criteria.
- The Voltage Profile / Voltage Regulation at the farthest end of the lines, technical losses, Power flow in each network element etc would be computed through load flow studies.
- Peak power losses in kW will also be derived from load flow studies. The Annual Energy losses in kWh (Peak power losses (kW) * LLF*Hrs in the year) may also be calculated for analysis purposes.
- Further, the system is again analyzed with projected load and proposed augmented system for various scenarios to achieve the targeted loading of the equipment/lines, targeted losses and voltage regulation within limits etc.
- Some time , in case the Real Time data is available from communicable meters, the real time power flow of the network is also analyzed to identify Low voltage pockets and High loss areas

- Least cost investment and operation cost are also computed for each solution to find the optimal cost solution

The Planning system studies may be carried out every year for any deviation in short term and Long term plan and the reasons for any deviation may also be highlighted.

(v) ECONOMIC AND FINANCIAL ANALYSIS

The investment to implement the plan may be based on :

- CAPEX -Capital expenses
- OPEX- Operational expenses
- TOTEX – Capex+Opex

For a good investment, it is necessary that the project is viable and generate revenue while repaying the capital expenditure in the shortest period of time without compromising any of the objective. Investment decisions should be made on alternate proposals based on minimum annual revenue requirement (lowest present value of all future cost) for different options available.

Keeping in view the shortage of funds with the distribution utilities for installation of Smart Meters in Pre-paid mode as per CEA Regulations & timelines notified by MOP, the adoption of TOTEX mode has been adopted under RDSS. Under the TOTEX mode, a single agency(AMISP) will be engaged /selected by Discoms for supplying, maintaining and operating the AMI infrastructure for the related data and services for a defined time period (say 8-10 Years) and will also make both capital and operational expenditure under DBFOOT (Design Build Fund Own Operate & Transfer) mode. The AMISP will be paid for a portion of its capital expenditure initially and the remaining payment over the O&M period on per month per Node basis based on the conditions of contract after meeting the Service Level Agreement (SLA).

The following parameters need to be checked for assessing the financial analysis/ viability of the projects/schemes:

- **Cost Benefit Ratio:** The method is based on cost & benefits for an entire life cycle (25-30 years period) of the system equipment. The financial analysis is usually done for the lifetime of the project considering the year-wise costs including interest, depreciation, operation and maintenance charges, and the expenditure on additional sale of energy and the year-wise gross benefits including the revenue from additional energy, and cost saving due to saving in losses etc. The year-wise Net Present Value (NPV) of the net benefits is calculated and the cumulative net present value of the net benefits is evaluated to ascertain the attractiveness and feasibility of a project.

- **Internal Rate of Return (IRR):** This method calculates the rate of interest needed for the present value of the returns to be the same as the present value of the investment needed. i.e. Net Present Value (NPV) to be zero. This is the point at which the project breaks even.
- **Payback period:** It is the ratio of the investment to the monetary value of benefits expected due to the execution of project. This method does not consider the time value of money and the life of investment after the payback period but this measure is used as an indication of the investment risk. Acceptable payback period for distribution projects may be as per approval of respective SERCs.

It is suggested that planning is a continuous process, so planning study should be done every year for the coming years and the reasons for deviation of the planned expected results vis-a vis actual should also be highlighted in the study.

In the above cases, it may be noted that some works required for reliability improvements & safety considerations like additional infra for N-1 condition, GIS S/S, UG cabling in densely populated areas/ reserved forest/tourist places/disaster prone areas, some IT /automation tools etc may not result in a reasonable payback period but these works are necessary to be taken up for meeting the safety/ reliability / regulatory compliances.

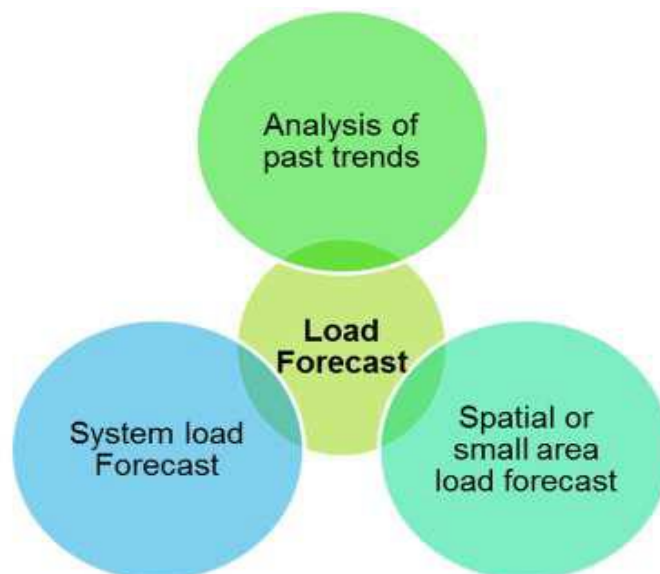
CHAPTER-3 LOAD FORECASTING

3.1 LOAD FORECASTING

The accurate forecasting of future load demand of distribution system is a critical component for effective and correct identification of infrastructure requirement and CAPEX requirement for power procurement and infrastructure works in a discom. In-accurate forecast may result in wrong planning of system by the system planner, either by over-planned or under-planned capacity in the system. The accurate load forecasting is required not only for power procurement, but also for the strengthening & expansion of the network, most economically.

Now a days, the accurate demand forecasting has changed into a complex process due to the availability of local generation in form of Solar Roof Top /BESS system, Demand Side Management, energy efficiency measures, deregulation of energy markets and change in consumer behavior etc. Therefore, adopting an appropriate forecasting model for a specific electricity network is a critical task. Although many forecasting methods are available now a days, but none can be generalized for all demand patterns. The process of load forecasting is to be done every year by the utilities for the process of power procurement and network strengthening & expansion for carrying out correction in the long term forecast and system planning, if required.

The Distribution System planning Involves establishment / Augmentation of substations & feeders, re-routing of feeders and many other decisions relating to both locations and capacity additions of distribution infrastructure. Hence, the load forecasting of the distribution system refers to the load forecasting of discom as a whole and granular forecasting at division, sub-division, feeder and DT level etc. A three step procedure should be adopted to obtain an accurate and definite forecast as mentioned below:



3.2 GENERAL GUIDELINES /SCENARIOS FOR LOAD FORECASTING OF THE DISCOM

- The forecast should be prepared for medium term (more than 1 year and up to 5 years) and also for longer term. The long term forecast should be for the next 10 years at least.
- The detailed power demand forecasting exercise should be undertaken in every 5 years. However, the forecast should be reviewed on yearly basis and should be updated, if required.
- The forecast should be prepared/reviewed/updated in consultation with all stakeholders such as industrial department, agricultural department, municipal corporation, drinking water department, weather department, transport department, Energy Efficiency Deptt, State Planning department, open access consumers, state nodal agencies for renewable energies and any other department entrusted with planning and implementing any electrical energy intensive plan/scheme.
- To start with, the base year for the forecast should ideally be taken as the three-year preceding the year (T-3) during which forecast exercise is being carried out. This is to be done to test the performance of the forecasting model by comparing the forecast results obtained for (T-2) and (T-1) years with actual available data (termed as Out of Sample Validation). For example, if forecasting exercise is being done in 2022-23, then the base year for the forecast should be 2019-20 and performance of the forecasting model should be tested by comparing the forecast results obtained for the years 2020-21 and 2021-22 with actual available data.

Note - If the data for T-3 year is showing some abnormal trends due to various factors such as extreme weather conditions, pandemic etc., then the last normal year till which some definite trends were observable should be considered as the base year.

- The base year for the forecast should subsequently be changed to T-1 after testing the performance of forecasting model.
- **Spatial Granularity** - The forecasts initially should be prepared at the Discom/State level . In addition, forecast at more granular levels i.e. Zonal level, Circle level, District level, Sub-Station Level, Feeder/Transformer level should also be carried out in case of availability of adequate granular data. Such granular forecasts would be more useful in power infrastructure planning.
- **Time Granularity** - The forecast should be carried out year-wise at least. In addition, month-wise/day-wise/hour-wise/time-block wise forecasts may also

be done, as per requirement and based on availability of adequate granular level data.

- The forecast should be carried out for at least three scenarios – Optimistic scenario, Business As Usual (BAU) scenario & Pessimistic scenario.

More scenarios may also be built up particularly considering different permutations and combinations of extreme (favourable or harsh) weather conditions. Some typical such scenarios could be – (i) hottest temperature scenario only (ii) coldest temperature scenario only (iii) highest rainfall scenario only (iv) lowest rainfall scenario only (v) hottest temperature and lowest rainfall scenario etc.

The optimistic scenario should consider hottest temperature and lowest rainfall scenario whereas the pessimistic scenarios should factor in lowest temperature and highest rainfall conditions. Since forecasting under BAU scenario should be based on normal past trends, the weather parameters need not required to be considered additionally in this case.

- The power demand forecast should be done under the unrestricted scenario which essentially is reflective of the case when all the unserved demand currently not served by the utilities due to various supply side barriers such as generation & network constraints (resulting in planned load shedding and unplanned outages) is also included.
- The method adopted for forecasting should aim at analyzing the past consumption data of each consumption category separately and factoring in impacts of emerging aspects to arrive at appropriate future growth trends. CEA traditionally adopts Partial End Use Method (PEUM) for carrying out Electric Power Survey (EPS) exercises, which is a bottom up approach focused on end use of energy by different category of consumer and it requires the category wise historical data.
- In addition to past growth trends, the medium-term forecast should also consider the assessment of impact of specific government policies, developmental plans and other emerging aspects in the definite quantum of electrical energy. One way to assess impact of emerging effects could be to take into account the expected additional load and multiply it with average specific energy consumption of the relevant consumer category.
- The long-term forecast should also be ideally based on the assessment of impact of specific government policies, developmental plans and other emerging aspects in the definite quantum of electrical energy in addition to past growth trends. However, if such assessments are not feasible beyond medium

term horizon, then the long term forecast should be based on further extrapolation of the growth trends estimated under medium-term period.

- The forecasting results obtained should be validated through at least one different method. Econometric Method should preferably be one of the methods adopted for forecasting, which uses economic and demographic information to forecast the load.
- The main aim of the forecast should be to cover accurate electricity demand projection for the utility system. In addition, forecast of the entire power consumption of the utility including demand meeting from distributed power sources such as CPPs, solar roof top, BESS etc should also be carried out so that a holistic picture of system could emerge.

3.3 INPUT DATA REQUIREMENT

- The category-wise consumption data should serve as the basic input for power demand forecasting.
- The consumption categories should be identified as per the tariff structure prevailing in the respective Discoms. The broad categories are Domestic, Commercial, Public Lighting, Public Water Works, Irrigation, LT Industries, HT Industries, Railways, Bulk Supply, Open Access & Others.
- The electricity consumption by Open Access consumers should be considered in the forecasting of the respective Discom due to the following reasons:
 - Open access consumers use the network of the Discom for supply of electricity.
 - The source of electricity may change but the location of load will remain the same.
 - Although Discoms need not have to consider the demand of open access consumers for power procurement, however, the same should have to be considered for augmentation of power network by the Discoms/States/UTs.
 - It will give a better picture for planning/augmenting the sub-transmission/distribution network for sourcing power to the open access consumer in the Discom/State.

- The input data should be collected at least for the past 10 years as per the following format:

Category	T-10	T-9	T-8	T-7	T-6	T-5	T-4	T-3	T-2	T-1	Current Year (T)
Energy Consumption (in MU)											
1. Domestic											
2. Commercial											
3. Public lighting											
4. Public Water Works											
5. Irrigation											
6. LT Industries											
7. HT Industries											
8. Railway Traction											
9. Bulk Supply											
10. Open Access											
11. Others											
Total (Energy Consumption)											
T&D losses -MU											
T&D losses -in %											
Energy Requirement (MU)											
Annual Load Factor - %											
Peak Load - MW											

The “Other” category generally includes energy consumption not fitting into any of the standard categories such as temporary connections consumptions etc.

- As far as possible, the unserved demand should be added category-wise as per the consumer mix profile of the concerned geographical areas. In case of unavailability of these details, such demand should be added to the “Others” category.
- The weather parameters (such as rainfall, temperature) should also be collected for arriving at the forecast range.
- There should be proper up-keeping of data so that the data for any forecasting exercise should be readily available and not suffer from any inconsistency.

3.4 FORECAST METHODOLOGY (PARTIAL END USE METHOD):

The forecast under Partial End Use Method is basically a bottom up approach focused on end use of energy by different category of consumer and it requires the historical data. In this method, the demand of each category of consumer is assessed and summed up along with expected losses to arrive at the total consumption figure at utility boundary level.

The energy requirement for each category of consumers is estimated taking into account the relevant parameters (such as number of consumers, connected load, annual rate of energy consumption per consumer or per kW of connected load, past trends etc.) and the total energy requirement of utility including the losses is estimated. Afterward, the peak demand is worked out from the total consumption by taking into account appropriate annual load factors keeping in view the nature and composition of loads and the past trend. The main steps in this methodology are as under:

- The annual growth rate in the past for each energy consumption category should be analysed. Two of the simplest and appropriate statistical methods for such purposes are “Least Square Method” and “Weighted Average Method”. The other advanced statistical tools may also be used to analyze growth rates.
- Based on availability of data, a hybrid approach may also be adopted for analysing growth trend of each consumption category separately. In this approach, various socio-economic and weather related independent variables (such as GDP, rate of industrialization, ground water depletion rate, urbanization etc.) over which the electricity demand depends may be identified for a dependent variable (i.e. energy consumption under a particular category) and an appropriate equation may be set up using statistical tools.
- The past growth trends for T&D losses (in energy terms) should also be analyzed separately for estimating future growth trends.
- In cases where Discoms are hopeful of reducing T&D drastically over a shorter period of time due to some planned measures, the reduction in losses should not be considered in complete isolation and accordingly, adjustments should be made by taking appropriate assumptions.
- The impact of emerging aspects expected in future should also be factored in the energy demand. The impact of energy efficiency may not be considered additionally if it is expected to follow similar trajectories in future as seen in the past as in such cases, the impacts are already captured intrinsically in the past time series data. However, if some major changes on account of energy efficiency are expected in future due to various factors such as some major

technological breakthroughs or implementation of some major government policies, then the impact should be factored in additionally. In such cases, the impact in a definite quantum of electric energy should be assessed.

- The total electrical energy requirement of a Discom should be worked out by adding its Distribution losses & Intra-State Transmission losses attributed to that particular Discom to its total category wise electrical energy consumption. The Distribution losses of a Discom should be computed as the difference between the net input energy to its system and the total energy consumed by its own consumers as well as by open access consumers if such energy is wheeled through its network. The Intra State Transmission losses for the whole state should be apportioned to each Discom in the ratio of their respective energy requirement (i.e. Energy Consumption + Distribution losses) if more than one Discom is present in any state.
- The peak demand forecast of a Discom should be derived from the energy requirement figure by applying appropriate load factor.

The Load Factor is calculated by dividing total electrical energy requirement for a given period of time by the product of maximum demand and that specific period of time. The formulae for calculating load factor on monthly and yearly basis are:

$$\text{Monthly Load Factor (in \%)} = (\text{Energy Requirement in MU} * 1000 * 100) / (\text{Peak Demand in MW} * \text{No. of days in the Month} * \text{No. of hours in a day}).$$

$$\text{Yearly Load Factor (in \%)} = (\text{Energy Requirement in MU} * 1000 * 100) / (\text{Peak Demand in MW} * \text{No. of days in the year} * \text{No. of hours in a day}).$$

- The appropriate load factors in the upcoming years should also be estimated based on its past trend. However, any expected change in specific consumer mix should also be accounted for. For example, in case of increase in industrial consumption share, an increase in load factor could be expected. If the pattern of specific consumer mix is expected to differ from the past, the expected load factor may be derived by examining load factors of other Discoms with similar consumer mix.
- If the pattern of specific consumer mix is not expected to differ appreciably from the past, then it should be assumed that the load factor trend observed in the past may continue.

- Peak electricity demand of the state, if state has more than one discom, should be estimated by applying suitable diversity factor, as per the past trends, to the sum of peak electricity demand of its all Discoms.
The diversity factor within a state for peak demand should be calculated as -

$$\text{Diversity factor} = \frac{\text{Sum of Peak Demand of Individual Discoms in a State}}{\text{Peak demand of State.}}$$

- The forecast under Business as Usual (BAU) scenario should be derived first and based on that, forecasting under other scenarios should be done. In the traditional Partial end Use method (PEUM), weather parameters are not considered separately as those are assumed to be inherent in the past energy consumption data. However, appropriate weather parameters, if available, may also be considered for developing more than one forecasting scenarios. Advanced statistical tools like Multivariate Regression Analysis may be used for this purpose.

3.5 IMPACT OF EMERGING ASPECTS ON LOAD FORECASTING

- The impact of emerging aspects should be quantified in sync with the targets set by the government. In case of non-availability of any target, suitable assumptions should be taken that should be spelled out clearly.
- In cases where government targets are available on yearly basis only, a yearly demand impact assessment should be done initially and then the granular impact like month/day etc may be derived. The solar roof top impact profile could be similar to any solar power generation project profile of the concerned geographical area. Another example is the impact of green hydrogen production which could have a straight line profile throughout the year.
- As far as possible, the impact of the emerging effects should be apportioned to the corresponding pre-defined consumption categories (For example, Electric Vehicle penetration could impact domestic and commercial consumptions, Green Hydrogen production could impact Industrial consumption, Solar pump penetration could impact irrigational consumption). In absence of any such suitable category, a new category could be created if the impact is substantial. Otherwise, it could be clubbed in “Others” category.

3.6 GENERAL CHECKS & BALANCES IN LOAD FORECASTING

- The Load Factor of a Discom/state should not be more than 1. The Load Factors for the Discoms/States were observed in the range of 40% to 80% in the past.

- If the system feeds industrial loads like aluminium and other process industries etc. having high electric load factor, the overall system load factor should ideally be high.
- The Diversity factor of the peak demand of a State calculated on the peak demand of its each Discom should be more than 1. Otherwise, it indicates wrong reporting of peak demand by any/all of the Discom or some loads are being missed in overall calculation.
- It should be ensured that every consumption is accounted for calculating the total energy requirement of a discom including consumption by small discoms taking power from this Discom, Franchisees, Temporary connection category etc.
- The possibility of double accounting of any energy across the concerned utilities should be checked and rectified like double accounting in case of –
 - a) Creation of new Discoms / franchisee
 - b) Merging of tariff slabs
 - c) Franchisees also reflected in Bulk Supply Category
 - d) Energy sold outside DISCOM/State etc.
- The consistency of the input data for energy requirement should be cross checked from demand as well as from supply side.

3.7 LOAD FORECASTING AT GRANULAR LEVEL IN DISTRIBUTION SYSTEM

The Trend Analysis method is generally used by the distribution utilities for load forecasting at granular level (i.e 11 kV feeder level) for preparing their short term Plan. The Trend Analysis techniques involve the methods of best fitting trend curves to basic historical data curve adjusted to reflect the growth trend itself.

3.8 BASIC METHODOLOGY TO FIND OUT THE TREND PEAK LOAD OF 11 KV FEEDERS

- Considering the diversity of the peak load on various feeders, the load of feeders can be downloaded from SCADA/ feeder meters and then a graph can be plotted for individual 11 kV feeder to decide the trend peak load. (In cases where SCADA data is not available, AMR meter data / concerned DT loads connected to respective feeders may be made use of, or otherwise the feeder data available in the S/S logging register may be used).

- Simultaneous peak loads of 11 kV feeders feeding a particular division should be considered to arrive at the peak load of divisions and Year on Year increment in the peak load of divisions is used to calculate load growth.
- Area specific load growth/ expected load addition on a feeder may be finalized after discussion with concerned divisions/region to capture bulk load that may come up in area.

For calculating load growth for a Financial Year , the sum of peak loads of individual feeders for last 3 years i.e Year-1, Year-2 & Year-3 for each Sub-divisions is calculated. Then average load growth in last 2 years is derived.

$$\text{Load growth (For FY2)} = \frac{(\text{Sum of loads of Y2}) - (\text{Sum of loads of Y1}) * 100}{\text{Sum of loads of (Y1)}}$$

$$\text{Load growth (For FY3)} = \frac{(\text{Sum of loads of Y3}) - (\text{Sum of loads of Y2}) * 100}{\text{Sum of loads of (Y2)}}$$

Afterward, the Average of load growth of the last two FYs (FY3 & FY2) are taken to derive the Trend Peak load of the area/ divisions.

Example:

For calculating load growth for FY 2022-23 & considering N feeders having trend peak loading for 2019-20 as (X1,X2,.....XN), 2020-21 as (Y1,Y2,.....YN) & 2021-22 as (Z1,Z2,.....ZN), the cumulative load for complete feeders in zone for 2019-20 would be (X1+X2.....+XN) say X. Similarly cumulative load for complete feeders in zone for 2020-21 would be (Y1+Y2.....+YN) say Y and Cumulative load for complete feeders in zone for 2021-22 would be (Z1+Z2.....+ZN) say Z.

Then average load growth in last 2 years would be,

$$\text{Average Load growth (For FY 2022-23)} = \frac{(\text{Y-X})/X + (\text{Z-Y})/Y}{2}$$

Note: In areas with higher load density, CAGR based on DT loading may also be considered to forecast the load growth.

The main purpose of load growth analysis is to test existing network by simulating pre-defined conditions after application of load growth for 2-5 years before load growth actually occur and to determine augmentation of existing network or requirement of new system elements like new S/S and Lines to meet the expected demand efficiently and economically.

The past trends of the load growth help to a large extent in estimating the future loads and infrastructure required for planned developments. In order to know the performance of the system networks, it is necessary to analyze the annual information in respect of the system, both in terms of maximum load demand it experienced and also the system behavior with respect to voltage drops and energy losses in the network at the maximum demand conditions.

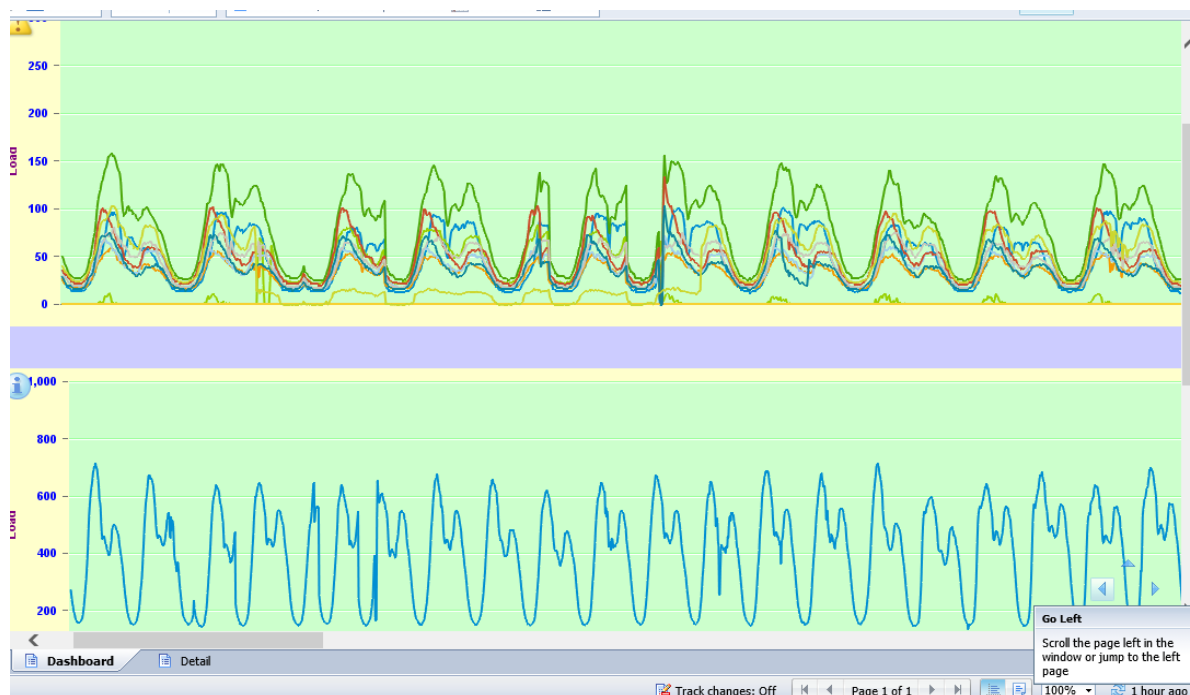
The forecasting models developed using trend analysis are used by the utility in preparing their Sub-transmission Plan for 5 Years and distribution system (11 KV & below) plan for short term (2 Years). For analyzing the augmentation plan for Power Transformers, District-wise load growth is applied on Power Transformer load corresponding to Grid Trend Peak load. For analyzing the augmentation of HV Lines, the simultaneous peak loading of power transformers corresponding to system peak condition are considered and District-wise load growth is applied. District-wise load growth is a weighted average of the load growth of all the Sub-divisions of the respective District. Some Grids may feed only one particular Sub-divisions, in such a case sub-divisional load growth would be applied to that District.

3.9 METHODOLOGY TO FINALIZE THE TREND PEAK LOAD OF 11 KV INTERCONNECTED FEEDERS

This method enables accurate load estimation by integrating various databases wherein trend peak load of Interconnected 11 kV feeders at a particular instant of time are considered instead of individual feeder's trend peak load so as to derive the Peak load of a particular area with a set of interconnected 11 KV feeders feeding that area.

The loading graph of the interconnected feeders may be plotted to get the visual effect of the trend. After finalizing the trend peak load for a set of interconnected feeders, load growth of that set of feeders is calculated for a Financial Year with the methodology described above taking into consideration the sum of peak load of set of individual feeders for Year-1, Year-2 & Year-3, taking Avg of load growth of last two FYs and then finalized for each Sub-divisions.

Sample Graph plotted for a set of interconnected feeders for analysis may be like as below:



Graph plotted for interconnected feeders to derive the peak of the set of interconnected feeders.

3.10 ESTIMATION OF AGRICULTURAL CONSUMPTION

Although all the consumer including Agriculture consumers should be metered but it is seen that many of the agricultural consumers are still unmetered in many states and hence, a correct assessment of agriculture energy consumption is difficult. However, Central Government through various Schemes is focusing on feeder segregation and thus providing funding for segregation of mixed feeders into agricultural and non-agriculture feeders. Also, 100% feeder metering & DT metering with communicable meters is targeted by the Central Government in a time bound manner. Hence, If agricultural feeders are separated and metered, then agriculture consumption may be noted directly from the respective feeder meter reading or from DT meter reading, in case DT is feeding only agriculture loads.

Basically, the agricultural consumption depends on three factors:-

- Number of agricultural pump sets
- Capacity of each pump
- Number of working hours of the pump in a day

Alternatively, in the absence of separate agriculture feeder or non availability of meter on segregated agriculture feeder, the following methods are being used by many utilities to assess the agricultural consumption: -

Method 1 :

Annual Ag consumption per Year = (Average capacity of pump set) X (total No of Pump sets) X (Avg Hrs of supply to Pump sets) units

Method 2:

Annual Ag consumption per Year = (Total connected kW load of pump sets) X (Average load factor) X (8760) units

Method 3:

Annual Ag consumption per year = (Consumption for one irrigation pump set / hectare x number of irrigation pump sets x total land under irrigation in hectares) units

(Sampling: Average consumption per H.P. is calculated from sampling techniques)

In case, agriculture consumers are not metered, then, Utilities should take up the initiatives for segregation of Mixed feeders into agriculture and non-agriculture feeders, install communicable meters on all Feeders and should note the actual agriculture consumption for better energy accounting and actual subsidy calculations. The solarization of segregated agriculture feeders should also be taken up under KUSUM scheme to reduce the subsidy burden of the State Govt.

3.11 SCIENTIFIC LOAD FORECASTING USING SOFTWARE TOOLS

For any power distribution utility, planning of adequate distribution system to cater existing as well as future load growth requirement is of utmost importance. The driving factors for planning of the system generally are consumer growth, consumption growth, change in consumption pattern of the consumers, dynamic price of electricity, energy efficient measures etc. The Discoms need to work out Electrical Energy Requirement Projections, Max Demand Projections, Trajectory of T&D losses, Selection of Load Factor, optimal design of the distribution system, Impact of DSM measures etc. through use of software tools available for distribution planning. As now a days, many software solutions are available in the market which may be used by the Discoms for the accurate load forecasting of the loads on short term & long term basis.

CHAPTER-4

SUB-TRANSMISSION SYSTEM (33 kV, 22 kV)

Generally, 33 kV and 22 kV grid sub-stations get the input feeds from Tranco Grid Sub-stations (i.e 220/33 kV, 132/33 kV , 110/33 kV etc) . Although, most of the utilities uses 33 kV Sub-Transmission system in the country, however, some utilities also using 66 kV or 22 kV sub –transmission also in their network. In case of 66 kV system, the Utilities may follow the Transmission Planning Criteria notified by CEA, however, the same criteria/ factors as suggested for 33 kV network in this chapter may also be adopted for 22 kV network .

4.1 PLANNING STANDARDS / CRITERIA FOR SUB-TRANSMISSION SYSTEM

- ❖ The location of Sub-stations should be near to the load center as far as possible. Generally, each 33/11 kV, 33/22 kV, 22/11 kV Sub-stations, subject to space constraints, should have two or more power transformers and two or more incoming feeders from two different sources for reliability considerations to meet N-1 contingency.
- ❖ If bay is not available at nearby Transco Sub-Stations for second source, a double circuits feeding line from different buses of single source substations of Transco should be planned. The feasibility of laying an interconnection feeder from nearby 33/11 kV or 33/22 kV or 22/11 kV Sub-Station may also be explored based on the load conditions. In case, both incoming feeders to a sub-station are from the same source (substation), each feeder shall supply independent sections of the 33/ 11 kV or 33/ 22 kV or 22/ 11 kV substation and the two sections should be isolated from each other by bus sectionalizer or isolators.
- ❖ In case of only two Power Transformers at one Sub-stations, both power transformers should have sufficient cyclic loading capacity to supply the sub-station maximum demand in the event of outage of single largest capacity transformer. As the load increases on the sub-station restricting the above condition, an additional transformer may be provided to meet the N-1 condition at the sub-station. The additional power transformer should also have sufficient cyclic loading capacity to supply the sub-station maximum demand in the event of outage of single largest capacity transformer.

Additionally, N-1 condition at Sub-station level may also be met through sufficient 11 kV network interconnection for shifting of load to nearby sub-station during any contingency. Hence, sufficient 11 kV system inter-connection capacity may be provided to enable to meet the demand in the event of outage

of any transformer or S/S feeding line, if additional transformer /line is not available to meet N-1 condition.

- ❖ The feeding 33 kV or 22 kV Circuits may be provided with direct connection from Transco Grid Sub-stations or through Loop-In Loop-Out (LILO) of existing Circuits, if there is an issue of bay availability at Transco Sub-Station. All LILO proposals should be shared with protection group to conduct Fault Level Analysis so as to keep Fault Levels within Limits.
- ❖ Each in-feed circuit should be designed to take up the full load of Sub-Station to meet the N-1 contingency. In case of increase in loading of Sub-station restricting single feed to take full load of Sub-Station, the additional in-feed may be provided at the Sub-Station to meet N-1 contingency.
- ❖ In case there are two U/G circuits coming to any Sub-Station, those should be on different geographical spread.
- ❖ If one of feeders has much longer route, the shorter feeder may normally feed the sub-station and the other one may be kept as Stand by to supply in case of an emergency or failure of other feeder to keep the losses minimum.
- ❖ The grid sub-station may be indoor, outdoor or underground type depending on the site requirement. The Sub-station may be Air Insulated (AIS), Gas Insulated (GIS) or Hybrid as per the requirement, however, only GIS Sub-stations should be planned in coastal areas /disaster prone areas. GIS / Hybrid sub-stations may also be adopted in urban areas where the sufficient land is not available for AIS.
- ❖ **Unitized Sub-stations:** In urban areas where it is difficult to get sufficient land for establishment of new Grid Sub-station near load area, a Unitized sub-stations with one power transformers (33/11 kV or 22/11kV) may be planned near load center without conventional control room with provisions of Ring Main Units (RMUs) at incomer and outgoing feeders for ensuring N-1 condition. The RMUs should be remotely controlled if SCADA is available. Each Unitized sub-station may get the power supply through RMU which may get in-feed supply from two separate Grid Sub-stations having 100% back up capacity for reliability purpose. The capacity of 11 KV feeders may also be designed such as to get full back up through RMUs from nearby feeders in case of any fault or emergency.
- ❖ On load tap changing device may be provided on HT windings of 33/11 kV or 22/11 kV power transformers of 3.15 MVA and higher rating for better voltage control by manual and automatic means.

- ❖ The installed capacity of 33/11 kV, 33/22 kV, 22/11 kV grid sub-stations should be planned to cater to the load growth for at least 5 year. The load sharing with nearby grid substations , at the time of contingency, should also be considered while designing the substation capacity. The maximum capacity of 33/11 kV, 33/22 kV and 22/11 kV Sub-stations shall be 100 MVA, 75 MVA and 75 MVA respectively and should be based on CEA Regulations as amended from time to time. However, the feeding line capacity should be planned for meeting the load of Sub-stations for minimum next 15 years.
- ❖ While deciding the capacity of the transformers, the de-rating due to increase in altitude and for cables, due to depth of burial in the ground, thermal resistivity and laying configuration should be considered.
- ❖ Before deciding the ratings of the equipment in a grid sub-station, it is necessary to prepare a schematic/lay out diagram of the substation. There are a number of arrangements dependent upon system voltage, position of the sub-station in the system, flexibility, reliability of supply and cost. The major factors to be considered while deciding the layout are:
 - All electrical safety requirements, clearances , fire detection & extinguishing system, earthing & ventilation etc should be as per Central Electricity Authority (Measures relating to Safety and Electric Supply) Regulations, 2023 or any successor or subsequent Regulations in this regard. It shall also be ensured in the layout to carry out equipment maintenance without interrupting the entire supply.
 - As far as possible, there should be alternate arrangements in the event of outage of any one important item of equipment/line.
 - The location & layout of Sub-station should be economical and should not hinder future expansion.
 - The lay out of the sub-stations shall be such that the fire, if any, shall not spread from one to other equipment and areas as far as possible.
 - Sub-station land area required shall be based on the present requirement and keeping in view the future expansion for next 10 to 15 years scenario. Sufficient space should be available to add additional power transformer along with 11 kV panels at grid stations to cater to future load requirement.
 - The sub-station or switchyard shall be designed and constructed to give a life of not less than 25 years.

- ❖ The sub-station shall have independent circuit breaker control of 33 kV and 22 kV incoming feeders and 22 kV or 11 kV outgoing feeders. The incoming feeders should also have independent circuit breakers at source end.
- ❖ Single Bus bar, Single Bus bar with Bus sectionalizer, main and transfer Bus, Double bus or mesh scheme are various types of layouts being adopted in the Sub-stations. Generally, a 33/11 kV sub-station with single bus bar with a sectionalizer on the 33 kV as well as 11 kV sides are preferred in rural areas due to economical consideration, however double bus system with sectionalizer / main & transfer bus system may preferably be adopted at 33/11 kV & 33/22 kV and 22/11 kV Sub-stations.
- ❖ Bus-bar of Sub-station shall be able to carry the expected maximum load current continuously without exceeding the temperature rise limit as per relevant IS. The capacity of a bus-bar shall also be checked for maximum temperature rise of the conductor under short circuit conditions.
- ❖ The incoming & outgoing feeder in new Sub-stations may be planned on multi ckt towers to minimize ROW requirement in future.
- ❖ In case, the loading of 33/11 kV, 33/22 kV, 22/11 kV power transformer reached beyond 70% of its capacity, some of the load may be shifted to other under loaded Power Transformer in the same S/S . If not possible, the loading may be reduced by shifting some of the load on the nearby under loaded Sub-station. In case, no nearby Sub-station with spare capacity is available, then the augmentation of Sub-station should be planned by installing additional transformer at the Sub-station. In case, the space is not available in the sub-station for additional transformer , the existing transformer may be replaced with higher capacity transformer after ensuring the alternate power supply to consumers during augmentation period. It should also be ensured that the incoming feeding lines of Sub-station have sufficient capacity to cater the additional load of Sub-station after proposed augmentation before taking up the augmentation work.
- ❖ Generally, Sub-station should be taken up for augmentation after reaching 70% of its capacity (without N-1 capacity). In case, Sub-station has the spare capacity to meet N-1 condition, the Sub-Station should be augmented if loading exceeds 110 % of its (N-1) capacity.

(Example: Suppose we have a 2x10 MVA S/S without N-1 condition and 3x10 MVA S/S having 1x10 MVA additional Transformer to meet N-1 condition. In the first case (without N-1 capacity), the augmentation of S/S may be planned when the S/S loading reaches 70% of S/S capacity(20 MVA) i.e 14 MVA while in other case with N-1 condition , the augmentation should be planned when the loading of S/S reached 110% of N-1 capacity(20 MVA) i.e 22 MVA)

- ❖ In case, augmentation of sub-station is also not possible due to some reasons like non-availability of space, Sub-station capacity restriction or inadequacy of incoming feeding lines etc, then a new Sub-station at the appropriate load center may be planned. The transformation capacity of new sub-station should be planned to meet the load at least upto 5 years while the feeding lines should be planned for meeting the load of the sub-station minimum upto 15 years due to ROW issues.
- ❖ Provision for bus coupler/sectionalizer should be kept at all bus bars to ensure the minimum outage time in case of fault.
- ❖ It shall be ensured that adequate capacity of switched/ fixed capacitor banks are available at all 11 kV Buses to meet the requirement of reactive power compensation, if any. However, only automatic switched capacitor may be installed at all new Sub-Stations. If any sub-station experience over voltage at off peak time, the suitable reactive compensation with capacitor & inductor may be installed.
- ❖ The New Sub-station should be provided with automation and coordinated operation through supervisory control and data acquisition system (SCADA) and the substations should be controlled from a remote centralized control center through SCADA for proper monitoring and control to improve reliability of the system. In case SCADA is not available in the existing Sub-stations, the installation of SCADA should be taken up in a phased manner with the approval of SERC for proper data monitoring & control of the sub-stations.

A development plan for Sub-Station must meet a number of criteria both under normal and abnormal operations. Augmentation plan should be proposed immediately when the grid substation is expected to be loaded more than 70% of the installed capacity (If spare transformer capacity is not there for N-1 Contingency).

4.2 SELECTION OF SUB-STATION SITE

The selection of site shall be done on the on the basis of the following:

- ❖ The site shall be near the load center.
- ❖ The site shall take into consideration the capacity and location of the feeding grid sub-station, load in the area, spatial load forecast, demographic factors, the existing network configuration, etc. and the economic, and environmental considerations
- ❖ Looking at space crunch and increasing cost of land , each planned substation should have enough space for additional Power transformer and Bays (for future load growth)

- ❖ Unitized sub-stations may also be considered in case sufficient land is not available with provisions of alternate supply system with RMUs.
- ❖ The site shall be such that it is convenient for terminating extra high voltage (EHV)/ high voltage (HV) lines/cables;
- ❖ The site shall not be in a low-laying area to avoid flooding during the rains. The rocky areas may also be avoided to have low earth resistance.
- ❖ The site shall be easily approachable in all the seasons. Easy accessibility by road for transport of heavy equipment like power transformers;
- ❖ The site for air-insulated sub-station shall be away from garbage dumping ground to avoid vulture faults;
- ❖ The land shall be reasonably leveled and shall not have any open drain/nallah or road crossing it.
- ❖ Far away from Slaughter houses to avoid bird fault.
- ❖ Not in the take-off or landing corridors of Aircraft
- ❖ Station switchyards shall have enough elevation for satisfactory and quick run off and drainage facility
- ❖ Adequate RoW should be available for laying of incoming & outgoing feeder of 33kV, 22 kV & 11 kV feeders.

4.3 LAYOUT OF SUB-STATION

The substation layout mainly depends on requisite installed capacities of the substation and rating of associated equipment along with future expansion plan. After finalizing the substation location, it is necessary to prepare a lay out diagram of the substation. The layout of a substation depends upon the following factors:-

- ❖ Installed capacity of the S/s based on the load requirements
- ❖ System Voltage / availability of in-feed voltage nearby
- ❖ Position of switch yard in the Sub-station
- ❖ Investment cost considering most optimal load usage/ availability
- ❖ Sufficient space for S/S to decide whether AIS/GIS/Hybrid, conventional/unitized , Outdoor/indoor etc
- ❖ Ease of carrying out equipment maintenance without interrupting the entire supply
- ❖ Type of Bus bar , location of control Room, battery room etc
- ❖ Layout of control room
- ❖ Location of station transformers, firefighting equipment
- ❖ Desired Reliability of power system-Provision for alternate arrangements in the event of outage of any one important item of equipment
- ❖ Economics of layout
- ❖ Sufficient space for future expansion.

A layout which is most economical and satisfies technical requirements as per actual site conditions should be adopted.

4.4 FACTORS TO BE CONSIDERED FOR SUB-TRANSMISSION SYSTEM PLANNING

1. 33 kV & 22 kV Network:

33 kV & 22 kV Network includes incoming circuits from Transco Grid Sub-stations , Interconnected circuits between Discom's Grids, 33 kV or 22 kV Line & Transformer Bays, 33 kV or 22 kV Bus bar, 33/11 kV or 33/22 kV or 22/11 kV Power Transformers, any generating units connected at 33 kV or 22 kV bus , Power & control Panels , Control Room etc. The Sub-stations also have the outgoing 11 kV feeders along with requisite panels.

2. Administrative Unit for Study:

Network study may be carried out in totality i.e., combined network of 33 kV , 22 kV & 66 KV (if available with Discoms) to find out the loading, voltage regulations and losses etc.

3. Load Growth data:

Load growth data for 11 KV feeders shall be required to assess load growth in Sub-transmission Network. Feeder wise weighted average/ DT average load growth shall be considered for each individual grid sub-station.

4. Time Horizon:

Keeping in view the ROW problem in laying of 33 kV or 22 kV lines frequently, the 33 kV or 22 kV network requirement may be studied for a period of minimum 15 years. The Grid requirement along with its associated lines may have to be planned /worked out for minimum 15 years as laying of in-coming lines may be difficult every 5 years while 33/11 kV , 33/22 kV or 22/11 kV Power Transformer capacity may be planned for at least 5 Years. New requirement at Transco Network / Power Transformer addition etc for next 3 to 5 years have to be finalized in consultation with Transco and the requirement should be informed to Transco well before time to enable Transco to take the requisite action within time.

5. Loading Conditions:

- **For Power Transformers:** For year of study, trend peak of individual Grid Sub- station would be taken as 70% of the installed capacity (without N-1). However, the individual grid station shall meet N-1 criteria at Transformer & feeding lines level.
- **Load flow study:** Simultaneous Load of each and every power transformers, feeding to DISCOM area, during the DISCOM system Peak of the year would be considered for the study. The sub transmission line

loadings would be considered up to de-rated capacity and for exigency, it may be considered upto 100% capacity.

6. Technical Losses

The Peak Technical Loss Limit for 33 kV Network shall be not more than 1.5%.

7. Construction of 33 kV and 22 kV Lines

- ❖ The lines shall be constructed keeping in view the prime factors of safety as well as electrical and mechanical design considerations.
- ❖ Utility while connecting the new installation to the Grid has to abide by the Central Electricity Authority (Technical Standards for Connectivity to the Grid) Regulations, 2007 as amended upto date and Central Electricity Authority (Technical Standards for Connectivity of the Distributed Generation Resources) Regulations, 2013 as amended upto date.
- ❖ The Utility shall arrange all required consents/approvals including civil aviation, road, river, rail, canal, power line crossings and environmental and forest clearances etc. from the concerned authorities before laying the lines.
- ❖ The Utility in accordance with the requirements of construction shall arrange right of way and way leave clearance and ensuring that compensation for right of way and way leaves shall be given as per applicable law, rules and regulations, guidelines/directives of local administrative/revenue authorities.
- ❖ The RoW width for 33 kV lines should generally be as under:

Conductor	Structure Type	Design Span (in m)	String Type	RoW (in m)
ACSR Bare conductor	Lattice type / Steel pole	250	"I" String/ Suspension Tension	15 meter
		150	"I" String/ Suspension Tension	12 meter
	Concrete Pole/ Rail Pole/ H- Pole / Single Steel Pole	100	Pin Insulator	9 meter
		60	Pin Insulator	8 meter
Covered conductor	Pole	100		6 meter

(as per CEA Construction Standards Regulations)

Table 4.1 RoW width for 33 kV lines

- ❖ System Earthing shall be as per Central Electricity Authority (Measures relating to Safety and Electric Supply) Regulations, 2023 or any successor or subsequent Regulations in this regard.
- ❖ The design and construction of the electric lines shall comply with the relevant IS. The system shall be constructed so as to ensure:
 - (a) voltage conditions are within permissible levels;
 - (b) improvement of reliability and security of power supply;
 - (c) improvement in quality of supply;
 - (d) adequate capacity for load growth for next 15 years.
- ❖ Independent feeders may be provided for essential loads such as water works, hospitals, defence, railways, airports and other sensitive installations and for selected consumers on request.
- ❖ Multi-circuit multi-voltage lines may be adopted as per requirement keeping in view the ROW difficulties in future.
- ❖ Extension of existing lines may be carried out after ensuring that the limits of voltage variations on the lines are not exceeded the limits prescribed.
- ❖ The route of the electric line shall be as short as possible and Angle points in the route shall be minimized.
- ❖ The routing of an electric line shall normally be avoided through following areas:
 - (a) Protected and reserved forest. In case it is not possible to completely avoid the forests or areas having large trees, keeping in view the overall economy, the route of the line may be aligned in such a way that cutting of trees is minimized or otherwise U/G cables may be used.
 - (b) National Parks and Wild Life Sanctuaries.
 - (c) Restricted areas such as civil and military airfields and aircraft landing approaches.
 - (d) Educational institutions, large habitations and densely populated areas.
 - (e) Rough and difficult country side, and natural obstructions, fruit gardens, lakes, rivers etc.
 - (f) Cremation grounds, slaughterhouses and garbage dumping grounds to prevent interruptions by bird hits.
- ❖ The electric line shall be close to a road for approach during construction and ease of maintenance.

- ❖ Railway and road crossings shall be minimum on the line route and in case it is not possible to avoid the same, the crossings at right angles shall be preferred but the crossing shall not be less than 60 degrees in any case. Alternately, U/G cable should be used for Railway/Road crossing.
- ❖ The supports for the Lines may be poles or towers /narrow based lattice towers with fully galvanised structure as per site requirement.
- ❖ The high strength poles like rolled steel joist, rail pole, spun pole, H-beam or steel tubular pole may be used as per requirement.
- ❖ In hilly areas appropriate snow or ice loading should be considered for design/selection of poles and towers.
- ❖ For locations involving long spans or higher clearances on account of crossing of power or communication lines or a railway line, specially designed poles/lattice towers or underground cable may be used as per requirement.
- ❖ Double pole structure may also be used as per site conditions ensuring safe operation of lines.
- ❖ Line span may be decided taking into consideration the topography, wind pressure, type of support, conductor configuration and ultimate tensile strength of conductor. Generally, a uniform span should be maintained as far as possible between consecutive poles/ Towers.
- ❖ While constructing a line, if a road crossing occurs at mid span, then a pole shall be placed on one side of the road so as to avoid mid span at the road crossing.
- ❖ While crossing another power line, the lower voltage line shall be underneath: Provided that the lower line shall normally not cross at mid span of the upper line.
- ❖ While placing poles on high ground, shorter poles can be used while maintaining proper ground clearance at the middle of the span.
- ❖ Poles shall normally not be placed along the edges or cuts or embankments of creeks and streams.
- ❖ At all the places where the new line crosses over roads or another existing line, adequately earthed guard wire mesh below the line shall be provided to avoid the conductor of the line falling over the areas below, in case of any break. In

case, where the new line passes below an existing line, the guard wire mesh shall be provided above the new line under construction.

- ❖ Insulators and its fittings shall confirm to relevant IS. Normally, pin insulators are used on lines up to 33 kV voltage level as per requirement. Suspension and Tension insulator strings with disc insulators or long rod insulators offering equivalent performance may be used on 33 kV or 22 kV lines ensuring that the number of insulators and creepage distance are selected based on electrical system parameters taking into account altitude of site, expected environmental and pollution conditions etc.
- ❖ For critical locations with high pollution level, anti-fog type insulators or polymer insulators may be used for better performance.
- ❖ Insulator and insulator string rating shall be selected such that.—
 - (a) under 100% design wind loading conditions, the load on insulator string shall not exceed 70% of its mechanical strength;
 - (b) under everyday temperature and no wind/snow conditions, the load on the insulator string shall not exceed 25% of its mechanical strength.
- ❖ The insulation shall be designed to avoid excessive concentration of electrical stresses in any section or across leakage surfaces.
- ❖ Protective Guard, anti-climbing devices and danger plates should be provided in accordance with Central Electricity Authority (Measures relating to Safety and Electric Supply) Regulations, 2023 or any successor or subsequent Regulations in this regard.
- ❖ The protection scheme for the system shall be finalized by the Utility based on prudent utility practice after discussion with Transco.

8. Voltage Regulation

The voltage variations at the farthest end of 33 kV, 22 kV and 11 kV lines should not exceed standard limits under peak loading conditions and normal system operation regime (As per relevant IS).

Voltage regulation	Voltage variation limits	
	Minimum	Maximum
33 kV	(-) 9 %	(+) 6%
22 kV	(-) 9 %	(+) 6%
11 kV	(-) 9 %	(+) 6%

Table 4.2 Voltage variation limits values

The necessary action should be initiated when the voltage regulation reaches (-) 8% or (+) 5% limits so as to avoid the violation of regulation limits. To achieve the desired voltage regulation, then provision for transferring of load to the nearby under loaded circuits may be taken up. The provision of automatic switched capacitors and on load tap changer on Power Transformers (as per IS) should be kept at Sub-station for voltage correction. Alternatively, augmentation of existing lines or construction of new lines may also be considered.

The efforts should also be made to extend 11 kV network up to the load center to reduce LT line and improving HT/LT ratio for loss reduction and enhancing voltage profile at consumer premises. HVDS system may also adopted at appropriated locations based on the field conditions and in the theft prone areas.

9. Standard Conductor / Cable Types

- The size of the conductor to be used in 33 kV and 22 kV lines shall depend upon the voltage regulation, factor of safety, power to be transmitted, length of line, line voltage and mechanical strength desired etc. The Standard conductor sizes should be adopted for all lines.
- Aluminium Conductor Steel Reinforced (ACSR) or equivalent All Aluminium Alloy Conductors (AAAC), All Aluminium Conductor (AAC), Aluminium Alloy Conductor Steel Reinforced (AACSR) or HTLS conductors along with requisite accessories may be used complying with relevant Standards.
- Most power utilities use ACSR conductors on account of price considerations although AAAC conductors are lighter in weight and have a longer life on account of their higher resistance to corrosion.
- The use of Underground cables, Aerial Bunched Cable (ABC) or covered conductor may also be taken up as per Regulations /site requirement like reserve forest / high density population areas/disaster prone areas etc. As per CEA Safety Regulations, in case of electric lines of 33 kV and below passing through the protected areas (National Parks, Wildlife Sanctuaries, Conservation Reserves, Community Reserves), Eco-sensitive zones around the protected areas and Wildlife Corridors, only underground cable shall be used.
- The configuration of conductors on the line can be triangular, horizontal or vertical depending upon the voltage level of the lines, terrain, right of way and clearances to be maintained. In case clearance from a building is difficult to secure, vertical arrangements of the conductor may be adopted or UG cable may be used.

- Suitable insulating paint may be provided on bare conductors in coastal areas to prevent corrosion.

Voltage	Conductor / cable
33 KV /22 kV	Panther, Wolf, Dog, Racoon, Rabbit, Coyote conductor, XLPE cables of different sizes HTLS conductor/ABC/Covered conductor
11 KV	Dog, Racoon, Rabbit, Weasel ,ABC, Covered conductor, XLPE cables of different sizes

Table 4.3 Indicative list of Conductors generally used

Note: Other conductors/ UG Cables/ new technology conductors/ cable may also be used by the utilities based on the requirements & availability.

The details of some of the Conductors generally used in Sub-Transmission & Distribution systems are detailed at **Appendix**.

10. Details of Max. Loading of generally used Conductors :

Conductor	Nominal Area (sq. mm)	Ampacity (Amps.) at 45°C
ACSR Panther	200	560
ACSR Wolf	150	470
ACSR Dog	100	360
ACSR Racoon	80	300
ACSR Rabbbit	50	240

Table 4.4 Max loading of ACSR Conductors (as per IS 398 part 2)

(Note: The equivalent AAAC conductors can also be used)

11. Cables (XLPE/ABC/Covered Conductor)

- Underground XLPE cables or aerial bunched cables or covered conductor of adequate rating conforming to relevant Standards can be used for supplying power as per requirement /site conditions/regulation requirement etc.
- In coastal areas, disaster prone areas, high density population/congested areas & protected areas (National Parks, Wildlife Sanctuaries, Conservation Reserves, Community Reserves), Eco-sensitive zones around the protected areas and Wildlife Corridors, only underground cable shall be used.

- Underground Cables shall normally be laid in trenches as per the relevant standards and utility practices. The direct burying of underground cables should not be adopted except where cables enter and take off from a trench. The cables may also be laid in pipes or cables with co-extruded pipes though trenchless method as per the site requirement.
- The underground cables shall be segregated by running in separate trenches or on separate racks or in separate pipes. Cables should also not be laid directly on trench floor.
- The route of cables should be finalized keeping in view that Cable trenches or pipes shall not be run through oil rooms and these should be properly sloped so as to drain freely any water, which may enter.

Cable Size	Direct in Ground at 30°C (Al Conductor)	In Air at 40°C (Al Conductor)
3Cx120 XLPE	215 A	262 A
3Cx150 XLPE	240 A	294 A
3Cx185 XLPE	270 A	336 A
3Cx240 XLPE	315 A	393 A
3Cx300 XLPE	355 A	450 A
3CX400 XLPE	405 A	519 A

Table 4.5 Typical Current Rating of XLPE Cables: (Based on IS 7098 Part 2)

* The above **typical** Cable ratings may be in somewhat(+/-) variance as per the manufacturers GTP.

Note:

- 33 kV Single Core Cables in place of 3 Core Cables may also used as per requirement.
- The current ratings of the cables would be subject to de-rating factors applicable for local conditions such as grouping, cable depth, soil type, temperature, etc as per relevant IS.

12. Preferred Capacity of Power Transformers (33/11 kV, 33/22 kV, 22/11 kV):

Area	KVA Rating
Urban	5 MVA, 6.3 MVA, 8 MVA, 10 MVA, 12.5 MVA, 16 MVA, 20 MVA, 25 MVA , 31.5 MVA
Rural	1.6 /3.15 / 5 /10/12.5 MVA

Table 4.6 The power transformers should comply relevant Indian Standard (IS 2026) and would be installed as per CEA Regulations

13. Maximum Transformation Capacity Installed at any grid sub-station for meeting loads at different voltage levels (as per CEA Regulations):

Sub-Station	Max Installed Capacity of Sub-station
33/11 kV Sub-station	100 MVA
33/22 kV Sub-station	75 MVA
22/11 kV Sub-station	75 MVA

Table 4.7 Sub-station and maximum installed capacity of sub-station

(The above capacities are as per CEA (Technical Standards for construction of Electrical Plants & Lines) Regulations 2022. However, the above capacities may be revised based on the existing provisions of CEA regulations as amended from time to time)

14. Power Transformer Loading considered for Planning the system

Normal Loading	Upto 70%
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15. Max. No. of 11 kV outgoing feeders from 33/11, 22/11 KV Sub-station

The Max. no. of 11 kV outgoing feeders from a 33/11 KV sub-station would depend upon the capacity of S/S, conductor used and associated load of the area. However, the following number of feeders may be considered for planning purposes: –

Sub-station/Transformer Capacity	No of Feeders
31.5 MVA	10
25 MVA	8
20 MVA	7
16 MVA	6
10/12 MVA	5
8 MVA	4
5 MVA	3

Table 4.8 Sub-station/Transformer capacity and No.of outgoing Feeder

16. Power Factor(PF):

Power Factor at grid station should be maintained close to unity under peak loading conditions for minimum reactive drawl from Transco grid. Minimum PF should be maintained at 0.95 PF. The adequate capacity of capacitors (fixed/ auto-switched type) should be available at the Sub-station for maintaining the PF close to unity.

17. Shunt Capacitor:

The ratings/ capacities of shunt capacitors should be decided based on rating of power transformer, type of load & reactive power profile of downstream network, and shall be finalized by conducting suitable system studies.

All 11kV Shunt Capacitor banks installed on 11KV Bus at a Grid S/s shall be coordinated with On-Load Tap Changer (OLTC) of respective Power Transformer to keep voltage regulation within limits. In case of switched capacitor banks, power electronic based/IED switching arrangement may be used.

18. General Standard Ratings of Bus-Bars in a Grid

The Bus- Bar should be able to carry the expected Maximum load current continuously without exceeding the temperature limit as per relevant IS. However, Fault current rating of bus- bar may generally be taken as under-

Voltage Level	Grid Type	Bus-Bar	Fault Current
33 kV	Indoor /Outdoor S/S AIS or GIS S/S	Single-Bus with Bus-section / Double Bus with bus coupler	25 kA for 1 sec
11 kV	Indoor/ Outdoor	Single-Bus with bus coupler	25 kA for 1 sec

Table 4.9 Fault Current Rating of Bus- Bar

The enhanced fault current capacity of bus bar section may be decided by the utilities based on the site conditions, load conditions, type of load etc.

19. Station Transformer /Auxiliary Supply to Grid S/S

A Distribution Transformer of suitable capacity shall be used as a station transformer at the 33/11, 33/22 kV and 22/11 kV Grid S/S. There shall be one Station Transformer per Grid Sub-Station. A secondary source may also be provided (preferably from different source) through separate connection to the Station Transformer.

Additionally, a suitable capacity battery system (preferably with SPV) for emergency lighting or a DG set may be provided at the S/S for emergency purpose. Separate Battery system may preferably be provided for control & relay system and for emergency lighting at the S/S for more reliability.

20. Protection Settings:

The protection settings adopted by Protection and Testing Group shall be as per Regulations.

21. SCADA compatibility of the Grid Sub-Station

It should be ensured that all the equipment proposed in the new grid S/s should be SCADA compatible.

4.5 CRITERIA FOR PROVIDING NEW ELECTRICAL EQUIPMENT /AUGMENTATION/ ASSETS IN DIFFERENT SCENARIO /NETWORK CONDITIONS

S. No.	Equipment	Criterion
1.	Feeders	Feeder is loaded more than 70% without N-1 condition
		Technical losses are more than: 1.5%
		Voltage regulation are not in limit for 33kV , 22 kV ,11kV feeders: (-9% to +6%)
2.	Power Transformer	Loading above 70% after load sharing within substation without N-1 conditions or with nearby sub-station

Table 4.10 Criteria for Electrical Equipment Provision in Diverse Network Conditions and Scenarios.

4.5.1 ADDITIONAL POWER TRANSFORMER AT EXISTING SUB-STATION

- The Scheme may be planned when the Peak Load of Sub-station reaches 70% of the installed capacity (without N-1) so as to complete the work before reaching the Max loading of S/S upto 90%.
- Shifting of load by re-shuffling within the same Sub-stations is not possible.
- Shifting of load to near-by grid is not feasible/possible.
- Augmentation of transformer is not possible (existing PTR is already of highest MVA rating, say 25/31.5 MVA)
- Space for additional power transformer is available.
- Sufficient in-feed capacity is available.

4.5.2 LAYING OF NEW 33 kV , 22 kV FEEDER

- If existing feeders are loaded more than 80% of the rated capacity after considering N-1 contingency.
- Load shifting within network is not feasible.
- Bay availability at near-by Transco grid is available and space is available for bay construction/additional panel at DISCOM end

4.5.3 33 kV, 22 kV FEEDER AUGMENTATION /REPLACEMENT

- Existing cable/ conductor has outlived its useful life causing frequent breakdowns.
- Existing cable /conductor is undersized and unable to carry full load/ Overloaded.
- ROW is not available for New Feeder/Bay is not available for new Feeder at nearby Transco Grid Sub-station
- As per requirement of consumers or external agencies (deposit cases).

4.5.4 EQUIPMENT REPLACEMENT AT GRID SUB-STATION

The Scheme for replacement of equipment at S/S may be planned due to following reason:

- Equipment outlived its useful life.
- Equipment is damaged due to fire or any other reason.
- Equipment is not repairable.
- Equipment is giving frequent trouble in operation and Spare parts are not available.
- Equipment is giving frequent trouble in operation and OEM has stopped manufacturing that equipment/spare part.

The availability of adequate spare parts for the S/s may be ensured by the utilities at the time of installation of new Sub-station.

4.5.5 NEW PANELS AT GRID SUB-STATION

The Scheme under this category shall be planned keeping in view the following :

- New Load to be released/ New feeder is required
- Sub-station is augmented
- Panel is Old and not compatible with new technologies like SCADA, DMS etc.

- Space is availability for new panels.

4.5.6 CAPACITOR BANK AT GRID SUB-STATION

Capacitor banks are connected at 11kV bus bar at grid Sub-station. Scheme under this category are planned under following condition:

- Power factor at 11 kV bus at grid is less than 0.9 and Capacitor bank is not available at 11 kV side of Power Transformer.
- Based on requirement by EHV O&M and system operation.
- In case, PF goes more than 1 during off peak period at some Sub-stations (Over Voltage problem), a combination of Inductor & capacitor of adequate capacity may be installed at Sub-station.

4.5.7 NEW GRID SUB-STATION

- Existing S/s has reached its maximum installed capacity as per CEA regulations and Power transformers are loaded more than 70%.(without N-1)
- Shifting of load at nearby Sub-station is not possible/feasible to reduce the loading.
- Augmentation of Transformer is not possible within Maximum Installed capacity
- Space for additional power transformer is not available in the existing S/s.
- In feed for maximum installed capacity of S/s is not possible from nearby Transco grid.

4.6 SUB-TRANSMISSION PLANNING DATA FOR SYSTEM STUDIES

Generally, the load flow study is carried out by Network Modeling through Load Flow Analysis software tools. The following data is required for the system studies for planning the Sub-transmission System (New / augmentation):

- 1) Existing Max Load of the area for new sub-stations and peak loading of each power transformers for Augmentation
- 2) Expected Load Growth

3) Line details

- 1) Peak Loading
- 2) Type of Conductor/Cable used
- 3) Length of used Conductor/Cable
- 4) Type of circuit (Single / Double Circuit)

4) Power Transformer details

- 1) Capacity (MVA) of Transformer
- 2) Transformation Ratio
- 3) Percentage Impedance
- 4) Vector Group
- 5) Max loading of all power transformers
- 6) Loading of each power transformer at the time of Discom Peak

5) HT Consumers/ Dedicated Loads

- 1) Connected load and Max Load
- 2) Power Factor

6) Capacitor Bank

- 1) Voltage Level
- 2) Total connected kVAr

7) Data for Reactive Power Planning:

- 1) Reactive power / energy flow data at exchange points with Transco/ other DISCOMs at 33 kV or 22 kV
- 2) Simultaneous loading of reactive power at Sub-stations to assess the optimum requirement of shunt compensation at 11 kV
- 3) For uncompensated 11kV Buses, trend of reactive power data shall be studied to check for any reactive power drawl or injection to propose new capacitor bank installation

8) Data for harmonic compensation planning:

- 1) Harmonics measurement at 33 kV level
- 2) Planning for harmonics compensation as per notified grid regulations.

The system studies for planning of the augmentation of existing system or installation at new Sub- transmission system (Sub- station, lines, reactive component etc) should be carried out for deciding the most optimal solution .

CHAPTER-5

PRIMARY DISTRIBUTION – 11 kV NETWORK

11 kV Feeders emanate from Grid Sub-stations (66/11 kV or 33/11 or 22/11 kV) to feed the loads to the LT consumers through Distribution Transformers. The Bulk consumers/HT consumers are also supplied through dedicated 11 KV feeders based on the load requirement. The number of Distribution Transformers on a 11 KV feeder depends on the size of conductor used, number of consumers to be supplied power, loads of various consumers to be fed and voltage regulations at the farthest end of the feeder.

Although, 11 kV Primary Distribution system is being used by most of the distribution utilities in the country. However, in some pockets in distribution areas, primary voltage of 6.6 kV or 3.3 kV is also being used by some utilities. The same criteria/ factors as suggested for planning of 11 kV network may also be adopted for 6.6 and 3.3 kV network.

5.1 PLANNING STANDARDS / CRITERIA FOR PRIMARY DISTRIBUTION (11 KV) NETWORK

The following factors should be considered for planning the 11 kV System:

Time Horizon: The 11kV network should be studied for at least 5 years for augmentation of existing feeders and planning new feeders.

Technical losses: The system should be planned to ensure that Peak Technical Loss Limit for 11 kV Network including DT's shall be **Max 2.5%**.

5.2 FACTORS USED FOR CALCULATION OF TECHNICAL LOSSES

a) Load factor (LF) means the ratio between the average load and the peak load over a period of time. It is a measure of the utilization rate of electrical energy usage. Load factor is generally defined as:

$$\text{L.F.} = \frac{\text{Average Load}}{(\text{Peak load during a defined period})}$$

The load factor may be calculated as under:

$$\text{L.F.} = \frac{\text{Energy served during the Period}}{(\text{Peak load} \times \text{Number of hours during the period})}$$

b) Load factor can also be calculated with the following equation on half hourly basis in case SCADA data is available:

$$LF = \left(\frac{1}{17520}\right) \sum_{n=1}^{17520} (\text{Load}_n / \text{Peak Load})$$

Where:

Load_n = the 30-minute average load in the nth period

Peak Load = the Peak 30-minute load.

c) Load Loss Factor (LLF): LLF is the ratio between the average load losses and the peak load losses over a year.

Loss Load Factor (LLF) calculation for 11 kV feeders-

Since the losses in the wires are proportional to the square of the current (and thus the square of the power), LLF is based on the square of the load and expressed as:

➤ In case 30 minute Data is available:

$$LLF = \left(\frac{1}{17520}\right) \sum_{n=1}^{17520} [(\text{Load}_n)^2 / (\text{Peak}_n)^2]$$

Where, Load_n = the 30 minutes average load in the nth period

Peak_n = the highest 30 minutes load in the nth period.

17520 = the number of 30 minutes load recordings in one year

In case, 15 Minute data is available, the LLF may also be calculated based on 15 minutes data with 15 minutes time blocks of 35040 in a year.

The above formula for Calculation purposes is approximated as:

$$LLF = k * (LF) + (1-k) * (LF)^2$$

Generally k is taken 0.2 for calculation of LLF

$$LLF = 0.2 * (\text{Load Factor}) + 0.8 * (\text{Load Factor})^2$$

The Technical Losses of the Feeder may be calculated as under:

The Technical Losses in a feeder for a given period (like in a one month) may be calculated by the equation below.

Technical loss in MU = $I^2 \times R \times L \times LLF \times 30 \times 24 \times 10^{-9}$

Where,

I = Max Current in amp.

R = Resistance of the conductor in ohms/ kilometre

L = Length of the feeder in kilometres

LLF = Load loss factor

5.3 DETAILS OF VARIOUS COMPONENTS OF PRIMARY DISTRIBUTION SYSTEM

a) DISTRIBUTION SUB-STATION (DSS)

- The Distribution sub- stations shall normally be located near load center.
- The DSS can be installed indoor or outdoor or underground as per site requirement.
- The DSS with dry type transformer can be used for rooftop installation provided that the building is suitable for bearing the load and adequate fencing or isolation arrangement is ensured.
- The DSS can be conventional, package type, completely self protected (CSP) type.
- DSS may be installed in vertical type (i.e RMU and LT switches above or below DT on another platform)
- The capacity of DSS shall be as per the load requirement keeping in view the future load growth for at least five years.
- In the selection of the equipment for the distribution substation, the de-rating factor due to increase in altitude and for cables due to depth of burial shall be taken into consideration as per the altitude or depth of burial at the site.

(i) DISTRIBUTION TRANSFORMER:

Distribution Transformer (DT) is one of the main components in the Distribution network which directly supplies the power to the consumer. Hence, the proper & efficient working of Distribution Transformers is the key factor for maintaining 24x7 reliable power supply to the consumers. The fault in Distribution Transformer not only interrupts the power supply to the consumers but also results in revenue losses to the discoms.

The Distribution Transformer shall conform to relevant IS and shall be ISI marked. The transformer can be oil filled(Mineral oil /K class oil) or dry type depending on requirements and shall be as per Central Electricity Authority (Measures relating to Safety and Electric Supply) Regulations, 2023 as amended / subsequent Regulations in this regard.

Utilities may also use Completely Self Protected (CSP) /Package distribution sub-stations as per their requirement/ site conditions conforming to the relevant IS. However, in coastal areas, Distribution Transformer shall be indoor or package type or plinth-mounted.

Iron & Copper losses for Distribution Transformers-

No Load losses & Load Losses for DT's would be as per manufacturer's specification (Iron & Copper loss) and should not more than as specified in relevant Indian Standards. (Total loss at 50 % loading & 100 % loading)

 **Standard Rating of Distribution Transformers(DTs):** Distribution transformer rating shall be as per IS 1180 (As amended till date) as given below:

➤ **3 - Phase Distribution Transformers (DTs)**

S.No	Nominal System Voltage	Standard Ratings (kVA)
1	Up to and including 11kV	*6.3, *10, 16, *20, 25, *40. 63,100,160, 200,250,315,400,500, 630, 1000, 1250, 1600, 2000, 2500
2	Above 11kV up to and including 22 kV	*6.3, *10, 16, *20, 25, *40. 63,100,160, 200,250,315,400,500, 630, 1000, 1250, 1600, 2000, 2500
3	Above 22kV up to and including 33 kV	*6.3, *10, 16, *20, 25, *40. 63,100,160, 200,250,315,400,500, 630, 1000, 1250, 1600, 2000, 2500
*Ratings are non-preferred.		

Table 5.1 Nominal Three Phase System Voltage And Standard Rating Of Distribution Transformer

➤ **Single Phase Distribution Transformers(DTs)**

S.No	Nominal System Voltage	Standard Ratings (kVA)
1	Up to and including 11kV	5,10,16, 25, *50, *75, *100
2	Above 11kV up to and including 22 kV	5,10,16, 25, *50, *75, *100
3	Above 22kV up to and including 33 kV	5,10,16, 25, *50, *75, *100
*Ratings are non-preferred.		

Table 5.2 Nominal Single Phase System Voltage And Standard Rating Of Distribution Transformer

Type of Distribution Transformers :

- Oil type (mineral oil / k class oil type) / Dry type/
- Conventional DSS/ CSP/ Compact SS
- Winding Aluminium/Copper
- Only Dry type DTs should be installed at all indoor locations, underground locations (residential/ commercial buildings) as per the relevant clauses of Safety Regulations of CEA.

 **Mounting of Distribution Transformers (DTs):** The mounting of DTs shall be as per relevant provisions of Indian standards IS 1180. As per IS 1180 clause 14,

- Single phase transformers are pole mounted type and shall be provided with two mounting lugs suitable for fixing the transformer to a single pole by means of two bolts of 20 mm each. Both mounting lugs are made with steel of minimum 5 mm thickness. For single phase transformers above 25 kVA, base channels may be provided as per agreement between the user and the supplier.
- Suitable pole mounting arrangement may be alternatively provided for 3 phase transformers up to 500 kVA, subject to agreement between user and supplier.

The mounting structure of DTs may be decided by the utilities considering the dead weight of Transformer along with other equipment such as Isolators, Breakers, LAs, Fuse units, Structural materials, L.T. Distribution box, LT Cables / Wiring, Tension of HT & LT Lines, & RMU etc.

As per Indian Standards (IS 1180) , single phase DTs and 3Ph DTs up to 500 KVA capacity can be installed on Poles and all DTs above 500 KVA should be installed on Plinth. Up to 500 KVA capacity DTs, the following mounting of 3 – Ph Distribution Transformers are suggested:

- Transformer up to 25kVA – May be mounted on single pole.
- Transformer above 25 KVA & up to 500 KVA- May be mounted on H Pole (2-pole or 4-Pole) or plinth.
- Transformer above 500 KVA- Shall be mounted on plinth only.

The above preferences may be modified by the utilities based on the site conditions/ practices being followed within the clauses of Indian Standards.

Further,

- The structures should be provided with anti-climbing devices and danger board.
- The plinth should be higher than the surroundings and made of Concrete or Metal (properly earthed) or fire resistant fibre glass of adequate strength to withstand the load
- The plinth foundation should be of concrete.
- Plinth mounted distribution sub-stations shall be adequately protected by fencing so as to prevent access to the equipment by unauthorized persons, animals and shall be provided with standard danger boards.

Loading of Distribution Transformer for augmentation:

- In case, the Peak Load experienced by the individual DT is more than 80% during last one year, the utilities should take steps to augment the DT capacity or to shift some of the load to the nearby under loaded DT.
- New Distribution transformer capacity shall have margin to take care load growth for 5 years as per CEA Regulations.

(ii) SURGE ARRESTERS

Surge arrester conforming to relevant IS shall normally be installed on the high voltage side of the Distribution transformer connected to overhead lines. Surge arrester should also be provided on the low voltage side in areas of high isoceraunic activity. Surge arresters of rating 9 kV on 11 kV, 20 kV on 22 kV and 30 kV on 33 kV outdoor type should be used for diverting the lightning surges to earth.

(iii) LT DISTRIBUTION BOX

The LT distribution box consisting of breaker and fuse cutouts and fittings conforming to relevant IS shall be provided on LT side from where distribution feeders shall be taken out. The size of the LT box should be suitable for accommodating moulded case circuit breaker, fuse cutouts, cable connectors, bus-bars etc. The distribution box should be mounted at a height of minimum 1.5 metres from ground for pole mounted distribution transformers. For single phase transformers, the distribution box can also be directly mounted on the body of transformer.

(iv) PROTECTION SYSTEM

The protection system of transformers shall be as per Central Electricity Authority (Measures relating to Safety and Electric Supply) Regulations, 2023 or any successor

or subsequent Regulations in this regard. However, the following may be taken into account, while planning a new DSS:

(1) 33/ 0.4 kV DSS and 22/ 0.4 kV DSS -

- (a) Suitable high rupturing capacity cartridge fuse or moulded case circuit breakers or miniature circuit breakers or air circuit break switch shall be provided on low voltage side.
- (b) The high voltage side of these transformers shall be protected by circuit breakers or drop out fuses.

(2) 11/ 0.4 kV DSS –

- (a) Suitable high rupturing capacity cartridge fuses or moulded case circuit breakers or miniature circuit breakers or air break switch shall be provided on low voltage side for transformers of 100 kVA and above: Provided that the high voltage side of these transformers shall be protected by drop out expulsion type fuses or circuit breakers.
- (b) Horn gap fuse with air break switch shall be provided on high voltage side and switch fuse unit or wire fuse on low voltage side shall be provided for transformers below 100 kVA.

(v) EARTHING OF DSS

Earthing shall be provided for the DSS complying with relevant Indian Standards and Central Electricity Authority (Measures relating to Safety and Electric Supply) Regulations, 2023 or any successor or subsequent Regulations in this regard.

(vi) LT CABLES

- XLPE cables, complying to relevant IS, should be used for connecting LT supply from transformer bushings to the LT circuit breaker in the distribution box and for taking out outgoing feeders from the fuse units to the overhead lines.
- The LT cables may be armoured or unarmoured for transformers rated less than 100 kVA and shall be armoured for transformers of 100 kVA and higher ratings.
- The cables shall be properly clamped to the support without damaging the insulation.

- A loop arrangement shall be made at the connecting end and laying of cables shall be in such a way that rain water does not enter.

(vii) METERS ON DISTRIBUTION TRANSFORMERS

A communicable Meter /Smart Meter should be installed on every DT in conformance to the Central Electricity Authority (Installation and Operation of Meters) Regulations, as amended upto date.

(viii) REACTIVE COMPENSATION

- Where the power factor is low, reactive compensation should be provided on the distribution transformers by fixed or automatic switched type capacitors of adequate rating.
- In case of fixed capacitors it should be ensured that the rating of the capacitors is such as to prevent over compensation during off peak period.
- In cases where loads fluctuate very fast or there is large intraday reactive variation, a suitable dynamic compensation like thyristor switched capacitors may also be considered.
- In loads which are rich in harmonics, suitable harmonics filters or de-tuned filter banks may be installed.

b) 11 KV /6.6 kV/3.3 kV FEEDERS:

- ❖ The 11 kV /6.6 kV /3.3 kV Feeders may be laid with core conductors, ABC, U/G cables, covered conductor as per requirement.
- ❖ The electric line shall be close to a road for approach during construction and ease of maintenance.
- ❖ The design and construction of the Feeders shall comply with the relevant IS. The Feeders shall be designed so as to ensure:
 - (a) voltage conditions are within permissible levels;
 - (b) improvement of reliability and security of power supply;
 - (c) improvement in quality of supply;
 - (d) adequate capacity for load growth for next 10-15 years.
- ❖ Independent feeders may be provided for essential loads such as water works, hospitals, defence, railways, airports /VVIP areas and other sensitive installations and for HT consumers on request/ as per regulations etc.

- ❖ Provision of alternate feed for Hospitals , Airports , water works etc and (N-1-1) redundancy for feeding the Critical loads /important areas may also be adopted.
- ❖ Multi-circuit multi-voltage lines may be adopted as per requirement keeping in view the ROW difficulties in future.
- ❖ Extension of existing lines may be carried out after ensuring that the limits of voltage variations on the lines are not exceeded the limits prescribed otherwise, a new feeder may be laid or augmentation of feeder may be taken up with higher capacity conductor.
- ❖ The route of the electric line shall be as short as possible and angle points in the route shall be minimized.
- ❖ The routing of an electric line shall normally be avoided through following areas:
 - (a) Protected and reserved forest. In case it is not possible to completely avoid the forests or areas having large trees, keeping in view the overall economy, the route of the line may be aligned in such a way that cutting of trees is minimized or otherwise U/G cables may be used.
 - (b) National Parks and Wild Life Sanctuaries.
 - (c) Restricted areas such as civil and military airfields and aircraft landing approaches.
 - (d) Educational institutions, large habitations and densely populated areas.
 - (e) Rough and difficult country side, and natural obstructions, fruit gardens, lakes, rivers etc.
 - (f) Cremation grounds, slaughterhouses and garbage dumping grounds to prevent interruptions by bird hits.
- ❖ Railway and road crossings shall be minimum on the line route and in case it is not possible to avoid the same, the crossings at right angles shall be preferred but the crossing shall not be less than 60 degrees in any case. Alternately, U/G cable should be used for Railway/Road crossing.
- ❖ The supports for the Lines may be poles or towers /narrow based lattice towers with fully galvanised structure as per site requirement. The Erection of poles/Towers should be carried out in accordance with the provisions of relevant IS.
- ❖ The poles may be selected from pre-cast concrete(PCC) pole, pre-stressed cement concrete(PSCC) pole, rolled steel joist, rail pole, spun pole, H-beam or steel tubular pole as per requirement. However, PCC and PSCC poles should not be used at cut-points and as end poles.

- ❖ In coastal areas/disaster prone areas, higher strength poles like rail poles or spun poles shall be used.
- ❖ In hilly areas appropriate snow or ice loading should be considered for design/selection of poles and towers.
- ❖ For locations involving long spans or higher clearances on account of crossing of power or communication lines or a railway line, specially designed poles/lattice towers or underground cable may be used as per requirement.
- ❖ Double pole structure may also be used as per site conditions ensuring safe operation of lines.
- ❖ Line span may be decided taking into consideration the topography, wind pressure, type of support, conductor configuration and ultimate tensile strength of conductor. Generally, a uniform span should be maintained as far as possible between consecutive poles/ Towers.
- ❖ While constructing a line, if a road crossing occurs at mid span, then a pole shall be placed on one side of the road so as to avoid mid span at the road crossing.
- ❖ While crossing another power line, the lower voltage line shall be underneath: Provided that the lower line shall normally not cross at mid span of the upper line.
- ❖ While placing poles on high ground, shorter poles can be used while maintaining proper ground clearance at the middle of the span.
- ❖ Poles shall normally not be placed along the edges or cuts or embankments of creeks and streams.
- ❖ At all the places where the new line crosses over roads or another existing line, adequately earthed guard wire mesh below the line shall be provided to avoid the conductor of the line falling over the areas below, in case of any break. In case, where the new line passes below an existing line, the guard wire mesh shall be provided above the new line under construction.
- ❖ Galvanized iron stay wires and stay rods of adequate size and minimum tensile strength complying with relevant IS may be used as per requirement. The stays are generally provided at:
 - angle locations;
 - dead end locations;

- tee off points;
 - steep gradient locations;
 - cut-points;
 - along the straight run at minimum two locations in one km.
- ❖ For double pole structure, four stays along the line, two in each direction and two stays along the bisection of the angle of deviation or as required depending on the angle of deviation should be provided.
 - ❖ When two or more stays are provided on the same pole, each stay should be grouted entirely separate from the other.
 - ❖ The angle between the pole and stay wire should be about forty five degrees and in no case it should be less than thirty degrees.
 - ❖ Stays should be anchored either by providing base plates, angle iron or rail. The Stay wires should be connected to the pole with IS complaint Porcelain Guy Strain Insulator.
 - ❖ The insulator shall be inserted in the stay wire at a height of minimum 3 m vertically above the ground level.
 - ❖ Protective Guard, anti-climbing devices and danger plates should be provided in accordance with Central Electricity Authority (Measures relating to Safety and Electric Supply) Regulations, 2023 or any successor or subsequent Regulations in this regard.
 - ❖ Cross-arms and the clamps should be hot dipped galvanised conforming to relevant IS.
 - ❖ Insulators and its fittings shall confirm to relevant IS. Normally, pin insulators are used in 11 kV /6.6 kV & 3.3 kV and LT lines as per requirement.
 - ❖ For critical locations with high pollution level, anti-fog type insulators or polymer insulators may also be used for better performance.
 - ❖ Insulator and insulator string rating shall be selected such that.—
 - (a) under 100% design wind loading conditions, the load on insulator string shall not exceed 70% of its mechanical strength;
 - (b) under everyday temperature and no wind/snow conditions, the load on the insulator string shall not exceed 25% of its mechanical strength.

- ❖ The insulation shall be designed to avoid excessive concentration of electrical stresses in any section or across leakage surfaces
- ❖ The protection scheme for the system shall be finalized by the Utility based on prudent utility practice after discussion with Transco.
- ❖ All required consents/approvals including civil aviation, road, river, rail, canal, power line crossings and environmental and forest clearances etc. should be arranged from the concerned authorities before laying the lines.
- ❖ Earthing of Poles should be provided as per relevant IS and Central Electricity Authority (Measures relating to Safety and Electric Supply) Regulations, 2023 or any successor or subsequent Regulations in this regard.

c) VOLTAGE REGULATION

The voltage variations at the farthest end of 11 kV /6.6 kV /3.3 kV lines should not exceed standard limits under peak loading conditions and normal system operation regime (As per relevant IS) as given below:

Voltage	Voltage variation limits	
	Minimum	Maximum
11 kV/6.6 kV/3.3 kV	(-) 9 %	(+) 6%

The necessary action should be initiated in case the voltage regulation limit reaches (-) 8% or (+) 5%. To achieve the desired voltage regulation, initially, the transferring of load to the nearby under loaded circuits may be taken up. The provision of automatic switched capacitors and on load tap changer on Power Transformers (as per IS) should be kept at Sub-station for voltage correction. Alternatively, augmentation of existing lines or construction of new lines may also be considered.

The efforts should also be made to extend 11 kV network up to the load center to reduce LT line and improving HT/LT ratio for loss reduction and enhancing voltage profile at consumer premises. HVDS system may also adopted at appropriated locations based on the field conditions and in the theft prone areas.

d) STANDARD CONDUCTOR / CABLE TYPES

- The Standard size of the conductor should be used for construction of 11 kV /6.6 kV/3.3 kV feeders. The size of the conductor would depend upon the voltage

regulation, factor of safety, power to be transmitted, length of line, line voltage and mechanical strength desired etc.

- Aluminium Conductor Steel Reinforced (ACSR) or equivalent All Aluminium Alloy Conductors (AAAC), All Aluminium Conductor (AAC), Aluminium Alloy Conductor Steel Reinforced (AACSR) or HTLS conductors along with requisite accessories may be used complying to relevant Standards.
- Most power utilities use ACSR conductors on account of price considerations although AAAC conductors are lighter in weight and have a longer life on account of their higher resistance to corrosion.
- The use of Underground cables, Aerial Bunched Cable(ABC) or covered conductor may also be taken up as per Regulations /site requirement.
- The configuration of conductors on the line can be triangular, horizontal or vertical depending upon the voltage level of the lines, terrain, right of way and clearances to be maintained. In case clearance from a building is difficult to secure, vertical arrangements of the conductor may be adopted or UG cable may be used.
- Suitable insulating paint may be provided on bare conductors in coastal areas to prevent corrosion as well as in power theft prone areas.

Indicative list of Conductors Generally used

Voltage	Conductor / cable
11 KV	Dog, Raccoon, Rabbit, Weasel ,ABC, Covered conductor, XLPE cables of different sizes

Table 5.3 List of conductors generally used

Note: Other conductors/ UG Cables/ new technology conductors/ cable may also be used by the utilities based on the requirements & availability

❖ Details of Max. Loading of generally used Conductors :

Conductor	Nominal Area (sq. mm)	Ampacity (Amps.) at 45°C
ACSR Dog	100	360
ACSR Raccoon	80	300
ACSR Rabbbit	50	240
ACSR Weasel	30	170

Table 5.4 Max loading of Conductors (as per IS 398 part 2)

(Note: The equivalent AAAC conductors can also be used)

e) CABLES (XLPE/ABC/COVERED CONDUCTOR)

- Underground cables or aerial bunched cables or covered conductor of adequate rating conforming to relevant Standards can be used for supplying power as per requirement /site conditions/regulation requirement etc
- Only XPLE cables should be used. PVC cables shall not be used in systems other than LT system.
- In coastal areas, protected forest areas and disaster prone areas, only underground cables should be used. Aerial bunched cables or insulated cables or covered conductor may also be used in the congested, theft and accident-prone areas. As per CEA Safety regulations, for electric lines of 33 kV and below passing through the protected areas (National Parks, Wildlife Sanctuaries, Conservation Reserves, Community Reserves), Eco-sensitive zones around the protected areas and Wildlife Corridors, only underground cable shall be used.
- Underground Cables shall normally be laid in trenches as per the relevant standards and utility practices. The direct burying of underground cables should not be adopted except where cables enter and take off from a trench. The cables may also be laid in pipes or cables with co-extruded pipes through trenchless method as per the site requirement.
- The underground cables shall be segregated by running in separate trenches or on separate racks or in separate pipes. Cables should also not be laid directly on trench floor.
- The route of cables should be finalized keeping in view that Cable trenches or pipes shall not be run through oil rooms and these should be properly sloped so as to drain freely any water, which may enter.

Cable Size	Direct in Ground at 30°C (Al Conductor)	In Air at 40°C (Al Conductor)
3Cx120 XLPE	215 A	262 A
3Cx150 XLPE	240 A	294 A
3Cx185 XLPE	270 A	336 A
3Cx240 XLPE	315 A	393A
3Cx300 XLPE	355 A	448 A
3CX400 XLPE	405 A	519 A

Table 5.5 Typical current rating of XLPE Cables: (based on per IS 7098 Part 2)

* The above **typical** Cable ratings may be in somewhat(+/-) variance as per the manufacturers GTP.

Note:

- **Under-ground cables de-rating factors:** The current ratings of the cables would be subject to de-rating factors applicable for local conditions such as grouping, cable depth, soil type, temperature, etc as per relevant IS.

 Max. Loading of ABC Cables:

Conductors/ AB Cables	Nominal area (sq mm)	Current Capacity(amp) in Air Amps (at 40C0
3x185+1x120	185	290
3x150 +1x95	150	250
3x120 +1x95	120	220
3x 95 +1x70	95	190
3x70+1x50	70	155
3x50+1x35	50	130

Table 5.6 Typical current rating of abc cables: (based on per IS 7098 Part 2)

* The above **typical ABC** ratings may be in somewhat(+/-) variance as per the manufacturers GTP.

- ❖ **Peak loading trend of feeder:** Trend peak of the last one year under Normal Operating Conditions.
- ❖ **N-1 back-up availability:** In case of radial feeder configuration, provision for Ring Main Units (RMUs) at DTs and at suitable points of Feeders may be provided to ensure the alternate path for uninterrupted supply.
- ❖ **Independent feeder:** Essential services (Water works, Hospitals, Defense, Railways, Airports & other sensitive Installations) , VVIP areas , HT consumers etc should have a dedicated feeder along with a back-up feeder from another source substation for reliability.
- ❖ **Feeder Configuration**
 - The 11 KV system configuration may be radial, ring or combination of both as per requirements.
 - The radial configuration should be minimized to improve reliability.
 - In densely loaded city centers and for essential services, the system should be of ring configuration.
 - The planning criterion relating to the redundancy aspect of the Feeder may be based on the demography it serves. 'N-1' criterion must be

maintained in an urban/ semi-urban settlement, while in a rural set-up, 'N-1' can be maintained in the network based on the cost effectiveness. However, the provision of alternate supply at 11 kV level should also be maintained for Rural areas for higher reliability.

- U/G cable should be preferred in densely populated areas, religious places, areas of tourist attractions , disaster prone areas and protected areas (National Parks, Wildlife Sanctuaries, Conservation Reserves, Community Reserves), Eco-sensitive zones around the protected areas and Wildlife Corridors etc

5.4 HVDS NETWORK

To improve quality (Voltage profile) of electric supply, reducing the theft and reducing the losses in the system, HVDS is used by the Discoms as an alternate to LVDS. In this system, 11 KV lines are extended up to or as nearer as possible, to the load center, and small size single phase distribution transformers ranging from 10KVA to 50KVA depending on load requirement are installed on poles to supply power to consumers. However, safety clearances are to be taken in to account during laying of 11 KV lines in the narrow streets. The HVDS system has more 11 KV Line and more DTs but virtually No LT lines or very less LT lines as compare to LVDS system.

Advantages of HVDS:

- i. Low technical losses due to reduction of LT lines
- ii. Reduction of commercial losses due to elimination of theft by direct tapping of bare conductor LT lines due to 11 KV OH line.
- iii. Improved voltage regulation at consumer end due to low voltage drop
- iv. Fault in any single DT will cause an outage for a limited numbers of consumers connected to it, leading to improved availability and reliability of power supply to the other consumer consumers in the area.
- v. Reduced physical zone of supply and number of consumer through a lower capacity DT will lead to development of community consciousness and ownership feeling. This will be helpful in timely maintenance of transformer and curb on theft.
- vi. HVDS would be beneficial for Agriculture connections also.

Disadvantages of HVDS:

- i. More maintenance Expenditure due to large numbers of DTs would be required.

- ii. This system would require more safety clearance due to 11 KV line with bare conductor, hence, would not be appropriate/preferred in narrow streets /lanes in cities/villages.
- iii. For conversion of already LVDS system into HVDS system would require the dismantling of existing LT system and laying of new HVDS system which is practically not possible in the already electrified areas. However, HVDS may be planned in the new areas for supplying electricity.
- iv. In the existing LVDS, the exiting bare conductor LT lines may be replaced with ABC Cable on the existing poles (with some added Poles) while in case of HVDS system, a whole new system has to be laid.

As with all systems, there exists pros and cons in HVDS also. Therefore, the selection of the HVDS over LVDS should be based on actual site conditions & Cost-Benefit Analysis.

5.5 PLANNING OF NEW FEEDERS IN RURAL AND URBAN AREAS

Planning criterion for rural and urban system in different scenario may be as follows:

i) Network based on Geo-graphical Layout: (External Peripheral Network)

Network configuration is to be decided based of geographical layout with due consideration to right of way. The approach shall be categorized as under:

- **Urban Areas:** The external peripheral network may be laid preferably through under-ground network with XLPE cables of suitable size up to main substation. The internal peripheral network may be as per actual site conditions.(OH/UG).
- **Semi Urban & Rural Areas:** The external peripheral network may be laid on overhead network with bare conductor/ ABC / covered conductor up to main substation where right of way/ mandatory clearances available or on under-ground network where right of way/ mandatory clearances are not available. The internal peripheral network may be as per actual site conditions.

ii) Network based on Area Profiling: (Internal Peripheral Network)

Network configuration to be decided based on area profiling with geographical layout of existing & proposed new loads. The approach shall be categorized based on Area Profile of existing/ proposed Consumers as under:

➤ **Residential & Commercial:**

1. Plotted Area: The electrification of a new area may be carried out on HVDS. In the existing plotted areas also, HVDS may be considered in phases.

2. Flat Area/High rise buildings: The electrification of new flat areas may be carried out based on site condition on (OH/UG Cables) with suitable capacities of DT's along with installation of feeder pillars & service pillars. The dedicated Distribution transformers of adequate capacity may be provided for High Rise buildings.

➤ **Industrial:**

The electrification of new industrial connections may be carried out as per the load requirement of HT consumer based on SOP issued by respective SERC. A dedicated feeder, if requested by a HT consumer, may also be provided.

➤ **Agricultural:**

All new agricultural connections may be provided on HVDS with meters on all agricultural connections and feeders. A separate 11 KV feeder for Agriculture loads may be laid from S/S to regulate the power supply to Agriculture consumers and to provide 24x7 supply to other consumers.

➤ **Power Supply to important /Critical Loads**

Separate dedicated feeders with alternate path (N-1 redundancy) should be adopted for extending the power supply to important loads. Further, (N-1-1) redundancy may be adopted for Critical Loads.

iii) Network Extension in Rural and Urban area:

The following criteria may be adopted for taking T-offs & LILO in case of overhead and underground network for extension of network:

➤ **Underground Network:** In purely underground network, LILO/Ring Main System may be proposed so as to provide back-up source in case of primary section outage. The LILO shall be connected with an RMU for suitability of switching during maintenance or back feeding conditions. All future extension of network should also be underground keeping in view the continuity with existing underground network.

➤ **Overhead Network:** In overhead network, T-off through overhead bare network is preferred arrangement.

- In case of ROW problem or safety clearance issues, HT ABC network or U/G cable be laid.
- LILO through underground cable be taken only if the upstream is having back-up connectivity and T-off through bare overhead & HT ABC is not feasible.
- HT ABC may be preferred in areas covered with trees and areas where bird electrocution is frequent, etc.

5.6 CRITERIA FOR PROVIDING NEW ELECTRICAL EQUIPMENT / ASSETS IN DIFFERENT SCENARIO / NETWORK CONDITIONS

S. No.	EQUIPMENT	CRITERION
1.	Distribution Transformer	• Peak loading above 80% even after load sharing within and near-by substation with LT re-networking.
2.	11 kV HT Feeder	• Loading/Ring Loading above 90% in rural areas and 80 % in urban areas. • Critical due to under-size/ old and aged sections. • Load growth • Voltage regulation not within (-9% to +6%)
3.	HT Switchgear	• Safety of operation (leakage in oil type switchgear) • Obsolescence of HT Switchgear (spare and technology like SCADA compatibility) • Flexibility in operation and to reduce down time.

Table 5.7 Criteria for new electrical equipment/assets in varied network conditions and scenarios

5.6.1 FACTORS TO BE CONSIDERED FOR PROVIDING NEW FEEDER / AUGMENTING OF EXISTING 11 KV FEEDER:

i) Criteria for providing New 11 kV Feeder:

- ✚ Essential services (Water works, Hospitals, Defense, Railways, Airports & other sensitive installations like VVIP areas) shall have independent feeder.
- ✚ If the load on the existing feeder and the projected load as per short term planning exceeds the normal current carrying capacity of the feeder or the

limits of voltage Regulations are being breached, then firstly some load of the feeder may be shifted to nearby lightly loaded feeder, if available. If overloading could not be mitigated by shifting some load to interconnected feeder/nearby feeders, then a new 11kV feeder would be needed.

- ✚ New feeder based on load requirement for deposit/dedicated case may also be taken up.
- ✚ New feeder may be provided for segregating the loads into Agriculture and non- Agriculture loads.

ii) Criteria for providing 11 kV Interconnector:

- ✚ Interconnector is provided to shift the load of overloaded feeder to lightly loaded feeder
- ✚ New feeder / interconnected feeder for maintaining N-1 redundancy to provide duplicate source to certain 11kV s/stn that are running on single source thereby enhancing reliability and improving the consumer reliability index (SAIDI, SAIFI etc.).

iii) Feeder Augmentation Schemes:

Feeder augmentation schemes are planned in following cases:

- ✚ Existing cable /conductor has outlived its useful life causing frequent breakdown.
- ✚ Existing cable /conductor is undersized /unable to carry full load.
- ✚ As per requirement of consumers/ external agencies (deposit cases).

5.6.2 FACTORS TO BE CONSIDERED FOR PROVIDING NEW DISTRIBUTION TRANSFORMERS / AUGMENTING OF EXISTING DISTRIBUTION TRANSFORMERS:

i) Augmentation of Distribution Transformers for addressing the Overloading

To address the issue of overloaded DTs where DT peak load found $\geq 80\%$ after applying load growth as per planning, the following steps may be followed:

- ✚ The first preference should be to divert the load on another DT, if exists at the same location & has some loading margin. With the help of GIS, utility may look for diverting the load on another nearby DT which has some load margin.

- ✚ If overloading still exist, then a new DT may be installed along with the existing DT and load may be bifurcated between these DTs.
- ✚ If the additional DT cannot be installed along with existing DT, due to space constraints, then a higher capacity DT may be installed in place of existing DT. The alternate supply arrangement for the consumers getting supply from this DT should be made for augmentation period to avoid any inconvenience to the consumers.
- ✚ The augmentation of DT will be considered to the next optimal capacity keeping in view the load growth of area for next 5 years.
- ✚ If augmentation of DT (by adding a new DT or replacing the existing DT with a higher capacity DT) is not possible due to space constraints, then feasibility is seen for augmenting nearby DT to shift some load from the overloaded DT to relieve particular DT.
- ✚ If all above proposal are not feasible, then new location for DT/substation may be searched in near-by area of load.
- ✚ In this context, provision to provide a Dry type DT may be considered in the following cases:
 1. Mandatorily in indoor installations as per CEA regulations.
 2. If requested by developing agency/ applicant for aesthetic or otherwise demanded.
 3. If safety is an issue owing to electrical clearances, proximity to park, public places, crowded place etc.

ii) Installation of New Distribution Transformers (DTs):-

New DTs may be planned in following case:

- ✚ In un-electrified areas
- ✚ New bulk load / dedicated load
- ✚ Area fed by long LT feeder
- ✚ Consumer facing low voltage problems
- ✚ High LT losses
- ✚ Existing DT capacity is overloaded and load sharing / shifting on nearby under loaded DTs is not possible.
- ✚ If space is not available in existing substation for addition of new Distribution transformer, the existing DT may be replaced by a higher capacity Distribution transformer

5.7 INSTALLATION OF RING MAIN UNITS (RMUS)/ AUTO-RECLOSER/ SECTIONALIZER/ FAULT PASSAGE INDICATORS(FPIS) :

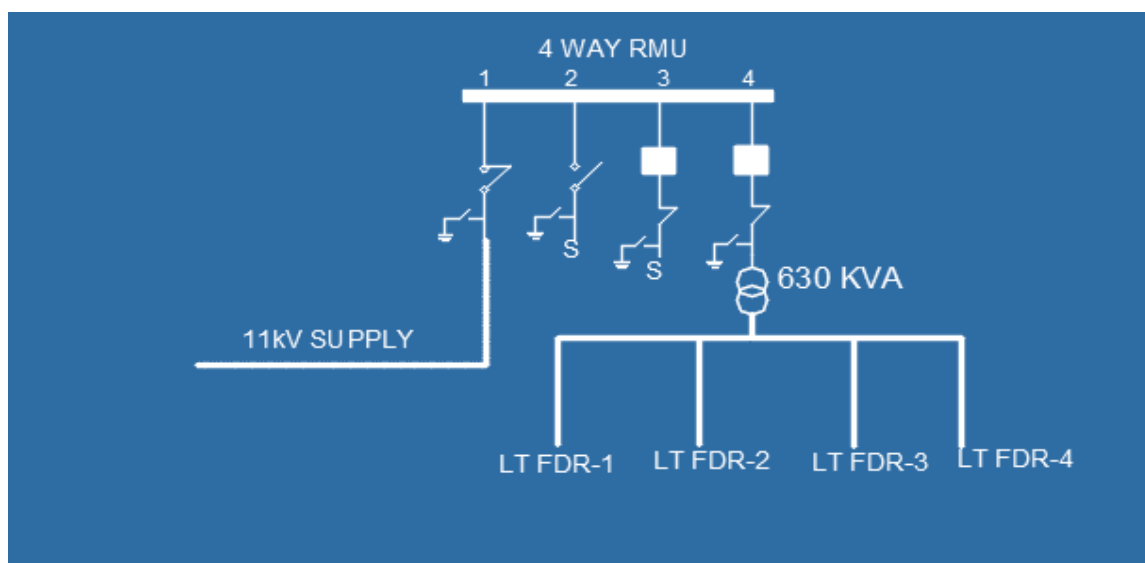
a) INSTALLATION OF RING MAIN UNITS (RMUS):-

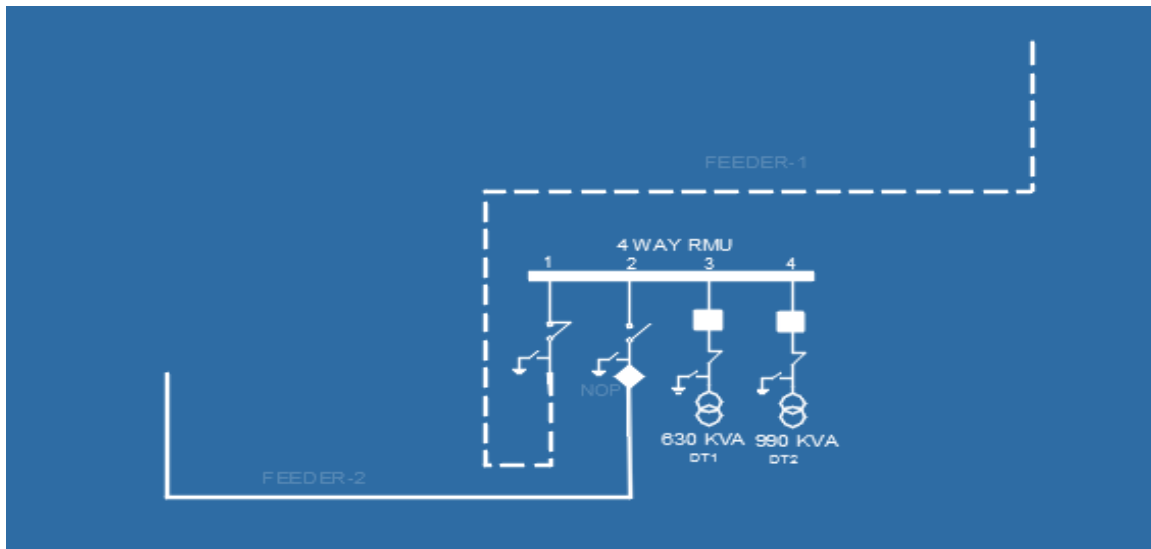
A 3 way or 4 way RMU (Indoor/Outdoor) type may be planned at DT level or at appropriate places on 11 kV feeder for providing N-1 redundancy in the system and improving reliability and load splitting. All RMUs may preferably be motorized and may be remotely operable, if required by the utility.

i) Criteria for providing RMU at DT / Feeder level:

RMU is proposed at T-Off or where 3 or more sections are emanating in order to segregate & sectionalize the lengthy network or controlling the network through breaker panel so as to improve the reliability of the network.

- RMUs may preferably be installed at all the Switching Stations / Distribution Sub Station. If not possible due some reasons like non availability of capital, RMUs may be taken up on alternate DTs/ important DTs.
- For interconnectivity of several feeders through RMU.
- For controlling DTs (subject to operational requirements).
- To address the safety issues such as multiple 11 kV feeders terminating/mounting on same pole(s).
- RMU is proposed where multiple DTs are connected from single source point.
- RMU should also be installed for controlling HVDS section





(b) INSTALLATION OF AUTO-RECLOSER AND SECTIONALIZERS

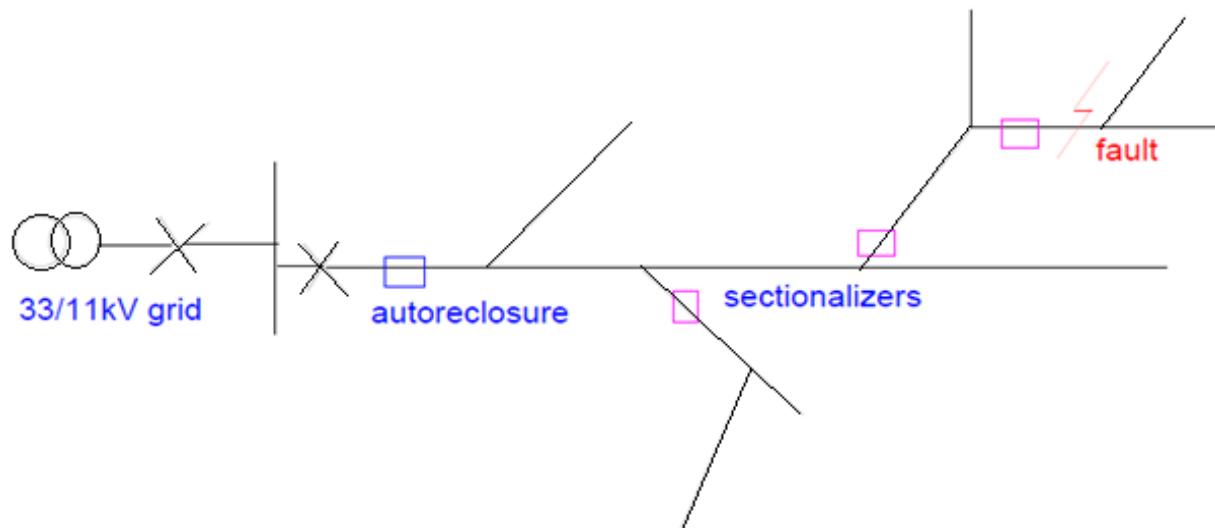
The Auto-Reclosers & Sectionalizers are used in the Distribution system to enhance the reliability of the system against the temporary or permanent faults. The auto-recloser is a type of circuit breaker, which opens when a short circuit occurs on the line such as a falling tree branch etc. The most significant difference between a recloser and a breaker is that the recloser was designed as a self controlled device. Then, the sectionalizer counts the successive openings and closings of the recloser, and after a pre-set number, it opens and isolate the faulty part of the line. Hence, a sectionalizer is a protective device that automatically isolates a faulted section of line from the rest of the distribution system.

i) Criteria for providing Auto-reclosure and Sectionalizers:

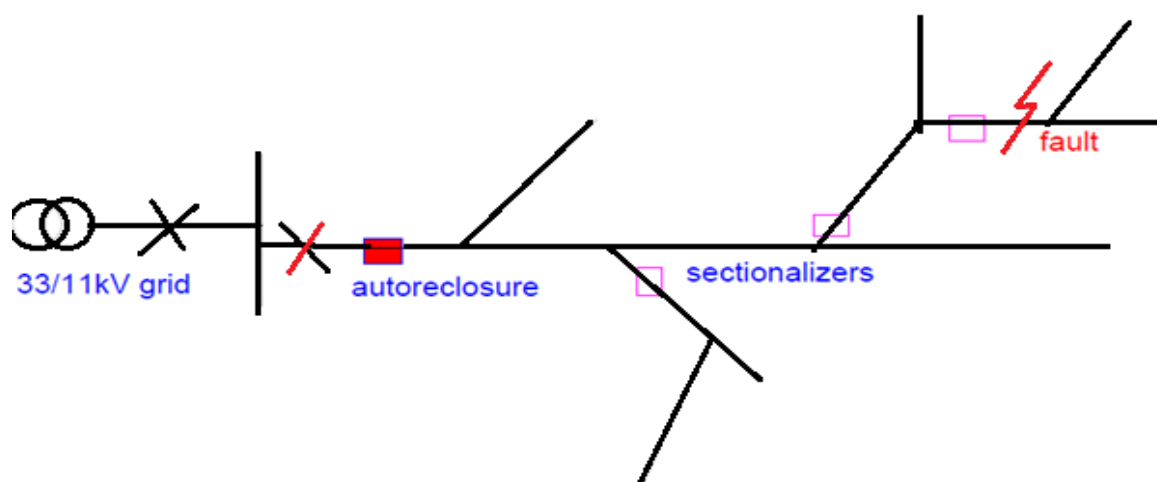
- Auto-reclosure is provided at the trunk section or main section of the O/H bare and where downstream sections are radial in nature
- Sectionalizers may be installed, where two or more branches are emanating after the main trunk section or branch. Sectionalizers may also be provided on
 - Long overhead sections with high no. of transient tripping.
 - Overhead sections with a large no. of T-off sections.
 - High Load density (KVA/Km)
 - Large No of Customer affected during faults
- In long overhead network (primarily in industrial areas), provision to install sectionalizers at Normally Open Point(NOP) points may be made based on study & suitability of installation/operation.
- Every First Switching Station (FSS) on a feeder may be controlled by Auto-recloser/ sectionalizer

ii) Working principle of Auto- Recloser and Sectionalizers

Maximum faults in overhead lines are of transient in nature. Therefore, auto-recloser & sectionalizer arrangement is very useful for fast restoration of such overhead feeders.

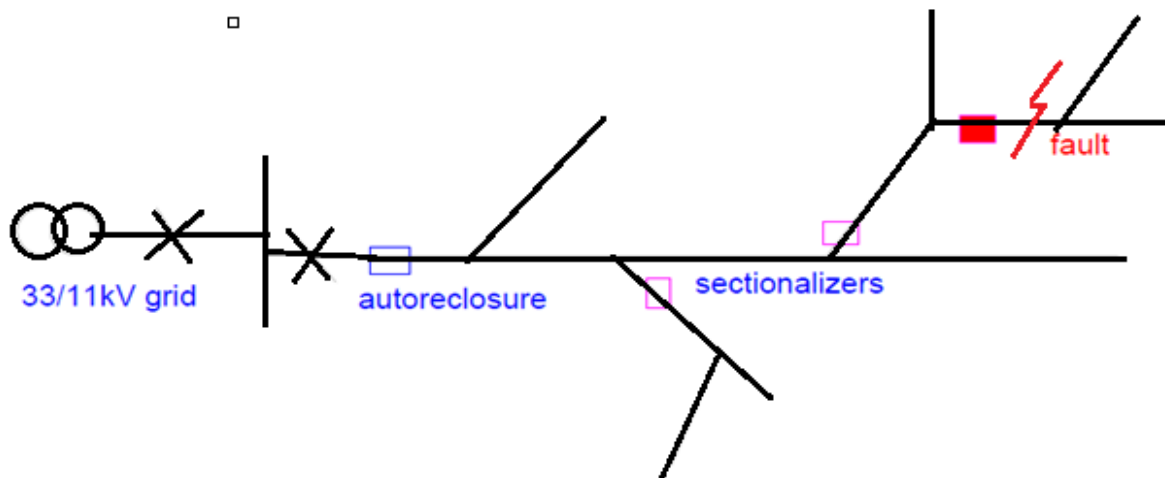


In case of occurrence of a fault in the marked section, initially auto-recloser will trip whole feeder. After some preset time, auto recloser will try to close and restore the supply. In case, fault is still there, it will trip the feeder.



Number of try set for sectionalizer is one less than auto-recloser. Now when auto-recloser attempts another tries, sectionalizer placed just upstream to affected area will trip and isolate faulty section and the remaining feeder is On. Thus prevent tripping of whole feeder. In this case, the faulty section of the line may be easily identified and

can easily be restored by the maintenance staff, thus improving SAIDI/ SAIFI. FPIs are also used on the lines to pin point the location of fault.



(iii) INSTALLATION OF FAULT PASSAGE INDICATORS(FPIS):

FPIs are used on the distribution lines to monitor the healthiness of lines and to find out the faulty section of the line to help in quick restoration. The status of FPIs may be monitored remotely through DMS and with the help of indicated location, the maintenance crew may be diverted to pin-pointed location of fault for early repair and restoration of supply.

CHAPTER-6

SECONDARY DISTRIBUTION NETWORK (LT NETWORK)

6.1 LT NETWORK

LT Lines emanate from distribution transformers to supply the 3 Phase or single phase power supply to the consumers. The Secondary Distribution Network is considered from Secondary of the Distribution Transformer up to and including service cable of consumers and meter at consumer premises.

The planning for LT System is similar to primary distribution planning process & starts with the updating of LT (400 V /230 V) distribution network for reliable & quality supply, reduction of technical & non-technical losses, customer satisfaction and equipment database as well as gathering of relevant information from various groups.

The consumer meter reading, generation of accurate Bill and collection of billed amount is one of the important activity of the distribution utility. The consumer data may be collected by downloading the meter data through optical port provided in the meter till the smart meters are provided. However, as the smart pre-paid meters/simple pre-paid meters are to be installed as per CEA Regulations / as per time line notified by Ministry of Power, the smart meters at consumer end would facilitate the availability of consumer consumption data automatically at data center without any human intervention. The smart meter would also provide real-time data about power consumption and allow customers to make informed choices about energy usage based on the TOU tariff notified by the Regulatory Commissions. The smart meters can also be disconnected or reconnected remotely from the data center in case of payment default by the consumers. Further, smart meters can also be used as pre-paid meters, net meters or post-paid meters as per the requirement. Smart meters in pre-paid mode would also facilitate the consumers to charge the meter as per their requirement and also help utilities to reduce their cash flow stress and financial losses, by avoiding loss of revenues from defaulting consumers.

After data gathering from consumer meters, the load estimation and peak load may be assessed on its connected LT feeder, Distribution Transformers and further on respective 11 kV feeders .

6.2 PLANNING STANDARDS / CRITERION FOR SECONDARY DISTRIBUTION NETWORK

- (i) **Time Horizon:** The LT network may be studied for a minimum period of 2 years and up to 5 year.

(ii) Loading Conditions:

- **LT feeders:** Based on the peak load data for distribution transformer feeding the LT feeders, the LT feeder loading to be proportionated on individual feeders depending upon connected load (KVA)/ sum of sanctioned load with relevant load factor or to be proportionated based on the peak loading data of LT Feeders available from smart meters data on the LT feeder. For this purpose, Peak Loading data of the last one year under normal operating conditions may be used for study purposes and firming up requirement for augmentation of the existing system.
- **Distribution Transformers:** The Peak Load experienced by the individual DT during last one year irrespective of the time of incident has to be considered for augmentation of the system.

(iii) Voltage Regulation:

+6% to -6% over declared System Voltage
(Supply Voltage would be as per CEA Regulation)

(iv) Allowable Technical Loss in Feeder:

The Peak Technical Loss Limit for LT Network shall be 3.5% max.

(v) Construction of LT Network:

- ✓ The size of the conductor for LT lines will depend upon the voltage regulation, factor of safety, power to be transmitted, length of line, line voltage and mechanical strength desired etc. The line may be laid with bare conductor /ABC/ UG cables/ covered conductor as per the requirement.
- ✓ Generally, Aluminium Conductor Steel Reinforced (ACSR) or equivalent All Aluminium Alloy Conductors (AAAC), All Aluminium Conductor (AAC) conductors along with requisite accessories are used in bare conductor lines.
- ✓ **LT Line Spacer:** To avoid clashing and accidental mutual touching of bare overhead conductors on LT lines, spacers of adequate dielectric strength, which can be either spiral or composite should be provided in between conductors at appropriate locations in different spans (particularly for lines having longer spans or lines having large sags encountering high winds).
- ✓ The Protective Guard, anti-climbing devices, danger plates and Earthing of lines shall be provided in accordance with Central Electricity Authority

(Measures relating to Safety and Electric Supply) Regulations, 2023 or any successor or subsequent Regulations in this regard.

- ✓ Underground cables or Aerial Bunched Cables or Covered Conductor or insulated cables of adequate rating conforming to relevant Standards can also be used for LT Lines based on site requirement. In Coastal areas, disaster prone areas, highly populated areas, congested areas, theft prone areas, tourist/religious places etc, underground cables should be preferred /used. Aerial bunched cables or insulated cables or covered conductor may also be used in the congested, theft and accident-prone areas.
- ✓ Underground Cables shall normally be laid in trenches as per the relevant standards and utility practices. The direct burying of underground cables shall not be adopted except where cables enter and take off from a trench: Provided further that cables may be laid in pipes or cables with co-extruded pipes may also be laid, though trenchless method as per the site requirement.
- ✓ The underground cables shall be segregated by running in separate trenches or on separate racks or in separate pipes.
- ✓ Cable trenches or pipes shall not be run through oil rooms and these shall be properly sloped so as to drain freely any water, which may enter. Cables shall also not be laid directly on trench floor.
- ✓ The installation of Automatic power Factor Controller(APFC) panel at LT level may be explored in case of low power factor.

a) Current Carrying capacity of Conductors/ Cables used in LT Network

Conductors (Nominal area)	Current Carrying Limit (45°C)
ACSR/AAAC Racoon(80 sq mm)	300 Amps
ACSR/AAAC Rabbit (50 sq. mm)	240 Amps
ACRS/AAAC Squirrel (20 sq.mm)	130 Amps
AAC- Wasp(100 sq mm)	295 Amps
AAC-Ant (50 sq mm)	190 Amps
AAC- Gnat (25 sq mm)	120 Amps

Table 6.1 Different types of conductor and their current carrying limit

XLPE/PVC Cables (IS 1554 part I for PVC and IS 7098 part I for XLPE)

Cables	Current Carrying Rating in Amps (Direct in ground 30°C) Al Conductor	Current Carrying Rating in Amps (in Air at 40°C) Al Conductor
XLPE-3 ½ x300 Cable	355	450
XLPE-3 ½ x240 Cable	315	393
XLPE-3 ½ x185 Cable	270	336
XLPE-3 ½ x150 Cable	240	294
XLPE- 3 ½ x120 Cable	215	262
XLPE-3 ½ x 95 Cable	196	220
PVC 3 ½ X300/150 Cable	305	315
PVC 3 ½ X240/120 Cable	275	280
PVC 3 ½ X185/95 Cable	235	240
PVC 3 ½ X150/70 Cable	210	205
PVC 3 ½ X120/70 Cable	185	180
PVC 3 ½ X95/50 Cable	165	155

Table 6.2 Different Types of XLPE/PVC Cables and Their Current Carrying Limit

* The above **typical XLPE/PVC cable** ratings may be in somewhat(+/-) variance as per the manufacturers GTP.

(Discoms may also use 4 core cables in place of 3 ½ Core Cable as per requirement due to increase in non linear current)

Preferred LT- ABC Cables

Aerial Bunched cable (Nominal area)	Current Capacity Limit at (40° C)
3x150+1x70+1x16	250 A
3x120+1x70+1x16	220 A
3x95+1x70+1x16	190 A
3X70+1x50+1x16	155A
3x50+1x35+1x16	130 A
3x35+1x25+1x16	105 A
3x25+1x25+1x16	82 A

Table 6.3 Different Types of Preferred LT-ABC Cables and Their Current Carrying Limit

* The above **typical ABC cable** ratings may be in somewhat (+/-) variance as per the manufacturers GTP.

In addition to above, other combinations of ABC cables may also be used as per availability and requirement.

b) N-1 Back-up Availability at LT level

Generally, the power supply is provided through LT radial feed (OH, U/G or LTABC) from Distribution Transformer upto the consumer level. However, this arrangement does not endure reliable supply in case fault on DT or LT line. Hence, a suitable back-feeding arrangement from nearby circuit may be provided through isolator / RMU / AC Distribution Box for enhancing the reliability of the power supply to consumers. This back-feed may be done from same Sub-station transformer or different Sub-station transformer based on capacity available, feasibility & least cost.

c) Allowable length of LT Circuit

The Max length of LT line will be based on the size of the conductor/ cable used, load on the feeders and the voltage regulation is within limits at the farthest end. However, the length of LT feeder including branches (if any) may not generally be more than 400 metres (Urban Area) & 500 metres (Rural Area).

d) Provision of MCBs/ MCCBs/ ACBs

Generally, LT feeders emanate from Distribution transformer through separate Fuses/ MCB's/MCCBs/ACBs of suitable capacity. All new LT Feeders proposed/ LT feeders currently coupled on under-rated ACBs should be controlled with separate ACBs/HRC fuses of adequate capacity.

However, the protection arrangement at LT Feeder emanating from Distribution Transformer sub-station shall be as per CEA (Measures relating to Safety and Electric Supply) Regulations, 2023 or any successor or subsequent Regulations in this regard.

Further, an earth leakage protective device shall also be provided at consumer premises as per requirement of Central Electricity Authority (Measures relating to Safety and Electric Supply) Regulations, 2023 or any successor or subsequent Regulations in this regard.

e) Number of LT feeders emanating from a Distribution Transformer:

Although the actual feeders emanating from one Distribution Transformer would depend on the capacity of DT, physical spreading of consumers and loading of consumers etc. However, the following number of LT feeders may be taken up for the planning purposes based on DT capacity:

- 1000 kVA – 6-10 LT feeders,
- 630 kVA – 4-8 LT feeders,
- 400 kVA – 3-6 LT feeders,
- 315 KVA – 3-6 LT Feeders

250 kVA – 2-4 LT Feeders
100 KVA - 2-4 LT Feeders

f) Criteria for laying of LT Network

Laying of new LT network are generally planned for the following conditions-

- ✚ New LT OH/ ABC/ UG Cable feeder schemes:
 - To mitigate overloaded existing LT feeder.
 - To release new connection.
 - To mitigate low voltage.
 - To share load of near-by DT.
 - Critical due to undersize/sick and aged sections.
 - To cater Load growth
- ✚ Conversion of LT OH line into LT ABC schemes :
 - Existing LT network with bare conductor has outlived its life and giving frequent trouble in operation
 - The area is prone to theft.
 - Safety concerns/ safety clearance are not available
 - HVDS System
 - More transient fault in bare conductor lines due to trees etc
- ✚ LT Extension schemes :
 - New development /extension of colonies.
 - Load growth in narrow streets where DT installation is not feasible.
 - Pending new connections
 - Voltage Regulation of extended feeder should be within limits.
- ✚ Installation of new LT switchgear / Feeder Pillar /Service Pillar:
 - To release new connections/ electrification schemes
 - Replacement of old /damaged LT switchgear / Feeder Pillar /Service Pillar.
 - Requirement for introduction of new technologies

g) Laying of Service Line

- The service line should be provided with insulated conductor, armoured cable or underground cable.

- The service line should have adequate margin to take care of load growth for at next 5-10 years.
- Over-head service connection should be provided either through independent service connection or through LT box.
- No tapping of service line should be permitted for supplying power to any other consumer.
- Feeder pillar-box should be used for providing underground service connection through cable to more than three or four consumers.
- Smart meters in pre-paid mode/ simple pre-paid meters may be provided in accordance with the Central Electricity Authority (Installation and Operation of Meters) Regulations, as amended upto date.

CHAPTER-7

SOLAR ROOF TOP SYSTEM

7.1 INTRODUCTION

There is concern around the world regarding the deteriorating environment on account of greenhouse gas emissions. Transition to non-fossil fuel sources of energy is essential to reduce emissions and most countries in the world have pledged to carry out this transition according to trajectories announced by them. India has not only achieved earlier committed trajectory but is ahead of it. India has emerged as a leader in energy transition in the world. The country had pledged that by 2030 more than 40% of the installed electricity generation capacity will be from non-fossil fuel sources. This target was achieved 9 years ahead of schedule— in November, 2021. The country is currently on the path to honour the pledge in COP26 at Glasgow that 50% of the electricity generation installed capacity will be met from non-fossil fuel sources by 2030.

Solar energy has become the most popular renewable energy source now a days wherein energy is extracted directly from sun using photo-voltaic (PV) modules. Govt of India's commitment regarding non- fossil fuel capacity is proposed to be met mainly from installation of solar and wind power capacities including cumulative installed capacity of 40 GW from grid connected rooftop solar. As most of the solar roof top systems would be connected at LT or 11 KV level at distribution system, it becomes important for Discoms to consider the effect of solar roof top while planning for distribution network.

Some of the advantages envisaged through integration of solar roof top system are as under:-

- Rooftop solar systems may contribute to reduce the Discom's energy requirement and some time peak demand. Thus, it may offset or delay CAPEX requirement for upgradation of distribution network and investment required to cater to growing energy demands.
- As the energy generated from Solar Roof top roof is consumed at or near where it is produced, hence, it will help in reduction of distribution losses of discoms.
- In some cases, smart inverters installed with roof top solar can provide voltage and reactive power control, resulting in additional service value from roof top solar generation.
- Roof top solar, in particular, if combined with an energy storage system, can help to provide backup power to meet load during peak hours and grid outages. This can provide significant benefit if used to supply power to critical loads, such as hospitals, industries, railways, metros etc during power outages.

- Rooftop solar system does not require an elaborate distribution network but it relieves the load on the distribution system. Thus, it decongests the distribution network.
- Roof top solar also helps in fulfilling the Discom's renewable purchase obligation (RPO).

Greater penetration of rooftop solar technology at the distribution transformer level may require some network up gradation on a case-to-case basis, in case there is a reverse flow of power from distributed solar generators to higher voltage level. The system studies will also be required for managing grid balance, scheduling & forecasting. Anti-islanding protection will also be a major concern, which needs to be tackled effectively.

A Solar Photo Voltaic (SPV) systems have an estimated lifetime of 25 years. Thus, a 25-year period is the preferred duration for the study framework for planning. Since the consumer mix at the distribution transformer (DT) level varies significantly with time, the impact of rooftop solar in reducing peak demand and DT loading will also vary by location. DTs with frequent overloading at day time peaks may be the prime targets for rooftop solar deployment to further improve the net benefits.

Many a times, depending on the type of applications and use, the Roof top SPV system may be accompanied with Battery Energy Storage Systems (BESS), which stores the excess generation of SPV and delivers the same during peak hours to enhance power supply reliability for consumers.

7.2 POWER QUALITY ISSUES WITH SOLAR PV INTERCONNECTION WITH GRID

In a grid connected SPV system, there are mainly two challenges related to power quality (PQ) -one is at source end like power factor, reactive power compensation, harmonics and voltage regulations and the other is handling the Power Quality (PQ) issues arising out of the nonlinear loads on this PV system, which can generate sag swells and switching transients in the network. In general, these power quality issues decrease the efficiency and longevity of the Distribution Transformers, Voltage regulators, capacitors and other equipment in the system. Any integration of renewable energy sources to the grid has to meet standard power quality requirements.

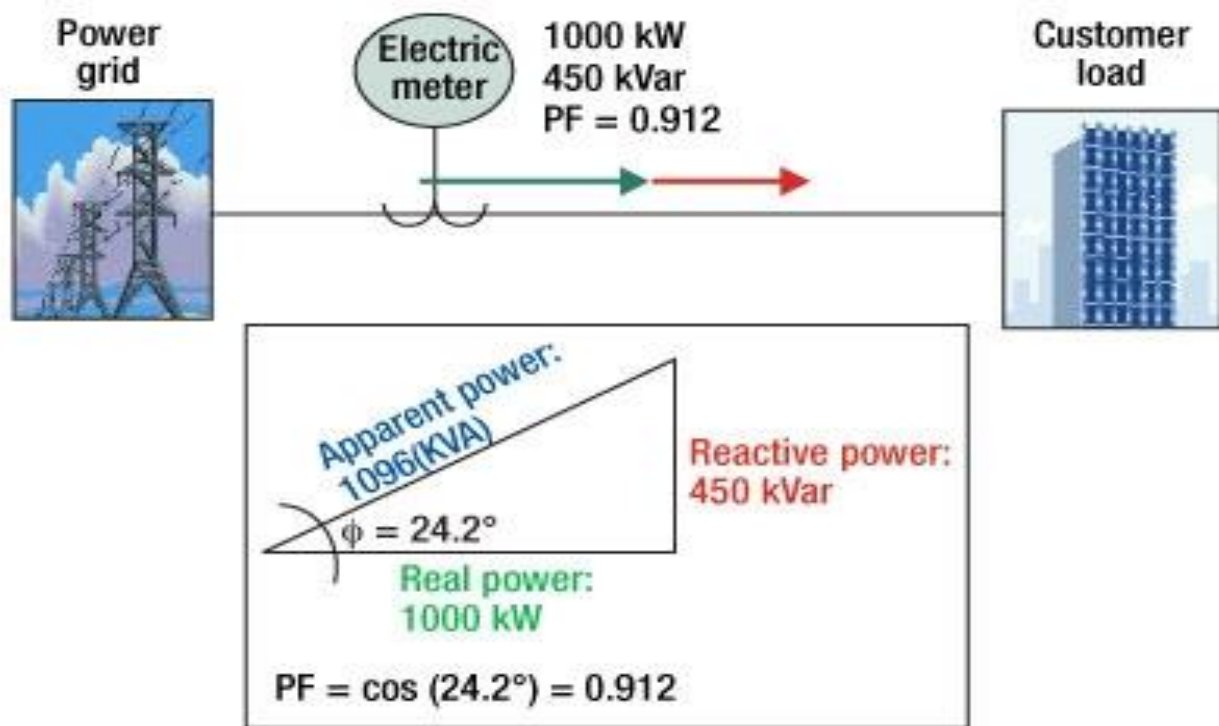
It is a known fact that capacitive loads in the grid cause leading power factor and over voltages, whereas inductive loads causes lagging power factor and under voltages. The low power factor of the system puts high transmission burden (and losses) on the power grid and because of this, most Regulators have provisions for allowing the utility to charge a penalty for low power factor mostly to bulk consumers.

Conventional SPV systems operate at unity power factor, regardless of reactive power needs of the utility network. Effectively, such PV system when connected to grid, reduces the power factor at the load end, as the part of the active power is met through SPV, (where SPV capacity is less than the load at consumer end), and grid is then supplying balance active power, but maintains the same amount of reactive power to the connected load. This can be explained through simple example as below:

Example:-

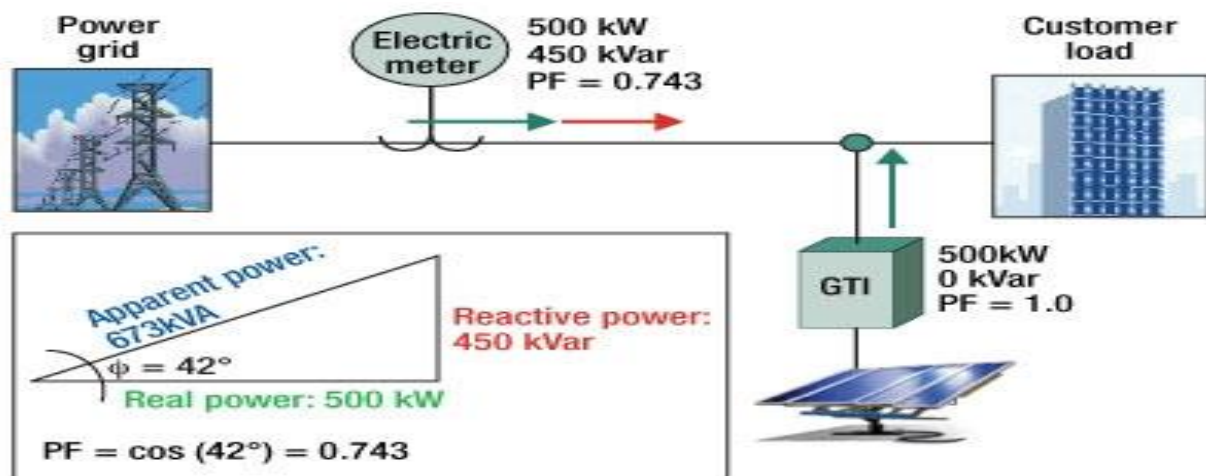
The premises as in Figure-1 is consuming 1000kW of active power, and 450KVar of reactive power, resulting in a power factor of 0.912 (lagging) and nominal lower system voltage.

Figure-1



In case, this premises installs a 500kW SPV system which exports power at a unity power factor, then only the active power that is imported from the grid would be reduced (to the extent of generation of SPV). The reactive power drawal from the grid will remain same. With 500 kW generation from the SPV plant, drawl from the grid will be 500kW and 450kVAR. Effectively, power factor of grid power will be 0.743 lagging and the voltage at load end would further dip as shown in Figure -2

Figure-2



Hence, with distributed power generation with more than one sources including SPVs, voltage control becomes more challenging. There may be similar situation of deterioration of power factor in case of leading power factor of load.

7.3 ANALYSIS OF THE PROBLEM

In the above case, if reactive power is either under or over supplied, the voltage on the SPV end of network may fall or rise. Such rise and fall of voltage in system may be required to be compensated with suitable switching on /off of Capacitor Banks or Reactors, depending on requirement at the load end of grid substation. In some cases, the voltage drop/rise may reach to a point where SPV Plants may have to be switched off to protect themselves, thereby decreasing the generation and causing further problems.

This problem of poor power factor can be addressed through the selection of appropriate inverter for SPV system. Multistage Smart Inverters having reactive power and harmonics control can be used which may be configured to produce both active and reactive power to give an output at a unity power factor and control the harmonics as well as the voltage. SPV inverter technology has the potential to overcome these barriers and provide significant added values beyond the simple kilowatt-hour production of energy.

7.4 SMART INVERTERS

Smart Inverters are an emerging technology that help to integrate solar energy and other distributed energy resources (DERs) into the electric grid effectively & efficiently. Smart Inverters go beyond the basic function of DC-AC Inverter with additional grid support functions, such as voltage regulation, frequency support, and ride-through capabilities etc. to increase its resilience, reliability, safety and security. Instead of just feeding power into the grid, smart inverters are capable of having two-way communication with the system through smart grid technologies to control the functioning of SPV system.

The main difference lies in their control algorithm and safety features. These Inverters are capable of functioning as a converter with step up transformer, automatic synchronization and de-synchronization (Isolator) with grid under various conditions such as failure of grid supply, exceeding/decreased grid voltage level or frequency limits etc along with tracking of power generation of SPV. The AC power received from Solar Roof top system can be consumed by the consumers itself with Net Metering /Net Billing or can be exported to utility grid on Gross Metering.

Smart inverters are programmed to respond to the grid in an automated way such that they not only react when there is disturbance in grid, but also provide grid supportive functionalities. To avoid harmful voltage fluctuations to the grid due to solar power, smart inverters can ride-through small disturbances (for example, voltage changes), meaning they can switch into standby mode and observe how long the disturbance takes place, then turn off only if the disturbance lasts too long. As the number of distribution renewable sources are increasing on the grid , the need for additional inverter functionality has grown. Additionally, existing codes and technical standards (International / India) are being updated to ensure that smart inverter capabilities can be fully realized.



7.5 SAFETY GUIDELINES FOR ROOF -TOP SOLAR

There are some concerns on the concepts of feeding generated power by the consumers to the grid from various renewable energy sources due the major issue of safety as consumers can produce and inject electricity using Grid connected roof top SPV without proper safety features.

As SPV modules generate DC voltage when they are exposed to light and there may be a risk of shock by these modules without proper earthing, even when they are physically disconnected from the grid. Further, there are chances of short circuit in SPV system as positive and negative potential co-exists on panel, inverters and junction boxes. So, due care must be taken to avoid shorting of terminals at any point of time during installation and maintenance.

The Smart Inverter installed with SPV helps to automatically stops supply of electricity to the grid when the grid is down and prevents accident in the grid. Also, in this condition, power would also not be available to the consumer premises. Also, every roof top installation of RE have to follow the Grid Connected Regulations notified by CEA for 33 kV & below level and as per these Regulations, as isolator at the appropriate site have to be installed which can be accessed by the utility personnel to physically isolate the SPV system at the time of maintenance of the Grid lines. The main provisions of CEA Regulations for connectivity of Renewables with grid at 33 KV & below are as under:

- (1) The applicant shall provide a reliable protection system to detect various faults and abnormal conditions and provide an appropriate means to isolate the faulty equipment or system automatically.
- (2) The applicant shall ensure that fault of his equipment or system does not affect the grid adversely.
- (3) The appropriate licensee shall carry out adequacy and stability study of the network before permitting connection with its electricity system.
- (4) The limits of injection of current harmonics at the point of common coupling by the user, method of harmonic measurement and other such matters, shall be in accordance with the IEEE 519-2014 standards, as amended, from time to time.
- (5) The measuring and metering of harmonics shall be a continuous process with power quality meters complying with the provisions of IEC 61000-4-30 Class A.
- (6) The data measured and metered as mentioned in sub-regulation (5), shall be available with the distribution licensee and be shared with the consumer periodically.

(7) The applicant seeking connectivity at 11 kV or above shall install power quality meters and share the recorded data thereof with the distribution licensee with such periodicity as may be specified by the appropriate Electricity Regulatory Commission:

(8) In addition to harmonics, periodic measurement of other power quality parameters such as voltage sag, swell, flicker, disruptions shall be done by the distribution licensee as per relevant IEC standard and the reports thereof shall be shared with the consumer.

The above rules and regulations must be taken into account while planning for solar roof top system. State Electricity Regulatory Commissions of the respective States have also issued rules and regulation for installation of Solar roof top systems , which should also be followed while planning the network.

Further, to ensure the safety & quality of the power through SPV system, following further steps should be ensured :-

1. Grid-interactive or grid tie inverter should have surge protection device at DC inputs and AC outputs. The design of inverter should be as per the Indian / International Standard.
2. The smart inverters should provide an alert on any internal damage leading to change in output power quality.
3. The Inverter should shut down automatically if there is a power blackout or a fault with SPV for safety of the personal and other equipment.
4. The Inverter, for meeting the requirement of compensation of harmonics and reactive power, should have an in built / separate filter unit along with Inverter.
5. The inverter should have inbuilt harmonics recording for monitoring of the harmonics.
6. For Harmonics, the inverter output should comply with the provisions of CEA Regulations on Standard for connectivity of Distributed Generation Resources as amended from time to time.
7. The effect of the change in loading pattern and any additional harmonic filter requirements need to be studied and incorporated based on the load of network in case of large PV generating stations.
8. As the power supply would be disconnected at the time of grid failure and consumers are in requirement of power during unavailability of Grid supply, it is mandatory as per CEA Regulations to use AC Isolation arrangement at grid connected point to isolate Grid supply by a mechanical Switch.
9. An Isolator should also be installed at the grid connected point of Solar roof top SPV system which should be accessible to the utility staff to isolate the system at the time of maintenance of the distribution system.
10. Generally un-armoured cables are used from panel to inverter. In case of any incidence like fire, the inverters cannot be isolated easily hence the fire may be catastrophic. The cables are live in day time and can also cause fire in case

of insulation is cut. The cables need to be properly dressed and taken through metallic conduits in such a way that rodent does not get access to cables.

11. A spark/ fire can damage surrounding area for roof top installations hence fire barriers and FRLS cables should be used in these installations.
12. In case of fire, the proper isolation is essential before start of any activity as the system is charged from both ends i.e. grid source/battery source and solar modules (where voltage always exists). So , proper labelling and marking of isolation point is required for emergency purposes and a clear and adequate access path-way should be ensured for safety.
13. Utility should also have a monitoring system in centralized control room for monitoring the status of SPV system installed at consumer premises for proper management & monitoring.

CHAPTER-8

ELECTRIC VEHICLES (EVs)

8.1 INTRODUCTION

The transition to electric mobility is a promising global strategy for decarbonizing the transport sector. India is among the leading countries that support the global EV30@30 campaign, which targets to have at least 30% new vehicle sales to be electric by 2030. An Electric Vehicle generally means any vehicle propelled, partly or wholly, by an electric motor drawing current from a rechargeable storage battery, or from other portable energy storage devices (rechargeable, using energy from a source off the vehicle at a residential or public electricity service).

The use of electric vehicles would provide a clean transport facility by reducing the GHG emission, thereby allowing India to align with their International goals. It would also facilitate the shifting of the transport sector's dependency on fossil fuels to the use of electrically powered vehicles, which will also help in reducing India's oil import.

An accessible and robust network of electric vehicle (EV) charging infrastructure is an essential pre-requisite to achieving this ambitious transition. The Government of India has instituted various enabling policies to promote the development of the charging infrastructure network. However, given the novel characteristics of this new infrastructure type, a practicable approach is needed to ensure the efficient and timely implementation of EV charging infrastructure, such that it meets local requirements and is optimally integrated within the electricity supply and transportation networks.

Main objectives :

- a) To enable faster adoption of electric vehicles in India by ensuring safe, reliable, accessible and affordable Charging Infrastructure and eco-system.
- b) To plan the creation of EV Charging Infrastructure and eventually create market for EV Charging
- c) To encourage preparedness of Electrical Distribution System to adopt EV Charging Infrastructure.
- d) To promote energy security and reduction of emission intensity of the country by promotion of entire EV ecosystem.

Electric Vehicles (EV) can be charged in various ways, depending on location and requirement. Accordingly, charging infrastructure for EVs is of different types and designed for different applications. Specifications and standards for EV chargers vary from one country to another, based on available EV models in the market and the characteristics of the electricity grid.

The interoperability between the Electric Vehicles and the various chargers made by multiple vendors is crucial for the success of the technology. At present the EV and EV Supply Equipment market is dominated by limited technologies with different connectors and communication protocols which raise concerns of interoperability. As the components and systems contained within the charger point are designed specifically for each system, hence, to change from one system to the other system would involve significant changes in the hardware well beyond mere swapping of plugs. However, manufacturing multi-standard charge points resolves the issue and it is relatively cost effective to include both systems at the time of production.

For encouraging the EV charging stations in the country, MoP has issued the “Charging Infrastructure for Electric Vehicles- the revised consolidated Guidelines & Standards “ in January, 2022, which stipulates that Electric vehicle charging equipment should be tested by any lab/facility accredited by National Accreditation Board for Testing and Calibration Laboratory (NABL). It also facilitate that EV charging operations have to be considered as a service and not as sale of electricity, hence, no license required for operating EV charging stations. Further, as electricity is being provided at concessional rates and also considering the fact that subsidy is being provided by the Central / State Governments in many cases for setting up the Public Charging stations, Govt is taking up the issue of fixing the ceiling of service charges to be charged by Public Charging Stations. Many SERCs have also issued separate Tariff orders for EV charging Stations.

MoP Guidelines stipulates that:

1. Owners may charge their Electric Vehicles at their residence/offices using their existing electricity connections.
2. Any individual/entity is free to set up public charging stations provided that, such stations meet the technical, safety as well as performance standards and protocols laid down below as well as norms/ standards/ specifications laid down by Ministry of power, Bureau of Energy Efficiency (BEE) and Central Electricity Authority (CEA) from time to time.
3. Public Charging Station (PCS), may apply for electricity connection and the Distribution Company licensee shall release connection in accordance with the timelines stated in section 4 sub.(11) of the Electricity (Rights of Consumers) Rules, 2020.
4. Any Charging Station/ Chain of Charging Stations may obtain electricity from any generation company through open access. Open access shall be provided for this purpose within 15 days of receipt of the application complete in all respect.

8.2 LOCATION OF PUBLIC CHARGING STATIONS:

In case of Public Charging Stations, the following requirements are laid down in MOP Guidelines with regard to density/distance between two charging points:

- At least one Charging Station shall be available in a grid of 3 Km X 3 Km. Further, one Charging Station shall be set up at every 25 Km on both sides of highways/roads.
- For long range EVs and/or heavy duty EVs like buses/trucks etc., there shall be at least one Fast Charging Station at every 100 Kms, one on each side of the highways/road located preferably within/alongside the stations. Within cities, such charging facilities for heavy duty EVs may be located within Transport Nagars, bus depots.
- Additional PCS/FCS can be installed even if there exists a PCS/FCS in the required grid or distance.
- The above density/distance requirements shall be used by the concerned state/UT Governments/their Agencies for the twin purposes of arrangement of land in any manner for public charging stations as well as for priority in installation of distribution network including transformers/feeders etc. This shall be done in all cases including where no central/state subsidy is provided.
- The appropriate Governments (Central/State/UTs) may also give priority to existing Retail Outlets (ROs) of Oil Marketing Companies (OMCs) for installation of Public EV Charging Stations (in compliance with safety norms) to meet the requirements as laid above. Further, within such ROs, Company Owned and Company Operated (COCO) ROs may be given higher preference.

8.3 PUBLIC CHARGING INFRASTRUCTURE (PCI) – REQUIREMENTS & SPECIFICATIONS:

EV charging involves supply of direct current (DC) to the battery pack installed inside the Vehicle. As electricity distribution systems supply alternate current (AC), a converter is required to provide DC power to the battery system, which may be outside or inside the vehicle. In the case of an AC EV Supply Equipment (EVSE), AC power is delivered to the onboard charger of the EV, which converts it to DC internally through onboard charger. A DC EVSE converts the power externally and supplies DC power directly to the battery, bypassing the onboard charger.

AC and DC charging are further classified into four charging modes, with Modes 1-3 pertaining to AC charging and Mode 4 pertaining to DC charging. Modes 1 and 2 are applicable for connecting an EV to a standard socket outlet, utilizing a cable and plug. Mode 1, also known as dumb charging, permits no communication between the EV and EVSE and its use is not recommended. The portable cable used in Mode 2 has an inbuilt protection and control capability and is typically used for home charging. Modes 3 and 4, which provide a separate charger device to supply power to the EV, have improved control systems and are used for commercial or public charging.

Every Public Charging Station (PCS) will comply with the following:

- I. An exclusive transformer with all related substation equipment including safety appliance, if required by Supply Code as approved by Appropriate Electricity Regulatory Commission.
- II. Appropriate civil works
- III. Appropriate cabling & electrical works ensuring safety
- IV. Adequate space for Charging and entry/exit of vehicles.
- V. Appropriate fire protection equipment and facilities
- VI. Public Charging Station shall have, any one or more chargers or any combination of chargers in one or more electric kiosk/boards.
- VII. Charging station for (two/three wheelers) e-vehicles shall be free to install any charger other than those specified subject to compliance of technical and safety standards as laid down by CEA.
- VIII. Tie up with at least one online Network Service Providers (NSPs) to enable advance remote/online booking of charging slots by EV owners. Such online information to EV owners should also include information regarding location, types and numbers of chargers installed/available, service charges for EV charging etc. However, The Captive charging infrastructure for 100% internal use for a company's own/leased fleet for its own use may not be required to have NSP tie ups.
- IX. Share charging station data with the appropriate State Nodal Agency (SNA) and adhere to protocols as prescribed by Central Nodal Agency (CNA) i.e. BEE for this purpose. The CNA and SNA shall have access to this database.
- X. Public Charging Stations for EVs shall comply with the provisions of Central Electricity Authority (Technical Standards for Connectivity of Distributed Generation Resources) Amendment Regulations, 2019 and Central Electricity Authority (Measures relating to Safety and Electricity Supply) Regulations, 2023.
- XI. Public charging station may also be installed by Housing Societies, Malls, Office Complexes, Restaurants, Hotels, etc. with a provision to allow charging of visitor's vehicles when permitted to come in its premises.

Public Charging Station (PCS) shall have, any one or more chargers or any combination of chargers from the table given below in one or more electric kiosk/boards:

Charger Type	S. No	Charger Connectors*	Rated Output Voltage (V)	No. of Connector guns (CG)	Charging vehicle type (W=wheeler)
Fast	1	Combined Charging System (CCS) (min 50 kW)	200-750 or higher	1 CG	4W
	2	CHArgedeMOve (CHAdemo) (min 50kW)	200-500 or higher	1 CG	4W
	3	Type-2 AC (min 22 kW)	380-415	1 CG	4W, 3W, 2W
Slow/ Moderate	4	Bharat DC-001 (15kW)	48	1 CG	4W, 3W, 2W
	5	Bharat DC-001 (15kW)	72 or higher	1 CG	4W
	6	Bharat DC-001 (10 kW)	230	3 CG of 3.3 kW each	4W, 3W, 2W

Table 8.1 Types of EV Chargers and specification

8.4 PUBLIC CHARGING INFRASTRUCTURE (PCI) FOR LONG RANGE EVs AND/OR HEAVY DUTY EVs:

Fast Charging Stations (FCS) i.e. Public charging stations for long range EVs and/or heavy duty EVs (like trucks, buses etc) will have the following:

- At least two chargers of minimum 100 kW (200-750 V or higher) each of different specification (CCS/CHAdemo Chargers for above capacity or BIS Standards for eBus Charging Station (Level-4: 250 to 500 kW) with single connector gun each.
- Appropriate Liquid Cooled Cables for high speed charging facility as above for onboard charging of Fluid Cooled Batteries (currently available in some long range EVs), if required.
- Such Fast Charging Stations (FCS) which are meant only for 100% in house/captive utilization, for example buses of a company, would be free to decide the charging specifications as per requirement, for its in-house company EVs.

Single-phase AC chargers, with a maximum power rating of 7-10 kW, are adequate for LEVs and cars with single phase on-board chargers. Three-phase AC chargers, with a power rating up to 22 kW, are required for e-cars with larger onboard chargers.

Input power supply for normal power charging can be provided from the standard electricity distribution network.

For high-voltage e-cars with battery capacities between 30-80 kWh, high-power DC charging of 50 kW is used. The power level of DC chargers in the market ranges between 22 kW and 50 kW. However, more higher powered DC chargers may be available in the near future. While high-power DC charging takes less time for e-cars, it requires higher electricity supply with additional infrastructure.

Wireless charging is a breakthrough technology that allows an EV owner to charge the vehicle using either inductive or capacitive power transfer techniques while in motion. The power generated by wind or solar resources nearby are connected to the road systems that are delivered wirelessly. Such vehicles can have smaller batteries that results in cost reduction of the vehicle and accelerate its adoption. The technology to enable effective dynamic Wireless Power Transfer (WPT) is still in nascent stage.

The battery swapping station is a standalone station , in which batteries are placed and removed manually from the individual slots, usually by hand. Manual swapping stations are modular and occupy a minimal amount of space. These are used for smaller vehicles battery applications, as the battery pack sizes are smaller and lower capacities so that the weight can be handled by one or two persons.

Central Electricity Authority (CEA) has amended the “Technical Standards for Connectivity of the Distributed Generation Resources Regulations ” to include the “charging point” and “charging station” separately and introduced standards for charging stations connected or seeking connectivity to the electricity system. CEA has also made amendment to “Measures relating to Safety and Electric Supply Regulations” to include general safety, fire prevention, and periodic maintenance and assessment for EV charging stations along with maintenance of technical, safety and performance standards, specifications, and protocols to be followed by public charging station installers/operators.

8.5 INDIAN STANDARDS FOR AC CHARGING EVs

IS 17017 is the key EV charging standard in India published by BIS. IS-17017- Part-1 provides the basic features of all EV charging systems. An AC EVSE must adhere to this standard, and specific AC connector standards in the IS-17017-Part-2. Both AC and DC EVSE need to conform to the technical standards IS-17017-Parts 21 & 22. Additional Indian standards for AC EVSEs have been approved for light EVs and e-cars (in the form of low cost charging points), for use in parking areas.

8.6 INDIAN STANDARDS FOR DC CHARGING EVs

IS-17017-Part-23 describes the requirements for DC charging stations, with power output of 50kW to 200kW. Beyond this, high power charging standards are required to cater to buses and other heavy vehicles.

Recently, the BIS has finalized the IS-17017-Part-25, which is specifically for providing low DC power of less than 7kW for light EVs. Due to the requirement of digital communications between the DC EVSE and the EV, data communication standards are specified in IS-17017-Part 24. When the Combined Charging System (CCS) standard is deployed, which can provide both AC and DC charging, communications will be as per the IS-15118 series.

8.7 EV CHARGING DEMAND ASSESSMENT

The EV charging demand assessment in a Discom area is an important aspect of charging infrastructure planning. It can be used as input data to set targets for the number of public EV charging stations, location planning for public charging infrastructure and to analyze grid capacity and the need for enhancements in existing distribution infrastructure etc.

EV charging demand at an urban or regional level depends on per capita vehicle ownership rates, EV penetration levels, vehicle utilization patterns and Govt policies. For estimating the requirements of EV charging demand, it should focus on the projected demand for public charging for different vehicle segments. This can help to assess the load requirement of EV with the help of number of public chargers required, type of chargers, No of vehicles to be charged at one station etc which in turn can be used to plan their distribution system for upcoming public charging infrastructure.

The following steps may be taken for the EV charging demand assessment and charging infrastructure estimation:

Step 1: Based on target EV penetration rates, estimate EV sales for different vehicle segments for horizon years 2025 and 2030. Segments can be divided into 2Ws, passenger and cargo 3Ws, personal and commercial cars, and other LCVs.

Step 2: Arrive at the daily kilometers driven by each vehicle segment, based on transport planning data or data from city development plans.

Step 3: Based on average battery capacity and driving range of each vehicle segment, calculate the daily energy requirement for EV charging.

Step 4: Based on existing experience/surveys with existing EV users, assign the share of charging to be fulfilled at public charging infrastructure for different vehicle segments. For instance, personal 2Ws and low capacity cars may fulfil most of their charging requirements at homes or offices, and may only depend on public charging for 10%-20% of their charging needs.

Step 5: From Steps 3 and 4, calculate the daily EV charging demand at public charging infrastructure for different vehicle segments.

Step 6: Based on the types of chargers available in the market, categorized by voltage level and power rating, the proposed planning of distribution infrastructure may be done.

Step 7 : The load to PCS may be provided on LT or HT level based on the load requirement of the PCS as per the provisions of Supply Rules notified by SERCs.

8.8 QUALITY POWER MANAGEMENT OF EV CHARGING- SMART CHARGERS

With growing EV adoption, a proper planning would be required for augmentation of 33 KV, 11 KV and DT level infrastructure due to increased charging loads at multiple levels, from the DISCOM's service area to the feeder level. The aggregated charging demand may also increase the peak demand in a DISCOM's service area or may create new demand peaks. Simultaneously, intermittent spikes in EV charging loads may also impact the quality of power supply particularly in areas where electricity feeders are overloaded or have low available capacity.

The unmanaged EV charging stations may hamper smooth operation of the electricity distribution system by causing voltage instabilities, harmonic distortions, power losses, and degradation of reliability indices. In cases where EV charging points draw electricity from an existing connection, a proper planning for suitable infrastructure along with other requisite equipment would be needed for maintaining the reliability of power supply and voltage instability in the electrical circuit of the host establishment.

Now a days, smart chargers use passive and active energy management measures to balance charging demand more evenly and to minimize the negative impacts of EV charging loads on the distribution system. Smart charging in coordination with passive management measures is effective in shifting a substantial share of the EV charging load to off-peak times, while still satisfying customers' charging needs. Further, managed EV charging can be leveraged to achieve higher renewable energy uptake, by synchronizing optimal vehicle charging times with peak renewable energy generation periods. Smart charging is also useful in charging use-cases where electricity for EV charging is drawn from an existing power connection. Smart chargers

with requisite capabilities can limit charging load by controlling charging power levels, in response to overall power demand to avoid exceeding the sanctioned load. At a feeder level or within a DISCOM service area, smart charging devices can respond to signals to control the rate of charging, in order to provide frequency response services and load balancing services. Hence, the smart charging equipment should preferably be used in all the Public Charging Stations.

Active charging management involves remotely controlled EV charging that responds to various triggers like changes in tariff, power demand, etc. Depending on the inputs, EV charging sessions can start or stop, and charging levels can ramp up or down automatically. “Smart chargers” with specific capabilities are needed to carry out active EV charging. Smart chargers can also handle Time-of-Use (ToU) tariffs, in which electricity tariffs are adjusted in real time based on demand.

An EVSE with advanced smart charging capabilities has the following characteristics:

- It can be programmed to respond appropriately and autonomously to signals from DISCOMs (e.g. electricity tariff), Central Management System (CMS), etc., to coordinate with ToD and ToU tariffs
- It can be monitored and managed over an app
- It is equipped with GPRS, 3G/4G or wired connection, and is connected to a cloud service
- It shares a data connection with an EV and a charging network
- It is compatible with the back-end communication protocol

Smart charging at scale requires a communication architecture to allow interactions between the different levels of the system i.e. between EVSEs and charging networks (or central management systems) between different charging networks, and between the Central Management System (CMS) and Distributed Energy Resources Management System (DERMS) etc.

8.9 ACTION POINTS FOR DISCOMS FOR FASTER ROLL OUT OF EVs

DISCOMs are responsible for providing electricity connections for EV charging infrastructure. They enforce and execute the electricity supply rules and regulations on-ground and interact with different classes of electricity consumers. EV owners and Charging Point Operators (CPOs) / Public Charging Stations (PCS) are a new class of customers for DISCOMs, with power connection requirements that are distinct from other consumer classes. In order to cater to these requirements, DISCOMs will have to implement regulatory measures such as EV tariff categories, establish standard operating procedures, and become familiar with planning and providing power connections for EV charging infrastructure. As the interface between the electricity

network and the CPOs/PCSs or EV users, DISCOMs can streamline the process of providing electricity connections for charging infrastructure. DISCOMs may undertake the following measures:

- Provide clear public guidelines on the application process for metered connections for EV charging and may create a single-window system for processing the applications.
- Prescribe a technical pre-feasibility check for public charging connections, for CPOs to assess the feasibility and estimated cost of procuring the required sanctioned load for a proposed charging facility at a given location.
- Set maximum timelines for expedited inspection and certification of charging facilities and award of EV charging connections.
- Publicly share the criteria and requirements for different types of connections and associated charges in a simplified format for CPOs.
- Lay out clear guidelines for owners of private charging (e.g. in homes and offices) on the requirements and processes to apply for metered EV connections, to take advantage of any available benefits like EV-specific tariffs and customized EV charging programs.
- Create a dedicated internal team, like an e-mobility cell, to respond to queries, coordinate with interested applicants and carry out site visits concerning EV charging connections.

CHAPTER-9

SMART DISTRIBUTION

ADVANCED TECHNOLOGIES IN DISTRIBUTION SECTOR

Presently, many Distribution utilities are grappling with variety of issues like technical and commercial losses, financial sustainability , large dues and pending recoveries/ subsidies, gap between average cost of supply and average revenue realized, transparent operations, poor asset management, inefficient operation , lack of consumer engagement etc. To overcome these issues, it is pertinent to adopt Smart distribution technologies which not only provide multiple benefits to all stakeholders but also empower the end customers.

A smart distribution is an electrical distribution grid with advanced automation systems and sensors to monitor and control power flows in real-time in the distribution system. Smart Distribution system generally refers to a range of new technologies to enhance reliability, availability, and efficiency of the system. The new smart technologies are also necessary for monitoring and controlling the increasing share of renewable energy (RE) resources that are intermittent in nature. In order to efficiently operate a grid with higher share of RE resources, it is imperative to forecast and balance both generation and demand in real-time. Smart digital tools could facilitate real-time monitoring of power flows, help forecasting RE generation & demand in near real-time, help manage flexible loads / generation & storage , predict overloading on grid elements along with a host of new services to utility & customers.

In the low voltage network, the power system operator has little visibility regarding flow of energy in various segments and consumption of electricity by various consumers without any automation. The Smart Distribution is an equipped system with intelligent sensors &, Smart meters connected with the utility control room, would facilitate remotely monitoring and controlling the flow of electricity in real time to the consumers. So, the evolving Smart Distribution in the Distribution system would drastically change the operation & control of the Distribution system.

A Smart Distribution system will help to manage the electricity consumption and to improve the lifestyle of millions of consumers. A robust Distribution system equipped with smart meters, smart sensors and controllers, will also help to monitor and analyses energy consumption on real time basis for increasing energy efficiency levels in Distribution system.

Some of the drivers for Smart Distribution in Indian context are as below –

a) Drivers for Utilities

- Reduction in Aggregate Technical and Commercial (AT&C) losses

- Remote connect /disconnect of power supply of consumer
- Use of pre-paid/post-paid facilities with same meter
- Peak load management – multiple options from direct load control to price incentives to customers /TOU tariff
- Reduction in power purchase cost through better management & analysis
- Better asset management by analysis of consumer meter data and other meters data (like DT Meters, Feeder meters etc.)
- Increased grid visibility
- Self-healing grid – faster restoration of electricity after fault through OMS
- Renewable energy integration/Net Metering
- Reduced operations and management costs for utilities, and ultimately lower power costs for consumers
- Reduced peak demand, which will reduce the requirement of additional network thus reducing the capital cost expenditure by the utilities

b) Drivers for Customers

- Improved reliability & quality of supply to all customers
- Pre-paid /postpaid /Net metering facility
- Know their power consumption on real time basis
- Consumer empowerment to control their consumption to enable energy conservation practices
- User friendly and transparent interface with utilities
- Increased choice for customers – including green power
- “Prosumer” enablement – can produce own electricity and consume or sell
- Options to save money by shifting loads from peak hours to off-peak periods

c) Drivers for Governments and Regulators

- Reliable & Quality power supply to consumers hence more Satisfied customers
- Financially sound utilities/Less AT&C losses
- Tariff Optimization with increased visibility of power consumption pattern
- Optimized system upgrade and modernization
- Reduction in emission intensity by efficient use of electricity and use of Renewables
- Introduction of Time of day metering & dynamic pricing readiness

- Efficient integration of large scale RE resources, Better integration of prosumer's distributed energy resources

d) Drivers for Society At Large

- Less carbon emission
- Energy Security
- Sustainable development

There has been sustained efforts from Ministry of Power for demonstration & adoption of State-of-the-art Smart Distribution technologies by distribution utilities through various schemes/programs. The outcome of pilot project sanctioned by Govt under RAPDRP/IPDS was mixed with success stories and lessons learnt including successful demonstration of smart metering benefits, use of multiple communication technologies (GPRS, RF & PLC), procurement issues to standard product development, capacity building, regulatory support etc.

e) Enablers for Smart Distribution

Although , the evaluation of smart distribution is a continuous process, however, based on the present scenario, the IT & OT technologies which are available for deployed for enablement of a Smart Distribution infrastructure are as follows:

- i. Advanced Metering Infrastructure (AMI)
- ii. Supervisory Control and Data Acquisition (SCADA)
- iii. Mini SCADA - Real Time Data Acquisition System (RTDAS)
- iv. Geographical Information System (GIS)
- v. Advanced Distribution Management System (ADMS)
- vi. Outage Management System (OMS)
- vii. Power Quality Management (PQM)
- viii. Distribution Transformer Monitoring System (DTMS)
- ix. Mobile Crew Management System
- x. Smart Street Lights (with noise and pollution sensors)
- xi. Customer Relationship Management
- xii. Automatic Demand Response
- xiii. Smart EV Charging Stations
- xiv. Smart Inverters
- xv. Vehicle to Grid (V2G) Charging
- xvi. Distributed Energy Resources and Renewable Energy Integration

- xvii. Smart Micro Grid
- xviii. Home Automation System / Smart Homes, Buildings Energy Management Systems /Home Energy Management Systems (BEMS/ HEMS)
- xix. Smart Energy Storage System

The details of some of the Smart Distribution technologies in distribution sector are as given as under:

9.1 ADVANCED METERING INFRASTRUCTURE (AMI) / SMART METERING

Advanced metering infrastructure (AMI) is an integrated system of smart meters, communications networks, and data management systems that enables two-way communication between utilities data center and smart meters at customer premises to measure, control, collect and analyzes energy usage of consumers either on request or on a schedule. Advanced metering infrastructure (AMI) differs from traditional automatic meter reading (AMR) as it enables two-way communications with the smart meters.

The goal of AMI is to provide real-time data about power consumption at utility data center and allow customers to make informed choices about energy usage based on the price at the time of use etc. The smart meters can also be disconnected or reconnected from the data center in case of payment default by the consumers. Further, smart meters can also be used as pre paid meters, net meters or post paid meters as per the requirement. Smart metering, if implemented in pre-paid mode would help utilities to reduce their cash flow stress and financial losses, by avoiding loss of revenues from defaulting consumers. All the meters including smart meters should be installed as per CEA Regulations as amended up to date.

Building Blocks of AMI: AMI is comprised of various hardware and software components to play the special roles in measuring energy consumption and transmitting information from smart meter to the utility . The main components of AMI include:

- a) **Smart Meters-** It is an Advanced Energy Meter having a communication module and a switch facilitating the energy meter to collect information about energy usage at various intervals, transmitting the data through fixed communication networks to utility, as well as receiving information like connection – disconnection signals from utility to operate accordingly.
- b) **Communication Network:** Advanced communication networks which supports two-way communication enables information from smart meters to utility data center and vice-versa. A suitable communication technology for

smart meters may be adopted as per Is-16444 based on geographical areas of the Discoms.

- c) **Meter Data Management System (MDMS):** MDMS is a host system which receives, stores and analyzes the metering information. It provides a platform to assess the performance of the energy usages on a real-time basis. By using the VEE (Validation, Edit, Estimation) Rule, MDMS generates Business Intelligence Reports, which helps in identifying the underperforming areas and initiate the planning for performance improvement etc.

9.1.1 SELECTION OF AN APPROPRIATE COMMUNICATION TECHNOLOGY FOR AMI

At present, the following communication technologies are typically used for AMI systems as per Is 16444, however, the utilities may choose the appropriate technology based on the actual ground conditions and availability of communication network in the operating areas.

- **Power Line Communication (PLC):** Smart Meters use the power line itself for data communication between the meter and the Utility's systems. All the Smart Meters are connected together in a mesh and transfer the data to the DCU, which further communicates the data to the control centre (HES/MDAS) through the cellular data network, Optical Fibre Cables, DSL, etc.
- **Radio Frequency (RF):** Smart Meters use RF for data communication between the meter and the Utility's systems. All the Smart Meters are connected together in a RF mesh and transfer the data to the access point/router/DCU, which further communicates the data to the control centre (HES/MDAS) through the cellular data network, Optical Fibre Cables, DSL, etc. In this case, number of Smart Meters communicating to any access point/router are dynamic in nature. The failure of any access point/router leads to re-designing of the network automatically to use another nearby DCU so that data communication is uninterrupted between the meter and the control centre.
- **Cellular Technology (GSM/GPRS/3G/4G/NB IoT):** Smart Meters directly communicate the data to the control centre by utilising the Telecom cellular data network (GPRS/3G/4G/NB IoT) and this system typically does not require any DCUs. Recently, the use of devices based on 'Internet of Things' (IoT), or simply 'Machine to Machine' (M2M) communication for wide ranging sensory devices have increased on a great pace, which is also a part of GPRS technology.

For implementation in the Indian context , wherein the cost of implementation plays a key role in ensuring that the solution is affordable. Optical Fibre Cable for communication between each smart meter may not be a feasible alternative. Accordingly, the advantages and disadvantages of three more common and mature technologies have been compared below.

Technology	Pros	Cons
Power Line Communication (PLC)	• <u>Infrastructure</u>: Leveraging use of existing infrastructure. • <u>Cost-effective</u>: Use of existing infrastructure and can transmit over long distances; advantage for utilities serving rural areas • <u>Useful grid analytics</u>: Enables preventive maintenance; Use of the distribution network to send signals, which enables analytics to isolate and troubleshoot problems with insulators, transformers and other grid devices	• <u>Network interference</u>: Large industrial customers may introduce noise and harmonics on the power line that may affect performance and distort communications • <u>Less bandwidth</u>: Narrower available bandwidth can impact data capacity and the speed or rate at which data can be accessed in some applications • <u>Poor Network conditions</u>: The existing network conditions in India may cause data loss
Radio Frequency Mesh (RF)	• <u>Distributed regionally</u>: Can target specific areas for deployment • <u>Self-healing</u>: In case of network failure in any particular link, the network automatically finds another path to communicate with the HES • <u>Self-forming</u>: The network's intelligence enables the signal to find the optimal route back to the HES; Important in areas with obstructions, like mountains or high-rise buildings	• <u>Infrastructure</u>: May require more infrastructure deployment /DCU than other options, especially in rural areas, where meters are more spread out across the service territory • <u>Proprietary technology</u>: The communication technology is proprietary to each vendor and therefore inter-operability becomes a challenge.
Cellular Network – 3G/4G/NB-IoT Technology	• <u>Faster deployment</u>: Enables long-range communication and can be rolled out quickly using the existing cellular data infrastructure • <u>Optimal for targeted applications</u>: Can be deployed cost-effectively to support even marginal consumer groups • <u>Proven technology</u>: In use for more than a decade, well established and fairly reliable • <u>Secure</u>: Serving billions of customers worldwide, cellular networks are already secure, advantage of which can be reaped by Utilities • <u>Common protocol</u>: Standardised protocol compliant which is vendor agnostic, making inter-operability seamless	• <u>Obsolescence issues</u>: Cellular networks tend to roll over prior to the useful life of the metering technology, raising concerns about how long a deployed technology will remain viable • <u>Network availability issue</u>: Sharing public cellular networks, often completely dependent on the carrier's (TSP's) priorities in the event of an outage

A suitable communication technology for various smart grid operations may be selected by the utilities/AMISP as per the actual site conditions.

9.1.2 ADVANTAGES OF SMART METERING SYSTEM OVER THE CONVENTIONAL METERING SYSTEM

The main advantages of smart metering system over the conventional metering system are as under: -

1. AT&C Loss Reduction	- Improved billing efficiency due to accurate and near real-time data capture of energy consumption and load profile - Allows for identifying pockets of pilferage for taking remedial measures – loss monitoring and action - Improved utility cash flows in case of pre-paid billing mode - Remote connect/disconnect from remote in case of no payment
2. Enhanced Energy Accounting	Near real time data enables mapping of consumer demand, feeder / DT wise loading, etc., enabling enhanced energy accounting to allow operational performance improvement interventions and optimise resources
3. Ease in Operations & System Control	- Ability to enforce commercial principles like ‘Disconnections’ of non-paying consumers remotely without manual intervention - Instantaneous update of regulatory directives such as tariff changes, preventing any revenue loss or dispute from consumer
4. Cost Savings for Utilities	- Reduction in manpower cost for meter reading and billing activities – manpower can be redeployed for optimising performance in other areas such as power purchase management, project implementation etc. - Remote connection /disconnection of meters without any manpower - Reduced operational expenditures on call centres with preventive complaint management and app enabled complaint resolution
5. Improved Network Planning & Performance	- Data analytics to accurately estimate consumer demand to forecast system load requirements appropriately - Improved capex planning with analysis of consumer data/system data - Greater visibility of network with real time assessment of system performance and faults – blackouts / brownouts
6. Enables Demand Management	Possibility of flattening demand curve through ToU and Demand Response (DR) / Demand Side Management (DSM) measures
7. Enables Dynamic Pricing	- Accurate view on Maximum Demand / Connected Load of consumer leading to accurate recovery of fixed charges upon implementation of two-part tariff - Ease of implementation of Time of Use (ToU) pricing for DSM - Market linked tariff mechanism is possible

8. Scalability to Future Market Structure	• Step towards wire and content separated market structure • Green Energy Compliant - block-chain ratification of green energy supply • Compliant with prosumer model and net metering compliant • Ease of integration with Behind the Meter solutions including EV
9. Improved Customer Satisfaction	• Less fault handling time through Outage Management system (OMS) • Accurate monitoring of reliability Indices like SAIFI, SAIDI, CAIFI, CAIDI etc. • Faster response time to specific consumer complaints such as billing, tariff issues etc., through real time remote meter access • Consumer has control over consumption through app with spend management and data analytics for consumption management

9.1.3 ACTION PLAN FOR IMPLEMENTATION OF SMART METERING (CAPEX/OPEX/TOTEX MODE)

The following steps are suggested in the AMI implementation :

- ❖ Selection of Project Management Agency (PMA) : In case, States/ Utilities do not have experience in the field of AMI, state/ Discom may appoint a Project Management Agency (PMA) for consultancy / assisting Discoms in Planning, and Project Management of AMI for next 8-10 years. In case, Utilities have enough experience, a dedicated cell for implementation of smart metering may be formed within the discom.
- ❖ Bidding process for selection of AMISP: Analyse and divide the Discom in to different zones like divisions / towns / smart cities etc and prepare the Zone wise /area wise tender documents based on selected mode of operation. The AMI Service provide (AMISP) would be selected through open bidding process by the Discoms. A SBD based on the Totex Mode of operation has also been released by MOP for assisting the bidding process by utilities.
- ❖ Procurement and Commissioning: After selection, AMISP will implement the AMI solution in the identified Zones . The AMISP may also take care O&M for the specified period as per terms & conditions of tenders. AMISP will also follow the Service Level Agreement (SLA) as agreed mutually. AMISP may also assist Discoms in handholding, capacity building & program management etc.

9.2 SUBSTATION AUTOMATION SYSTEM (SAS)

Distribution utilities generally operates three layers of network i.e.

- Sub transmission (33 KV),
- Primary Distribution (11 KV) and
- Secondary Distribution (0.415 KV).

Any interruption at sub transmission and Primary distribution level accounts for outage to thousands of customers. Thus, it is necessary to monitor and control each and every network element in the sub transmission and primary system remotely.

Many of the existing and old Substations consisted of mechanical relays and meters that barely supported recording and had no means of communication. Fault recorders were capturing information mainly in the form of paper charts, so reading and analyzing the information was not a straightforward process. Lack of data availability regarding any maintenance or troubleshooting may cause delay in providing reliable supply.

Electric utilities have to tap the useful information of the network equipment installed in field, and making this information available for improved analysis and decision-making. Substation automation systems provide a mechanism that will enable utilities to establish effective data acquisitions, control and undertake condition based maintenance activities.

With the introduction of microprocessor technology, digital protection and control devices, the system became more intelligent. New intelligent electronic devices (IEDs) can collect and record information on many different parameters of a system, process them based on complex logic in a fraction of a second and make decisions on abnormal situations to send control commands to switches and breakers to clear the fault.

In addition to their superior processing capability, modern substation devices can also hold information in their internal storage for a certain period and transfer this information to various applications for further study and analysis. IEDs can now send information to a local or remote user via different types of communication. This gives operators more flexibility on how and when to process the information to provide a fast recovery time from an interruption in the substation.

With more information remotely available, new supervisory systems were developed to facilitate the task of a system administrator in the control center. A Supervisory Control and Data Acquisition (SCADA) system can collect information from various IEDs in an electrical system via different methods of communication and then control

and monitor them using various visualizing technologies – even automating the supervision task based on predefined parameters and algorithms.

This system would be the best approach to have a technological up-to-date protection system and would also provide cost-effective inputs required by the SCADA. Substation Automation may be implemented on an open platform that may allow to purchase different Intelligent Electronic Devices (IEDs) from different vendors. This way, replacement all old dilapidated equipment as well as protection and control devices from grids substation with state of the art switchgear and make them SCADA compatible, can happen. Also, it provides an integrated monitoring, control and protection system having a number of advantages over the conventional equipment. This reduces installation costs, improve reliability of equipment required for feeding data to the SCADA system.

Further, to reduce maintenance costs without compromising equipment reliability, it is crucial for utilities for replacing conventional periodic inspection and maintenance practices with “condition-based” maintenance practices. Condition based practices enable the utility to increase routine inspection intervals (i.e., perform fewer inspections) and perform major teardown inspections only when the equipment exhibits symptoms of incipient failures.

9.3 SUPERVISORY CONTROL AND DATA ACQUISITION SYSTEM (SCADA)

SCADA, which itself stands for Supervisory Control and Data Acquisition, is the software application program for acquiring the data on real time basis from each connected network equipment, be it normal condition or abnormal condition due to any fault, and provides this data to the control center for facilitating decision making for switching operation of network elements remotely for faster action.



Benefits of SCADA:

- Information readily available within seconds to enable quick actions and faster restoration of supply while ensuring data security
- Enables the understanding of real time health of equipment and assets.
- Provides alerts for significant events, thus facilitate elimination of the risk of equipment damage
- Enhanced safety in working environment
- Improved reliability indices like SAIDI, SAIFI, CAIDI, etc.
- Prepares the system for unmanned grid stations.
- Better handling of the reactive power support equipment.
- Replaces erstwhile ad-hoc maintenance practices with a more scientific and reasoned maintenance practices.
- Facilitates reduced manpower matrix, enabled with defined and focused targets to reduce the maintenance cost

9.4 MINI SCADA- REAL TIME DATA ACQUISITION SYSTEM (RT-DAS)

As the implementation of full SCADA require a major expenditure and time, the utilities may use Mini SCADA i.e RT-DAS in the smaller towns / urban areas for data acquisition purposes. The major areas of concern in the power distribution sector are high AT&C loss and poor power distribution reliability. To address these problems, the real time accurate measurement & diagnosis of the system data is required which may also be possible with the RT-DAS system in place of full SCADA. The objective of the RT-DAS is to accurately measure reliability of power distribution network and facilitate utility to take suitable administrative action for enhancement of power reliability.

FRTU based SAIFI/ SAIDI measurement system in Non-SCADA towns may be take up with the use of RT-DAS to accurately measure the reliability of the power distribution network and facilitate utility to take suitable administrative action for enhancement of power reliability. It shall also facilitate utility to take appropriate measures for improvement of SAIDI/ SAIFI by knowing the reason of poor values of indices.

➤ Broad Scope of RT-DAS

- RT-DAS at Data Centre
- FRTUs at S/S
- Essential compliance to IEC101/104 protocols for communication with FRTU and Modbus with Multi-Function Transducers (MFT)
- Cyber security/security compliance
- GPS Time synchronization
- SLD and mimics for monitoring at S/S and Data center

➤ Advantages of RT-DAS

- Accurate real time system of measurement
- Rugged and robust to withstand in S/S HV environment
- Notifying S/S and consumer (IT gateway) about outage
- Generation of Reports (SAIFI /SAIDI reports as per regulator defined criteria)
- Operation monitor for switching devices to have preventive maintenance
- Historical data, MIS and analytics
- Future compatibility with SCADA / AMI etc



RT-DAS- Sub-station Monitoring

9.5 DISTRIBUTION AUTOMATION (DA) AND DISTRIBUTION MANAGEMENT SYSTEM (DMS)

Distribution Automation (DA) is a smart technology that is implemented in sync with the Distribution Management System (DMS). It is prudent to identify strategic automation points by doing the reliability analysis to control or restore almost 100% network. This arrangement not only helps in improving the network reliability significantly but also *reduce the Mean time to Restore (MTTR) value significantly*. In terms of restoration, substations with DA capabilities not only immediately identify that the outage has happened but also pinpoints the switching devices which is experiencing the fault.

Further, Distribution Management System (DMS) is a set of applications designed to monitor and control the distribution network system devices efficiently. It acts as a decision support system to the network operator stationed in control Center with the monitoring and control of MV distribution system. It accesses real time data and provide all required information on a single console at the control center in an integrated manner. This helps to detect, report and correct outages which includes the estimation of fault Location and Service Restoration System. Application is also used for optimizing the network conditions including the Network Reconfiguration and the Volt-Var Control functions.



Advantages of DMS & DA:

- Improved monitoring and control of Distribution Network.
- Better control of power quality and enhanced use of reactive power sources.
- Chances of manual error can be eliminated, as all grid stations are unmanned and centrally controlled.
- Improved customer service on load shedding feeders through load forecasting and scheduling applications.
- Faster fault isolation and restoration to reduce the interruption time
- Improved reliability Indices at Distribution Network
- Provide for maximum use of the installed equipment in terms of best configuration and/or best settings of controls to reach specific objectives such as minimum losses.
- Provide the real time analysis of the system and provides means to analyze the present and hypothetical operating conditions of the distribution network to respond what if type of questions.

9.6 ADVANCE DISTRIBUTION MANAGEMENT SYSTEM(ADMS)

The latest trend in the distribution utilities is to implement the unified SCADA, DMS and OMS which is solution of the same box. An Advanced Distribution Management System (ADMS) is the software platform that supports the full suite of distribution management and optimization. An ADMS includes functions that automate outage restoration and optimize the performance of the distribution grid. ADMS functions being developed for electric utilities include fault location, isolation and restoration; volt/var optimization; conservation through voltage reduction; peak demand management; and support for micro grids and electric vehicles.

Applications of ADMS looks for certain data which can be fed to this system through GIS which contains the asset, network and consumer modelling of utility. Based on this data, all applications can be run successfully provided the data in GIS is maintained and updated judiciously and always in live condition as available in field.

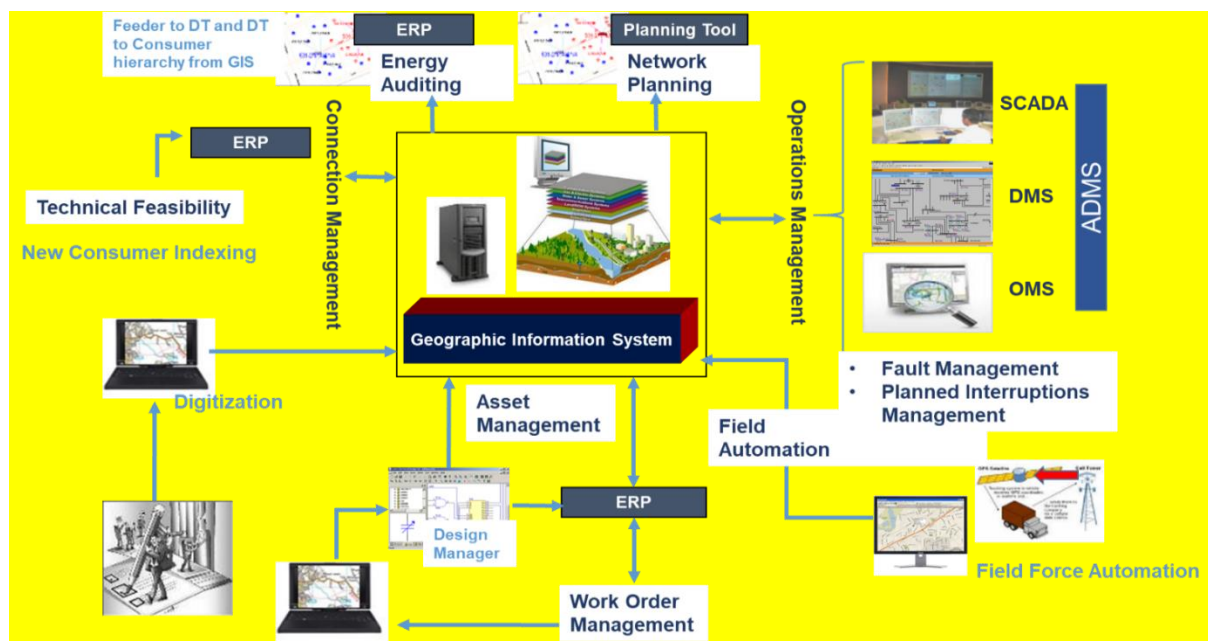
9.7 GEOGRAPHICAL INFORMATION SYSTEM (GIS) - CONSUMER INDEXING & ASSET MAPPING

GIS is the system which leverages the actual information of lay out of power system on the geographical map digitally. GIS helps in addressing the challenges of utilities whose assets and network are spread across the geography for providing services to their consumers. This is very helpful application for utilities like electric distribution utilities, Gas & water utilities, telecom utilities etc. This is the optimal platform and foundation technology for utilities which contains the complete information as mentioned below:

- Geo coordinates controlled Asset record management.
- Network topology for operation service management.
- Consumer's location and indexing with network and asset for service delivery.
- Field Crew movement and tracking for ease of services to the customers.
- Geo-fencing of the consumers for both commercial and maintenance operations, alongside vigilance activities
- Commercial operations and O&M staff tagged to the assets and consumers with each geo-location

Generally, GIS is required the regular data updation as per changes in the actual field conditions but some time GIS loses its shine due to lack of timely data updation in GIS. With lack of latest data, the integration of GIS with other business systems gets impacted and the overall objective of GIS gets completely derailed. The use of GIS can help various other processes which include SCADA, Distribution Management

System, Outage Management System, Network Planning, Energy Auditing, Field Force Automation, Asset Management, Customer Relationship Management and other associated processes. Typical diagram of GIS is as given below:



Some of the important applications of GIS in distribution networks are as under:

Operation management: Network hierarchy along with consumer mapping from GIS can help the network operator using DMS and OMS for further taking decision on operation Management including optimization for commercial operations, vigilance and O&M, based on field data available through the GIS location data of consumers and assets.

Asset Management: All new assets can be mapped and managed in an integrated environment where information can be flow from GIS to System Application and Products (SAP) and vice versa to have a robust asset management.

Commercial management for new connection: Consumer mapping is being utilized for verification of dues and technical feasibility before release of new connection. This would result in to reduction in releasing of new connection cycle time.

Energy Audit: Consumer mapping with Pole No. is being utilized for further indexing with supply points and its linkage with source points for carrying out energy audit at various service level.

Network Planning: Network and consumer mapping can be utilized for carrying out the planning of new network and optimization of investments.

Vehicle Tracking: Tracking of vehicle devices on GIS result in enhancing the productivity and adoption of shortest route, etc.

9.8 CUSTOMER RELATIONSHIP MANAGEMENT (CRM) SYSTEM

CRM system is implemented in the utilities for better consumer interaction and for facilitating in day to day decision making by the Management of the company.

CRM Software is a tool which is designed to help the Discoms to build better relationship with consumers by providing a complete picture of consumers, keeping track of sales /billing of consumers, prioritizing their requirement and facilitating collaboration between various deptt of the organization.

The information/option available in CRM can be broadly categorized into following major categories

- Search Options – In CRM, Multiple options are available for searching the consumer
- Fact Sheet – Information w.r.t Business Master Data Technical Master Data of a consumer is available
- Notification – In CRM, User can perform action like new connection, attribute change, billing, metering complaint, no supply and street lighting service requests w.r.t notification.
- Report – User can also view the different reports developed for different departments. These reports are used by user for analyzing consumer account in detail.



Benefits of CRM

- Call Center Executive may use this application for answering the consumer query or registering the consumer complaint due to which productivity of executive is improved. With implementation of CRM, the productivity of call center executive can be improved by about 25 %. The increase in productivity ensures that utility can answer more call without increasing the number of operators in the commercial call center.
- Unified call center to attend to all type of complaints (commercial or operational i.e. No Supply).
- In case of No Supply, Call Center operator is able to identify the consumer and answer the consumer query in very less time due to which the average talk time (ATT) is reduced.

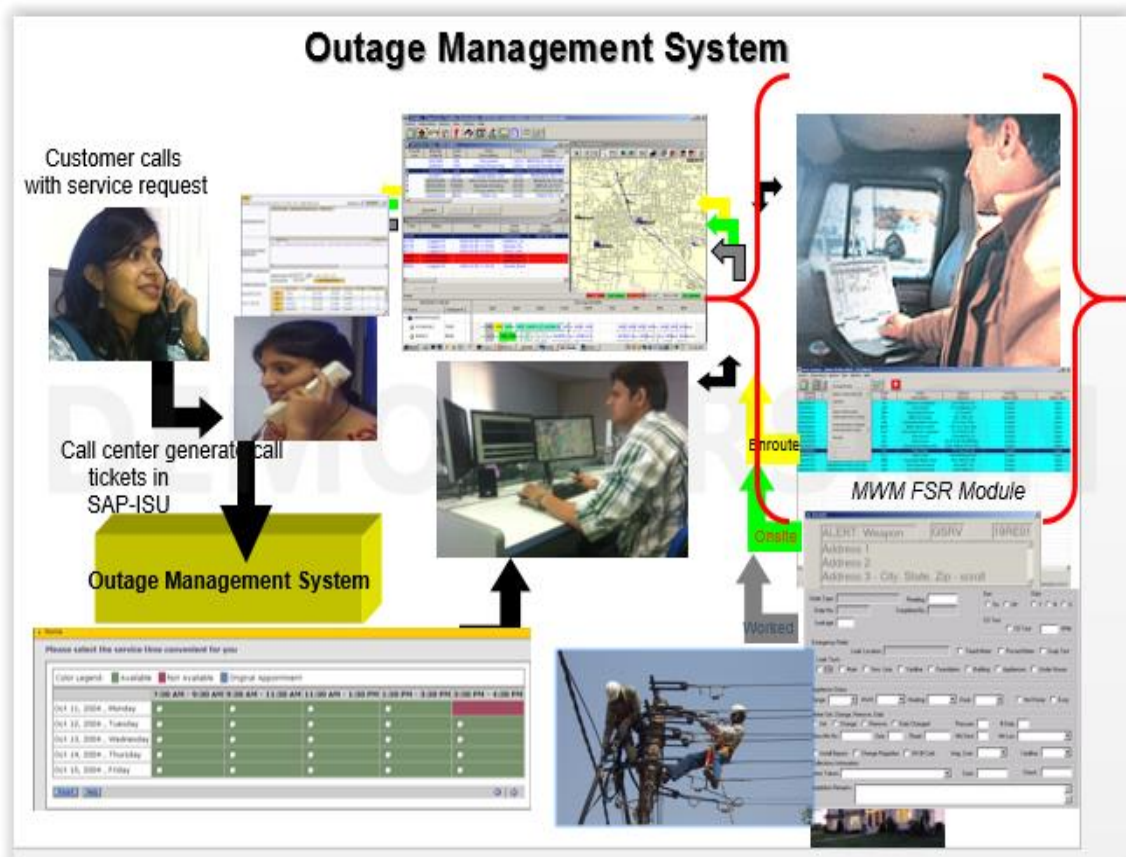
9.9 OUTAGE MANAGEMENT SYSTEM (OMS)

Outage Management System (OMS) provides the capability to efficiently identify and resolve outages and to generate and report valuable information. OMS typically works in conjunction with Geographic Information System (GIS) and Customer Information System (CIS) to give proactive response to the consumer regarding supply restoration status by predicting the location of faulty network component which has contributed to Outage to the consumer. On operational front, it helps in prioritizing the restoration efforts and managing resources based upon the criteria such as locations of emergency facilities, size and duration of Outage. It also helps in analyzing repetitive nature of faults and help maintenance crew in prioritizing their maintenance schedule.

OMS applications predicts the outages encountered by customers. To predict the outages of customer, it is prerequisite to have complete network hierarchy from customer to the LT network followed by distributions transformers, 11 KV substations and 66/33 KV substations. The requirement of complete hierarchy can be obtained through GIS platform by maintaining and sustaining of up to date network, assets and consumer mapping into GIS. Based on the either numbers of calls from customers or outage information from SCADA/DMS trigger the system application to predict the numbers of affected consumers. The list of affected consumers is sent to CIS for providing proactive intimation to consumers experiencing outages and assigning of field crew for early restoration of outages.

Benefits of OMS:

- Enables recording of end to end Outage data creating invaluable interruption data
- Predicts the consumer spectrum affected by outages and enables consumer information to be available on a real-time basis
- Improves Quality of service to Customers
- Reduction in Outage duration, Restoration time and Non-outage complaints
- Reduction in O&M costs and better regulatory relations with consumers
- Enables the customer care centre to prioritize the complaint handling sequences for business purposes
- Enables crew management and optimization for maintenance and restoration activities
- Improves performance assurance standards



9.10 DEMAND RESPONSE (DR)

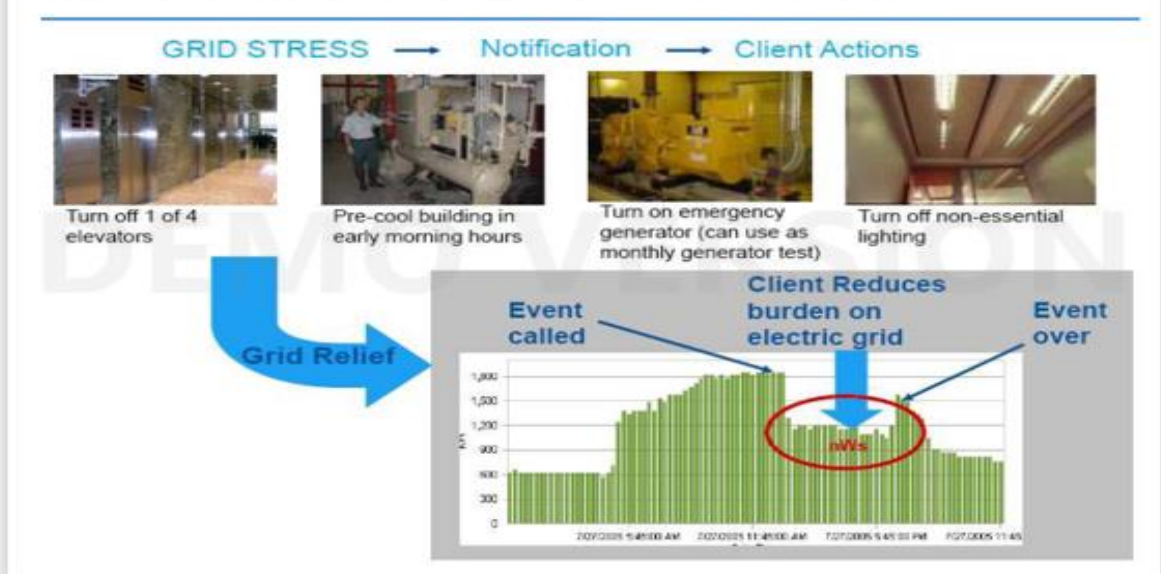
Numerous contributions to overall improvement of the efficiency of energy infrastructure are anticipated from the deployment of smart grid technology, in particular including **demand-side management**, for example turning off air conditioners during peak time / higher electricity price. When Peak Demand is high in the system for the utility or price is high for the consumers, Automatic Demand Response System sends control signals to smart devices installed at the home/business/ industries to cut off some of the non essential load for a short period in order to prevent system overload.

Automatic Demand response system allows interaction between availability of power and loads to interact in an automated fashion in real time, coordinating demand to flatten spikes. Eliminating the peak spikes in demand that may occur for a short time would eliminate the cost of adding reserve generators, and allows users to cut their energy bills by managing low priority devices to use energy only when it is cheapest. Thus , ADR also helps in reducing greenhouse gas emissions by avoiding the need to run expensive peaking plants at the time of system peak. This all would be possible with various smart grid technologies .

A typical DR implementation would consist of three main entities:

- An entity at the utility which stores the program information, generates and communicates the DR signal to consumer premises.
- An entity at the consumer premises capable of receiving the utility DR signal and controlling the load accordingly.
- An entity for measurement and verification.

Typical Demand Response (DR) Event



9.11 ENTERPRISE RESOURCE PLANNING (ERP)

The profitability of the distribution sector is directly governed by the 'meter-to-cash' cycle and the total energy accounting process. Utilities require an ERP system to address the challenges that they face today. It includes the integration of connection services, revenue management and customer relationship management to streamline the entire process chain. They require tools to identify operational bottlenecks, improve efficiency, enhance customer satisfaction and facilitate accurate energy audit. ERP solutions includes the Maintenance Management across network layers of Utility. It also enables focused maintenance practices mainly based on the condition monitoring of the assets. The key benefits which can be achieved by ERP solutions are as below:

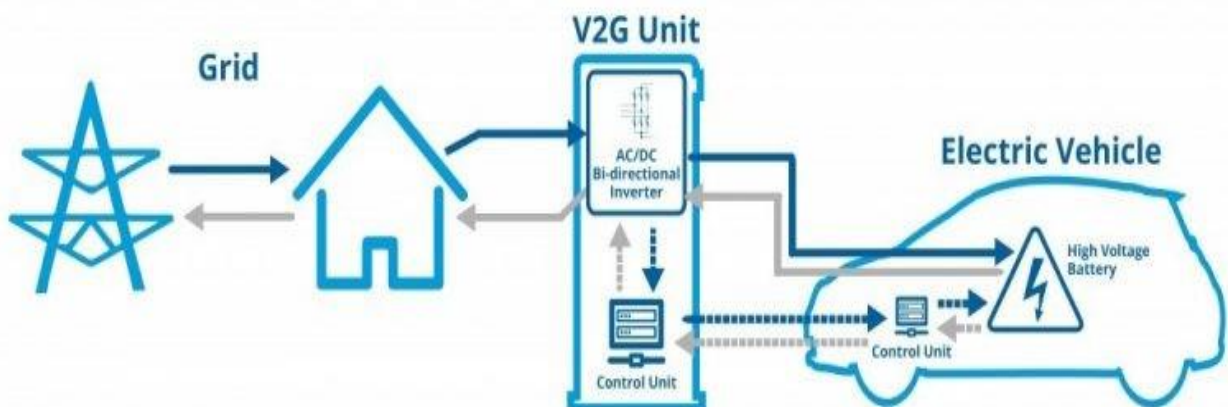
- Increased efficiency in billing and collections
- Improved revenues through reduction in losses
- Adaptability to future tariff and regulatory changes
- Effective planning and monitoring of cash flows
- Business insights into day-to-day revenue operations and credit control activities
- Real-time, informed and timely decision making
- Improved Work Control.
- Improved Planning and Scheduling.
- Enhanced Preventive and Predictive Maintenance.
- Improved Parts and Materials Availability.
- Improved Materials Management in Integration with GIS and Design Manager Application.
- Improved Reliability Analysis.
- Increased Capability to Measure Performance and Service.

The screenshot displays the SAP Project Builder interface for Project PR/S0512/00004. The interface is divided into several sections:

- Project Structure:** A tree view on the left showing the project hierarchy. The selected project is "Stolen tube well trf & conductor scheme" (PR/S0512/00004). Below it, there are sub-projects like "Estimate for installation of materials" (PR/S0512/00004.1) and "Estimate for transformer" (PR/S0512/00004.2). The "Estimate for transformer" sub-project is expanded, showing a list of materials and their quantities, including "TRANSFORMER 25 K 0200 101000049", "BOX DIST WITH 40A : 0210 301000375", "FUSE UNIT DD 11 KV 0220 601000002", "LA 9KV 5KA FOR 11K 0230 301000066", "CONDUCTOR AL RAI 0240 401000124", "PIPE G.I. 40MM DIA 'A' 0250 601000289", "PIPE G.I. 20MM DIA 'A' 0260 601000284", "WIRE STAY GI 7/10 S 0270 601000049", and "CHANNEL MS SIZE 1 0280 601000013".
- Identification and view selection:** A section on the right with fields for "Project def." (PR/S0512/00004) and "Detail:" (Stolen tube well trf & conductor scheme). There are also buttons for "Overview(s)" and "Control data".
- Basic data:** A tab in the right-hand panel showing various project details. It includes fields for "Status" (System Status: REL, User status: REL APRD), "Project coding mask" (Screen: PR/XXXX/00000.0.0.0, Mask ID:), "Responsibilities" (Person Respons.: 660, Applicant no.: , HOG(TS&P) - Bawana), "Dates" (Start date: 05.09.2007, Finish date: 05.09.2007, Factory calend.: ND, Time unit: D, Fcst start date: 05.09.2007, Finish date (F): 05.11.2007), and "Organization" (CO area: NDPL, Company code: NDPL, Business area: , Plant: , Location: , Functional Area: , Profit Center: , Proj. currency: INR).

9.12 EV TO GRID CHARGING

EV Batteries can be charged to store energy when renewable energy is present in the grid and may feed it back into the grid later, whenever required (V2G). The capacity of using electric vehicle batteries as a distributed storage system to balance generation and load fluctuation depends not only on the connectivity of the car and charger, but also on the capacity of the grid to manage charging and discharging processes. This capacity of the grid can be improved by having access to information about the local status of the grid, which is usually obtained from smart meters. The availability of information concerning the grid (provided by smart meters) allows an optimisation of the EV loading process, by taking into account the needs and limitations of the local grid. However, presently, our country has the technical limitations regarding discharging process of EV batteries into grid and have very little experience in this field due to current conditions of grid infrastructure and status of EVs market. Furthermore, during the charging or discharging process, the energy losses are around 10% and 15%.

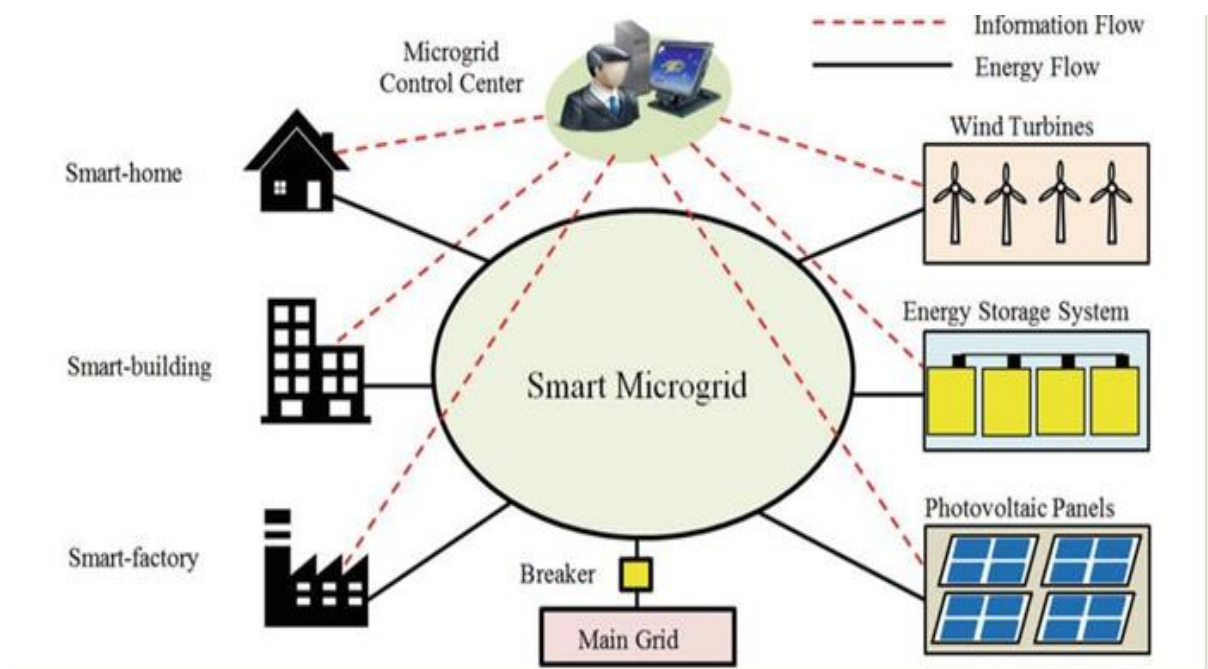


9.13 SMART MICRO GRID

Microgrids are an integrated energy system intelligently organizing interconnected loads and distributed energy resources and capable of operating in parallel with, or separately, from the existing utility grid. They achieve specific local goals, such as reliability, carbon emission reduction, diversification of energy sources, and cost reduction, established by the community being served. Like the bulk power grid, smart micro-grids generate, distribute, and regulate the flow of electricity to consumers, but do so locally. Smart micro-grids are an ideal way to integrate renewable resources on the community level and allow for customer participation in the electricity enterprise.

Smart Micro grids may contribute in reducing GHG emissions and help cities meet their climate goals by integration and aggregation of renewable energy sources, thanks to their ability to balance energy production and usage within the microgrid through distributed, controllable generation and storage etc. It would also reduce the transmission losses because of proximity of load to generation point. Smart Microgrids can strengthen and increase resilience of the central grid by reducing grid vulnerability by coping with impending power outages and safeguarding against potential cyber-attacks on energy infrastructure. They may also sustain energy service during emergencies or natural disasters, especially for critical public services etc.

Smart Micro grid leverages the various functionalities of smart automation system to take the decision for providing the green, optimal, reliable and quality power in the area of operation.



9.14 HOME AUTOMATION SYSTEM

Home Automation includes connecting all electrical devices of the home with a common central controlling unit which automates the devices depending on the user inputs. In addition to managing the control of electrical appliances, the concept of Home Automation further extends to managing the security systems of home, controlling programming devices like thermostats and sprinkler systems, operating your garage doors through a one-touch action on your smartphone, etc.

Thus in short explanation, Home Automation helps build what is called as “**Smart Home**”.



One clear advantage of home automation is the unmatched potential for energy savings, and therefore cost savings.

Smart Home

A smart home is a home that includes automated, IOT connected devices connected to mobile applications. Using these IoT devices, users can control many things in their home from lights to security systems to appliances etc. Now a days, many homes are being provided with the smart facilities but technically, any home with an internet connection may be converted into smart home by introducing IoT controlled devices.

Home automation works on three levels:

- **Monitoring:** Monitoring means that users can check in on their devices remotely through an app.
- **Control:** Control means that the user can control these devices remotely, like panning a security camera to see more of a living space.

- **Automation:** Finally, automation means setting up devices to trigger one another, like having a smart siren go off whenever an armed security camera detects motion.

Home automation systems offer a variety of services and functions. Apart from control and monitoring of electrical appliances, the following other services may also be integrated in Smart Home system:

- Fire and carbon monoxide monitoring
- Temperature control of Home
- Appliance control
- Home automation security systems and cameras
- Live video surveillance
- Alarm systems
- Real-time text and email alerts
- Digital personal assistant integration
- Keyless entry
- Voice-activated control

Advantages of Home Automation

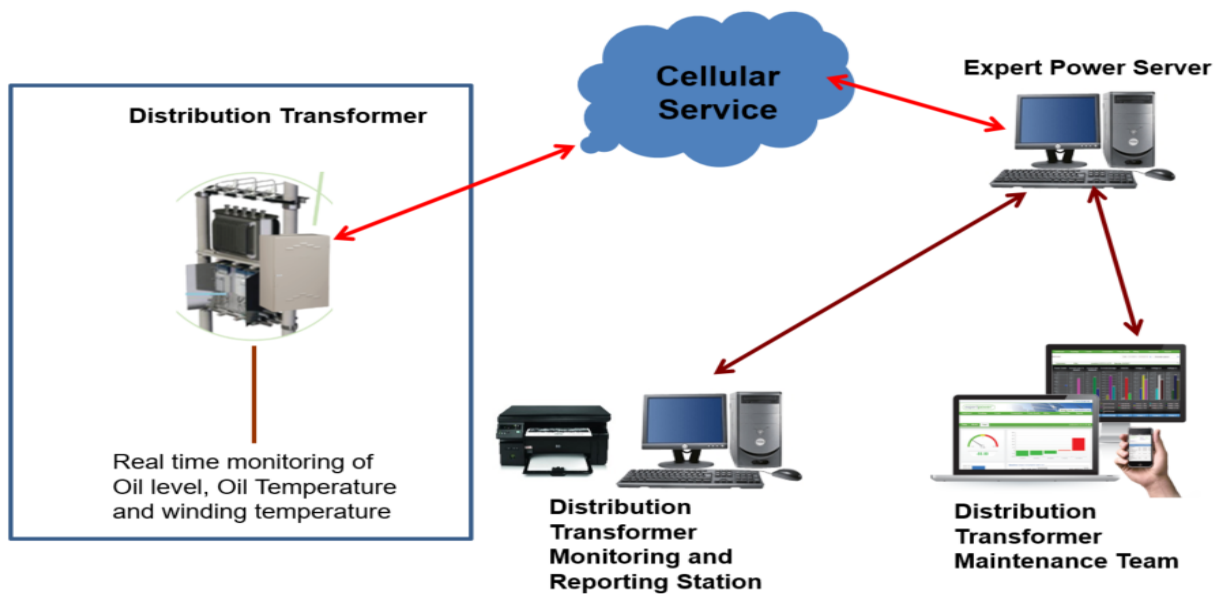
- **Energy Savings:** Self-automated light bulbs, fans, and switchboards save energy, cutting utility costs over time.
- Home Safety
- User Convenient
- Better Control
- Remote Access etc.

9.15 DISTRIBUTION TRANSFORMER MONITORING (DTMU)

One of the key components in smart distribution system is monitoring of Distribution Transformers (DTs). The failure of distribution transformers (DTs) is one of the major aspect hampering the reliability of power supply to the consumers. Hence, the remote health monitoring of Distribution Transformer will prevent failure of transformers by taking the appropriate action by discoms timely. With DT monitoring systems, overloaded DTs can be identified and replaced with higher capacity DTs as load in the locality increases. Additionally, the actions may be taken by discoms in case the information is available regarding oil level is less or temperature of oil is above threshold limits etc. The monitoring of the health of distribution transformers improves the visibility into the low voltage (LV) network and provides insights that help the utility to utilize the power network in an optimum way.

Transformer monitoring can bring a lot of benefits for utility companies, including the following:

- To recognize when transformers are on the brink of collapse (overloaded) and take remedial performance related actions. Often a utility may lose a transformer because of the lack of information regarding the overloading of transformers.
- To improve visibility of the low voltage power network which helps utility to deliver high quality electricity to customers. The system provides real time information about voltage, power factor, current, harmonics and unbalance from the LV network; and based on this information, utility may take necessary action to solve problems as they occur.
- Decrease outage duration. If one transformer collapses, it normally takes some time as specified in Supply Code by Regulators to replace the Transformer, thus disrupting the power supply for this period. However, the analysis of the health parameters of Distribution transformer may send an emergency signal to the Central system and utility may take necessary action to avoid the failure of transformer. For example, in case, the system identify that a particular transformer is working with more than 90% of its capacity, the utility may take necessary step to augment the transformer as soon as possible.
- The useful information from the transformer monitoring system may be utilized to make decisions about distribution network planning.
- The transformer monitoring information would also be used for asset management and preventive maintenance.
- The energy data at distribution transformer would also be used for energy auditing and accounting purposes and also to pin point the high loss / theft prone areas in the system.



9.16 SMART STREET LIGHT SYSTEM

Latest entrant in the smart distribution is the adoption of smart street lighting in smart cities. Typical street lights using sodium vapour lamps consume huge amount of power. These are being replaced with LED lamps in many cities and also in small towns. The new LED lights can be remotely controlled and have features like increase/decrease luminosity, switch off alternate lights during lean hours etc are possible. The lights can be connected on GPRS, RF Mesh or WiFi in the city for its remote operation. The newest trend is to install noise sensors and pollution sensors on the street light poles (cobra heads) which will leverage the same communication band-width to transmit the data to the control centres for monitoring noise and air pollution.

9.17 SMART ENERGY STORAGE SYSTEM

Energy Storage Systems (ESS) is fast emerging technologies as an essential part of the evolving clean energy systems of the 21st century. India is committed to reducing emission intensity up to 33-35% from the 2005 level by 2030 and set the target of 450 GW of renewable energy by 2030. Integration of such massive amounts of RE which are intermittent and distributed in the power system pose serious challenges to grid stability. ESS is going to play critical role in grid integration and management of RE as the share of RE in the grid increases. The energy storage system may also be used by the utilities at the peak time to reduce the peak power charges. The main technologies being used as energy storage are Battery energy Storage System (BESS) and pumped hydro plants.

Key areas for Energy Storage applications are:

- Integrating renewable energy with transmission grids and distribution grids
- Setting up rural micro grids with diversified loads or stand-alone systems
- Developing storage component for electric mobility plans
- Replacement of DG sets with battery based energy storage systems (BESS)



Presently, Grid scale energy storage installations in India are mostly in the form of pumped hydro storage plants, however, the pilots for deployment of large-scale battery energy storage projects has already been started in the country. Many distribution utilities have also installed medium size BESS in their system for grid stabilization, better peak load management, for system flexibility, enhance reliability and to protect critical facilities etc.

CHAPTER-10

ASSESSING & REDUCING AT&C LOSSES

Energy losses occur in the process of supplying electricity to consumers due to technical and commercial reasons. The technical losses occur due to energy dissipated in the conductors and equipment used for transmission, transformation, sub-transmission and distribution of power. These technical losses are inherent in the system and can be reduced up to an optimum level only. The losses can be further sub-grouped depending upon the stages of power transformation, transmission & distribution system as Transmission Losses (765kV/400kV/220kV/132kV/66kV), Sub transmission losses (33 kV, 22kV) and Distribution losses (11kV/0.4kV).

Pilferage by hooking of lines, bypassing the meters, defective meters, errors in meter reading and in estimating un-metered supply of electricity are responsible for part of the commercial losses and when added to technical losses gives Transmission & Distribution (T&D) losses. There is another component of commercial losses, which is attributable to non-recovery of the billed amount and is reflected in collection efficiency. T&D losses together with loss in revenue collection give us Aggregate Technical & Commercial (AT&C) losses.

The losses in any system depend on the pattern of energy use, intensity of load demand, load density, and capability and configuration of the transmission and distribution system that varies for various system elements. However, it should be reasonable to aim for total AT&C losses around 10% in the different States in India.

10.1 TECHNICAL LOSSES

Technical losses can further be grouped as permanent technical losses and variable technical losses.

➤ Permanent / Fixed Technical losses

Fixed losses do not vary according to current. These losses take the form of heat & noise and occur as long as a transformer is energized.

Some of the fixed losses on a network may be:

- No load Losses of Transformers
- Corona Losses
- Leakage Current Losses
- Dielectric Losses
- Losses caused by continuous load of control and measuring elements

➤ Variable Technical losses

Variable losses vary with the amount of current flow for electricity distributed and are proportional to the square of the current. Around 3/4 of technical losses on distribution networks are variable Losses.

By increasing the cross sectional area of lines and cables for a given load, would reduce the technical losses as it would reduce the resistance of the line / cable. This leads to a direct trade-off between cost of losses and cost of capital expenditure. The variable losses consist of I^2R losses in lines at each voltage level, Impedance losses and losses caused by contact resistance etc.

The major amount of technical line losses (about 70% of the total system line losses) are in primary and secondary distribution lines (LT and 11kV network); while transmission and sub-transmission lines (33kV and above) contribute approximately 30% of the total system technical line losses. Therefore, the primary and secondary distribution lines must be properly planned to ensure losses are within acceptable limits.

10.1.1 MAIN FACTORS FOR HIGH TECHNICAL LOSSES

The main factors contributing to the increase in the technical losses in the primary and secondary systems includes:

- Lengthy Distribution Lines
- Inadequate Size of Conductor
- Distribution Transformers not located at Load center
- Over loading of Distribution Transformers and Lines
- Low Voltage (less than declared voltage) at Transformers and Consumers Terminals
- Bad Workmanship Resulting in Poor Contacts at Joints and Connections
- Unbalanced 3 phase loads
- Unequal load distribution among three phases in L.T system causing high neutral currents leaking and loss of power
- Abnormal operating conditions at which power and distribution transformers are operated
- Low voltages at consumer terminals causing higher drawl of currents by inductive loads.
- Poor quality of equipment used in agricultural pumping in rural areas, cooler air conditioners and industrial loads in urban areas leading to injection of reactive power into the system etc.

10.1.2 MEASURES REQUIRED FOR REDUCTION OF TECHNICAL LOSSES:

The details of some of the measure for reducing the technical losses in the system are under:

Removing overloading of existing lines and substation equipment:

The transmission lines and sub-stations are designed for optimal use. However, in most of the cases, the consumers draw higher load than the sanctioned one, resulting in overloading of distribution lines and equipment, which results in higher losses.

The overloading of the system may also occur due to load growth in the area. Due to high growth rate in demand for power, the lines and equipment supplying power get overloaded and require frequent upgradation, relocation of distribution sub-stations and for provision of additional Distribution Transformers (DTs) etc. Overloading of lines and equipment results in high technical losses.

To remove overloading of the lines and equipment, it requires carrying out loss-diagnostic studies by modelling the whole network from high voltage (HT) feeder level down to consumer level. The results give information regarding the overloading of the system elements and these elements may be taken up for removing overloading by reconfiguration, resizing and re-conductoring the network where required, augmenting the overloaded transformers and placing adequate sized power factor correction capacitors.

Preparation of long term plans on regular basis for phased strengthening and improvement of the distribution system along with associated transmission lines is also required for reduction of high technical losses in the system.

Improving Low HT:LT line ratio:

As higher current flows in the low voltage (LT) lines for the same amount of power in comparison to HT lines, therefore, technical losses are more in LT lines. For achieving a better level of network losses, HT:LT ratio should be close to 1 or higher. However, it requires detailed study and careful planning to reach an optimum level. Presently, the HT/LT ratio in State utilities ranges much below 1 showing the availability of more LT lines as compare to HT lines causing more technical losses. High Voltage Distribution System (HVDS) helps in increasing the HT/LT ratio as this brings the 11 kV line & distribution transformers in proximity of consumers with minimal LT line which results in low technical losses. HVDS system also helps in reducing commercial losses due to reduction in theft.

Tackling poor repair and maintenance of equipment:

Distribution utilities generally do not take up regular maintenance of lines and equipment, which result in higher technical loss and frequent failure of equipment. For low failure rate and low losses, it is essential to carry out timely preventive maintenance of lines and equipment.

Installation of adequate capacitors/reactive power equipment:

Installation of sufficient capacitors is essential in the system to maintain the power factor close to unity, so that technical losses can be kept to a minimum. However, due to non-availability of sufficient funds, utilities are not able to install sufficient capacitors/reactive power equipment. Utilities should take proactive action to install the suitable capacity of capacitors at appropriate places for improving the power factor in the system.

The system should be planned so as to keep the technical losses in a distribution system less than 8% keeping in view the large distribution system in the country.

10.2 COMMERCIAL LOSSES

Commercial Losses, are caused by actions external to the power system and are caused by conditions beyond the technical losses. Commercial losses are difficult to measure because these losses are often unaccounted for by the system operators and thus have no recorded information. The commercial losses are generally segregated by reducing the technical losses from total AT&C losses.

The main Commercial losses may be due to the following factors:

- Losses due to inefficient Metering, use of defective meters, error in meter reading
- Losses due to inefficient billing
- Losses due to theft/pilferage of energy, bypassing of meters, hooking etc
- Losses due to inefficient Collection
- Error in estimating un-metered supply of electricity

Metering and billing for electricity actually consumed by users is integral to commercial management of an electricity utility. Another critical task in the distribution business is the collection of the billed amounts. Effective performance in both functions is critical to ensure the financial viability of the company. From the operational point of view, metering-billing and collection are separate functions and they require specific management approaches. The use of smart meters mode would eliminate the cumbersome process of manual reading of meters, generation of bills, delivery of bills and then collection process. The smart meters can also be disconnected – reconnected remotely in case on non payment/ payment by the consumers.

10.2.1 MAIN FACTORS FOR HIGH COMMERCIAL LOSSES

- Unauthorized extensions of loads
- Billing on flat rate tariff / non- receiving of full subsidy
- Tampering the meter readings (like placement of powerful magnets etc)
- Stopping the meters by remote control.
- Willful burning of meters, bypassing the meter.
- Changing C.T. ratio and reducing the recording.

- Errors in meter reading and recording.
- Improper testing and calibration of meters.
- Wrong assessment of unmetered consumers and a class of consumers getting free electricity
- Low collection efficiency etc.

It is clear that the amount of electricity involved in commercial losses are being consumed by users but they do not pay for that. However, commercial losses represent an avoidable financial losses for the utility and can be reduced to zero, in case , they take appropriate actions to tackle each of the causes.

10.2.2 MEASURES FOR REDUCING COMMERCIAL LOSSES

The measures for reducing commercial losses depend on the factors that cause them. These are as mentioned below:

1) Measures for controlling thefts

- Installation of Smart meters on consumers, feeders and Distribution transforms as per CEA regulations and using of smart metering data for regular energy auditing and accounting
- Use of aerial bunched cables/ insulated conductor / Underground lines;
- High Voltage Distribution System as an effective method for reduction of technical losses, prevention of theft, improved voltage profile and better consumer service.
- Regular Inspections / Enforcement at Zonal & Corporate Level
- Installation of theft prone Bus-Bar Boxes at Distribution Transformers.
- Public relation and awareness campaigns by utility
- Energy meter /CT/PT housed in a sealed box for HT consumers
- Armored cables should be used as service mains
- Active Vigilance and quickly disposal of theft cases
- Theft of electricity should be publicized as a social and economic crime and people should be informed of the provisions in electricity laws in this regard.

2) Measures for improvement in billing and collection efficiency

Correct billing, timely delivery of bills and easy collection facilities for consumers go hand to hand in improving the revenue collection for the utility. The installation of smart meters would solve the cumbersome process of manual billing, issuing & distribution of bills and collection through collection centers.

Some measures to ensure proper billing efficiency include:

- Replacing existing meters with Smart pre-paid meters /simple pre-paid meters as per CEA Regulations

- Re-engineering of Commercial Processes and Centralization
- Consumer Segmentation for Differentiated Services & Focus
- Automatic Meter Reading(AMR)/ Smart Meters for Key Consumers & High Revenue Based Consumers
- Second attempt on Unread cases / undelivered bills
- DT wise communicable /smart metering for energy accounting & auditing

Some measures to ensure proper collection efficiency include:

- Increased number of Customer Friendly Collection Centers
- Addition of Bill Payment Avenues for Consumer Conveniences
- Drop Boxes for post paid consumers / more recharge counters for pre-paid consumer
- On line pre-paid facilities for consumers
- Any Time Payment Machines (ATPM's)
- Online Payment through various modes
- Remote disconnection on nonpayment through smart meters
- Proper analysis of arrears
- Timely receiving the subsidy from respective State Govt.
- Association of RWA, User's Associations, Panchayats and Franchisees etc in Billing and Collection etc.

10.3 ADDITIONAL MEASURES FOR REDUCTION IN AT&C LOSSES:

Various other measures which are helpful in reduction of losses are as follows:

- a) Professional management and change in work culture in the distribution sector
- b) Implementation of High Voltage Distribution System (HVDS) and Aerial Bunched Cables (ABC) may be used in theft prone areas and agriculture connections
- c) Technical losses can be substantially reduced by using higher star rating of distribution transformers (3 star/4 star/ 5 star), using copper cables (instead of Aluminum) etc.
- d) Extensive energy audit should be undertaken at each feeder /DT level and a feeder manager may be appointed by the utility who should be made responsible for containing AT&C losses on that feeder.
- e) Random checking may be carried out by the vigilance department.
- f) A Roll out plan may be made for installation of Smart Pre-paid meters/simple pre-paid meters as per CEA Regulations with the approval of SERCs/JERCs
- g) Regular issuing of tariff orders by SERC/JERCs

- h) Simplified procedures for consumers to obtain legal metered connections,
- i) IT enabled Consumer centric billing /collection procedures to reduce manual intervention/discretion,
- j) Enabling mechanisms for speedy resolution of billing disputes, prompt disconnection of non-paying customers etc.
- k) State Electricity Regulatory Commissions (SERCs)/ Joint Electricity Regulatory Commissions (JERCs) may also set reasonable targets for reduction in AT&C losses with suitable incentive/disincentive for improved/poor performance as compared to targets.
- l) setting up of Special Courts and special police stations for speedy disposal of theft related cases.

10.4 MEASURES FOR CONTROLLING THEFT OF ELECTRICITY AS PER IE ACT, 2003:

Theft of electricity is one of the major contributing factors impacting the financial health of power utilities. This also contributes to poor quality of power supply, frequent load shedding and unscheduled outages. State Government is primarily responsible for the distribution sector and losses are primarily in the distribution segment.

To enable effective control of theft of electricity, the Electricity Act, 2003 has incorporated specific provisions for detection of theft, speedy trial of theft related offences and also for recovery of the charges of electricity stolen. Government of India, Ministry of Power has amended Section 135 and Section 151 of the Electricity Act, 2003 through the Electricity (Amendment) Act, 2007 making the offence punishable under Section 135-140 and Section 150 as cognizable and non-bailable. Moreover powers have been vested with the police officer in line with Chapter XII of the Code of Criminal Procedure, 1973 (2 of 1974). The definition of theft has been expanded under Section 135 to cover use of tampered meters and use of electricity for unauthorized purpose by insertion of provisions (d) and (e) under Section 135(1) of the Electricity Act, 2003.

The State Governments may also take necessary actions for setting up the special police stations and setting up of Special Courts as provided in Section 153 of the Electricity Act, 2003 for speedy disposal of theft related cases.

REVISED METHODOLOGY FOR CALCULATION OF AT&C LOSS

A	Input Energy (MkWh)	Energy Generated - Auxiliary Consumption + Energy Purchased (Gross) — Energy Traded/ Inter State Sales.
B	Transmission Losses (MkWh)	
C	Net Input Energy (MkWh)	A-B
D	Energy Sold(MkWh)	Energy Sold to all categories of consumers excluding units of Energy Traded/Inter-State Sales.
E	Revenue from Sale of Energy (Rs. Cr.)	Revenue from Sale of Energy to all categories of consumers (including Subsidy Booked) but excluding Revenue from Energy Traded /Inter-State Sales.
F	Adjusted Revenue from Sale of Energy on Subsidy Received basis (Rs. Cr.)	Revenue from Sale of Energy (same as E above) minus Subsidy Booked plus Subsidy Received against subsidy booked during the year
G	Opening Debtors for Sale of Energy (Rs. Cr.)	Opening debtors for sale of Energy as shown in Receivable Schedule (Without deducting provisions for doubtful debtors). Unbilled Revenue shall not be considered as Debtors.
H	Closing Debtors for Sale of Energy (Rs. Cr.)	i) Closing debtors for Sale of Energy as shown in Receivable Schedule (Without deducting provisions for doubtful debts). Unbilled Revenues shall not be considered as Debtors ii) Any amount written off during the year directly from (i)
I	Adjusted Closing Debtors for sale of Energy (Rs. Cr.)	H (i+ii)
J	Collection Efficiency (%)	$(F+G-I)/E \times 100$
K	Units Realized (Mkwh) = [Energy Sold * Collection efficiency]	$D \times J / 100$
L	Units Unrealized (Mkwh) = [Net Input Energy—Units Realized]	C—K
M	AT&C Losses (%) = [{ Units Unrealized / Net Input Energy}*100]	$L/C \times 100$

CLARIFICATIONS FOR CALCULATION OF AT&C LOSSES

Parameters	Sub- Parameter	Treatment of parameters for computation of AT&C losses
Net Input Energy / Energy Sold (MU)	Open Access/ Wheeling	Open Access/ wheeling units shall not be included in Net input Energy and Energy sold while calculating Billing Efficiency
Energy Purchased (Gross)		DISCOMs are required to give gross energy purchased i.e. Total Power Purchased including transmission losses
Revenue from Sale of Energy (Rs Crores)	Unbilled Revenue	No adjustment shall be made in revenue from sale of energy on account of un billed revenue.
Adjusted revenue from sale of energy on Subsidy received Basis (Rs Crores)	Subsidy Received against subsidy booked during the year	Total Tariff Subsidy received during the year including arrears (if any) shall also be included while calculating Adjusted revenue from sale of energy on Subsidy Received Basis.
Collection Efficiency (%)		Collection Efficiency of subsidy received and realization from sale of power together will be restricted at 100%

DEFINITIONS

- **Connected load** means the aggregate capacity of all electrical devices (lamps, appliances, equipment etc.) which are connected by the consumer to the supply system is called Connected Load.

The definition of connected load, is for the purpose of making an assessment of consumption, in case when the meter is not recording.

- **Maximum demand** means the highest load measured in kVA or kW at the point of supply of a consumer for a continuous period of 15 minutes or as specified by the Commission, during the billing cycle.
- **Demand factor:** The ratio of the maximum demand to the total connected load is called the demand factor.
- **Load Factor** is the ratio of the average load or demand for a period of time to the maximum demand during the period.
- **Diversity:** Load diversity is the difference between the sum of the maximum demands of two or more individual consumers' loads and the maximum demand of the combined loads.
- **Diversity factor:** The diversity factor is the ratio of the sum of maximum demands of each of the component loads to the maximum demand of the load as a whole. This is one of the important factor for economic planning and design of distribution facilities.
- **Utilization factor:** The ratio of the maximum demand of a system to the rated capacity of the system is known as the utilization factor. The factor indicates the degree to which a system is being loaded during the load peak with respect to its capacity. The rated capacity of a system is usually determined by thermal rating coupled with the voltage drop.
- **“Average Power Factor”** means the ratio of kWh (kilo Watt hour) to the kVAh (kilo Volt Ampere hour) registered during a specific period.
- **Area of Supply** means the geographic area within which Licensee is, for the time being, authorized by his license to supply electrical energy;
- **“Billing cycle” or “Billing period”** means the period as approved by the Commission for which regular electricity bills are to be prepared by the Licensee for different categories of consumers;

- **Harmonics**” means a component of a periodic wave having frequency that is an integral multiple of the fundamental line frequency of 50 Hz, causing distortion to pure sinusoidal waveform of voltage or current;
- **Point of Supply** means the point at the outgoing terminals of Licensee’s meter/ up-to consumer's cut-out/ switchgear installed in the premises of the consumer: Provided that in case of high tension and extra high tension consumers, point of supply means the point at the outgoing terminals of the Licensee’s metering cubicle placed before such consumer’s apparatus;
- **Sanctioned load** means the load in kW or kVA (kilo Watt or Kilo Volt Amp) which the Licensee has agreed to supply from time to time as per the governing terms and conditions and shall be subject to relevant orders of the Commission, as may be issued from time to time;

➤ **AAC- All Aluminum Conductor**

This conductor is also known as aluminium stranded conductor. This conductor is manufactured from electrolytically refined (E.C.GRADE) aluminium, having purity of minimum 99.5% of aluminium. All aluminium conductors are made up of one or more strands of aluminium wire depending on the end usage. These conductors are also used extensively in coastal areas because it has a very high degree of corrosion resistance.

INDIAN STANDARD (IS 398 PART 1)

CODE NAME	AREA (mm ²)	SIZE Al/St/Dia. (mm.)	WEIGHT (Kg/Km)	Current Carrying Capacity at 45°C* (Amp)
Gnat	25	7/2.21	74	120
Ant	50	7/3.10	145	189
Grasshopper	80	7/3.91	230	255
Wasp	100	7/4.39	290	295
Peony	150	19/3.18	415	363
Caterpillar	185	19/3.53	511	395
Spider	240	19/3.99	654	500
Butterfly	300	19/4.65	888	700
Tarantula	750	37/5.23	2192	1200

➤ **AAAC- All Aluminum Alloy Conductor**

This conductor is made from aluminium-magnesium-silicon alloy of high electrical conductivity containing enough magnesium silicide to give it better mechanical properties after treatment. These conductors are generally made out of aluminium alloy . AAAC Conductor has a better corrosion resistance specially in sea coast areas and in polluted industrial areas due to absence of steel core and improved electrical conductivity than ACSR Conductor on equal diameter basis.

INDIAN STANDARD (IS 398 PART 4)				
CODE NAME	AREA (mm ²)	SIZE Al/St/Dia. (mm.)	WEIGHT (Kg/Km)	Current Carrying Capacity at 45°C* (Amp)
Squirrel	22	7/2.00	60.16	105
Weasel	34	7/2.50	94.00	155
Rabbit	55	7/3.15	149.20	210
Raccoon	80	7/3.81	218.26	290
Dog	100	7/4.26	272.86	325
Wolf	173	19/3.40	474.02	460
Panther	232	19/3.94	636.63	520

➤ **ACSR- Aluminum Conductor Steel Reinforced**

ACSR is widely used in overhead transmission line for primary and secondary distribution. It is manufactured of one or more aluminum as outer wire & wire stranded with zinc coated high strength steel core wire. It provides excellent mechanical strength without compromising the ampacity. These type of conductors provide excellent design benefit for extra-long spans, river crossing etc.

INDIAN STANDARD (IS 398 PART 2)				
CODE NAME	AREA (mm ²)	SIZE Al/St/Dia. (mm.)	WEIGHT (Kg/Km)	Current Carrying Capacity at 45°C* (Amp)
Rose	18	6/1/1.96	72	100
Squirrel	20	6/1/2.11	85	130
Weasel	30	6/1/2.59	128	170
Rabbit	50	6/1/3.35	214	240
Raccoon	80	6/1/4.09	320	300
Dog	100	6/4.72+7/1.57	394	360
Wolf	150	30/7/2.59	726	470
Panther	200	30/7/3.00	974	560
Goat	320	30/7/3.71	1489	630
Zebra	420	54/7/3.18	1622	860

- The mechanical properties of the core wire should be as per IS 398 Part II.
- Joint: No Joint of any kind should be in the finished coated steel wire.
- Coating: Heavy zinc coating is done as required by IS-4826
- Tests for ACSR: Various routine tests & acceptance tests such as breaking load test, ductility test, wrapping test, resistance test and galvanizing test should be done in the BIS accredited laboratories

Acronyms

ABC	Aerial Bunched Cable
ADB	Asian Development Bank
ADMS	Automatic Demand Management System
ADR	Automatic Demand Response
AMI	Advanced Metering Infrastructure
AMISP	Advanced Metering Infrastructure Service Provider
AMR	Automatic Meter Reading
APDRP	Accelerated Power Development and Reforms Programme
APFC	Automatic Power Factor Correction
ARR	Annual Revenue Requirement
AT&C	Aggregate Technical and Commercial
CAGR	Compound Annual Growth Rate
CCS	Combined Charging Station
CEA	Central Electricity Authority
CERC	Central Electricity Regulatory Commission
CGS	Central Generating Stations
CRM	Customer Relationship Management
DA	Distribution Automation
DBFOOT	Design Built Finance Own Operate & Transfer
DCU	Data Concentrator Unit
DDUGJY	Deen Dayal Upadhyaya Gram Jyoti Yojana
DEEP	Discovery of Efficient Electricity Price
DER	Distributed Energy Resources
DISCOM	Distribution Company

DMS	Distribution Management System
DPP	Distribution Perspective Plan
DR	Demand Response
DSM	Demand Side Management
DT	Distribution Transformer
EESL	Energy Efficiency Services Limited
EPS	Electric Power Survey
ERP	Enterprise Resource Planning
ESCO	Energy Service Company
EV	Electric Vehicle
EVSE	Electric Vehicle Supply Equipment
FCS	Fast Charging Station
FI	Financial Institution
FPI	Fault Passage Indicator
GIS	Gas Insulated Substation
GPRS	General Packet Radio Service
GPS	Global Positioning System
HT	High Tension
HVDS	High Voltage Distribution System
IED	Intelligent Electronic Device
IPDS	Integrated Power Development Scheme
IT	Information Technology
ICT	Information & Communication Technology
LT	Low Tension
MDMS	Meter Data Management System
MSDE	Ministry of Skill Development Enterprise

MU	Million Unit
MW	Mega Watt
NABL	National Accreditation Board for Testing and Calibration Laboratory
NEF	National Electricity Fund
NSP	Network Service Provider
O&M	Operation and Maintenance
OFC	Optical Fibre Communication
OLTC	ON-Load Tap Changer
OMS	Outage Management System
PCS	Public Charging Stations
PFA	Power For All
PFC	Power Finance Corporation
PLC	Programmable Logic Controller
PMKVY	Pradhan Mantri Kaushal Vikash Yojana
PPP	Private Public Partnership
PSDF	Power System Development Fund
PV	Photo- Voltaic
RAPDRP	Restructured Accelerated Power Development and Reforms Program
RDSS	Revamped Distribution Sector Scheme
REC	Rural Electrification Corporation
RF	Radio Frequency
RMU	Ring Main Unit
RPO	Renewable Purchase Obligation
SAS	Substation Automation System
SAUBHAGYA	Pradhan Mantri Sahaj Bijli Har Ghar Yojana

SCADA	Supervisory Control and Data Acquisition
SERC	State Electricity Regulatory Commission
SLA	Service Level Agreement
SLD	Single Line Diagram
SLDC	State Load Dispatch Centre
SOP	Standard of Performance
T&D	Transmission and Distribution
TBCB	Tariff Based Competitive Bidding
ToD	Time of Day
TOTEX	Total Expenditure (Capex+ Opex)
UT	Union Territory



CENTRAL ELECTRICITY AUTHORITY

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