# GUIDELINES
# FOR
# DISTRIBUTION UTILITIES
# FOR
# DEVELOPMENT OF DISTRIBUTION INFRASTRUCTURE

**(Ver-1)**


**Government of India**

**Ministry of Power**

## CENTRAL ELECTRICITY AUTHORITY

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**Chairperson & Ex-officio Secretary to the Government of India**

## Foreword

Distribution of Electricity is the most crucial area of the power sector and as per Indian Electricity Act 2003, the responsibility of providing quality, reliable and affordable electricity to the consumers is primarily lies with Discoms of the respective States. Central Government supplements the efforts of the States by providing funding to the Discoms through various schemes launched from time to time . With the commencement of various schemes like DDUGJY, IPDS, UDAY and SAUBHAGAYA launched by Govt of India, the work for augmentation/creation of distribution infrastructure including IT/ Metering/ SCADA/GIS etc. are being taken up by the Discoms for electrification of remaining unelectrified households and to introduce reliability, efficiency and transparency in the system. These programmes also include measure related to reduction of AT&C losses and 100% metering of consumers, feeders & DTs etc.

In order to facilitate Discoms for taking appropriate decisions to choose the appropriate technologies for developemnet of their distribution infrastructure such as choosing Transformers of CRGO or Amorphous core type, use of overhead lines with bare conductors or underground (U/G) cables or Aerial Bunched Conductor (ABC), choosing the appropiate communication technology for AMI, installation of Distribution Transformers on pole or plinth and use of HVDS etc, CEA has prepared these guidelines under the guidance of Ministry of Power. The guidelines also include the Cost Benefit

Analysis(CBA)/Comparisons of cost of Installations etc. for the benefit of the Discoms.

Although, the development of distribution infrastructure is generally depend on the actual requirement in the field and as per the past practices of Discoms, the present Guidelines would provide an informed choice for the Discoms so as to make the system more robust and economical.

These Guidelines have been prepared by Distribution Planning & Technology and Distribution Monitoring divisions of CEA and would be updated regularly to include the new technologies. I hope that these guidelines would serve as a guiding tool for all the distribution utilities for developing an efficient & economical distribution infrastructure in the country.

14/06/18

(रविन्द्र कुमार वर्मा)

# ACKNOWLEDGEMENT

In order to facilitate Discoms to take the appropriate decisions to choose the appropriate technology for developement of thier distribution infrastructure, these Guidelines have been prepared by Central Electricity Authority under guidance of Ministry of Power.

These guidelines have been prepared after active consultations with various Discoms in the country and also suitably got updated with the inputs from Discoms & power departments. In preparing these guidelines, the assistance and inputs provided by the various Discoms/Power Departments mainly TPDDL Delhi, BRPL & BYPL, Delhi, Tata Power Mumbai, DGVCL Gujarat, DHVBNL Hayrana, MPPVNNL Jabalpur , BESCOM Karnataka & CESC Kolkata are well appreciated and acknowledged with thanks.

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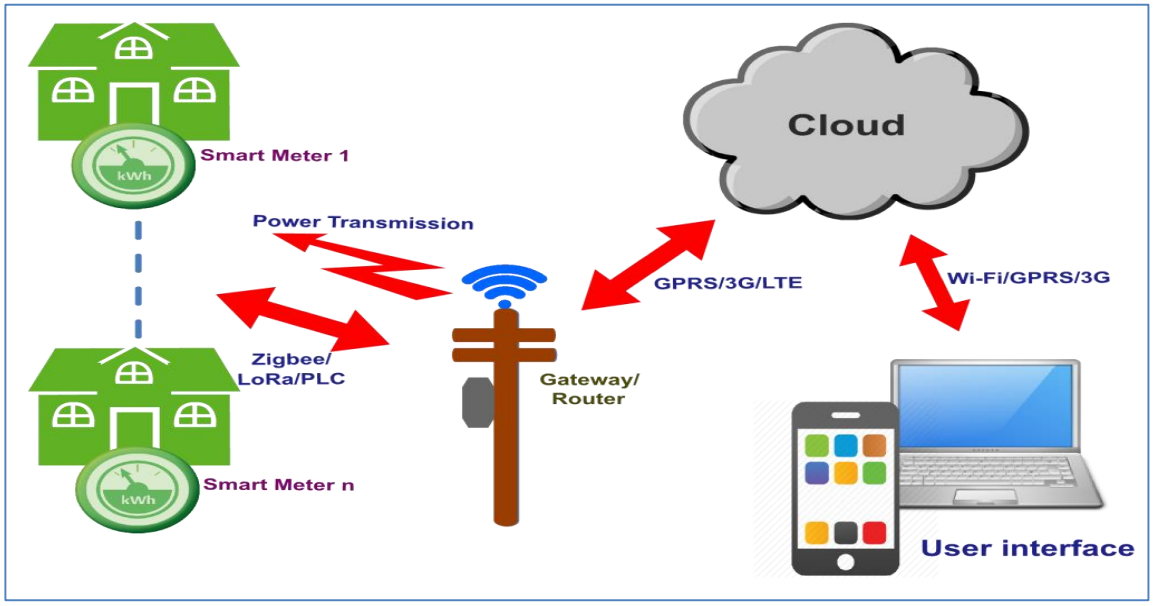
# USAGE OF PROPER

# COMMUNICATION SYSTEM

# IN

# ADVANCED METERING INFRASTRUCTURE (AMI)



1. **REQUIREMENT OF ADVANCED METERING INFRASTRUCTURE (AMI):** The following are the essential parts of Smart Metering/AMI -

- Smart Meters -Single Phase & Three Phase whole current smart meters shall comply with the Technical Specifications (As per IS 16444)
- Communication infrastructure – RF/PLC/Cellular or combination of these
- Head End System(HES)
- Meter Data Management System (MDMS)

Along with, the following are also essential for consumer empowerment and consumer participation in management of load-

- Web application with updated on-line data of consumers etc.
- Mobile App through which consumer shall be able to see information related to his energy consumption. App shall also provide platform for implementation of peak load management functionality by providing existing tariff & incentives rates, participation options etc.

The success of smart metering depends upon strong and reliable communication technology. In communication technology, there are various medium available to choose like PLC/RF/GPRS etc. These all have their own distinct advantages and disadvantages based on the area to be covered and the network back bone available in the area.

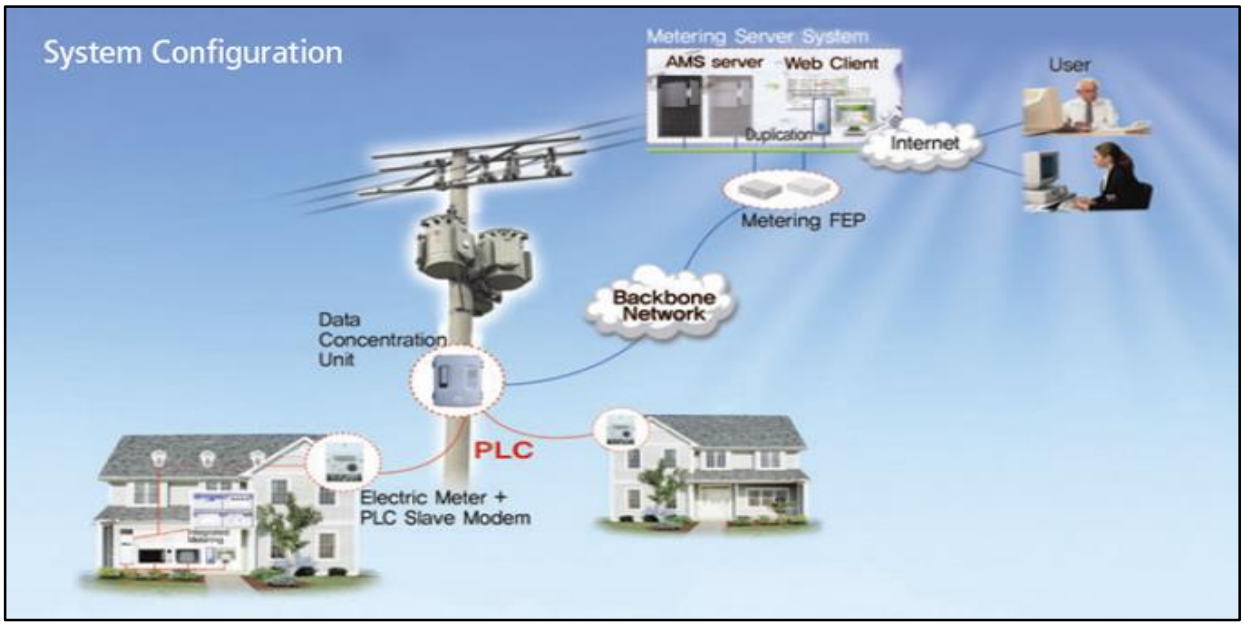
2. **POWER-LINE COMMUNICATION** (**PLC**) is a communication technology that uses electrical wiring to simultaneously transmit both data and electric power without any interference as both are at different frequency. The PLC system is very old and reliable communication medium as compared to all other mediums. In the PLC communication, the network should be rugged, confined and parameter like phasing etc. are taken care since beginning of network laid. Some of the limitation of this technology are:

- Slower data transfer
- Interruption on operation of switches, disconnections in Electrical system
- Distortion of signals during passing through power transformers, inductors etc

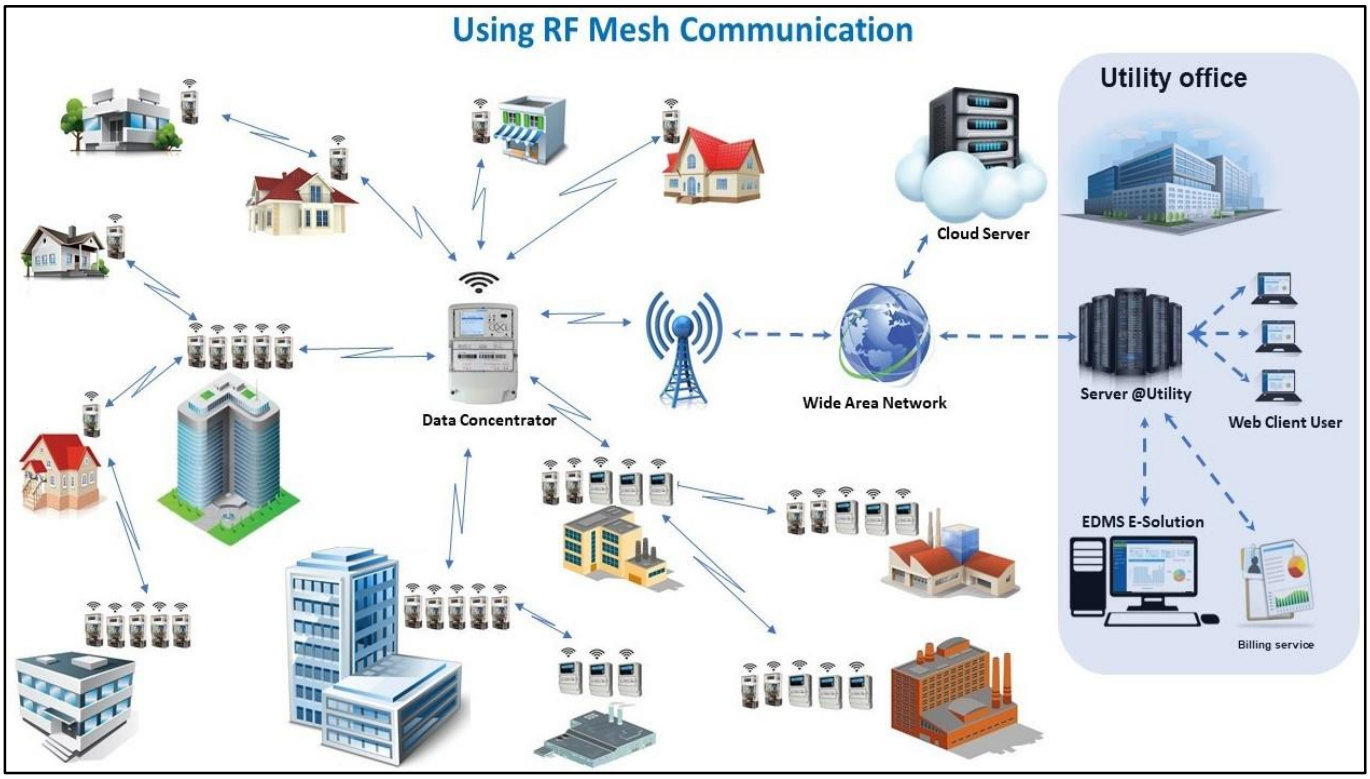
Power-line carrier communication (PLCC) is currently being effectively used for telecommunication, tele-protection and tele-monitoring between electrical substations through EHV power lines and proved to be best low cost communication media but the use of PLC through LT distribution lines from consumer meter up to the DCU would depend upon the conditions of the distribution lines . For effective PLC communication in AMI, the distribution system should not have any loose joint or connections etc, as it may impede flow of data through the distribution lines.

However, depending up on the network strength and site feasibility, PLC may be used in the smart metering of apartments and colonies where the system is robust and data can be

collected at a central server through PLC communication. IPv6, G3-PLC and PRIME are widely used protocols to enable large scale PLC communication on the electrical grid.




**3.** **RADIO FREQUENCY (RF)** is the communication technology, in which frequencies lies in the range extending from around 20 kHz to 300 GHz. Typically, these are used in radio communications. This is also called as wireless communication as compared to wired connection between point of communication in PLC or PLCC.



In RF, higher is the frequency lower is the bandwidth available and thus reducing the range of communication. The distance over which radio communications can be used depends on various factors like wavelength, transmitter power, receiver quality, type, size, and height of antenna, mode of transmission, noise, and pressure of interfering signals, line of Sight etc.

As the allocation of special spectrum for the DISCOMs for meter data transfer usages is a lengthy process and involve the recurring cost, it may not be cost effective for project and would be advisable to consider the use of license free ISM band for use of RF communication.

In India, following are the free band as notified by department of the telecommunication.

a. Frequency Band: 865-867 MHz – Use: Low power RFID equipment or any other low power wireless devices or equipment
   - Power: Maximum transmitter output power of 1 Watt (4 Watts Effective Radiated Power)
   - Carrier Bandwidth: 200 KHz,
   - Reference: GSR 564 (E) dated 30 July 2008

b. Frequency Band: 2.4-2.4835 GHz, Use : Low power equipment
   - Power: Maximum transmitter output power of 1 Watt (4 Watts Effective Radiated Power)
   - Carrier Bandwidth: spectrum spread of 10 MHz or higher,
   - Reference: GSR 45E dated 28.1.2005

c. Frequency Band: 5.825 to 5.875 GHz, Use : Low power equipment
   - Power: maximum transmitter output power of 1 Watt (4 Watts Effective Radiated Power)
   - Carrier Bandwidth: spectrum spread of 10 MHz or higher
   - Reference: GSR no 38E dated 19.1.2007

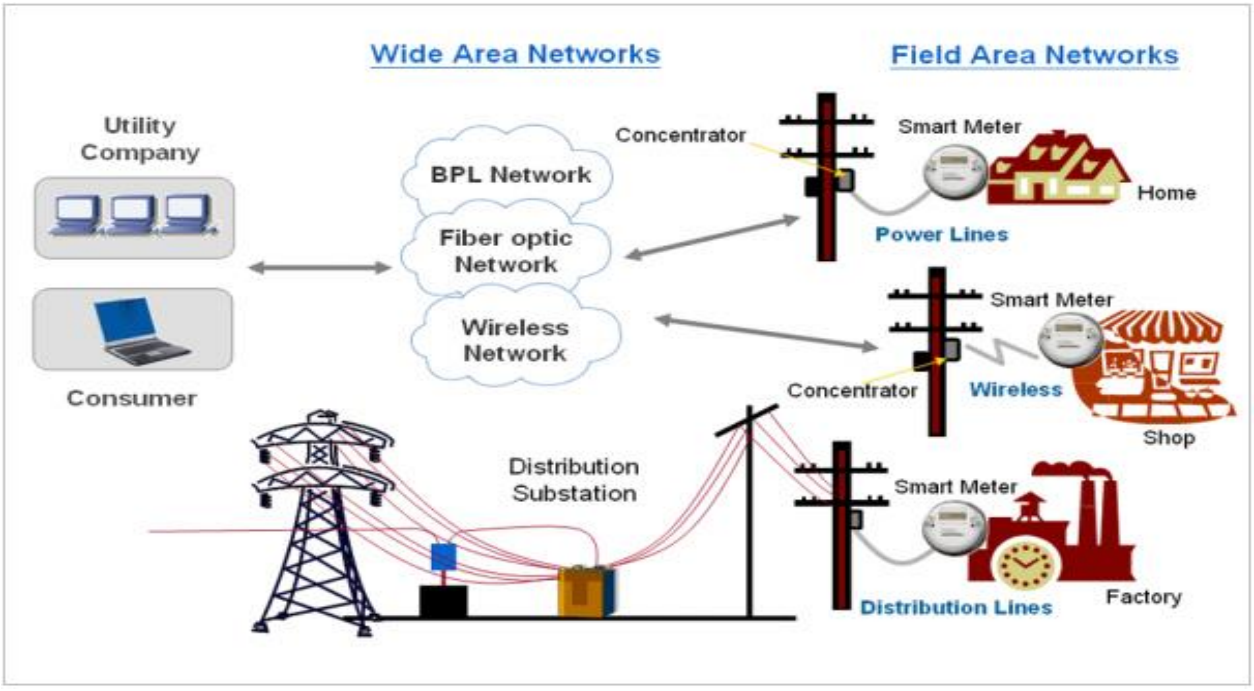
The best part of this technology is that the data transmission range can be increased by hopping of the signal over the modems/ frequencies to reach the target destination. For effective hopping of the signal, the overlapping of the range of each radio frequency is very important and should be considered while designing a network RF canopy.

With the use of this technology, there is an advantage that there is no running cost for using this technology and hence it turns out to be economical for utilities in long run. Only one-time canopy installation cost is the main cost which can be recovered in few years of operation.

There is one challenge in RF due to reduction in range when line of sight of modem/radio is not clear as the signals does not penetrate through concrete structures. To mitigate this, the use of repeaters and high gains antennas need to be installed according to the network

topology and geological positioning of modems. As such this technology may not be suitable for hilly terrains. Additionally, there is also an interoperability issue as the smart meter would be designed based on the NIC card/ RF card of only one company which would provide the communication medium from smart meter to MDM. However, now-a-days, a plug and play type configuration of smart meters are available from where the NIC card of one company may be removed and another may be put up in case of change of communication provider.

This technology can be used in smart meters with proper management of the RF canopy communication back bone in any confined area like city or townships etc. The use of this technology ensures lower costing hence lower impact on tariff of consumers in long run.




**4. CELLULAR NETWORK - 3G/4G TECHNOLOGY:** This is fast changing wireless mobile telecommunications technology as this has been evolved every around 5-10 year interval form 1G,2G with GPRS to 3G and latest 4G. From 2G GPRS to 3G& 4G, the mobile technology has developed to handle more & more voice and data on the same network with good speed.

As this wireless network has expanded upto many small towns/villages, this technology may be used widely in remote area also. Many countries have used 3G technology in smart metering successfully transferring data to central servers of utility.

This is best suitable technology to use the wide spread existing network of mobile operator for handling data. With use of this technology, the utilities are relived from the maintenance of communication network but they have to bear the monthly rentals/ data charges for using the network of Mobile service provider. This technology provides data at faster speed and found very beneficial in many cities where competition between service providers ensures lower cost along with good network reach, however, there may be data delay/data loss in the remote areas/ villages where the network strength is poor.

This is having a disadvantage that there is running cost involved for each meter and in long run and for large area coverage, the cost turns out to be significant part of operating cost. Also, there may be many dark patches where we don't get good network coverage many times so collecting data from meters installed in those areas shall pose a challenge in remote villages.

This will have big challenge of obsolesce of the technology in long run ( as from 3G to 4 G and from 4G to 5 G etc) hence the maintenance of communication modems and chips along with rental charges may increase the OPEX budget of utilities.

## 5. COMPARISON OF VARIOUS COMMUNICATION TECHNOLOGIES

In comparison of the PLC and RF, the initial investment cost for implementation of PLC at micro level is higher than laying the RF network as more number of collectors are required compared to RF. Also the biggest advantage of RF over other media is self-healing nature of RF hence more reliable. Sometime PLC communication may be affected by interference/noise in some cases.

Once the RF canopy is developed then all the other smart equipment can also be communicated over the same canopy hence there shall be leap in automation in micro level and better monitoring of the network and effective implementation of Smart Grid.

A comparative study of RF, PLCC and GPRS is given as below to enunciate the needs:

| Functionality Description | Fully owned RF Based AMI | Third party owned GSM/GPRS based AMI | PLCC based AMI |
|---|---|---|---|
| Quality of Service | ↑ | ↑ | ↑ |
| Latency | ↑ | ↓ | ↓ |
| Total Cost of Ownership over 10 years | ↓ | ↑ | ↓ |
| Initial Cost of Investment | ↑ | ↓ | ↑ |
| Independent Infrastructure Augmentation | ☑ | ☒ | ☒ |
| Auto-discovery and self-healing | ☑ | ☒ | ☒ |
| Independent Troubleshooting | ☑ | ☒ | ☑ |
| Communication success rate | ↑ | ↓↑ | ↑ |
| Dependency on network provider | ↓ | ↑ | ↓ |
| Additional network IED inclusion without any network augmentation | ☑ | ☒ | ☒ |

| | | | |
|---|---|---|---|
| Power Consumption | ⬇ | ⬆ | ⬆ |
| Maintenance cost | ⬇ | ⬇ | ⬆ |

## 6. RECOMMENDATIONS / SUGGESTIONS

Depending on the utility road map for implementation of Smart Metering and Smart Grid implementation, the utilities needs to choose the appropriate communication technologies keeping in view the geographical conditions of the area, long term benefits & minimal total owning cost in long run etc. However, the ideal solution for choosing appropriate communication for successful implementation of AMI may be the mix of all the technologies based on the geographical and network conditions in a particular area.

# GUIDELINES FOR

# USAGE

# OF

# AIR INSULATED SUBSTATION (AIS)

# OR

# GAS INSULATED SUBSTATION(GIS)

# 1. Introduction

Substations are an important part of the electrical distributions. They transform the voltage from high to low level, and provide the ties, transformation, switching and protection of the distribution systems. A typical distribution substation houses transformer, bus-bar, conductor, breaker, isolator, protection devices etc. Type of insulation medium used in sub-station is a major factor in determining the size of a sub-stations. The following sections will deliberate on various types of distributions sub-stations used in the country and their advantages and disadvantages and factors to be considered before going for a typical type of sub-stations.

## 1.1 Air Insulated Substations (AIS)

The conventional Substations use air for insulation between various live parts and ground in the substations and mostly are being used in power sector. These substations require more space than Gas insulated Substations.

## 1.2 Gas Insulated Substations (GIS)

Gas Insulated Substations (GIS) are different from Air Insulated Substations as all the substation equipment such as bus bars, circuit breakers, current transformer, potential transformers and other substation equipment are placed inside the modules filled with SF6 gas. SF6 gas having high dielectric property acts as insulating medium between the live parts and

ground. Generally, Gas Insulted Substations (GIS) are indoor type and it requires substantially less space compared to the conventional air-insulated substations.

## 1.3 Hybrid Switchgear

The Hybrid switchgear is a mix of AIS and GIS technology and can be installed indoor as well as outdoor. Outdoor installation is preferred because of the saving in civil works of building. Following are the features of Hybrid Switchgear:

- Represents a complete bay
- Approx. 30% Less Switch Yard Area
- Approx. 9 No. Lesser Foundations per bay
- Quick installation
- Plug and Play Unit
- Dry Type Ring CTs. Less damage in case of CT burst event.

2. **AIS Vs GIS Vs Hybrid Technology:** The following table shows the comparative analysis between AIS, GIS and Hybrid based on various parameters:

| S.No | Parameters | AIS | GIS | Hybrid |
|---|---|---|---|---|
| a | Land /Space Required<br>2x10 MVA S/S<br><br>3x25 MVA S/S | ~3500 Sq. M.<br>(70x50 sq. M.)<br><br>~ 6800 sq m<br>(80x85 sq m) | ~ 1600 sq. M.<br>(40x40 sq. M.)<br><br>~ 2400 sqm<br>(60x40 sq m) | ~ 2500 sq. M.<br>(50x50 sq. M.)<br><br>~4200 sq m<br>(60x70 sq m) |
| b | Features | • All Bay Equipment installed in Outdoor Area<br>• Individual Equipment are connected with Jumpers having minimum clearances and offering higher contact Resistance | • Indoor Type Panels<br>• Unitise system with all equipment housed in single unit | • Outdoor Type Equipment<br>• Unitised system with all bay equipment housed in single unit |
| c | Strength / Weakness | • Outdoor Yard involved<br>• Larger Space required<br>• Less Cost<br>• Regular Maintenance<br>• Higher losses<br>• Higher Maintenance Cost<br>• Personnel Safety is less<br>• Low Reliability (prone to breakdowns) | • GIS Building to be constructed<br>• Smaller Space for substation<br>• High Cost<br>• Low Maintenance Required<br>• Low losses<br>• High Reliability<br>• More Safety for Personnel<br>• High cost of spares<br>• More downtime<br>• Dependency on same contractor for bay extension | • GIS Building need not to be constructed<br>• lesser Space for substation compared to AIS, but 50% more than that in GIS<br>• Moderate Cost<br>• Easy addition of bays(Flexibility)<br>• Low Maintenance<br>• Low losses<br>• Moderate reliability<br>• Safety of operating personnel<br>• High cost of spares |
| d | Capital Cost Comparison (without cost of land ) | Let us assume it X | 1.5 X | 1.2X |
| e | Maintenance Cost | Moderate | Less | Moderate |

Note: Cost may vary depending upon substation installed capacity, bus bar configuration (Single bus, Double bus, One-an-half breaker etc.) , current rating and land cost in a particular city/ town.

## 3. Economics – Life cycle cost (LCC) comparison

The initial capital investment is more in GIS as compare to AIS / Hybrid but due to less maintenance cost over the years, the overall higher initial cost can be recovered in subsequent years through savings in maintenance cost of GIS S/S. However, after considering the less requirement of land cost, the difference in initial capital cost of GIS and AIS is very less now a days. Also, for evaluation of overall substation project cost, the **Life Cycle Cost (LCC)** should be considered, including primary hardware cost, maintenance cost, operation cost, outage cost and disposal costs etc.

The LCC comparison of AIS and GIS is as follows:

### 3.1 Primary hardware

Primary hardware for primary equipment, **GIS is more expensive than AIS**. However, the price of land and auxiliary equipment such as support, conductors, land, installation, control, protection and monitoring can lead to small cost difference between the two systems.



### 3.2 Maintenance

The failure rate of circuit breaker and disconnecting switch in GIS is **one-fourth of that of AIS and one tenth in case of busbar**, thus the maintenance cost of GIS is less than that of AIS over the lifetime.

### 3.3 Operation cost

The operational cost of GIS and AIS is **same**. The cost for training personnel engaged in GIS Operation is higher than in AIS.

### 3.4 Outage cost

The failure rate of GIS is lower, **resulting in less outage cost compared to AIS**.

### 3.5 Disposal cost

The cost of decommissioning and disposal after use should be capitalized. The value of future expenses must be taken into account.

### 3.6 Typical LCC evaluation of AIS and GI

| Life Cycle Cost | Air insulated substation (AIS) | Hybrid substation | Gas insulated substation (GIS) |
|---|---|---|---|
| **Planning and Engineering** | 100% | 90% | 80% |
| **Real estate** | 100% | 60% | 40% |
| **Primary equipment** | 100% | 110% | 120% |
| **Secondary equipment** | 100% | 100% | 100% |
| **Earthwork, civil work, structures** | 100% | 90% | 60% |
| **Electrical assembly and erection** | 100% | 80% | 70% |
| **Maintenance** | 100% | 70% | 50% |
| **Outage** | 100% | 70% | 50% |
| **LCC after 10 years** | **100%** | **Max 80%** | **Max 70%** |

### 3.7 Safety

As the enclosures of GIS are at earth potential there is no possibility of accidental contact by service personnel to live parts. In conventional open terminal AIS, personnel have to be doubly sure before taking maintenance tools, ladders, vehicles etc.

### 3.8 Environmental impact

The latest GIS technology has less environmental impact than previous technology. **The SF6 leakage rate is less than 1% (in experiment <0.5%).** Due the design characteristics, GIS has a better impact on environment than AIS. All current breaking parts of switchgear of GIS are contained in the metal enclosure, resulting in an extreme reduction in corona noise level.

## 4. Decision Matrix

The following matrix has been prepared based on the above discussion on various parameters of analysis:

| S. No. | Parameters | AIS | GIS | Hybrid |
|---|---|---|---|---|
| 1 | Land Requirement | High ↑ | Low ↓ | Moderate ↔ |
| 2 | Initial Cost | Low ↓ | High ↑ | Moderate ↔ |
| 3 | Civil Cost | Low ↓ | High ↑ | Low ↓ |
| 4 | Flexibility | High ↑ | Low ↓ | High ↑ |
| 5 | Safety | Low ↓ | High ↑ | Moderate ↔ |
| 6 | Reliability | Low ↓ | High ↑ | Moderate ↔ |
| 7 | Maintenance Cost | High ↑ | Low ↓ | Moderate ↔ |
| 8 | Maintenance Periodicity | High ↑ | Low ↓ | Moderate ↔ |
| 9 | Maintenance Hours/year | High ↑ | Low ↓ | Moderate ↔ |
| 10 | Breakdown Restoration Time | Low ↓ | High ↑ | Low ↓ |
| 11 | Losses | High ↑ | Low ↓ | Moderate ↔ |

## 5. Analysis /Observations

- GIS is an advanced technology, needs lesser space (35%), lower maintenance costs and outages compared to AIS.
- Initial cost of GIS is higher by about 50% than AIS but when the cost of land is considered in capital cost, the overall capital cost is comparable.
- Wherever land is a constraint, GIS is the only option.
- Hybrid Technology that is a mix of AIS & GIS combines the benefits of both AIS and GIS (Initial capital cost -20% higher than AIS)
- Hybrid technology requires moderate land size (50% of AIS and 50% higher than GIS).
- Flexibility in term of future expansion in Hybrid technology is high (similar to AIS).

## 6. Recommendation:

- Wherever land is a constraint, GIS technology should be adopted. It would also provide more safety and reliability. Keeping in view the space constraint and higher cost of land in big cities/ towns, GIS should be preferred.

- The future expansion of existing AIS substations may be done with hybrid technology keeping in view the less space requirement.

- Wherever sufficient land is available, AIS substations may still be preferred due to low upfront cost. Hybrid Technology may also be used, wherever we want to optimize in terms of space & cost and may be most useful in extension of existing substations.

# GUIDELINES

# FOR

# USAGE OF

# POLE MOUNTED

# OR

# PAD/PLINTH MOUNTED

# DISTRIBUTION TRANSFORMER SUSBTATONS

# 1. Introduction

Nowadays, finding a suitable and convenient location for installation of Distribution Transformer (DT) substation or Grid substation is one of the challenge being faced by DISCOMs. The problem is severe in Urban areas and therefore, DISCOMs/power departments need to plan for a suitable location for installation of appropriate capacity of DT Substation considering the load in the area, load center, feasibility and further expansion etc.

The Distribution Transformer may be mounted on a single pole, H pole structure or on a plinth depending upon site requirements, size and weight of the transformer. Accordingly, the decision for installation of a Pole mounted DT substation or Pad/Plinth mounted DT substation is to be taken by DISCOMs based on the capacity of the DT and availability of space.

As per CEA (Technical Standards for Construction of Electrical Plants and Electric Lines) Regulations, the mounting of distribution transformers shall be as per relevant Indian Standards IS 1180. As per provisions of IS 1180, transformers upto 500 KVA capacity may be mounted on the poles. Based on this, DTs above 500 KVA have necessarily to be mounted on a plinth and DTs of capacity less than 500 KVA may be mounted on single pole, double pole, 4 pole or on a pad/plinth based on the size of DT, space available and practices being followed in the DISCOMs etc.

These two type of mounting of DT substation are discussed as below:

## 2. Pole mounted Distribution Transformer substation (DT S/S)

It is the most common type of outdoor type substation, designed by DISCOMs/power department conveniently at load centers. Normally, single phase DT upto 25 KVA capacities are installed on single pole/2 pole structure and 3 Phase DTs up to 500 KVA capacities are mounted on 2 pole (H- pole) or 4 pole structure or on plinth. The two poles structure is made of poles with channels and associated accessories creating a H type pole configuration to locate the DT at certain minimum height from the ground level to meet the ground clearance. This arrangement of pole type S/S needs about 3 meters by 2 meters space (on ground) around the H Pole structure to locate Distribution box and other accessibility. This area also to be provided with suitable fencing and lockable doors to prevent unauthorized access to Distribution box. The structures should also be provided with anti-climbing devices and danger board.

In case of single phase transformers upto 25KVA capacity, the transformers can normally be installed on single pole or on H pole structure at appropriate height from the ground on the roadside which is easily accessible. These single phase transformers do not require distribution boxes as it directly feed to a group of consumers and no additional ground space is required.

| Figure-1(a) Single phase Pole Mounted DT substation | Figure-1(b)Three phase-Pole Mounted DT substation (Hole) |
|---|---|

## 3. Pad /Plinth mounted DT Substations

As per IS 1180, DTs above 500 KVA have necessarily to be mounted on a plinth. However, lower capacity DTs may also be mounted on plinth as per the practices being followed in DISCOMs.

The Pad, which is a low height platform/plinth, normally made of concrete structure. It can also be prefabricated by fiber blocks on which the transformers can be mounted. However, the strength of the fiber block has to be ensured by the DISCOMs before installation. The Pad should be capable to carry the weight of the DT and should also have the facility for cable entry and exit at two sides as per the terminals available at the Transformers.

The plinth shall be higher than the surroundings and plinth foundation is normally made of concrete. Plinth mounted distribution sub-stations should be adequately protected by fencing so as to prevent access to the equipment by unauthorized persons, animals and should be provided with standard danger boards. The enclosure should also permit free circulation of air on all sides

This type of DT substations is best suitable for higher load center areas, where adequate land is available such as in urban areas, housing complex, office complex and other developed areas.

This substation can be indoor type or outdoor type and the rating of Transformer may normally be more than 250KVA to 1000KVA depending on load requirement in the localities and also for economic reasons as this needs control gears/ switchgears and proper enclosed wall boundary.

The height of Pad/plinth should be designed by considering the factors such flood level & topography of the locality etc and should be adequately protected by fencing so as to prevent access by any unauthorized persons.

Depending upon the distribution system available in the area, the provisions for entry of cables or for connection with overhead systems at DT primary and the exit from secondary side with underground arrangement for laying the LT lines upto consumer premises is made accordingly.

Plinth Mounted Distribution Transformer Sub-stations

**Case Study – Tata Power Delhi**

- **Usage of Elevated Platform for installation of Higher Capacity Transformers**

In plinth mounted substation, transformer up to 1000 KVA can also be installed at an elevated platform at suitable height considering the minimum ground clearance. However, structure shall be capable to withstand the load of transformer. The associated electrical equipment's like LT & HT switchgear can be installed below the transformer. The lower part of substation shall be covered with fencing for public safety and shall be provided with danger plates.

**Elevated Platform Installation**

- **Use of Lifted Plinth Column**

The transformers up to 500kVA can also be mounted on lifted plinths columns ( I Shaped column) as shown below. The associated electrical equipment like LT & HT switchgear can be installed below the transformer.

The Distribution Utilities may choose the suitable mounting structure for mounting of the distribution transformers keeping in view the safety, site conditions , capacity of the transformers and past practices of the utilities etc.

# GUIDELINES

# FOR

# USAGE OF

# HIGH VOLTAGE DISTRIBUTION SYSTEM VS

# LOW VOLTAGE DISTRIBUTION SYSTEM

## 1. LOW VOLTAGE DISTRIBUTION SYSTEM (LVDS) SYSTEM

For supplying the power to the consumers, it is generally a practice of Distribution company (Discom) to lay 11KV lines from 33/11KV Substation, erect a 3phase 11kv/0.415 KV Distribution Transformer (DT) substation at one convenient location, and then lay long LT lines up to the nearest load center to give connections to the consumers /households.

In this case, DTs of various capacities, depending on load requirement are installed to supply the power to one or more than one consumers. If loads of consumers are less, then even more consumers would be supplied from one DT.

**Disadvantages with LVDS**

i. Poor tail end voltages/poor voltage regulation.
ii. High technical losses due to more line losses in longer LT lines.
iii. More scope of power theft due to accessibility of bare LT lines
iv. Frequent jumper cuts and fuse blow outs at DT level due to over loading etc.
v. Fault in a single high capacity DT like in LVDS affects the entire consumers connected to it, and this causes a total outage, poor availability and reliability of power supply to the consumers in the area.
vi. Difficulty to augment the DT capacity (in case the existing DT is overloaded) due to non-availability of space (for DT beyond 200KVA capacity). To accommodate bigger size DTs, changes would be required in DT mounting structure or DT to be installed on Plinth structure.
vii. To avoid the pilferage of electrical energy due to theft by hooking/ tapping the LT lines, conversion of longer LT overhead lines with bare conductors to Aerial Bunched Cables (ABC) through overhead or underground system is more expensive.

High Voltage Distribution System(HVDS), as discussed below, is one of the techniques to overcome above disadvantages.

## 2. HIGH VOLTAGE DISTRIBUTION SYSTEM(HVDS)

To improve quality (Voltage profile) of electric supply and reduce losses in the system, HVDS can be used by the Discoms as an alternate to LVDS, in which 11 KV lines are extended upto or as nearer to the load center as possible, and small size transformers ranging from 10KVA to 100KVA etc, depending on load requirement can be installed to supply power to consumers.

To avoid the pilferage of electrical energy due to theft by hooking the LT lines, LT line with insulated wires like Aerial Bunched Cables (ABC) can be installed

through overhead or undergone system. This system requires more DTs, its associated accessories, more HT lines and less LT lines than LVDS system.

**Advantages of HVDS:**

i. Low technical losses due to reduction of LT lines
ii. Loss due to theft/tapping can be reduced /eliminated in smaller length of LT lines & by use of ABC conductors with less expenses.
iii. Improved voltage regulation at consumer end due to low voltage drop resulting from less loading and shorter line length.
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. Ease of augmentation of DT capacity in case of increase of load.
vii. Help in reducing the demand in distribution, transmission and generating system when used in large scale by Discoms.

**Disadvantages of HVDS:**

i. More Capital expenditure and more O&M Expenditure due to large numbers of DTs and its related accessories.
ii. More requirement of associated accessories and stocks need to be maintained.
iii. HVDS will contribute more for increase in system fault level, and therefore, there will be a need to upgrade short circuit level of equipment, protection system and re-coordination of the settings in the protection system after certain time period.

As with all systems, there exists pros and cons in HVDS also. Therefore, the selection of the HVDS over LVDS should be based on Cost-Benefit Analysis arrived at by comparing two systems under similar conditions for entire useful life.

## 3. COST BENEFIT ANALYSIS

In order to carry out the Cost-Benefit Analysis of LVDS and HVDS, a simple LVDS network and converted HVDS network configuration as given in Exhibit-1 has been considered. In order to compare with LVDS system, two configurations of HVDS have been considered. The first configuration of HVDS system comprises of 11 kV HT bare overhead line and 415 V bare LT line, while the second configuration comprises of 11 kV HT bare overhead line and 415 V ABC cable. The second configuration will also reduce any possibility of theft at LT lines. For computation purposes, it is assumed that second configuration will also reduce energy loss by additional 5%. Other assumptions are as under:

**Assumptions:**

1. Load in the area, has been maintained same on both the systems, except in the HVDS with ABC in LT Lines, reduced load has been considered to the extent of the theft existing in LVDS (considered at 5% of load).
2. Similar Star rated transformers in both the system have been considered
3. Uniform 3-phase system for LT side and HT side, and same conductor have been considered.
4. Average Unit Rate of Electricity has been considered at Rs 4.5 /Unit (for calculation system loss to equivalent Rs loss for Payback period.)
5. Load Factor of 0.6 has been considered to arrive at energy loss
6. Cost Estimates:
   a) 11 kV OH line (with Bare conductor) = 4.5 lacs/km (3-phase, 3-wire)
   b) LT OH line (with Bare conductor) = 3.5 lacs/km (3-phase, 4-wire)
   c) LT OH line (with ABC conductor) = 8.0 lacs/km (3-phase, 4-wire)
   d) Cost of installation of DTs and related parameters

| Rating (KVA) | Max. Losses at 50% loading (Watts) | Max. Losses at 100% loading (Watts) | Cost of Dist S/S along with installation & panels etc (in Lac) |
|---|---|---|---|
| 12.5 | 120 | 375 | 1.35 |
| 25 | 175 | 480 | 1.57 |
| 50 | 360 | 550 | 2.15 |
| 63 | 400 | 580 | 2.50 |
| 100 | 520 | 1800 | 3.00 |
| 250 | 1117 | 3688 | 6.50 |

**Findings**:
Based on above network configuration and assumptions, the comparison of LVDS and HVDS system are as under:

**a) Network Components**

| **Items** | **LVDS System** | **HVDS System** |
|---|---|---|
| No. of DTs | 1 | 8 |
| Capacity of DTs, KVA, each | 250 | 2x50+6x25 |
| Capacity of DTs, KVA, aggregate | 250 | 250 |
| Length of HT line, kms | 0.5 | 3.0 |
| Length of LT line, kms | 3.5 | 1.5 |

**b) System Loss and Cost:**

| Sl No | LVDS | HVDS (with bare LT line) | HVDS (with ABC in LT line) |
|---|---|---|---|
| Loss (in Wattage) | 31367 | 6458 | 5860 ( considering extra saving of 5% due to theft) |
| Annual Loss (in unit) | 164865 | 33889 | 30800 |
| Annual Loss (Rs in Lac) | 7.42 | 1.52 | 1.39 |

**c) System Cost**

| | LVDS | HVDS (with bare LT line) | HVDS (with ABC in LT line) |
|---|---|---|---|
| System Cost (Rs in Lac) | 21.00 | 32.47 | 39.22 |
| O&M cost per year | 0.42 | 0.65 | 0.78 |

**d) Comparison of HVDS system with LVDS system**

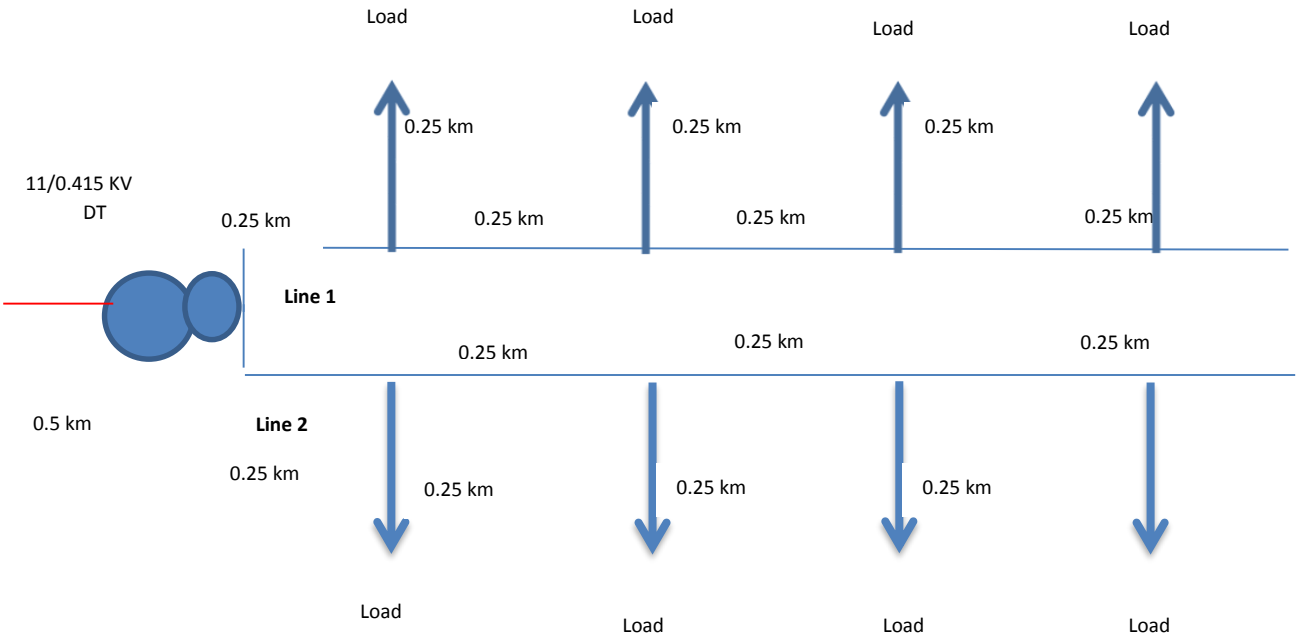
| Items | HVDS (with bare LT line) | HVDS (with ABC in LT line) |
|---|---|---|
| Additional system cost (Rs in Lac) | 11.47 | 18.22 |
| Additional O&M Cost (Rs in Lac) | 0.23 | 0.36 |
| Annual Energy Saving (Rs in lac) | 5.89 | 6.03 |
| Payback period (years) | 2.02 | 3.21 |

## 4. CONCLUSION:

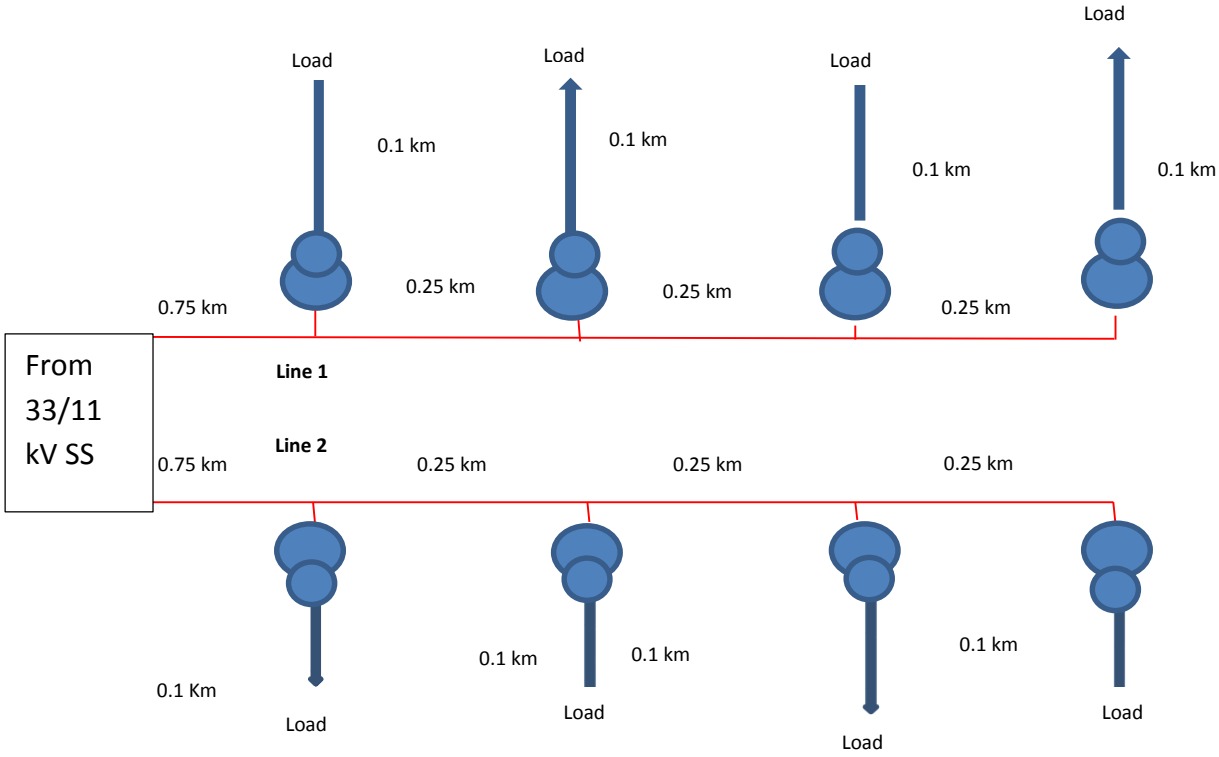
From the above analysis presented above, it can be concluded that if a system with higher loads in LVDS is replaced by HVDS (with ABC or bare conductor in LT system), then, not only the cost of investment is recovered in very short span of time, but it would also help in improving the consumer satisfaction on account of reliable power supply and stable voltage profile available in the feeder.

# Network Configuration of LVDS and HVDS

## LVDS




## HVDS



# GUIDELINES

# FOR

# USAGE

# OF

# AMORPHOUS CORE

# OR

# CRGO CORE

# DISTRIBUTION TRANSFORMERS

## INTRODUCTION:

Distribution transformers (DTs) constitute one of the largest group of equipment in the electrical network and therefore losses in the Distribution Transformers constitute the major amount of total losses in the network. The most efficient distribution transformers, which are in service continuously record a loss of approximately 2 to 4% of the electricity they conduct, and electric utilities and industries are constantly striving for methods and technologies to reduce transformer losses.

Distribution transformers carry a load, which varies from time to time during the day & night but generally capacity of these Transformers are adequate to cater for the maximum load during the day. However, often the average load on DT is far less than the peak load which occur only for few hours in a day. Keeping in view the average loading of Distribution Transformer, all day efficiency or efficiency at lighter loads have much more significance for reducing network losses.

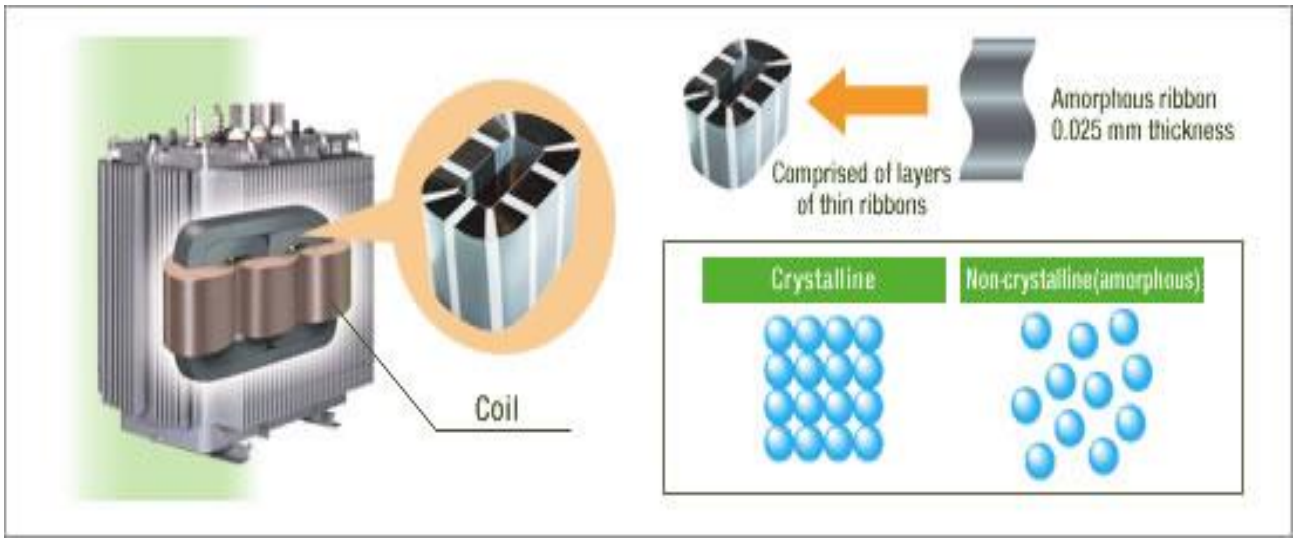
## LOSSES IN DISTRIBUTION TRANSFORMERS:

Losses in a distribution transformer consist of no-load losses, which are independent of the load, and load losses which are dependent on the loading of transformer. A low load factor means that no-load losses can form a high percentage of the total losses in the transformer, and the design of distribution transformers is focused strongly on reducing these no-load losses without compromising the performance of the transformer.

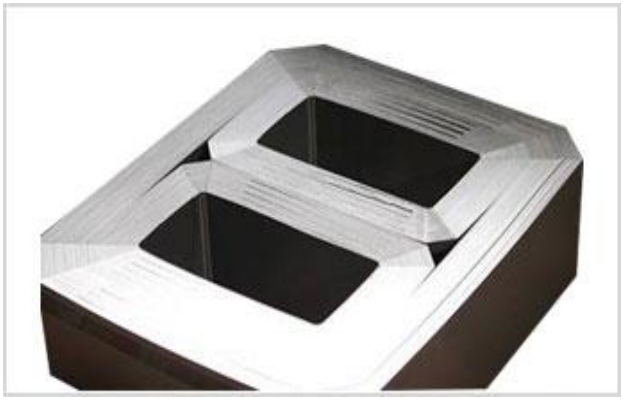
The prime component of losses i.e no-load loss, can be reduced by better design and using core made of superior grades of electrical steels. By using improved grades/ superior grades of CRGO laminations, the no load loss can be reduced significantly. The development of Amorphous Metal Distribution Transformers (AMDT) offers further reduction of core losses of transformers as compared to CRGO core losses.

Amorphous core material (AM) offers both reduced hysteresis loss and eddy current loss because this material has a random grain and magnetic domain structure which results in high permeability giving a narrow hysteresis curve compared to conventional CRGO material. It is observed that the use of second hand and impure CRGO results into higher loss for DTs.

Eddy current losses are reduced by the high resistivity of the amorphous material, and the reduced thickness of the film. The laminations comprise of thin ribbons and the thickness of the sheet is about 1/10th that of the CRGO, i.e. approximately 0.025 to 0.030 mm. Amorphous core transformers offer a 70 to 80% reduction in no-load losses compared to transformers using CRGO core material for the same rating of Distribution Transformers.




**Amorphous Core**



**CRGO Core**

***The typical comparative figures of No load losses of AMDT and CRGO core are given below:***

| Transformer size (kVA) | AMDT (watt) | CRGO DT(watt) | % Loss reduction |
|---|---|---|---|
| 100 | 65 | 145 | 55% |
| 250 | 110 | 300 | 63% |
| 400 | 170 | 430 | 60% |

| Material | Saturation flux density (T) | Electrical resistance (μΩ- cm ) | Iron loss (W/kg) | Thickness (mm) |
|---|---|---|---|---|
| Silicon steel (Crystalline) | 2.03 | 50 | 0.440 | 0.23 |
| Amorphous Alloy (Non-crystal line) | 1.56 | 130 | 0.070 | 0.025 |

**COMPARISON OF CRGO AND AMORPHOUS CORE DTs:**

- AM cores have a lower saturation point- amorphous metal cores saturate at a lower flux density than CRGO, which requires larger coils for the same capacity.

- Due to small thickness and low saturation factor, larger core and consequently larger coils and tank size are required as compared to CRGO core transformers.

- The other significant difference between amorphous core transformers and CRGO transformers is the cross-sectional structure of the core. Because of the difficulty of producing amorphous strips, there are limited production sizes available (typically 213 mm, 170 mm, and 140 mm). Although conventional CRGO transformers can be oval or round in cross-section, amorphous cores may be square or rectangular in shape.

- For a given capacity, the cost of the amorphous core transformer is generally more than CRGO core transformer.

- The AM Core material cannot be re-used in case of burning of the core, while CRGO core can be reused by repairing some of the stamping of the Core.

- From the repair and service point of view, DISCOMs and Power Departments raised apprehension about the repair services of the failed transformers with amorphous core and opined that these transformers are difficult to repair and cost of repair is higher, hence increase in the Opex cost of the DISCOMs and Power Departments. However, recently manufactures of AMDT have clarified the apprehension of DISCOMs and Power Departments, and manufacturers of AMDT have conducted many workshops at various DISCOMs.

- There are observations of utilities that overload handling capacity of the Amorphous core transformers is less and overloading causes more failures of amorphous core transformers than CRGO type. To protect the transformers with amorphous core there is practice of using the overload protective device with these transformers.

**COMPARISON CHART:** The comparison chart of the identical rating transformer with CRGO and amorphous core is as below:-

| Sr. No. | Comparison point | CRGO | Amorphous core |
|---|---|---|---|
| 1 | **Initial cost** | Comparatively Low | Comparatively High |
| 2 | **Maximum losses for particular rating** | As per IS | As per IS |
| 3 | **No load losses** | Higher | Lower |
| 4 | **Efficiency at full load** | More efficient as load losses are less | Less efficient as load losses are more |
| 5 | **Size of transformer** | Less | Slightly more |
| 6 | **Weight of transformer** | Heavy | Lighter in weight |
| 7 | **Repair** | Easily Repairable | Difficult to repair any defect in core |
| 8 | **Repair agency** | Easily available | Limited |
| 9 | **Repair cost** | Low | High |
| 10 | **Overloading capacity** | Can take short interval overloads | Overloading is very detrimental for life of transformers |

**Requirements of Distribution Transformer as per Indian Standard (IS 1180)**

Since long most of DISCOMs and Power Departments are procuring DTs with CRGO core, but after the notification of IS 1180:2014 & the Gazette Notification issued by Ministry of Power from 2014 to 2016, it has become mandatory to procure Transformers which meet the norms of Losses. As per CEA (Technical

Standards for Construction of Electrical Plants and Electric Lines) Amendment Regulation 2015, Distribution Transformer should be as per relevant Indian Standards.

As per the quality control order all the distribution transformers have to comply to the IS 1180 part 1 guidelines and the total losses shall be within the limits of specified in IS 1180 and complying to BE star labeling. The recommended maximum losses as per IS 1180 are as below:

| Sl No. | Rating (kVA) | Impedance (Percent) | Maximum Total Loss (W) | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | Energy Efficiency Level 1 | | Energy Efficiency Level 2 | | Energy Efficiency Level 3 | |
| | | | 50 % Load | 100 % Load | 50 % Load | 100 % Load | 50 % Load | 100 % Load |
| (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) |
| i) | 250 | 4.50 | 1 050 | 3 150 | 980 | 2 930 | 920 | 2 700 |
| ii) | 315 | 4.50 | 1 100 | 3 275 | 1025 | 3 100 | 955 | 2 750 |
| iii) | 400 | 4.50 | 1 300 | 3 875 | 1 225 | 3 450 | 1 150 | 3 330 |
| iv) | 500 | 4.50 | 1 600 | 4 750 | 1 510 | 4 300 | 1 430 | 4 100 |
| v) | 630 | 4.50 | 2 000 | 5 855 | 1 860 | 5 300 | 1 745 | 4 850 |
| vi) | 800 | 5.00 | 2 459 | 7 300 | 2 287 | 6 402 | 2 147 | 5 837 |
| vii) | 1 000 | 5.00 | 3 000 | 9 000 | 2 790 | 7 700 | 2 620 | 7 000 |
| viii) | 1 250 | 5.00 | 3 600 | 10 750 | 3 300 | 9 200 | 3 220 | 8 400 |
| ix) | 1 600 | 6.25 | 4 500 | 13 500 | 4 200 | 11 800 | 3 970 | 11 300 |
| x) | 2 000 | 6.25 | 5 400 | 17 000 | 5 050 | 15 000 | 4 790 | 14 100 |
| xi) | 2 500 | 6.25 | 6 500 | 20 000 | 6 150 | 18 500 | 5 900 | 17 500 |

The Bureau of Energy Efficiency has upgraded the star ratings of DTs in December 2016 (applicable from 1st July 2017) and assigned maximum permissible losses based on loading for each rating are as below:

| Standard Losses in watts up to 11 KV Class | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Rating (kVA) | Star 1 | | Star 2 | | Star 3 | | Star 4 | | Star 5 | |
| | 50 Per cent. Load | 100 Per cent. Load | 50 Per cent. Load | 100 Per cent. Load | 50 Per cent. Load | 100 Per cent. Load | 50 Per cent. Load | 100 Per cent. Load | 50 Per cent. Load | 100 Per cent. Load |
| 16 | 135 | 440 | 120 | 400 | 108 | 364 | 97 | 331 | 87 | 301 |
| 25 | 190 | 635 | 175 | 595 | 158 | 541 | 142 | 493 | 128 | 448 |
| 63 | 340 | 1140 | 300 | 1050 | 270 | 956 | 243 | 870 | 219 | 791 |
| 100 | 475 | 1650 | 435 | 1500 | 392 | 1365 | 352 | 1242 | 317 | 1130 |
| 160 | 670 | 1950 | 570 | 1700 | 513 | 1547 | 462 | 1408 | 416 | 1281 |
| 200 | 780 | 2300 | 670 | 2100 | 603 | 1911 | 543 | 1739 | 488 | 1582 |

| Standard losses in watts up to 11 KV Class (For ratings above 200 kVA) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Rating (kVA) | Per Cent. Impedance | Star 1 | | Star 2 | | Star 3 | | Star 4 | | Star 5 | |
| | | 50 Per Cent. Load | 100 Per Cent. Load | 50 Per Cent. Load | 100 Per Cent. Load | 50 Per Cent. Load | 100 Per Cent. Load | 50 Per Cent. Load | 100 Per Cent. Load | 50 Per Cent. Load | 100 Per Cent. Load |
| 250 | 4.5 | 980 | 2930 | 920 | 2700 | 864 | 2488 | 811 | 2293 | 761 | 2113 |
| 315 | 4.5 | 1025 | 3100 | 955 | 2750 | 890 | 2440 | 829 | 2164 | 772 | 1920 |
| 400 | 4.5 | 1225 | 3450 | 1150 | 3330 | 1080 | 3214 | 1013 | 3102 | 951 | 2994 |
| 500 | 4.5 | 1510 | 4300 | 1430 | 4100 | 1354 | 3909 | 1282 | 3727 | 1215 | 3554 |
| 630 | 4.5 | 1860 | 5300 | 1745 | 4850 | 1637 | 4438 | 1536 | 4061 | 1441 | 3717 |
| 1000 | 5 | 2790 | 7700 | 2620 | 7000 | 2460 | 6364 | 2310 | 5785 | 2170 | 5259 |
| 1250 | 5 | 3300 | 9200 | 3220 | 8400 | 3142 | 7670 | 3066 | 7003 | 2991 | 6394 |
| 1600 | 6.25 | 4200 | 11800 | 3970 | 11300 | 3753 | 10821 | 3547 | 10363 | 3353 | 9924 |
| 2000 | 6.25 | 5050 | 15000 | 4790 | 14100 | 4543 | 13254 | 4309 | 12459 | 4088 | 11711 |
| 2500 | 6.25 | 6150 | 18500 | 5900 | 17500 | 5660 | 16554 | 5430 | 15659 | 5209 | 14813”; |

It may be seen that level–II of IS 1180 :2014 has been made as new Star 1 and level–III of IS 1180 :2014 has been made as new Star 2 by BEE and have introduced new losses for star 3 , 4 & 5. To alien with the BEE notified losses, BIS is in process of amending IS 1180 and the same would be applicable as and when notified by BIS.

All the Distribution Transformers either having CRGO core or Amorphous core have to comply with the total losses ( No load losses + load losses) at 50% and 100% loading given in the IS 1180 and BEE notifications. The load losses of the distribution transformers also play a major role in calculation of total losses at 50% and 100% loading as the winding of DT may be designed by using proper size of Aluminum or Copper winding to meet the total losses criteria keeping in view the no load losses of available core of CRGO or Amorphous.

Also during year 2017-18 in a tender for BIS Level – II for 25 kVA & BIS Level - III for 200 & 315 kVA DTs floated by the MPPKVVCL Jabalpur, it was observed that lowest rate of 25 kVA DTs was with CRGO core material & lowest rate of 200 & 315 kVA DTs was with amorphous material. This shows that cost of CRGO core material is lowest in lower level class and cost of amorphous core material is lowest in higher level.

**SUGGESTIONS:**

- DISCOMs should give equal opportunity to both type of Distribution Transformers i.e AMDTs & CRGO DTs by specifying the energy efficiency level as notified in IS :1180 / as notified by Ministry of Power while procuring the DTs. However, Utilities may decide/ notify the type of DTs–AMDT or CRGO DTs at the time of tendering that may be considered more suitable to meet their requirement as per their past practice and experience.

- If DISCOMs are following Total Owning Cost (TOC) principle for evaluation of tenders, then they may evaluate the successful bidder on the lowest Total Owning Cost formula as specified in Bid documents, based on the Cost of DT and Losses guaranteed in the bid. The formula for TOC has been given in the SBD of DDUGJY and IPDS.

- As no load losses of AMDTs are less than CRGO core DTs, these DTs may be preferred in villages where peak load comes for a short period and most of the time DT remains lightly loaded.

# GUIDELINES

# FOR

# USAGE

# OF

# UNDER GROUND(UG) CABLE SYSTEM

# OR

# OVERHEAD(OH) CONDUCTOR SYSTEM

## 1. INTRODUCTION

Distribution of electricity involves the transfer of electrical energy from one electric substation to another electrical substation ( like from 220/33 KV S/S to 33/11 KV S/S and 33/11 KV S/S to 11/0.4 KV Distribution Transformer S/S etc) through sub-transmission and distribution lines. These lines may be Overhead lines or Underground cables. Each of the two types has its merits and demerits.

The choice of Overhead Network or Underground network depends on many factors like safety requirement, Availability of Right of way, cost , aesthetic look etc. Despite being expensive, Underground cables have several advantages over OH lines. These are mostly used where safe clearances for Overhead Network is not available particularly in densely populated areas. Overhead Network is cheaper, easy to install/upgrade and easy to maintain.

### a. OVERHEAD NETWORK

In overhead power lines, a structure based network is used to transmit electrical energy from one point to another. It consists of adequate size of conductors , commonly three conductor in 66 KV , 33 KV or 11 KV lines or four conductor in 11 KV lines or 5 conductor in LT lines ( $5^{th}$ conductor for street lighting) for three phase lines and two conductors for single phase lines suspended through towers or poles and generally comprising of the items- such as Poles, Conductors, Cross arms, pin insulators, Stay Wires, Stay Rod, Stay Anchor, Guy Insulator, earthing materials, Guard wire, Barbed wire and Danger plate etc

The Poles for the electrical network may be a Steel Poles (Tubular Poles, Rolled Steel Joists and Rails),Concrete Poles (RCC Poles, PCC poles and Pre-Stressed Concrete -PSC) Pole) of various heights of 9 meters to 13 meters (IS: 5613 (Part 1, 2, 3) depending on site location, minimum safety clearance and Voltage (230Volts, 415Volts, 11KV and 33KV etc) of the overhead network system. Along with these poles, Rail poles, which have more strength then other poles, are generally used in overhead network along and across the Road, Public Places, Residential areas, River crossing etc.

Sometimes, for supporting different voltages on the same poles and to maintain the adequate clearance between the different lines of different voltage levels, poles with higher heights are used, and in such cases, guard wires are also provided to prevent accidental over charging of lines of lower voltage system due to conductor snapping etc.

The conductors for the overhead network can be a bare conductor or an insulated conductor (ABC) depending on the requirement. It is an important component of overhead electrical transmission and distribution systems. The choice of conductor depends on the power carrying capacity, cost, growth of the load, and reliability & efficiency. While selecting an ideal conductor, some of the following features such as -i) maximum electrical & thermal capacity and cost effectiveness etc are considered.

As per CEA (Technical Standards for construction of Electrical Plants and Electric Lines) regulations 2010, as amended upto date, adequate capacity AAC (All Aluminium Conductor), AAAC (All Aluminum Alloy Conductor), ACSR (Aluminum Conductor Steel Reinforced), ACAR (Aluminum Conductor, Aluminum Reinforce) or any new technology higher current carrying conductors (AL-59, HLTS etc) may be used in sub –transmission and Distribution system. Since, the insulations between the conductors is provided by air, overhead power lines are generally the lowest-cost method of power transmission for large quantities of electric energy from one point to another.

In addition to above types of bare conductors, Insulated conductors (Aerial Bunched cables) may also be used in Overhead network system. The use of Aerial Bunched Cables (ABC) is a good concept for overhead power LT distribution where the electrical clearance is not available or area identified as theft prone. When compared with the overhead distribution system with conventional bare conductors, ABC provides higher safety and reliability and system economy by reducing theft. This system is ideal for rural distribution and especially suitable for installation in difficult terrains such as hilly areas, forest areas, coastal areas etc. Aerial Bunched Cables is

also considered to be the best choice for power distribution in congested urban areas with narrow lanes and by-lanes.

Some other advantages of use of ABC are-

- ABC provide safety to human life when used in congested area and narrow lane areas.
- ABC provides flexibility to use multiple circuits of different voltages strung on the same set of poles.
- ABC provides better adaptability to run concurrently with other overhead system with bare conductor and also with communication lines without any interference.
- ABC provides insulation resistance to earth in all seasons and negligible leakage of currents and thereby, the reducing losses due to leakage.
- ABC is unaffected by atmosphere pollution.
- ABC, also eliminates the theft of energy as it can not be tapped i.e. it prevents the use of illegal hooks etc. on LT lines in the theft prone areas and helps to improve the AT&C losses of the system.

### b. UNDERGROUND NETWORK

In Under Ground cable system, the power is transferred from one point to another through underground cables laid in the ground in place of overhead lines on poles/ towers. As these cables are not exposed to the air/ atmosphere, they are less susceptible to outages due to various atmospheric conditions like high wind, storm, thunder storms, heavy snow or ice storms etc. As these cables are not visible on ground, these provide an aesthetic look to the area as compared to OH lines. However, the U/G cables are more costly and have to be laid in the proper tranches and also have more restoration time in case of any fault as compared to OH lines.

While selecting the cables to be used, some of the parameters such as Current carrying capacity, Voltage drop and short circuit rating are important factors to be considered to arrive at economical and optimum size of cable.

The cable generally comprises of the conductor, insulation material, bedding, beading/ armoring, and outer sheath etc. Although, the armoring and outer sheath takes care of the physical safety of cable , adequate care has to be taken by cable manufactures during manufacturing of the cable.

Normally the lifespan of a cable is about 20 to 25 years. But over the time, the insulation of cable may get damaged or weakened due to ageing. Wrong handling of cables and damages due to bending or wrong laying of cable also weakens the insulation of the cables. Normally, some of common cable faults are:

i. A short circuit between two conductor due to failure of insulation between the conductors
ii. An earth fault, i.e., fault between conductor and ground due to failure of outer insulation sheath
iii. An open circuit fault, caused due to break in conductor etc.

On the road crossing and other congested areas, the Horizontal Directional Drilling (HDD) method for laying of cables may be adopted based on the site suitability and requirements. The cables laid by HDD method have to be protected with protective cover or pipe or cable having special protective cover over outer sheath.

The choice to use overhead line (OHL) or underground cable (UGC) must be made keeping in view the safety, reliability and operational constraints. The choice between OHL and UGC is driven by technical, environmental and economic considerations.

## 2. COMPARISON OF UG SYSTEM AND OH SYSTEM - FEASIBILITY ANALYSIS

The comparison of Overhead and Underground line on various points is classified below:

### i. COST OF INSTALLATION

Underground network installation is more expensive than OH lines , since the cost of cables include cable charges along with road restoration charges which make the per unit coat of UG cabling system several times greater than overhead system.

### ii. FAULT LOCATION IDENTIFICATION & REPAIRING TIME

The identification of fault finding and repairing on overhead wire is easy as compared to UG cables, as UG cables are buried in the ground and it requires specialized techniques to find out the fault location as compared to

OH lines. Some time, it may take several days or weeks to find and repair the fault in underground system.

**iii. COST OF REPAIR A FAULT**

In underground cables, when a fault occurs, the cost of finding its location, trenching, cable splicing, and re-embedment is sometimes 5 to 10 times more expensive than repairing a fault in an overhead line where the conductors are visible, readily accessible and easier to repair.

**iv. LINE OUTAGE DURATIONS**

As extended repair time is required in underground system, services to customers may be disrupted for a long time in UG system. However, the time duration of customer outages can be reduced by using additional feeders with Ring Main Units (RMUs) in UG system which involves much more cost as compared to OH system.

**v. LINE MODIFICATIONS**

Overhead power lines are easily tapped, rerouted or modified to serve customers; while underground lines are more difficult to modify after the cables have been laid. Such modifications to underground power lines are more expensive because of the inability to readily access lines or relocate sections of lines.

**vi. EFFECT FROM WEATHER CONDITIONS**

Overhead Lines are more prone to damage from severe weather conditions (mainly lightning, hurricanes/cyclones/typhoons, tornados, other winds, and freezing) than Underground Network.

**vii. RANGE OF ELECTROMAGNETIC FIELDS (EMF) EMISSION**

The electric current in the conductor produces a magnetic field around it. However, the closer grouping of underground power cables reduces the resultant external magnetic field and hence provides less magnetic effect as compared to OH line conductors. Further to reduce the magnetic effect in cables, a shielding is also provided over the cables which further reduces the magnetic effect in surrounding areas.

**viii. SPACE REQUIREMENT**

Underground cables do not need physical ground space as these are laid under the ground in the dedicated tranches whereas an overhead line requires a corridor on ground along with surrounding clearance strip permanently clear for safety, maintenance and repair.

**ix. HAZARD TO WILDLIFE**

Underground cables generally pose no hazard to wildlife as compared to overhead network, as live wires are not exposed to be touched.

**x. ILLEGAL CONNECTION/THEFT OF POWER /PILFERAGE**

In underground cabling system, it is generally impossible to have illegal connection by tapping the conductor for theft of power. These are also less prone to sabotage, and damage from armed conflict.

**xi. AESTHETICS**

As UG cables are not visible from outside, these provide a clean and aesthetic view of the city /town where UG cables are laid. The above space may be used for any other purposes like making of roads, providing green environment/trees on sidewalks etc having environmental benefits and increase of property values etc.

**xii. FLEXIBILITY TO INCREASE LINE CAPACITY**

Overhead lines can easily be upgraded/ augmented by modifying line clearances and power poles to carry more power while underground cables cannot be up-rated and must be supplemented by laying another cables or to be replaced to increase the capacity.

**xiii. LINE LIFE**

Insulation deterioration takes place in underground cables much faster because of various loading cycles during their lifetimes as compared to OH conductor which do not have any insulation layering. As time passes, the cables insulation weakens, which increases the potential for a line fault.

**xiv. SAFETY**

As OH conductor are exposed in air, a minimum safety clearance is required for the overhead line from any surrounding like surrounding building /trees etc. which may not be available in densely populated areas, while underground cables do not require such clearances. Also, the snapping of the overhead conductors in densely populated areas poses serious safety hazard. Hence, UG cables are preferred in the densely populated areas.

## 3. COST ANALYSIS

As discussed above, the estimated cost of the UG cabling system is about 3-4 times than the equivalent OH system ( like the Est cost of 11 KV OH S/C line with Dog conductor is around Rs 5-6 Lakh/ km while the Est cost of 1 km of 3 x300 sq mm 11 KV cabling system would be around Rs 20 Lakh/km). The tentative unit costs of 11 KV OH lines and UG cabling system are given in Annex. These are only the suggestive figures and the actual costs may vary frm utility to utility based on there technical requirement / schedule rates etc.

Following is the cost comparison for installation of one kilometer of underground and Overhead lines:

| S No. | Voltage Level | Tentative Estimated Cost Per km (lacs) | | |
|---|---|---|---|---|
| | | OH | UG | ABC |
| 1 | LT | 3.5 | 13 | 8 |
| 1 | 11 kV | 5.0 | 20 | 13.5 |
| 3 | 33 kV | 12.0 | 35 | |
| 5 | 66 kV | 45.0 | 80 | |

*The above cost may vary depending upon road restoration cost for installation of the underground cables/ overhead poles. The cost is much higher for installation of underground cables depending on the nature of the road surface to be disturbed and area of installation (Metropolitan/Rural area etc).*

## 4. RECOMMENDATION

It may be seen that both overhead & underground network have their own advantage and disadvantage over each other and also have virtually no cost comparison for cost benefit analysis. As a sub-transmission and distribution line cover the landscape and population structure within the city/town/village throughout its length, the choice between OH and U/G cabling system has be taken based on safety, esthetic look, clearance available, rules and regulations in force and other factors. The sub transmission and distribution lines may also be a mix of both as per actual site conditions. Underground power distribution system is an expensive choice but is mandatory to supply electricity in highly populated areas.

**Annex**

**(NOTE: These are the typical examples of cost estimate of OH line/UG cables.The actual estimates of the Discoms may differ depending upon their schedules cost estimates as approved by their competent Authorities in Discoms)**

| TYPICAL COST ESTIMATE FOR 1KM 11 KV (SINGLE CIRCUIT) OVERHEAD HT LINE WITH DOG CONDUCTOR ON STEEL TUBULAR POLE | | | | | |
|---|---|---|---|---|---|
| **S. No** | **Particulars** | **Unit** | **Qty** | **Rate** | **Amount(Rs)** |
| 1 | ST Pole 9 Mtr. | No. | 25 | 2904 | 72600 |
| 2 | X-arm M.S. Angle 65x65x6mm V Type | No. | 25 | 597 | 14925 |
| 3 | Cross arms holding clamps | No. | 25 | 57 | 1425 |
| 4 | 11 kV Pin insulators with GI Pins(320CD) | Nos | 75 | 67 | 5025 |
| 5 | 45 kN disc insulators | Nos | 6 | 533 | 3198 |
| 6 | F-bracket for fitting top insulator | No. | 25 | 228 | 5700 |
| 7 | ACSR Dog conductor | Km | 3.09 | 59579 | 184099 |
| 8 | Jointing sleeve for ACSR DOG | No. | 3 | 171 | 513 |
| 9 | Danger Plate | Nos | 25 | 155 | 3875 |
| 10 | Barbed wire | Kg. | 8 | 68 | 544 |
| 11 | Stay Set Complete | No. | 8 | 1140 | 9120 |
| 12 | Sectional D/P on Steel Tubular Pole | No. | 1 | 45593 | 45593 |
| 13 | Concreting of supports ST Pole | No. | 25 | 969 | 24225 |
| 14 | Stone pad 300x300x75mm | No. | 25 | 182 | 4550 |
| 15 | Earthing complete | No. | 6 | 570 | 3420 |
| | Material Cost in Rs | | | | **378812** |

| TYPICAL COST ESTIMATE FOR 1KM 11 KV (SINGLE CIRCUIT) OVERHEAD HT LINE WITH DOG CONDUCTOR ON STEEL TUBULAR POLE | | | | | |
|---|---|---|---|---|---|
| **S. No** | **Particulars** | **Unit** | **Qty** | **Rate** | **Amount(Rs)** |
| | Misc. Items (Like Nut & Bolts,Clamps,Binding Wire,Aluminium Tape etc) @ 0.5 % of the material cost | | | 0.50% | 1894 |
| | Contingency @3% of Material Cost | | | 3% | 11365 |
| | **Total Material Cost (Part-I)** | | | | **392090** |
| | *Labour Cost for execution of the Scheme, Overhead charges including Transportation, Establishment & Supervision Charges for Erection, Testing & Commissioning **(Part-II)** | | | 14% | 54893 |
| | Total Cost (Part-I+Part-II) | | | | 447082 |
| | **Say in Rs. Lakhs** | | | | 4.47 |

| TYPICAL COST ESTIMATE FOR 1 KM HT OVERHEAD LINE WITH 11KV ABC CABLE WITH SPAN 30 METERS | | | | | |
|---|---|---|---|---|---|
| **Sl.No** | **Particulars** | **Unit** | **Qty** | **Rate** | **Amount(Rs)** |
| 1 | PCC Poles 11 M | No. | 35 | 5465 | 191275 |
| 2 | ABC Cable 3CX150+150 mm2 | Kms | 1.02 | 760013 | 775213 |
| 3 | Clamp Suspension LT ABC 3X120-150 SQMM | EA | 35 | 244 | 8540 |
| 4 | EYE HOOK ANCHOR/ SUSPENSION CLAMP 300MM | EA | 35 | 118 | 4130 |
| 5 | Anchor HT ABC 3CX120 TO 150 SQMM | EA | 10 | 349 | 3490 |
| 6 | EYE HOOK ANCHOR/ SUSPENSION CLAMP 300MM | EA | 10 | 118 | 1180 |
| 7 | Stay Set Complete | No | 10 | 1140 | 11400 |
| 8 | Stay Wire GI,7/8 SWG | kg | 100 | 65 | 6500 |
| 9 | Full clamp assembly (alongwith Nuts,Bolts and Washers) for stay | No | 10 | 57 | 570 |
| 10 | Egg insulators | No | 10 | 13 | 130 |
| 11 | Barbed wire | kg | 35 | 68 | 2380 |
| 12 | Pipe earth G.I. 40MMX2.5/3 M 'B' CLASS | EA | 40 | 706 | 28240 |
| 13 | PIPE HDPE SIZE 25 MM | EA | 120 | 22 | 2640 |
| 14 | WIRE STAY GI 7/10 SWG | KG | 400 | 65 | 26000 |
| 15 | LUG AL Crimping 70 SQMM XLPE SINGLE HOLE | EA | 160 | 20 | 3200 |
| 16 | GI Strip 25x6 mm , 9 meter for earthing | No | 7 | 570 | 3990 |
| 17 | Phase plate for each phase set of 3 (on each H-Pole & 4-Pole) | Set | 35 | 57 | 1995 |
| 18 | Danger Plate | No | 35 | 155 | 5425 |
| 19 | Number Plate | No | 35 | 70 | 2450 |

| TYPICAL COST ESTIMATE FOR 1 KM HT OVERHEAD LINE WITH 11KV ABC CABLE WITH SPAN 30 METERS | | | | | |
|---|---|---|---|---|---|
| 20 | JT. KIT O/D HT ABC 3CX150+1CX150 HS ONE | EA | 12 | 1797 | 21564 |
| 21 | COVER INSULATION REOPENABLE ON INSULATOR | EA | 9 | 2251 | 20259 |
| 22 | CHANNEL MS SIZE 75X40MM | KG | 89 | 65 | 5785 |
| 23 | ANGLE MS SIZE 50X50X6MM | KG | 41 | 33 | 1353 |
| 24 | FLAT GI SIZE 50X6MM | KG | 15 | 123 | 1845 |
| | **Total Material Cost(Part-I)** | | | | **1129554** |
| | *Labour Cost for execution of the Scheme, Overhead charges including Transportation, Establishment & Supervision Charges for Erection, Testing & Commissioning @14% of Total Material Cost**(Part-II)** | | | 14% | 163651 |
| | Total cost in Rs.(Part-I+Part-II) | | | | 1332688 |
| | **Say(Rs. In Lakhs)** | | | | 13.33 |
| | | | | | |

| TYPICAL COST ESTIMATE FOR 1 KM 11KV UNDERGROUND XLPE CABLE (3CX300 SQ.MM. ) | | | | | |
|---|---|---|---|---|---|
| **Sl. No.** | **Particulars** | **Unit** | **Qty.** | **RATE** | **Amount** |
| 1 | HT 11 kV 3CX300 sq.mm XLPE cable | M | 1000 | 1137 | 1137000 |
| 2 | 11kV outdoor Joint Kit 3X300 Sq. mm. | No. | 2 | 2471 | 4942 |
| 3 | 11 kV Straigth Through Joint Kit 3X300 Sq.mm. | No. | 3 | 5846 | 17538 |
| 4 | RCC Hume Pipe,150MMX2M | Nos. | 50 | 355 | 17750 |
| 5 | Collar RCC Hume Pipe 150MM | Nos. | 30 | 55 | 1650 |
| 6 | Route and Joint indicating stone | No. | 30 | 130 | 3900 |
| 7 | RCC cable cover( 2 feet long) | No. | 1666 | 243 | 404838 |
| 8 | Sand | No. | 250 | 388 | 97000 |
| 9 | Pipe earth G.I. 40MMX2.5/3 M 'B' Class | EA | 2 | 706 | 1412 |
| 10 | Pipe HDPE Size 25MM | M | 6 | 22 | 132 |
| 11 | LUG AL Crimping 70 SQMM XLPE Single HOLE | EA | 8 | 20 | 160 |
| 12 | FLAT GI Size 25x6 MM | KG | 7 | 78 | 546 |
| 13 | Cleat HDPE for Cable Support | KG | 4 | 763 | 3052 |
| 14 | Pipe G.I. 100MM DIA 'B' CLASS | M | 6 | 716 | 4296 |
| 15 | FLAT GI Size 50x6 MM | KG | 10 | 123 | 1230 |
| 16 | Channel MS Sixe 75x40MM | EA | 60 | 65 | 3900 |
| | Material Cost | | | | **1699346** |

| TYPICAL COST ESTIMATE FOR 1 KM 11KV UNDERGROUND XLPE CABLE (3CX300 SQ.MM. ) | | | | | |
|---|---|---|---|---|---|
| **Sl. No.** | **Particulars** | **Unit** | **Qty.** | **RATE** | **Amount** |
| | Misc Material like nuts & Bolts, Lugs etc. @ 0.5% of the material cost | | | 0.50% | 8495 |
| | Contingency Charges @3% | | | 3% | 50972 |
| | **Total Material Cost (Part -I)** | | | | 1758557. |
| | Labour cost for execution of the scheme, overhead charges including Transportation, Establishment & Supervision charges for erection, testing & commissioning Part (II) | | | 14% | 246198 |
| | Total Cost (Part I +Part II) in Rs. | | | | 2004856 |
| | **Total Cost Rs. in Lacs** | | | | 20.05 |

(Standard cost estimation mentioned above shows that the total cost of 11 kV Underground cable network is nearly 4 times the cost of installation of overhead network of same voltage rating.)

# GUIDELINES
# ON
# INTRODUCTION
# OF
# AUTOMATION
# IN
# DISTRIBUTION SECTOR

## 1. INTRODUCTION

The growth of a Country depends upon the certain basic pillar of infrastructure and one of such basic infrastructure is availability of quality and reliable power in the country. The country needs 24x7 uninterrupted power supply to all the consumers along with transparency in the operation of sector and consumer participation. Since the enactment of the Electricity Act 2003, Indian power distribution utilities have come a long way but still distribution is the weakest link in the entire value chain of the Electricity sector. Thus, there is a need of introduction of IT and automation in operation of distribution utilities.

Considering the current situation of distribution utilities, there are following keys challenges with distribution utilities in the country :

- Poor Metering Billing and Collection efficiency resulting high AT&C losses.
- Weak & inadequate distribution network
- Obsolete/ageing infrastructure at sub transmission and distribution level which is not compatible to the automation and Intelligent Electronic Devices (IEDs).
- Poor forecasting and inadequate power procurement planning resulting in expensive bilateral transactions and power exchanges
- Capacity and capability constraints of the existing workforce including technology embracing barrier.
- Poor financial performance due to lack of accountability and high power theft.

It is very crucial to overcome the present challenges and move towards a smarter utilities showcasing the best performance in terms of reliability and accountability. New stakeholders are entering the power distribution industry, shifting a historically monopolistic sector into a highly competitive business.

The following would be the key features of the UTLITY of FUTURE :

- Low AT&C losses leading to improved financial condition of Distribution Utilities
- Customers' expectations would be high in terms of supply, reliability and quality of power supplied to them.
- Automation of the distribution system including Smart Grid to study the consumer data like consumption pattern, billing details, energy conservation, and outages information etc.
- Increase in Distribution Energy Resources (DER) with high availability and low cost like use of roof top renewable resources which would make the existing consumers as the generator feeding at distribution level. They would not only consume but would also inject power to grid through rooftop and community

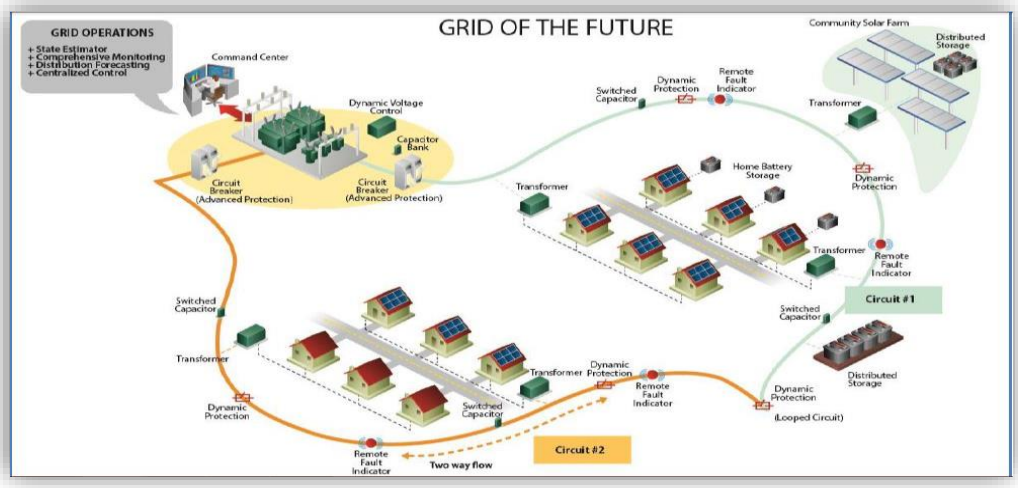
solar as and when available, thus there would be a paradigm shift from Unidirectional flow of power to Bi-directional power flow.

- Penetration of Electric Vehicles (EVs) slowly replacing the conventional petrol/ diesel/ gasoline vehicles. Thus, establishment of Electric charging stations and design of distribution system would have its impact on electrical distribution system.

## 2. ENABLERS FOR THE USE OF AUTOMATION IN DISTRIBUTION SECTOR :

To achieve **affordability, reliability, quality** and **environmentally acceptable** power supply in the country**,** there are certain enablers which a smart utility must have:

- A well planned and maintained network infrastructure
- Automated process flow supported by automated monitoring and control of network topology
- Automated process flow supported by state of art information Technology based Metering, Billing & Collection (MBC) , Customer Relation Management (CRM) and Enterprise Resource Planning (ERP) System.
- Automated process flow for field crew management for all practical purposes
- Advanced metering infrastructure and meter data management(MDM) system to bring about transparency, customer engagement and efficiency in utility operation.
- Advanced business analytics to bring out actionable reports.
- Robust communication system
- Updated GIS with automated data maintenance process.
- Technology oriented capability of workforce.
- Compliance for Cyber security etc.



A smart combination of Information technology (IT) and Operational Technology (OT) can allow us to optimize across the technologies on both the supply and demand side to achieve the affordable, reliable & clean power as per satisfaction of the consumers.

## 3. INFORMATION TECHNOLOGY (IT) AND OPERATIONAL TECHNOLOGY (OT) INTEGRATION

Information Technology plays a major role in the success of effective decision making at the utility level. Data and application integration, business intelligence, hardware capabilities to run complex algorithms and display mapping features, workflow coordination and reporting are some of the elements that IT facilitates to the business groups for efficient operations. The information system concept promises to increase operational efficiency, reduce cost and be more environment friendly. Real Integration of IT & OT not only helps to fulfill that promise, but enhances the opportunities to add more value and effectiveness to the energy value chain. Integration of IT & OT brings together real time systems such as SCADA, EMS and DMS with corporate applications such as ERP, Billing, CRM etc.

Above all, the information system requires a more holistic view of how a utility operates at both the business and field levels, which translates to greater cooperation between IT and OT teams. IT as a part in the rollout of customer management and billing applications, has enhanced its standing within the business. Realizing many of the benefits of smart meter deployments such as more flexible pricing, improved customer understanding, participation and the deployment of new services requires a significant investment in IT.

IT has a leading role in the development of customer management systems and it is also playing a growing role in delivering operational efficiency in areas such as outage management, asset management, and workforce management systems, where there are clear benefits from a broader integration of enterprise and operational data. Even in core operation systems like DMS and Energy Management Systems (EMS), there is a trend toward greater integration across systems as IT has capabilities related to system security and large-scale data management and analysis.

These developments are driving organizational and cultural changes as IT and OT teams learn to work together to meet common goals. IT and OT are not simply different departments but they also reflect different skills and different priorities. The need to define and deploy new IT systems to support the operational system is driving greater collaboration between IT and OT and is also providing a set of common objectives that can bring diverse teams together. *This integrated IT and OT approach basically paves the way for moving forward towards the "SMARTER GRID"*.

The details of some of the Operations Technology applications are as under -

## (a) SUPERVISORY CONTROL AND DATA ACQUISITION (SCADA)

Distribution utilities generally operates three layers of network i.e. Sub transmission (66 KV and 33 KV), Primary Distribution (11 KV) and Secondary Distribution (0.415 KV). Any interruption at sub transmission 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 system remotely.

SCADA where name 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
- 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.
- More consistent process for operating the power system at least for sub-transmission system and above.
- Better handling of the reactive power support equipments.

**(b) SUBSTATION AUTOMATION SYSTEM (SAS)**

Electric utilities have to tap the useful information of the network equipments installed in field, and making this information available to persons of organization 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.

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 shall 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.

***Benefits of Substation Automation:***

- Technologically advanced solutions at the substation level provide the best form of gathering data for local and remote support of functions.
- Open protocols and standards provide the possibility to implement a vendor independent solution.

- Amount of data available for monitoring and control including the power quality related data is at least about 10 times more in substations designed with SAS as compared with conventional substations.
- Provision for reconfigurations that require the change of settings remotely.
- Provides the implementation of remote maintenance of the relays in terms of change of settings.
- IEDs have built in diagnostics that announce equipment failures thus avoiding malfunctions.

## (c) DISTRIBUTION MANAGEMENT SYSTEM (DMS)

Distribution Management System (DMS) is a set of application designed to monitor and control MV distribution network reliably and 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.

Snapshot of DMS control center

## (d) DISTRIBUTION AUTOMATION (DA)

Distribution Automation (DA) is a smart Grid 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 with a philosophy of 20% control can restore 80% of the network. This arrangement not only helps in improving the network reliability significantly but also *reduce the Mean time to Restore (MTTR) value by 50%*. 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.

***Benefits 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 been 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
- 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 means to analyze the present and hypothetical operating conditions of the distribution network to respond what if type of questions.

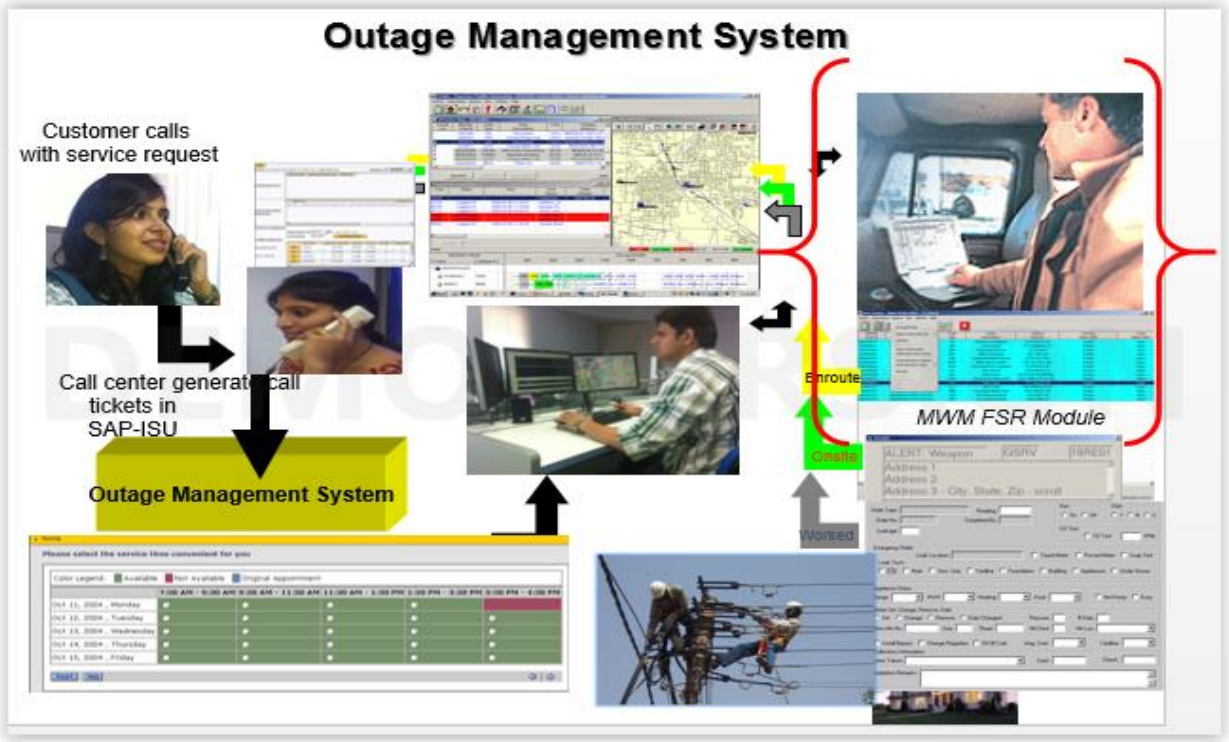
## (e) OUTAGE MANAGEMENT SYSTEM (OMS)

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*
- *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*
- *Improves performance assurance standards*




**(f) ADVANCED 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.
In fact, an ADMS transitions utilities from paperwork, manual processes, and siloed software systems to an integrated system with real-time and near-real-time data and automated processes.

The decision to implement an ADMS starts with a vision of where the utility would like to be in future that is based on the externalities specific to the utility.


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.

Applications of any system run effectively and efficiently in intergradation mode. To function effectively, it requires interfacing with GIS data, CIS, SAS as well as getting integration with forthcoming system like Field Force automation, Power portfolio module, weather forecasting, Smart grid technologies etc.

**(g) GEOGRAPHICAL INFORMATION SYSTEM (GIS)**

Many of us tend to associate GIS (Geographic Information System) and GPS (Global Positioning System) technology with research and its applications in agriculture, space, or climate change. But GIS/GPS is also a powerful tool in the hands of those who shape the destiny of India. It is already making major impact in some cities and towns of India in addressing specific challenges of service delivery.

It is the system which leverages the information of geography into your system/ mobile/ Tablet. 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 and water utilities, telecom utilities etc.

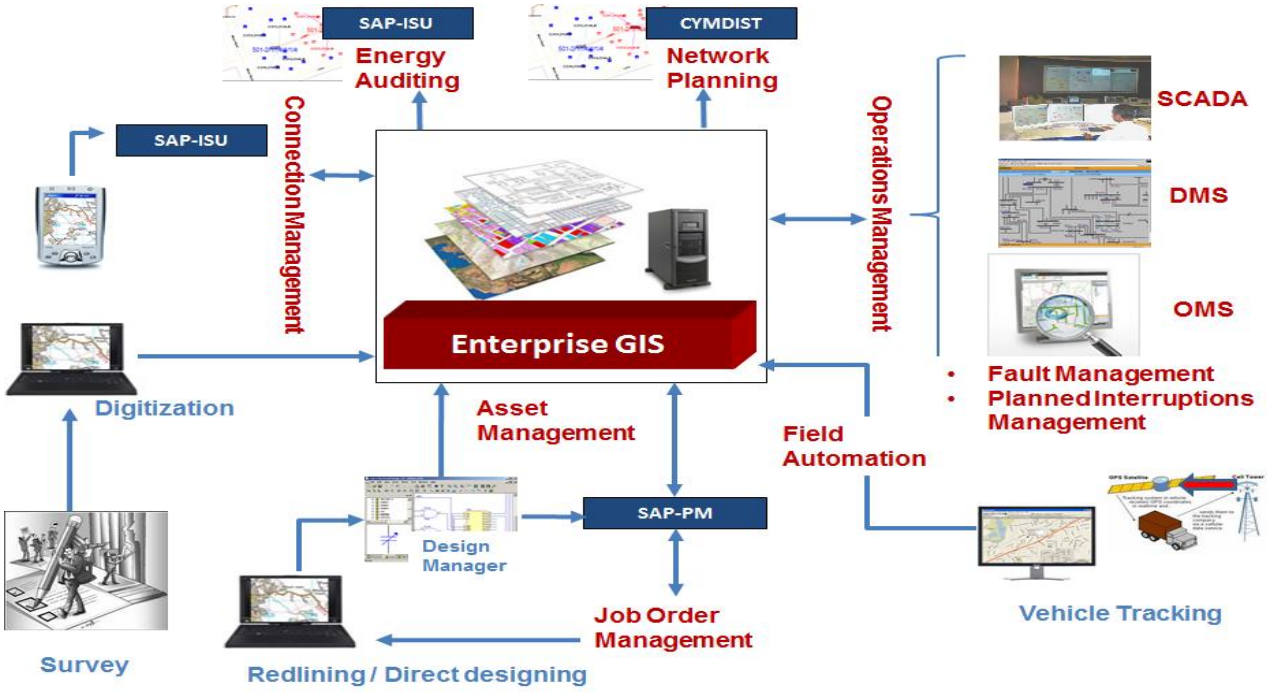
This is the optimal platform and foundation technology for utilities which contains the complete information as mentioned below:

- 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.

Generally, GIS is presumed to be used as standalone system for data updation from various user groups and most of 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.

Landscape of GIS which can help various other processes includes SCADA, Distribution Management System, Outage Management System, Network Planning, Energy Auditing, Field Force Automation, Asset Management, Customer Relationship Management and other associated processes.



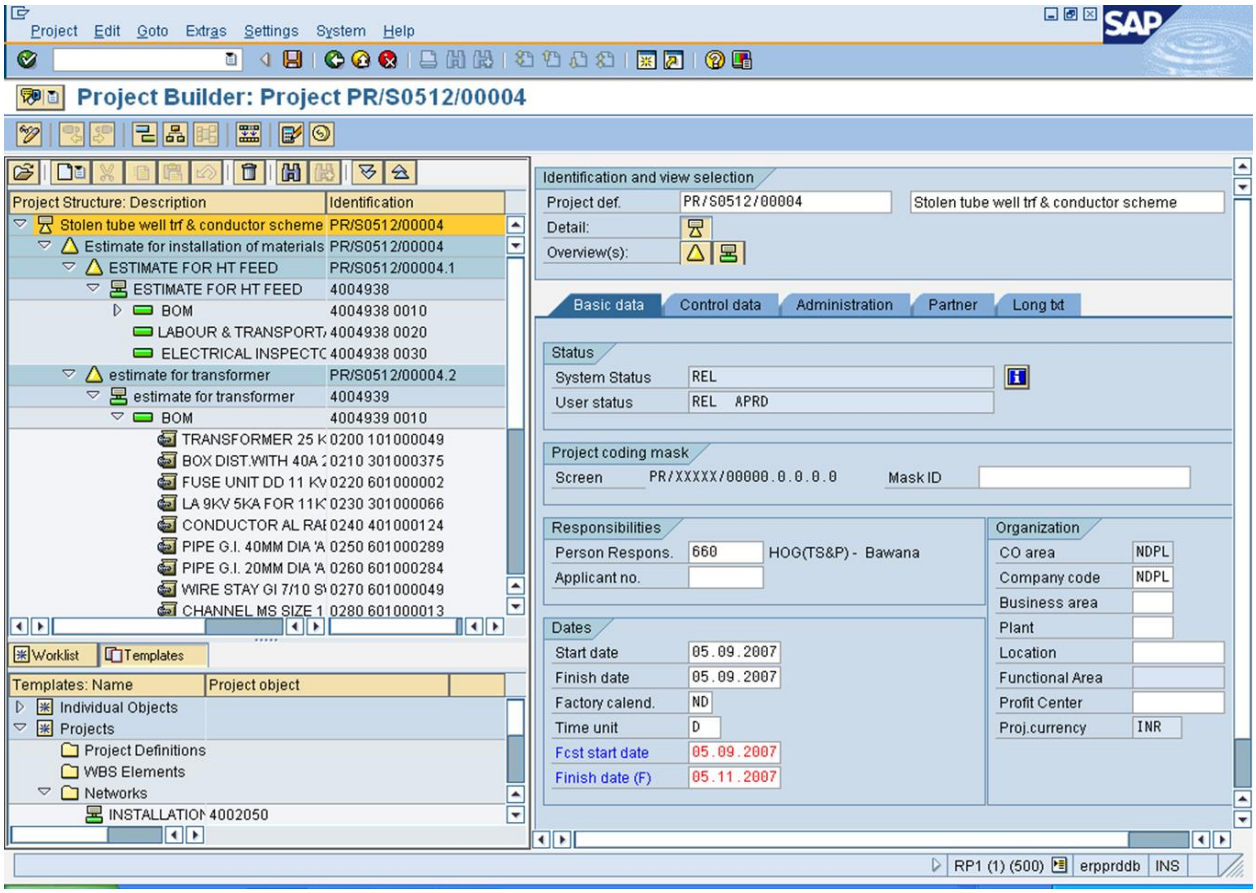

- **Operation management:** Network hierarchy along with consumer mapping from GIS can help the network operator using DMS and OMS for further taking decision on operation Management.
- **Asset Management:** All new assets can be mapped and managed in an integrated environment where information can be 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.

(h) **ERP… FOR UTILITY INTERNAL USE*:*** ERP like SAP (illustrative, though there are solutions available from various OEMs) includes the Maintenance Management across network layers of Utility. The key benefits which can be achieved by ERP solutions are as below:

- Improved Work Control.
- Improved Planning and Scheduling.
- Enhanced Preventive and Predictive Maintenance.
- Improved Parts and Materials Availability.
- Improved MRO Materials Management in Integration with GIS and with Design Manager Application.
- Improved Reliability Analysis.
- Increased Capability to Measure Performance and Service.
- Increased Level of Maintenance Information

Snapshot of the ERP solution of SAP is shown below:

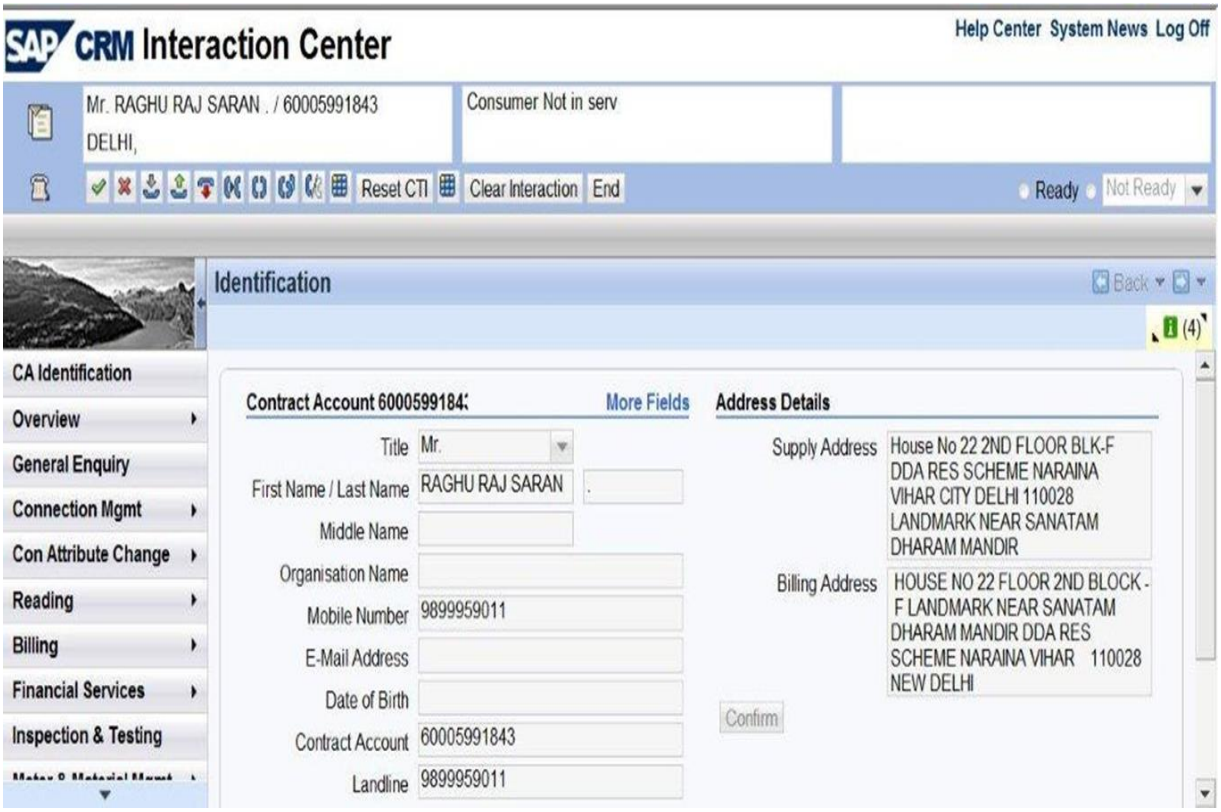


### *(i) CUSTOMER RELATIONSHIP MANAGEMENT (CRM)*

CRM is implemented for providing information in concise form to front staff for better consumer interaction and to back office for facilitating in day to day decision making. 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

Snapshot of the CRM User Interface is shown in the snapshot given below:




**Benefits of CRM**

- Call Center Executive will use only one 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.

## (j) SMART GRID TECHNOLOGIES

A smart grid is an electrical grid which includes a variety of operational and energy measures including smart meters, smart appliances, renewable energy resources, and energy efficient resources. Electronic power conditioning and control of the production and distribution of electricity are important aspects of the smart grid. To ensure a seamless transition from existing approach to Smart Grid scenario, focus of any distribution utility must be structured around four key priorities. These are:

- Empower Customers to better manage and control their electricity use.
- Improve Reliability.
- Maintain Privacy and Security.
- Support Renewable integration and economic development.

In order to address the above mentioned priorities, Smart Grid technologies need to be implemented in conjunction with the existing application / technology. Smart grid generally refers to a class of technology that is being considered to bring paradigm shift in power distribution utility's performance.

The Smart Grid represents an unprecedented opportunity to move the energy industry into a new era of reliability, availability, and efficiency that will contribute to economic and environmental health. The benefits associated with the Smart Grid include:

- More efficient transmission of electricity
- Quicker restoration of electricity after power disturbances
- Reduced operations and management costs for utilities, and ultimately lower power costs for consumers
- Reduced peak demand, which will also help lower electricity rates
- Increased integration of large-scale renewable energy systems
- Better integration of customer-owner power generation systems, including renewable energy systems
- Improved security

Some components of Smart Grid are:

- **Distributed Energy Resources (DER):**

Conventionally, Grid substation have been designed to transmit power from receiving station to end user for consumption. However, as the penetration of Distributed Energy Resources (DER) is going to increase, grid substations shall be used as carrier of bi-directional energy flows. The penetration of DER such as distributed generation, Electric storage, Electric Vehicles (EV) and demand response may significantly affect the operation of Distribution Grid substations. On the other hand, this DER development will help in reduction of $CO_2$ emission, reduction in loading on the network and increase in self – consumption.

DER serves as a flexibility service provider within the power distribution network i.e. facilitates a power adjustment sustained for a given duration in order to balance supply and demand at a given moment. DER creates opportunities for customers to self-provide energy, manage load profiles, improve power quality and help meet clean energy goals.

Key motivating factors for the adoption of DER, for both customers and the grid, are :

**Economic Benefits**. Avoided costs, increased efficiencies, and gained revenues. For customers owning DERs, benefits can be tied to incentive payments as well as avoided costs associated with electricity bills. For utilities, regulators, and ratepayers, benefits can be tied to more efficient utilization of the grid and deferred investments.

**Deferred or Avoided Network Investments**. Avoided expansion of generation, transmission, or distribution facilities. This benefit applies to the grid which can indirectly benefit all ratepayers. Apart from providing economic benefits, DERs can also help avoid lengthy siting processes or can provide options where technical challenges exist around traditional capacity expansion. In some cases, the utilization of DERs can provide a quick or novel means for addressing grid challenges

**Resiliency and Power Quality**. Uninterrupted service in the event of loss of grid service and the ability to ride through transient and short-term interruptions. This can be applied to both customers who seek to reduce outage times or power quality events, and the utilities that are coordinating outage recovery efforts and managing grid power quality.

**Clean Energy**. Social, regulatory, and economic reasons to invest in low or no-emission DERs. Many customers are motivated to purchase clean DERs to support clean energy goals. Likewise, many utilities are doing the same, often motivated by goals or explicit targets. The net effect on emissions, however, has to be investigated per system because the displacement of centralized generation can have different effects on total emissions

- **Advanced Metering Infrastructure (AMI)**

Advanced metering infrastructure (AMI) is an integrated system of smart meters, communications networks, and data management systems that enables two-way communication between utilities and customers. Customer systems include in-home displays, home area networks, energy management systems, and other customer-side-of-the-meter equipment that enable smart grid functions in residential, commercial, and industrial facilities.

Advanced Metering Infrastructure (AMI) refers to systems that measure, collect, and analyze energy usage, and communicate with metering devices such as electricity meters, either on request or on a schedule. These systems include hardware, software, communications, consumer energy displays and controllers, customer associated systems, meter data management software, and supplier business systems. Advanced metering infrastructure (AMI) differs from traditional automatic meter reading (AMR) in that it enables two-way communications with the smart meter.

It is architecture for automated, two-way communication between a smart utility meter with an IP address and a utility company. The goal of an AMI is to provide utility companies with real-time data about power consumption and allow customers to make informed choices about energy usage based on the price at the time of use.

***Building Blocks of AMI***

AMI is comprised of various hardware and software components, all of which play a role in measuring energy consumption and transmitting information about energy, water and gas usage to utility companies and customers. The overarching technological components of AMI include:

- ***Smart Meters-***Advanced meter devices having the capacity to collect information about energy, water, and gas usage at various intervals and transmitting the data through fixed communication networks to utility, as well as receiving information like pricing signals from utility and conveying it to consumer.
- ***Communication Network:***Advanced communication networks which supports two-way communication enables information from smart meters to utility companies and vice-versa.
- ***Meter Data Acquisition System-***Software applications on the Control Centre hardware and the DCUs (Data Concentrator Units) used to acquire data from meters via communication network and send it to the MDMS
- ***Meter Data Management System (MDMS):***Host system which receives, stores and analyzes the metering information.

**Benefits:-**

Benefits associated with AMI deployment can be broadly categorized as:

- System Operation Benefits
- Customer Service Benefits
- Financial Benefits

**System Operation Benefits** - primarily associated with reduction in meter reads and associated management and administrative support, increased meter reading accuracy, improved utility asset management, easier energy theft detection, and easier outage management.

**Customer Service Benefits** - Primarily associated with early detection of meter failures, billing accuracy improvements, faster service restoration, flexible billing cycles, providing a variety of TOD tariff options to customers, and creating customer energy profiles for targeting Energy Efficiency/Demand Response programs.

**Financial Benefits** - these accrue to the utility from reduced equipment and equipment maintenance costs, reduced support expenses, faster restoration and shorter outages, and improvements in inventory management.

- **Automated Demand Response**

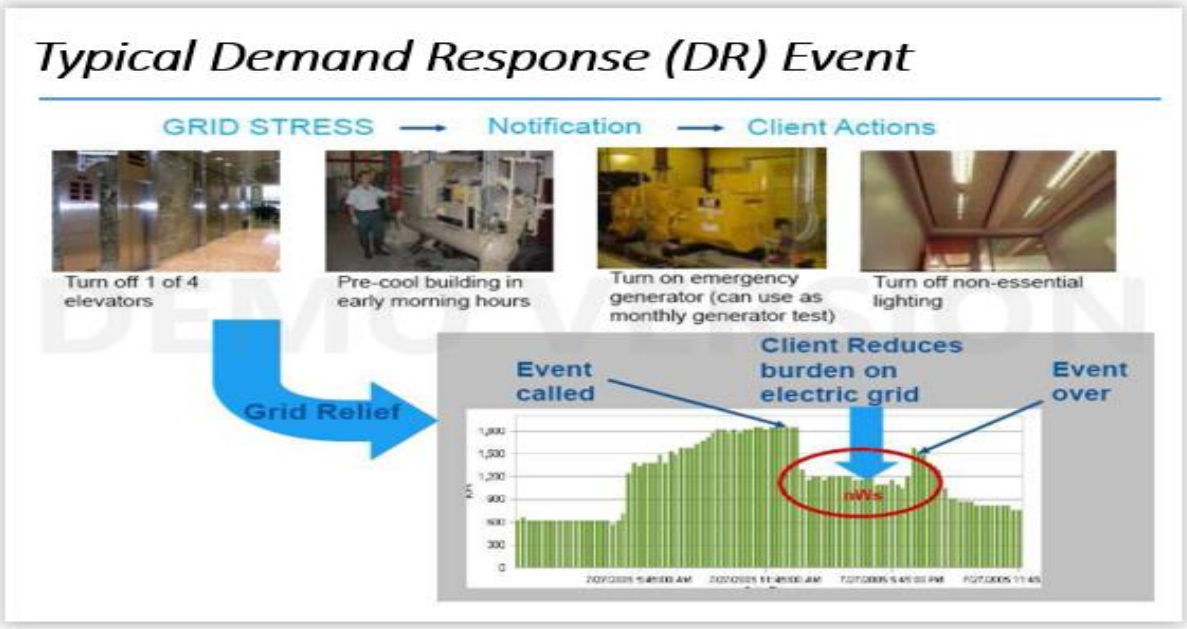
Numerous contributions to overall improvement of the efficiency of energy infrastructure are anticipated from the deployment of smart grid technology, in particular including **demand-side management**, for example turning off air conditioners during short-term spikes in electricity price. To reduce demand during the high cost peak usage periods, communications and metering technologies inform smart devices in the home and business when energy demand is high and track how much electricity is used and when it is used. It also gives utility companies the ability to reduce consumption by communicating to devices directly in order to prevent system overload.

Demand response support allows generators and loads to interact in an automated fashion in real time, coordinating demand to flatten spikes. Eliminating the fraction of demand that occurs in these spikes eliminates 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. In addition, ADR helps reduce greenhouse gas emissions and the need to run expensive peaking plants, which typically sit idle until customers require more electricity than the utility is able to provide using its primary, base-load generators.

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.




➢ **Communication Infrastructure**

To support information collection, distribution and analysis, as well as automated control and optimization of the power system, the smart grid communication system will rely on two major subsystems: a communication infrastructure and a middleware platform.

**Communication infrastructure**. The communication infrastructure is responsible for providing the connectivity service among individual electric devices or entire grid sub-systems. In the context of smart grids, the key priorities of this communication network are: (a) to ensure reliable and real-time data collection from an enormous number of widely dispersed data sources, and (b) to support the various communication services that are needed by power control applications to distribute commands and configuration instructions in the power system. This communication infrastructure is envisioned as a collection of interconnected networks that will be structured into a hierarchy of at least three main tiers or domains: (1) local area networks for the access grid segment and the end customers, (2) field area networks for the distribution segment, and (3) wide area networks for the utility backbone. A variety of technologies, network topologies and communication protocols are considered for each of these categories.

**Middleware platform**. The middleware is a software layer running above the communication network, which provides communication and data management services for distributed applications, as well as standard interfaces between applications and smart grid devices. Different types of middleware solutions exist that differentiate from each other for the set of abstractions and programming interfaces they provide to applications, such as distributed objects, event notifications, distributed content management, synchronous/asynchronous communication functions, etc. Furthermore, middleware is increasingly used to

create peer-to-peer (P2P) overlays, i.e., distributed systems in which devices self-organize into a network and cooperate with each other by contributing part of their (storage, computing, bandwidth) resources to offer useful services, such as data search, distributed storage, or computational intelligence. Given the ability of P2P technologies to scale with increasing numbers of devices and services, several studies have proposed to use P2P-based middleware technologies to deal with the complexity of managing and controlling smart grids.

- ***MDMS (Meter Data Management System)***

MDM system analyzes the data collected and sent by the Smart Meter to set electric power costs and to let consumers use energy efficiently. Collecting the metered data from consumers in real time makes it possible for electric power suppliers to understand how electricity is being used. Additionally, it improves the efficiency of recovery work after natural disasters or accidents happen to the power grid itself.

Consumers can use the data managed by MDMS to help them use electricity more efficiently.

An MDM system will typically import the data, then validate, cleanse and process it before making it available for billing and analysis. An MDM system performs long term data storage and management for the vast quantities of data delivered by smart metering systems. This data consists primarily of usage data and events that are imported from the head end servers that manage the data collection in Advanced metering infrastructure (AMI) or Automatic meter reading (AMR) systems.

It provides Meter-to-Cash system, workforce management system, asset management and other systems. Also an MDMS may provide reporting capabilities for load and demand forecasting, management reports, and customer service metrics. An MDMS provide application programming interfaces (APIs) between the MDMS and the multiple destinations that rely on meter data. Besides this common functionality, Advanced MDM may provide facility for remote connect/disconnect of meters, power status verification/ power restoration verification and On demand read of remote meters.

- Store all meter reads as the system of record.
- Validate the accuracy and performance of meter reads and outage event data.
- Assess possible diversion situations or issues requiring a field visit.
- Improve estimation and validation using multi-dimensional analytics.
- Synchronize data between MDMS, AMR/AMI databases and master systems.
- Improve utility back office operations and understand the potential of the AMI investment.

- ***Business Intelligence and Business Analytics***

Business intelligence (BI) is a technology-driven process for analyzing data and presenting actionable information to help corporate executives, business managers

and other end users in making more informed business decisions. BI encompasses a wide variety of tools, applications and methodologies that enable organizations to collect data from internal systems and external sources, prepare it for analysis, develop and run queries against the data, and create reports, dashboards and data visualizations to make the analytical results available to corporate decision makers as well as operational workers.

The potential benefits of business intelligence programs include accelerating and improving decision making; optimizing internal business processes; increasing operational efficiency; driving new revenues; and gaining competitive advantages over business rivals. BI systems can also help companies identify market trends and spot business problems that need to be addressed.

BI data can include historical information, as well as new data gathered from source systems as it is generated, enabling BI analysis to support both strategic and tactical decision-making processes. Initially, BI tools were primarily used by data analysts and other IT professionals who ran analyses and produced reports with query results for business users. Increasingly, however, business executives and workers are using BI software themselves, with the development of self-service Business Intellegence(BI) and data discovery tools.

Business intelligence combines a broad set of data analysis applications, including ad hoc analysis and querying, enterprise reporting, online analytical processing (OLAP), mobile BI, real-time BI, operational BI, cloud and software as a service BI, open source BI, collaborative BI and location intelligence. BI technology also includes data visualization software for designing charts and other info graphics, as well as tools for building BI dashboards and performance scorecards that display visualized data on business metrics and key performance indicators in an easy-to-grasp way.

ERP Business Intelligence and Business Objects (BI/BO) is being proposed for analytical reports, monitoring reports and management dashboards. Data will be collected from all IT and OT systems in ERP BI/BO for analysis and reporting.

- **Enterprise Service Bus:**

System engineering is an approach to manage complexity. A system engineering approach is more appropriate during smart grid system design than a power systems automation or general information technology point of view and is well-matched for supporting application-to-application (A2A), substation automation and control room integration designs.

System engineering integration methods can be employed to plan complex systems and serve as smart grid project accelerators. These integration methods are based on using enterprise-class integration tools and information management

technologies to support a highly decoupled design with scalability, maintenance, tuning and security mechanisms.

A key smart grid integration method is the accommodation of multiple ESB domains to communicate across the operation center, enterprise and substation. This approach brings with it all the native ESB advantages for A2A integrations and an in-depth security approach to supporting integrations with systems that interact with the power system. The approach has its challenges; however, extending the use of a single corporate ESB will not address adequately all needs of a utility's smart grid environment.

Utilities typically design their substation automation schemes to support operations within the substation local-area network (LAN) and for remote monitoring and control via supervisory control and data acquisition (SCADA). IEDs play a critical part in the life cycle asset management of power system devices based on the functionality of newer IEDs. IEDs also can be used by software to provide useful analysis to warn the user of undesirable events and operating conditions. By integrating the appropriate information with the utility's SCADA system and smart grid data repository, the utility can gain the most value from deploying these new IEDs inside its substation.

Smart grid solution architecture should support the operation of the power system via substation automation/SCADA integrations and substation automation/enterprise integrations supporting asset management and troubleshooting of missed events. Substation automation operational information should go from the substation to the control room via SCADA, and the substation automation non-operational information should go from the substation to the enterprise via a different communication infrastructure designed to support the non-operational data and security requirements.

Given the complexity in utilities' managing distribution smart grid systems, systems engineering approach and integration methods can ensure that the systems are scalable, secure and may provide the ability to leverage information for future data activities. Utilities should support an in-depth security paradigm through multiple ESB domains and use the auditing and logging functionality of the ESB. Substation automation data concentrators/data gateways are key architectural components for security and dual-access paths into the substation LAN. Centralized DMS/SCADA applications must coordinate with the respective substation automation and autonomous schemes. The substation automation solution should report errors and remediation failures back to the DMS/SCADA system. Acknowledge that the field work force is a key factor to maintaining a zero-latency power system model in the DMS.

- **Home Automation**

As with other industries, use of robust two-way communications, advanced sensors, and distributed computing technology will improve the efficiency, reliability and safety of power delivery and use. It also opens up the potential for entirely new services or improvements on existing ones, such as fire monitoring and alarms that can shut off power, make phone calls to emergency services, etc.

Automation is, unsurprisingly, one of the two main characteristics of home automation. Automation refers to the ability to program and schedule events for the devices on the network. The programming may include time-related commands, such as having your lights turn on or off at specific times each day. It can also include non-scheduled events, such as turning on all the lights in your home when your security system alarm is triggered.

Energy savings is one of the most important aspect of home automation. One clear advantage of home automation is the unmatched potential for energy savings, and therefore cost savings. Your thermostat is already "smart" in the sense that it uses a temperature threshold to govern the cooling system. In most cases, thermostats can also be programmed with different target temperatures in order to keep energy usage at a minimum during the hours when you're least likely to benefit from the cooling.

At the most basic level, home automation extends that scheduled programmability to lighting, so that you can suit your energy usage to your usual daily schedule. With more flexible home automation systems, electrical outlets or even individual devices can also be automatically powered down during hours of the day when they're not needed.

*Benefits of Home Automation: -*

- *Convenience for the consumers*
- *Home Security*
- *Remote Access Control & Connectivity*
- *Energy Efficiency*

## (k) SCIENTIFIC DISTRIBUTION SYSTEM PLANNING USING PLANNING S/W 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 Discoms generally are Consumer growth, consumption growth, Price of Electricity, Financial Aid, Energy Efficient Measures, Plausible Decline in the number of High Value Consumers, Risk of Migration of consumers to open access etc. The Discoms need to work out Electrical Energy Requirement Projections, Electrical Demand Projections, Trajectory of T&D losses, Selection of Load Factor,

Impact of DSM measures etc through use of software tools available for distribution planning.

The planning for distribution system includes the analysis of existing system and planning of optimal future requirement of sub transmission and Distribution lines & Distribution Substations keeping in view the futuristic approach . This would also include the requirement of adequate Communication system and IT infrastructure like SCADA, DMS, OMS, AMI etc

Through this approach, a distribution company should be able to analyze the distribution network for following:

- Optimization of loading of Transformers (power transformers and distribution transformers) and Feeders.
- Ensuring an adequate network for existing as well future need with N-1 redundancy in the network i.e. at Medium Voltage (MV) (11 KV) and High voltage (HV) (66 and 33 KV).
- Reduce technical loss by optimizing the network configuration.
- Ensure voltage regulation in line with the Regulations.

The system is planned with the primary objective of meeting load growth and maintaining the desired redundancy level in the system to meet current supply requirements. System is to be analyzed during contingency condition and loading of various network elements to be reviewed, cases where space and transmission up-stream network availability is there have to be considered in the plan. Area wise loss level is also assessed along with the ground reality for future T&D loss reduction trajectory.

Through the use of system software , the new development/addition/augmentation can be studied against the overloaded network element based on the degree of overloading (Transformers/ Feeders/ grid stations/ Substations). The works required to upgrade IT tools/software to meet various business requirements, install compatible hardware and provide better connectivity between various offices, Grid Substations etc are also to be planned for introducing transparency in the system.

## 4. BENEFIT OF INTEGRATION OF IT AND OT FOR CUSTOMER CONVENIENCE.

Power Distribution utilities generally select and implement technological solutions on piece-meal basis and various systems operate in isolation to each other. Operating the systems in isolation, deprives the user of reaping the full benefits of investments. By having various systems integrated, the overall increase in operational efficiency

and resource optimization can be achieved. For example, the following systems have a dedicated works as stated under-

- SCADA system is capable of informing about the status of the breaker controlling sub-transmission/distribution lines but cannot let the utility operator know who the affected customers are.
- GIS system has got the network and customer hierarchy but cannot update the consumers, in case they are out or even cannot know which of the device in field is out at any given point of time.
- Any Maintenance Module of any ERP is capable of maintenance planning and asset management but due to an equipment being out for maintenance, which of the customers will be out, cannot be ascertained.
- CRM system is capable of taking consumers complaint but cannot update the status until feedback is received from any other system.

In case, all the above IT enabled systems run in isolation, it would not provide an overall picture of the system but if all of the above systems are designed to operate in integration with each other and implemented in integrated mode, then it will provide the operator an wholesome picture which not only increases the operational efficiency but also optimize the human resources required.
The integrated approach helps in

- Proactive response for the customer outages due to tripping of SCADA monitored devices with the help of integration with SCADA/DMS/GIS for getting status update of the out devices, integration with GIS for list of affected customers from GIS network hierarchy and with SAP CRM for updating the customer records for updating the customers.
- Prediction of location of faulty network component which has contributed to outage to the customer by utilizing the GIS network hierarchy and calls registered due to outage of any non SCADA monitored device which helps in curtailing downtime.
- Prioritizing restoration efforts and managing resources based upon pre defined criteria such as locations of emergency facilities, size of outages, and duration of outages etc.
- Providing information on extent of outages and number of customers under outage to the call centre so that the consumers can be kept updated.
- Updation of estimated time of restoration based on historical data for first cut and then on the basis of crew feedback.
- Advance intimation to customers about outages to the customers in case of planned maintenance outages.

Thus, with the use of integration of various IT and OT modules would facilitate the utilities to be smart and proactive and would increase the satisfaction level of the consumers.

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# GUIDELINES

# ON

# POWER QUALITY

# &

# SAFETY ISSUES

# IN USAGE

# OF

# ROOF-TOP SOLAR PV SYSTEM

## 1. INTRODUCTION

Solar energy has become the most popular renewable energy source wherein energy is extracted directly from sun using photo-voltaic (PV) modules, but due to the intermittent nature of solar radiation availability and other weather conditions, there is challenge to provide reliable power through Solar PV(SPV) system.

Though SPV are basically either Grid connected or Off grid, following four configurations are commonly used for solar PV system: -

i. Grid connected SPV system without battery storage,
ii. Grid connected Net Metering system with Battery storage- system disconnected from Grid in the event of use of battery at the time grid failure
iii. Off-grid standalone SPV system (micro grid) with battery- system supplying power to a cluster of houses
iv. Off grid dedicated standalone SPV system used for independent houses, street lights, pump sets etc.

In first three systems, there is a requirement of inverter, while the fourth system may require inverter and battery based on type of appliances used and user requirement.

The output power of PV system can be harnessed to full extent under various atmospheric conditions of solar intensity and temperature by use of modified control strategy with the help of Maximum Power Point Traker (MPPT) design. The inverter is nothing but power electronics converters which also works as voltage regulators for output power but may develop harmonics in output voltage during conversion from DC to AC which would be injected in to the grid leading to various power quality problems in the grid.

Many a times, depending on the type of applications and use, the SPV system is accompanied with either a battery system of adequate capacity for absorbing the intermittency in generation of SPV and delivering stable voltage to grid or to act as an energy storage system like Battery Energy Storage Systems (BESS), which stores the excess generation of SPV and delivers the same during peak hours to enhance power supply reliability in the grid for consumers.

In a grid connected SPV system there are 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 machines etc.. Any integration of renewable energy sources to the grid has to meet standard power quality requirements.

The following section describes how the PQ issues particularly, the power factor, reactive power compensation, harmonics and voltage regulations at SPV end and the safety issues with SPV can be addressed.

## 2. PQ ISSUES ON POWER FACTOR , REACTIVE POWER COMPENSATION, HARMONICS AND VOLTAGE REGULATIONS AT SPV END

The rush to harness solar energy from the sun to make electricity has displaced a good portion of conventional power generation, and at the same time, the loads with sizable reactive component can actually deteriorate power factor in the system. With increased penetration of Solar PV Plants (SPV), importance of power factor, power factor correction, reactive power requirement and harmonics will be relevant for consumers as well as utilities.

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.

In case, this premises installs a 500kW SPV system which exports power at a unity power factor, 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. Thus, the voltage at load end would further dip.

**Figure-1**

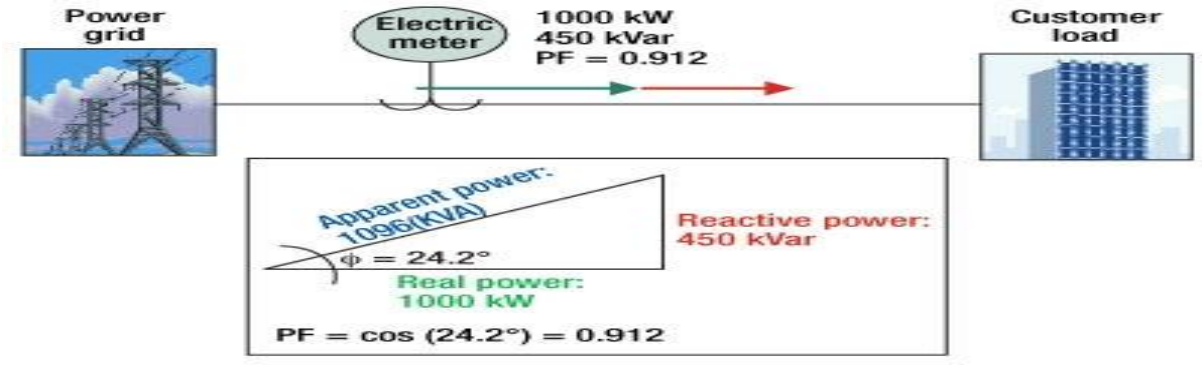
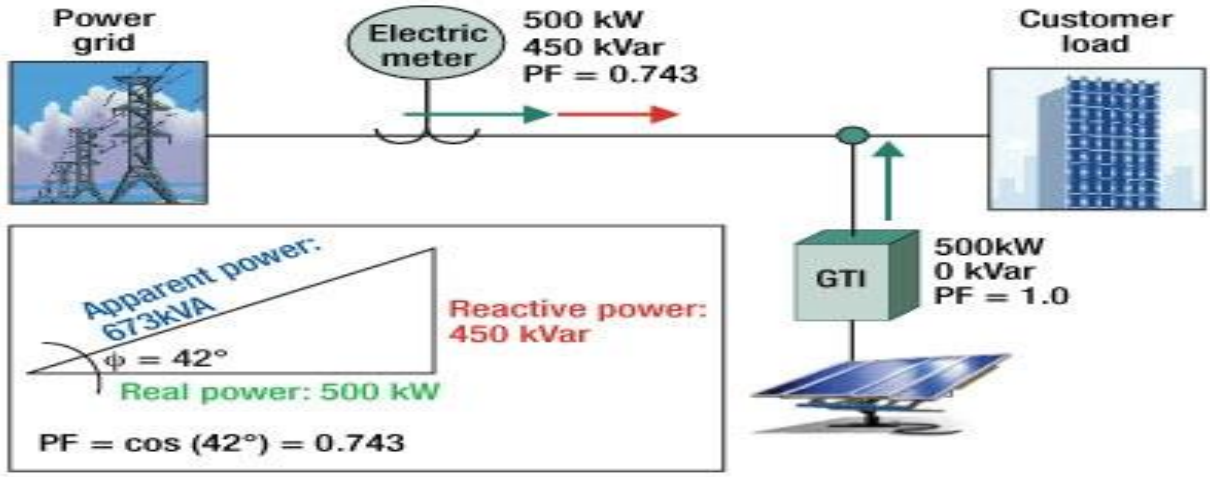


**Figure-2**




There may be similar situation of deterioration of power factor in case of leading power factor of load. Generally, voltage regulators and capacitors work well for controlling voltages on radial circuits. But with distributed power generation with more than one sources including SPVs, voltage control will be more challenging.

In the example 2 above, SPV power helps in displacing 50% of utility real power. In this case, the grid and SPV power each feed 500kW to the load. The consumer draws only 500kW of real power and the full 450kVARs of reactive power from Grid and the result is that the power factor has dipped to 0.743 lagging.

## 3. ANALYSIS OF THE PROBLEM:

As mentioned above, 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. Multistage Inverters having reactive power and harmonics control can be configured to produce both active and reactive power, i.e. an output that is at a non-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.

## 4. QUALITY OF INVERTER:

The Grid-Tie Inverters (GTI), works on principle of a conventional stand-alone DC-AC inverter/converter but with some additional smart features. The main difference lies in their control algorithm and safety features. GTI is 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 mains supply, or exceeding/decreased grid voltage level or frequency than limits and Tracking of power generation of SPV. GTI basically takes a variable DC voltage from the source i.e. solar panels array and inverts it to AC and also boost the same to enable synchronization/interconnection with the grid power (inverter function).

This inverted power of SPV Array can be consumed by owner of SPV or can be exported to utility grid while in parallel with the grid depending on SPV generation and the load connected with owner's premises. The GTI also take helps in getting the maximum electricity output from SPV by use of Maximum Power Point tracker (MMPT) technology.

Multistage Inverters are useful for maintaining the power factor, reactive power as well as limiting the harmonics injection to grid when designed, set and tuned properly. These Multistage Inverters are designed with Inductance(L) /Capacitance (C) circuitry and with the harmonic filter circuitry with combination of Resistance (R), Inductance(L) and Capacitance (C) for maintaining the reactive power and harmonics control at the SPV end respectively.

## 5. SAFETY CONCERNS IN CASE OF ROOF -TOP SOLAR/WIND

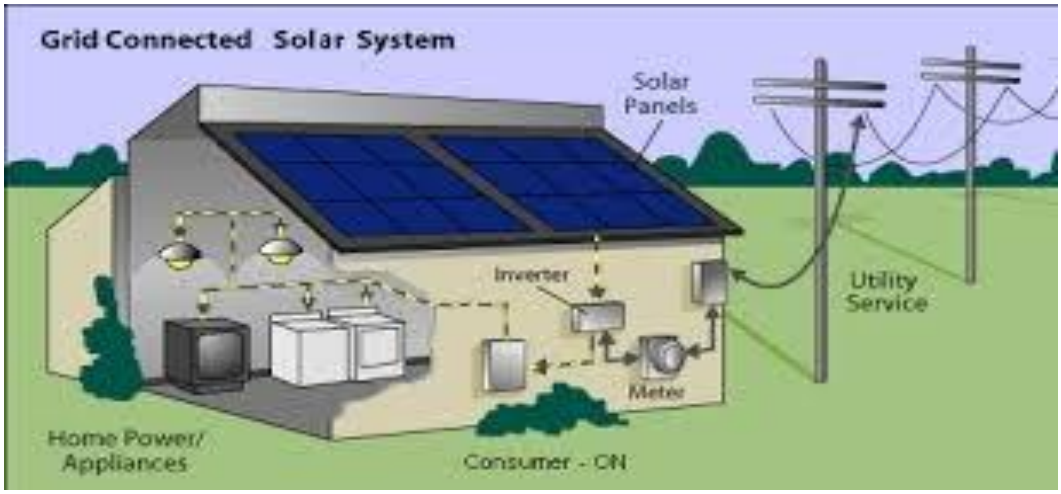
Some distribution utilities have voiced their concerns on the concepts of feeding generated power by the consumers to the grid from various renewable energy sources and micro scale generator units due the major issue of safety. Several utility sectors have warned that power injection in distribution grid by mass-scale distributed generators as well as consumers may cause possibility of electrocution, because consumers can produce electricity using Grid connected systems primarily made up of SPV/Wind Power technology without proper safety features.

PV modules generate DC voltage when they are exposed to light and even when physically disconnected from the grid, so there may be a risk of Shock by these modules without proper earthing. Chances of short circuit always present 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 as an ARC/spark may lead to damage.

The intelligent Inverter (GTI) installed with SPV helps in providing power to consumers and also feeds excess electricity generated in SPV than the required at consumers premises into the grid. It would also automatically stops supply of electricity to the grid when the grid is down. Therefore, GTI automatically stops back feeding of electricity

of SPV 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.

As per CEA (Installation and Operation of Meters) Amendment Regulations 2014, In case consumer want to use SPV power for its use at the time of grid failure, he has to install an automatic switching system to isolate its supply with SPV system from Grid to get the supply from SPV with Battery system safely.




To ensure the safety & quality of the power through SPV system, following suggestions should be followed :-

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 and efficiency of the inverter should be more than 97%.
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 as notified by CEA (Standard for connectivity of Distributed

Generation Resources) regulation 2013 and CEA (Technical standard for connectivity of the Grid) regulation 2007, as amended from time to time.

7. The effect of the change in loading pattern to be monitored by the owner/ agency installing the PV system 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 invertor. 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.

# GUIDELINES

# FOR

# CODE BASED

# NATIONAL LEVEL

# FAILURE ANALYSIS SYSTEM

## OUTAGE CODIFICATION FOR DISTRIBUTION SECTOR

A common standard codes for analysis & evaluation of outages in particular category/equipment across all the Discoms/States is a necessity to analyse the problems on national level. Also, financial implication of outage due to business loss and loss of supply of power needs to be analysed against each independent category. Presently, due to different forms of reporting done by various Discoms, it is not possible to analyse the same.

In the present guidelines, the task to codify the various outages in sub-transmission and distribution segment has been formulated for devising an easy & comprehensive methodology to codify the outages so that the same may be adopted by each and every Discom irrespective of its size and nature.

Accordingly, multi level codes varying from two to four digit have been developed and combined in particular sequence to provide analysis based on various categories, voltages, fault types, etc. This can be predetermined or can be customized through filter/sort mode in a progamable mode like in MS excel etc.

The details of the coding are as below:

i. Multi level codes(alphanumeric) consisting of 2 digit to 4 digit codes have been devised. The first level of codes are alphabetic and rest level are numeric or alphanumeric.

ii. First level code of four alphanumeric and are voltage dependent. Outage Equipment operating voltage or Primary or highest voltage of s/s is to be given here.

iii. Second level codes are two alphabetic code and for equipment identification where outage has occurred.

iv. Third level code is two digits and depend on major reason of outage.

v. Fourth level code is two digits and depend on detailed reason of outage depending on major reason selected in third level. These codes are variable and give sub-reason of outage. If no specific reason, then “00” is indicated.

vi. Fifth level code is two digits, depend on fourth level reason of outage and also gives specific reason, equipment part and type of outage. If no specific reason, then “00” is indicated.

vii. Each code is associated with code one level higher. However, there may not be any specific reason in next level, therefore such codes are kept as “00”.

viii. Procedure & database for codification and de-codification would be same for particular method.

ix. This codification method is open ended and therefore more levels can also be added in the end without affecting the working of this codes. However, no. of digits and its nature i.e. alphanumeric/alphabetic/numeric should not be changed. This can be changed with appropriate changes in software but only by an expert.

x. More levels, if required can be inserted in between. Levels can also be interchanged keeping the no. of digits same. However, this require changes in software.

The Utilities have to device a suitable software for compilation and analysis of various outage/ failure data of various equipment.

The details of the Level of codes along with Example are as given below.

**Voltage Level**
**Level-1**

| Item | Code |
|---|---|
| 66 KV | 66KV |
| 33 KV | 33KV |
| 22 KV | 22KV |
| 11 KV | 11KV |
| 6.6 KV | 06KV |
| 3.3 KV | 03KV |
| 415V | 415V |
| | |

**Equipment type**
**Level-2**

| Items | codes |
|---|---|
| line/Cable | LL |
| transformer | TR |
| breaker | BR |
| bus coupler | BC |
| capacitor | CC |
| reactor | RR |
| insulator | IR |
| lighening arrestor | LA |
| Busbar | BB |
| tower | TW |
| Earthswitch | ES |
| Isolator | IS |
| LT Distribution box | DB |
| Solar Rooftop | SR |

**Major Categories of outages**
**Level-3**

| Fault type | codes |
|---|---|
| Protection/Relay | 01 |
| Burst/Fire/Break | 02 |
| Grid side | 03 |
| Auxiliaries | 04 |
| Animal intrusion | 05 |
| Natural calamity | 06 |
| Maloperation | 07 |
| Maintenance | 08 |
| Miscreants/theft | 09 |
| Leakage | 10 |
| Mechanism fail | 11 |
| Communication | 12 |
| Spares & tools | 13 |
| Accidents | 14 |

Auxiliaries -CT/PT/CVT/battery bank/UPS/DC supply i.e. items at 110 V AC/DC In case of Transformers, highest of primary or secondary voltage to be taken.

Major Categories of outages

Level-3

| Fault type | codes |
|---|---|
| Protection/Relay | 01 |
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Level-4/3-1

| Protection type | codes |
|---|---|
| Over current | 01 |
| Earth fault | 02 |
| P to P fault | 03 |
| NGR fault | 04 |
| Differential | 05 |
| Busbar fault | 06 |
| Bucholz Trip | 07 |
| Overflux | 08 |
| Wrong setting | 09 |
| Phase imbalance | 10 |
| Power factor | 11 |
| Consumer | 12 |
| Backfeed | 13 |
| Harmonics | 14 |
| | |

Level-4/3-2

| Burst/Fire/break | codes |
|---|---|
| Conductor snap | 01 |
| Joint break | 02 |
| Burst/fire/Damaged | 03 |
| Tower/pole collapse | 04 |
| Leakage | 05 |
| Hot spot/spark | 06 |
| Lead burnt | 07 |
| Cable damage | 08 |

Level-4/3-3

| Grid Side | codes |
|---|---|
| Load shedding | 01 |
| Conjestion | 02 |
| Power swing | 03 |
| O/U drawl | 04 |
| O/U frequency | 05 |
| O/U voltage | 06 |
| Load encroach | 07 |

Level-4/3-4

| Auxiliaries | codes |
|---|---|
| CT/PT/CVT | 01 |
| Battery bank/UPS | 02 |
| DC/AC standby supply | 03 |
| | |

Level-4/3-5

| Animal intrusion | codes |
|---|---|
| Lizard/snake | 01 |
| Monkeys | 02 |
| Big Jungle animal | 03 |
| Birds | 04 |

Level-4/3-6

| Natural calamity | codes |
|---|---|
| Heavy Rain | 01 |
| Fog/smog | 02 |
| Earthquake | 03 |
| Flood/Cyclone | 04 |
| Darkness | 05 |
| No approach | 06 |
| ROW | 07 |
| Strike | 08 |

Level-4/3-7

| Maloperation | codes |
|---|---|
| Loose/wrong wiring | 01 |
| Wrong setting | 02 |
| Saturation | 03 |
| Relay failure | 04 |
| Failure of aux. equipment | 05 |

Level-4/3-8

| Maintenance | codes |
|---|---|
| Planned | 01 |
| Breakdown | 02 |
| Preventive | 03 |
| Opportunity | 04 |
| Augmentation | 05 |
| Construction | 06 |
| Repair | 07 |

Level-4/3-9

| Miscreants/theft | codes |
|---|---|
| Terrorism | 01 |
| Theft | 02 |
| Accidents | 03 |
| Strike | 04 |
| | 05 |

Level-4/3-10

| Leakage | codes |
|---|---|
| GIS-SF6 | 01 |
| Vaccum | 02 |
| Oil | 03 |
| Air | 04 |

Level-4/3-11

| Mechanism fail | codes |
|---|---|
| Breaker | 01 |
| Vaccum | 02 |
| Isolator | 03 |
| Earth switch | 04 |
| Tr. Tap fail | 05 |
| Interlock | 06 |

Level-4/3-12

| Communication | codes |
|---|---|
| PLCC | 01 |
| Optic Fibre | 02 |
| RTU | 03 |
| PMU | 04 |

Level-4/3-13

| Spares & tools | codes |
|---|---|
| Lugs/nut/bolt | 01 |
| Plier/cutter | 02 |
| Fuse/MCB | 03 |
| Discs/conductor/cable/GI | 04 |
| Bushing/oil | 05 |
| Civil material | 06 |
| Grease etc. | 07 |

Level-4/3-14

| Accidents | codes |
|---|---|
| No Precautions | 01 |
| Engineer not present at work | 02 |
| Pole damage by vehicle | 03 |
| Line damage by vehicle | 04 |
| Electric shock to human/animal | 05 |
| Burning due to spark | 06 |

Level-5/4/3-1-1

| Protection type | codes |
|---|---|
| Not known | 00 |
| High load | 01 |
| Extra losses | 02 |
| Leakage | 03 |
| High/low PF | 04 |

Level-5/4/3-1-2

| Protection type | codes |
|---|---|
| Not known | 00 |
| Short circuit | 01 |
| Smoke | 02 |
| Tree falling | 03 |
| Insulation failure | 04 |
| Disc failure | 05 |

Level-5/4/3-1-3

| Protection type | codes |
|---|---|
| Not known | 00 |
| Air swing | 01 |
| Smoke | 02 |
| spacer problem | 03 |
| Tree touching | 04 |
| Insulation failure | 05 |
| Disc failure | 06 |

Level-5/4/3-1-4

| Protection type | codes |
|---|---|
| Not known | 00 |
| NGR open | 01 |
| | 02 |
| | 03 |
| | 04 |
| | 05 |
| | 06 |

Level-5/4/3-1-5

| Protection type | codes |
|---|---|
| Not known | 00 |
| Internal Faults | 01 |
| Loose wiring | 02 |

Level-5/4/3-1-6

| Protection type | codes |
|---|---|
| Not known | 00 |
| Internal Faults | 01 |
| Loose wiring | 02 |
| External fault | 03 |

Level-5/4/3-1-7

| Protection type | codes |
|---|---|
| No specific | 00 |
| Wdg fault | 01 |
| Oil quality low | 02 |
| Wdg Insulation poor | 03 |
| Maloperation | 04 |
| Oil level low | 05 |

Level-5/4/3-1-08

| Protection type | codes |
|---|---|
| No specific | 00 |
| overvoltage | 01 |
| underfrequency | 02 |
| line loading low | 03 |
| shunt compensation | 04 |
| core material | 05 |

Level-5/4/3-1-09

| Protection type | codes |
|---|---|
| No specific | 00 |
| Distance | 01 |
| Phase sequence | 02 |
| CT/PT connections | 03 |
| Multiplier | 04 |
| Timer | 05 |
| Curve | |

Level-5/4/3-1-10

| Protection type | codes |
|---|---|
| No specific | 00 |
| unbalanced load | 01 |
| Traction | 02 |
| Phase open | 03 |
| breaker contact | 04 |
| | |

Level-5/4/3-1-11

| Protection type | codes |
|---|---|
| No specific | 00 |
| Reactive load | 01 |
| Underloading | 02 |
| Overloading | 03 |
| Renewable gen. | 04 |
| SVC/capacitor out | 05 |

Level-5/4/3-1-12

| Protection type | codes |
|---|---|
| Not known | 00 |
| No light | 01 |
| Fuse blown | 02 |
| MCB trip | 03 |
| Socket Problem | 04 |
| Meter problem | 05 |
| Cable spark | 06 |

Level-5/4/3-1-13

| Protection type | codes |
|---|---|
| Not known | 00 |
| Less/No load | 01 |
| Reverse flow | 02 |
| Excess generation | 03 |

Level-5/4/3-1-14

| Protection type | codes |
|---|---|
| Not known | 00 |
| Relay heating | 01 |
| Measurement error | 02 |
| Cable heating | 03 |
| Neutral heating/voltage | 04 |
| Capacitor destruction | 05 |
| Transformer saturation | 06 |

Level-5/4/3-2-1

| Burst/Fire/break | codes |
|---|---|
| Not known | 00 |
| Fall on tree | 01 |
| Fall on ground | 02 |
| Other conductor | 03 |
| On earth guard | 04 |

Level-5/4/3-2-2

| Burst/Fire/break | codes |
|---|---|
| Not known | 00 |
| Bushing fail | 01 |
| Termination joint | 02 |
| Jumper fail | 03 |

Level-5/4/3-2-3

| Burst/Fire/break | codes |
|---|---|
| Not known | 00 |
| Tr. Tank fire | 01 |
| Tr. Tank burst | 02 |
| DB fire | 03 |
| DB burst | 04 |

Level-5/4/3-2-4

| Burst/Fire/break | codes |
|---|---|
| Not known | 00 |
| High wind | 01 |
| Cyclone | 02 |
| Accident | 03 |
| Loose soil | 04 |
| Structure break | 05 |
| Terrorism | 06 |

Level-5/4/3-2-5

| Burst/Fire/break | codes |
|---|---|
| Not known | 00 |
| Tank oil | 01 |
| Reactor oil | 02 |
| Breaker vaccum | 03 |
| Conservator | 04 |
| Isolator | 05 |

Level-5/4/3-2-6

| Burst/Fire/break | codes |
|---|---|
| Not known | 00 |
| Corona | 01 |
| Bushing | 02 |
| Jumper | 03 |
| DB | 04 |
| Isolator | 05 |
| Insulator string | 06 |
| Pole | 07 |

Level-5/4/3-2-6

| Burst/Fire/break | codes |
|---|---|
| Not known | 00 |
| Corona | 01 |
| Bushing | 02 |
| Jumper | 03 |
| DB | 04 |
| Isolator | 05 |

Level-5/4/3-2-7

| Burst/Fire/break | codes |
|---|---|
| Not known | 00 |
| Termination | 01 |
| Meter lead | 02 |
| Transformer | 03 |

Level-5/4/3-2-8

| Burst/Fire/break | codes |
|---|---|
| Not known | 00 |
| Sheath broken | 01 |
| Insulation fail | 02 |
| conductor problem | 03 |
| External damage | 04 |
| Duct work by others | 05 |

Level-5/4/3-3-1

| Grid Side | codes |
|---|---|
| Not known | 00 |
| Manual LS | 01 |
| AULFS | 02 |
| DF/Dt | 03 |
| Planned LS | 04 |
| Instruction-SLDC | 05 |

Level-5/4/3-3-2

| Grid Side | codes |
|---|---|
| Not known | 00 |
| Line loadings | 01 |
| Over drawal | 02 |
| Under drawal | 03 |
| Reduced margin | 04 |
| Commercial | 05 |
| | |

Level-5/4/3-3-3

| Grid Side | codes |
|---|---|
| Not known | 00 |
| Large angle | 01 |
| Loop flow | 02 |
| | |
| | |
| | |
| | |

Level-5/4/3-3-4

| Grid Side | codes |
|---|---|
| Not known | 00 |
| Over drawal | 01 |
| Under drawal | 02 |
| | |
| | |
| | |
| | |

Level-5/4/3-3-5

| Grid Side | codes |
|---|---|
| Not known | 00 |
| Over Frequency | 01 |
| Under Frequency | 02 |
| | |
| | |
| | |
| | |

Level-5/4/3-3-6

| Grid Side | codes |
|---|---|
| Not known | 00 |
| U/O generation | 01 |
| U/O loading of lines | 02 |
| high/low capacitance/reactance | 03 |
| voltage spikes | 04 |
| | |
| | |

Level-5/4/3-4-1

| Auxiliaries | codes |
|---|---|
| Not known | 00 |
| Failure/Burst/Fire | 01 |
| Measurement error | 02 |
| Saturation | 03 |
| Loose connection | 04 |
| Accuracy | 05 |

Level-5/4/3-4-2

| Auxiliaries | codes |
|---|---|
| Not known | 00 |
| Battery voltage low | 01 |
| Battery backup | 02 |
| Battery old | 03 |
| Switching error | 04 |
| Battery charger | 05 |

Level-5/4/3-4-3

| Auxiliaries | codes |
|---|---|
| Not known | 00 |
| Circuit problem | 01 |
| Voltage drop | 02 |
| Aux. transformer | 03 |
| Switching error | 04 |
| Interconnections | 05 |

Level-5/4/3-5-1

| Animal intrusion | codes |
|---|---|
| Not known | 00 |
| Busbar SC | 01 |
| Cable SC | 02 |
| MCB/DB SC | 03 |
| | |
| | |

Level-5/4/3-5-2

| Animal intrusion | codes |
|---|---|
| Not known | 00 |
| Line SC | 01 |
| Bushing SC | 02 |
| LA fail | 03 |
| Spacers | 04 |
| | |

Level-5/4/3-5-3

| Animal intrusion | codes |
|---|---|
| Not known | 00 |
| Line SC | 01 |
| Bushing SC | 02 |
| Pole tilt/collapse | 03 |
| | |
| | |

Level-5/4/3-5-4

| Animal intrusion | codes |
|---|---|
| Not known | 00 |
| Line SC | 01 |
| Bushing SC | 02 |
| | 03 |
| | |
| | |

Level-5/4/3-6-1

| Natural calamity | codes |
|---|---|
| Not known | 00 |
| Line fault | 01 |
| Tr. Fault | 02 |
| Ingress of water | 03 |
| SC due to Moisture | 04 |
| Precautionary Measure | 05 |

Level-5/4/3-6-2

| Natural calamity | codes |
|---|---|
| Not known | 00 |
| Line fault | 01 |
| Tr. Fault | 02 |
| SC due to Humidity | 03 |
| | 04 |
| | 05 |

Level-5/4/3-6-3

| Natural calamity | codes |
|---|---|
| Not known | 00 |
| Tower collapse | 01 |
| Conductor snap | 02 |
| Tr. Collapse | 03 |
| S/s buidling | 04 |
| | 05 |

Level-5/4/3-6-4

| Natural calamity | codes |
|---|---|
| Not known | 00 |
| Tower collapse | 01 |
| Ingress of water | 02 |
| Tr. Collapse | 03 |
| S/s buidling collapse | 04 |
| Precautionary measure | 05 |

Level-5/4/3-6-5

| Natural calamity | codes |
|---|---|
| Not known | 00 |
| Could not work | 01 |
| Could not reach | 02 |
| Extension of work | 03 |
| | |
| | |

Level-5/4/3-6-6

| Natural calamity | codes |
|---|---|
| Not known | 00 |
| Road damaged | 01 |
| Flood | 02 |
| Mud/paddy fields | 03 |
| ROW | 04 |
| Strike | 05 |

Level-5/4/3-6-7

| Natural calamity | codes |
|---|---|
| Not known | 00 |
| Manpower availability | 01 |
| | |
| | |
| | |
| | |

Level-5/4/3-6-8

| Natural calamity | codes |
|---|---|
| Not known | 00 |
| Manpower availability | 01 |
| | |
| | |
| | |
| | |

| | |
|---|---|
| Danger to life | 06 |

Level-5/4/3-7-1

| Maloperation | codes |
|---|---|
| Not known | 00 |
| CT/PT/CVT | 01 |
| Battery bank/UPS | 02 |
| DC/AC standby supply | 03 |
| Relays | 04 |
| | |

Level-5/4/3-7-2

| Maloperation | codes |
|---|---|
| Not known | 00 |
| Distance setting | 01 |
| Time setting | 02 |
| Current % | 03 |
| Voltage % | 04 |
| Curve | 05 |

Level-5/4/3-7-3

| Maloperation | codes |
|---|---|
| Not known | 00 |
| CT | 01 |
| PT | 02 |
| CVT | 03 |
| Relays | 04 |
| | |

Level-5/4/3-7-4

| Maloperation | codes |
|---|---|
| Not known | 00 |
| Mechanical | 01 |
| Numerical | 02 |
| Static | 03 |
| | |
| | |

Level-5/4/3-7-5

| Maloperation | codes |
|---|---|
| Not known | 00 |
| CT/PT/CVT | 01 |
| Battery bank/UPS | 02 |
| DC/AC standby supply | 03 |
| Relays | 04 |
| | |

Level-5/4/3-8-1

| Maintenance | codes |
|---|---|
| Not known | 00 |
| Line/Cable | 01 |
| DT/Transformer | 02 |
| Auxiliary | 03 |
| Reactor | 04 |
| Capacitor | 05 |
| General | 06 |
| Inspection | 07 |
| Insulator | 08 |
| Fibre Optic | 09 |

Level-5/4/3-8-2

| Maintenance | codes |
|---|---|
| Not known | 00 |
| Line/Cable | 01 |
| DT/Transformer | 02 |
| Auxiliary | 03 |
| Reactor | 04 |
| Capacitor | 05 |
| General | 06 |
| Inspection | 07 |
| Insulator | 08 |
| Fibre Optic | 09 |

Level-5/4/3-8-3

| Maintenance | codes |
|---|---|
| Not known | 00 |
| Line/Cable | 01 |
| DT/Transformer | 02 |
| Auxiliary | 03 |
| Reactor | 04 |
| Capacitor | 05 |
| General | 06 |
| Inspection | 07 |
| Insulator | 08 |
| Fibre Optic | 09 |

Level-5/4/3-8-4

| Maintenance | codes |
|---|---|
| Not known | 00 |
| Line/Cable | 01 |
| DT/Transformer | 02 |
| Auxiliary | 03 |
| Reactor | 04 |
| Capacitor | 05 |
| General | 06 |
| Inspection | 07 |
| Insulator | 08 |
| Fibre Optic | 09 |

Level-5/4/3-8-5

| Maintenance | codes |
|---|---|
| Not known | 00 |
| Line/Cable | 01 |
| DT/Transformer | 02 |
| Auxiliary | 03 |
| Reactor | 04 |
| Capacitor | 05 |
| General | 06 |
| Inspection | 07 |
| Insulator | 08 |
| Fibre Optic | 09 |

Level-5/4/3-8-6

| Maintenance | codes |
|---|---|
| Not known | 00 |
| Line/Cable | 01 |
| DT/Transformer | 02 |
| Auxiliary | 03 |
| Reactor | 04 |
| Capacitor | 05 |
| General | 06 |
| Inspection | 07 |
| Insulator | 08 |
| Fibre Optic | 09 |

Level-5/4/3-8-7

| Maintenance | codes |
|---|---|
| Not known | 00 |
| Line/Cable | 01 |
| DT/Transformer | 02 |
| Auxiliary | 03 |
| Reactor | 04 |
| Capacitor | 05 |
| General | 06 |
| Inspection | 07 |
| Insulator | 08 |
| Fibre Optic | 09 |

Level-5/4/3-9-1

| Miscreants/theft | codes |
|---|---|
| Not known | 00 |
| Bomb blast | 01 |
| Air Strike | 02 |
| War | 03 |
| Law & Order | 04 |
| | |

Level-5/4/3-9-2

| Miscreants/theft | codes |
|---|---|
| Not known | 00 |
| Tapping overhead | 01 |
| Tapping underground | 02 |
| Tapping meter | 03 |
| Meter alteration | 04 |
| Non payment | 05 |

Level-5/4/3-9-3

| Miscreants/theft | codes |
|---|---|
| Not known | 00 |
| Law & order | 01 |
| No access | 02 |
| No manpower | 03 |
| ROW | 04 |
| | |

Level-5/4/3-9-4

| Miscreants/theft | codes |
|---|---|
| Not known | 00 |
| Court case | 01 |
| Subjudice | 02 |
| Compensation | 03 |
| Stay order | 04 |
| | |

Level-5/4/3-10-1

| Leakage | codes |
|---|---|
| Not known | 00 |
| Breaker | 01 |
| Line/Cable | 02 |
| Disconnector switch | 03 |
| Earthing switch | 04 |
| Busbar | 05 |
| Transformer | 06 |

Level-5/4/3-10-2

| Leakage | codes |
|---|---|
| Not known | 00 |
| Breaker | 01 |

Level-5/4/3-10-3

| Leakage | codes |
|---|---|
| Not known | 00 |
| Tr. tank | 01 |
| Breaker | 02 |
| Tr. Bushing | 03 |
| Tr. Taps | 04 |
| | |

Level-5/4/3-10-4

| Leakage | codes |
|---|---|
| Not known | 00 |
| Breaker | 01 |
| | |
| | |
| | |
| | |

Level-5/4/3-11-1

| Mechanism fail | codes |
|---|---|
| Not known | 00 |
| Breaker spring | 01 |
| Breaker contact | 02 |
| | |

Level-5/4/3-11-2

| Mechanism fail | codes |
|---|---|
| Not known | 00 |
| Pressure gauge | 01 |
| Compressor | 02 |

Level-5/4/3-11-3

| Mechanism fail | codes |
|---|---|
| Not known | 00 |
| handle | 01 |
| contact | 02 |

Level-5/4/3-11-4

| Mechanism fail | codes |
|---|---|
| Not known | 00 |
| handle | 01 |
| contact | 02 |
| | |

Level-5/4/3-11-5

| Mechanism fail | codes |
|---|---|
| Not known | 00 |
| solenoid valve | 01 |
| contact | 02 |
| Online | 03 |
| Offline | 04 |

Level-5/4/3-11-6

| Mechanism fail | codes |
|---|---|
| Not known | 00 |
| Switch | 01 |
| Contactor | 02 |
| | |
| | |

Level-5/4/3-12-1

| Tr. Taps | codes |
|---|---|
| Not known | 00 |
| Contact | 01 |
| Ratio | 02 |
| Interturn | 03 |
| Voltage | 04 |

Level-5/4/3-12-2

| Tr. Taps | codes |
|---|---|
| Not known | 00 |
| Contact | 01 |
| Ratio | 02 |
| Interturn | 03 |
| Voltage | 04 |

Level-5/4/3-13-1

| Communication | codes |
|---|---|
| Not known | 00 |
| Capacitor | 01 |
| Filter | 02 |
| Circuit | 03 |
| | |

Level-5/4/3-13-2

| Communication | codes |
|---|---|
| Not known | 00 |
| Fibre cut | 01 |
| Jointing | 02 |
| Interference | 03 |
| | |

Level-5/4/3-13-3

| Communication | codes |
|---|---|
| Not known | 00 |
| No data | 01 |
| Non-current data | 02 |
| Mapping into SCADA | 03 |
| | |

Level-5/4/3-13-4

| Communication | codes |
|---|---|
| Not known | 00 |
| No data | 01 |
| Non-current data | 02 |
| Mapping into SCADA | 03 |
| | |

Level-5/4/3-13-5

| Communication | codes |
|---|---|
| Not known | 00 |
| No data | 01 |
| Inter-mittant data | 02 |
| Mapping into SCADA | 03 |
| | |

Level-5/4/3-14-1

| Spares & tools | codes |
|---|---|
| Not known | 00 |
| Non-availability | 01 |
| Outage delayed | 02 |
| start of work delayed | 03 |

Level-5/4/3-14-2

| Spares & tools | codes |
|---|---|
| Not known | 00 |
| Non-availability | 01 |
| Outage delayed | 02 |
| start of work delayed | 03 |

Level-5/4/3-14-3

| Spares & tools | codes |
|---|---|
| Not known | 00 |
| Non-availability | 01 |
| Outage delayed | 02 |
| start of work delayed | 03 |

Level-5/4/3-14-4

| Spares & tools | codes |
|---|---|
| Not known | 00 |
| Non-availability | 01 |
| Outage delayed | 02 |
| start of work delayed | 03 |

Level-5/4/3-14-5

| Spares & tools | codes |
|---|---|
| Not known | 00 |
| Non-availability | 01 |
| Outage delayed | 02 |
| start of work delayed | 03 |

Level-5/4/3-14-6

| Spares & tools | codes |
|---|---|
| Not known | 00 |
| Non-availability | 01 |
| Outage delayed | 02 |
| start of work delayed | 03 |

Level-5/4/3-14-7

| Spares & tools | codes |
|---|---|
| Not known | 00 |
| Non-availability | 01 |
| Outage delayed | 02 |
| start of work delayed | 03 |

Level-5/4/3-14-8

| Spares & tools | codes |
|---|---|
| Not known | 00 |
| Non-availability | 01 |
| Outage delayed | 02 |
| start of work delayed | 03 |

Level-5/4/3-15

| Accidents | codes |
|---|---|
| Not known | 00 |
| Gloves/Earth mat | 01 |
| Failed to switch off | 02 |
| No grounding | 03 |
| Static electricity | 04 |

Level-5/4/3-15-2

| Accidents | codes |
|---|---|
| Not known | 00 |
| Arrived late | 01 |
| No supervision | 02 |
| No permissions | 03 |
| Wrong orders | 04 |

Level-5/4/3-15-3

| Accidents | codes |
|---|---|
| Not known | 00 |
| Pole tilt | 01 |
| Pole collapse | 02 |
| Vehicle accident | 03 |
| Wrong driving | 04 |

Level-5/4/3-15-4

| Accidents | codes |
|---|---|
| Not known | 00 |
| Pole tilt | 01 |
| Pole collapse | 02 |
| Vehicle accident | 03 |
| Wrong driving | 04 |

Level-5/4/3-15-5

| Accidents | codes |
|---|---|
| Not known | 00 |
| Supply Leakage | 01 |
| Domestic supply | 02 |
| Industrial supply | 03 |
| Agricultural | 04 |
| Commercial | 05 |

Level-5/4/3-15-6

| Accidents | codes |
|---|---|
| Not known | 00 |
| Fire in buildings | 01 |
| Fire in godown | 02 |
| Fire in fiels/jungle | 03 |
| Fire in substation | 04 |

## Example

| Discom | Element | From Date | From time | ToDate | to time | | code4 | Remarks |
|---|---|---|---|---|---|---|---|---|
| ABC | Transformer | 12-Feb-17 | 15:00 | 12-Feb-17 | 17:00 | | 33KV-TR-01-07-01 | 33/11KV transformer tripped on Bucholz winding temp. high |

| Level-1 | Level-2 | Level-3 | Level-4 | Level-5 |
|---|---|---|---|---|
| 33 KV | transformer | Protection/Relay | Bucholz Trip | Wdg fault |
| 2 | 2 | 1 | 7 | 2 |
| 33KV | TR | 01 | 07 | 01 |

| Item | Code |
|---|---|
| 66 KV | 66KV |
| 33 KV | 33KV |
| 22 KV | 22KV |
| 11 KV | 11KV |
| 6.6 KV | 06KV |
| 3.3 KV | 03KV |
| 415V | 415V |
| | |

| Items | codes |
|---|---|
| line/Cable | LL |
| transformer | TR |
| breaker | BR |
| bus coupler | BC |
| capacitor | CC |
| reactor | RR |
| insulator | IR |
| lightening arrestor | LA |
| Bus bar | BB |
| tower | TW |
| Earth switch | ES |
| Isolator | IS |
| LT Distribution box | DB |
| Solar Rooftop | SR |

| Fault type | codes |
|---|---|
| Protection/Relay | 01 |
| Burst/Fire/Break | 02 |
| Grid side | 03 |
| Auxiliaries | 04 |
| Animal intrusion | 05 |
| Natural calamity | 06 |
| Mal-operation | 07 |
| Maintenance | 08 |
| Miscreants/theft | 09 |
| Leakage | 10 |
| Mechanism fail | 11 |
| Communication | 12 |
| Spares & tools | 13 |
| Accidents | 14 |

| Protection type | codes |
|---|---|
| Over current | 01 |
| Earth fault | 02 |
| P to P fault | 03 |
| NGR fault | 04 |
| Differential | 05 |
| Busbar fault | 06 |
| Bucholz Trip | 07 |
| Over flux | 08 |
| Wrong setting | 09 |
| Phase imbalance | 10 |
| Power factor | 11 |
| Consumer | 12 |
| Back feed | 13 |
| Harmonics | 14 |

| Protection type | codes |
|---|---|
| No specific | 00 |
| Wdg fault | 01 |
| Oil quality low | 02 |
| Wdg Insulation poor | 03 |
| Mal-operation | 04 |
| Oil level low | 05 |
| | |

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