सत्यमेव जयते

भारत सरकार /Government of India

विद्युत मंत्रालय /Ministry of Power

केन्द्रीय विद्युत प्राधिकरण /Central Electricity Authority

वितरण आयोजन एवं प्रौद्योगिकी प्रभाग /Distribution Planning & Technology Division

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No.CEA/DPT/O&M/2025 **Dated: 30th Januray 2025**

To

All Stakeholders of Power Sector

विषयः वितरण उपयोगिताओं के लिए संचालन एवं रखरखाव मानदंडों की बेंचमार्किंग के लिए दिशानिर्देश

Subject: Guidelines for Benchmarking of Operation & Maintenance Norms for Distribution Utilities - reg.

As per Clause 20(6) of the Electricity (Second Amendment) Rules, 2023, notified by Ministry of Power on 26th July 2023,

"The operation and maintenance norms for distribution licensee shall be determined by the State Commissions in accordance with the guidelines issued by the Authority."

Accordingly, Central Electricity Authority has prepared the "Guidelines for Benchmarking of Operation & Maintenance Norms for Distribution Utilities" after extensive deliberations with various stakeholders including distribution utilities. The approved Guidelines is attached herewith for kind information .

भवदीय

विवेक गोयल 30/1/25

विवेक गोयल

मुख्य अभियन्ता (वि.आ. एवं प्रौ. प्रभाग)

सत्यमेव जयते

Guidelines for Benchmarking of Operation & Maintenance (O&M) Norms for Distribution Utilities

केविप्रा
cea

Central Electricity Authority

2024

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Chapter 1

BENCHMARKING PROCESS & MAINTENANCE PRACTICES

1.1 BENCHMARKING PROCESS

Benchmarking is a process for developing the performance indices to be adopted by entities for improving their performance and identifying areas needing improvement. The goal of benchmarking is to improve the current processes of a utility to meet the higher standards set up by other utilities. It is a continuous process improvement to be amongst the best utilities in the country. The benchmarking process can reveal potential areas where a particular Discom's performance is lacking and point to directions for further detailed examination to identify any underlying contributing causes or mitigating factors to the performance gap.

Benchmarking is also a performance management tool that can strengthen all business aspects of an organization. Benchmarking is defined as a process of systematic and continuous measuring and comparing one's business processes against comparable processes in leading organizations to obtain information that will help organizations to identify strengths and weaknesses of their existing performance. Benchmarking not only act as a valuable information tool to support quality-led continuous improvement programs of an organization, but also can cause a change of the attitude and behavior of the organization to identify the gaps and weaknesses of its maintenance works as per benchmarking best practices. One of the major benchmarking for the Discom would be to adopt the best practices in O&M of the distribution system and to minimize the O&M costs.

The main benchmarking process with special emphasis on maintenance management may constitute the following steps:

1) identifying the key maintenance performance variables that need to be benchmarked;
2) selecting good information sources for benchmarking;
3) collecting and measuring maintenance data;
4) normalizing and adjusting the collected and measured maintenance information to a meaningful database;
5) analyzing the maintenance data against other organizations that are known to be superior performers ;
6) changing and improving the maintenance performances.

For improving the efficiency of its operation including consumer satisfaction, every DISCOM needs to have a well-defined Operation and Maintenance (O&M) Plan. An O&M plan is made up of an interconnected ecosystem of training, management, budgeting, maintenance and business practices that work together to improve the working of a distribution utility. It involves day-to-day operational activities necessary to function and to perform designated tasks efficiently as well as proper maintenance of physical systems and associated strategies. The maintenance activities includes preventive maintenance, condition-based (predictive) maintenance and reactive maintenance. Advanced analytical tools also help in planning & maintenance strategy for various distribution system components including cost optimization and consumer satisfaction.

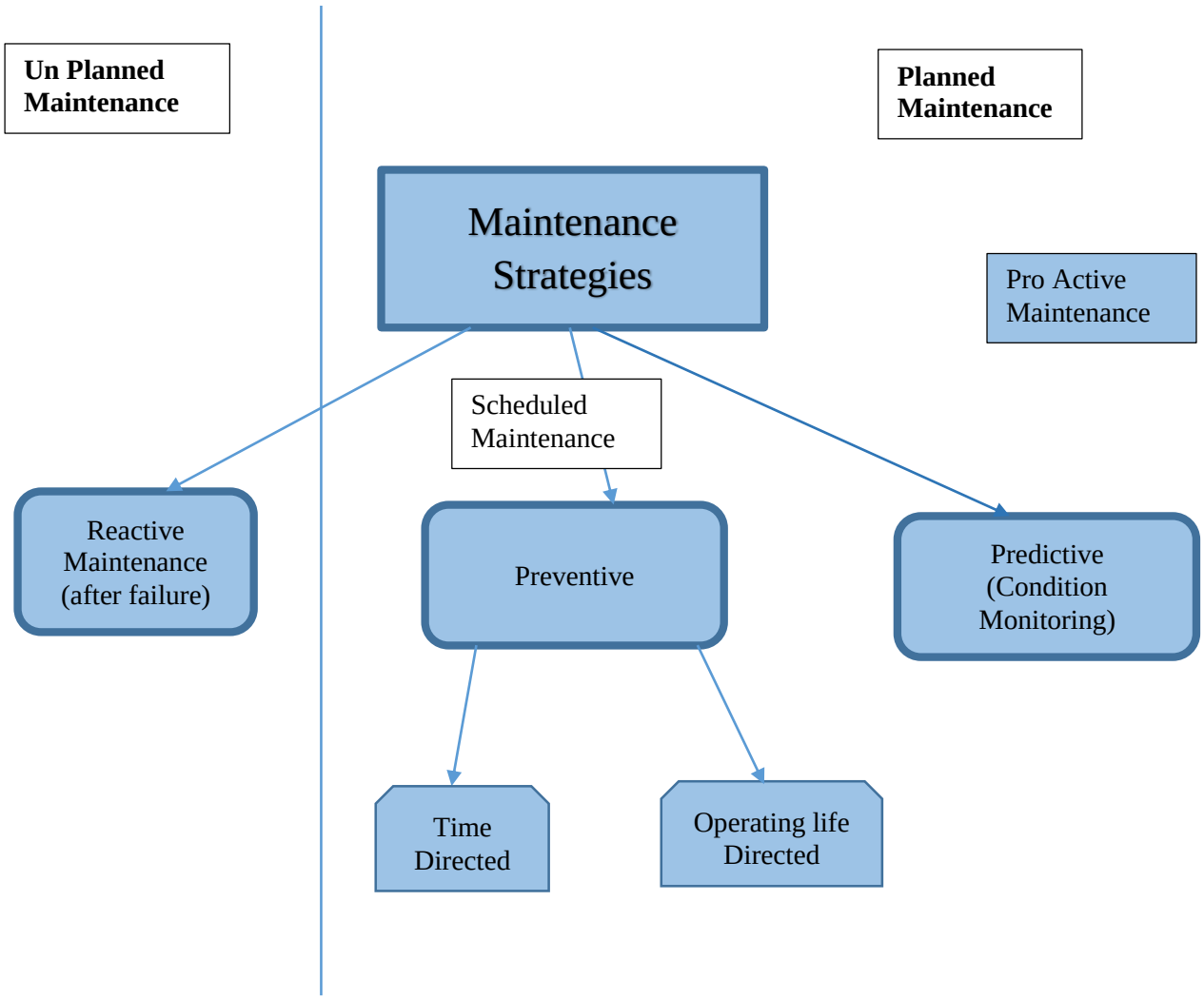
1.2 MAINTENANCE PRACTICES

An unwanted and unplanned outages due to fault occurred in distribution systems or failure of equipment are some of the main concerns of distribution companies to ensure 24x7 reliability and quality power supply at all times, in compliance with the established regulatory framework and Standard Operational Practice (SOP) notified by SERCs. To ensure the healthy system, a proper maintenance schedule should be prepared by all the utilities.

Generally, the Maintenance of the equipment in distribution sector may be Planned or Un-Planned. The following Maintenance Practices are being taken up in distribution sector by the utilities:

- Preventive Maintenance
- Predictive Maintenance
- Reactive /Break down Maintenance

In general, the Reactive Maintenance is a practice which is unplanned and is carried out after failure has occurred and to restore the equipment to perform the requisite function while all other maintenance practices are Planned activities. The Planned Maintenance strategies are Pro-active in nature and can be Preventive & Predictive /Condition Based Monitoring.



1.3 PREVENTIVE MAINTENANCE

The Preventive maintenance is interpreted as a pre-emptive maintenance action to be taken by the utilities to maintain the system in order to continue to operate efficiently according to its function by preparing a systematic inspection, detection and correction to prevent the occurrence of greater damage.

The Preventative Maintenance of distribution equipment is the key to ensure the reliability of power supply to the consumers. Preventive maintenance is carried out on system components to increase the reliability, availability, security and performance of the components based on the condition Monitoring of the equipment in operation. A successful preventative maintenance program needs to be customized to suit the specific needs of Discoms and to prevent any potential failures using cost-effective and reliable methods.

Preventive maintenance extends the life span of equipment and assets, ensuring they last as long as possible. Keeping a very close eye on the state of equipment helps to prepare budget for asset replacement when it does reach the end of its life span, thus protecting the DISCOMs from huge unplanned expenses and improving forecasting capabilities.

The Preventive Maintenance, which is also called Scheduled Maintenance is carried out at regular intervals based on the 2 basic conditions:

- Time Directed maintenance is carried out based on number of operations, operating hours or seasonal changes etc.
- Operating / Useful life based maintenance is carried out when the condition of equipment reaches a limit or satisfactory operation is not ensured to prevent incipient failure of equipment.

Here are some of the common practices that DISCOMs follow and are generally carried out under O&M expenditure:

1. **Regular inspection of equipment**: DISCOMs conduct regular inspections of electrical equipments such as transformers, circuit breakers, and other components to detect any issues before they become major problems.

2. **Cleaning and lubrication of equipment**: Regular cleaning and lubrication of electrical equipment is essential to prevent corrosion, wear and tear, and other types of damage.

3. **Testing of equipment**: DISCOMs perform testing of equipment to detect any potential failures or malfunctions before they occur. This includes testing of insulation, electrical connections and other components.

4. **Replacement of worn-out components**: When components such as fuses, switches, or breakers become worn-out or outdated, DISCOMs replace them with newer and more efficient components.

5. **Tree trimming and vegetation management**: Overgrown trees and vegetation can cause power outages by interfering with the power lines. DISCOMs regularly trim trees

and manage vegetation to prevent such incidents.

6. **Upgrading of equipment**: As technology advances, DISCOMs may upgrade their equipment to improve efficiency and reliability.

7. **Regular maintenance of substation equipment**: Substations are an essential component of the power distribution system. Regular maintenance of substation equipment such as transformers, switchgear, and breakers is essential to ensure the reliability and safety of the distribution system.

By following these preventive maintenance practices, DISCOMs can minimize the risk of power outages, reduce maintenance costs, and ensure the safety of the distribution system, however, preventive maintenance should be planned in such a way so that there is minimal consumer interruption.

1.4 PREDICTIVE MAINTENANCE/ CONDITION MONITORING:

Predictive Maintenance is used to create a schedule for maintaining the performance & condition of the monitored equipment. The Predictive maintenance schedule is prepared based on the condition monitoring data taken periodically to determine equipment condition trends, data comparisons & statistical analysis processes, etc. The Condition monitoring based maintenance is Predictive in nature and is carried out as & when deemed necessary before failure, based on the condition monitoring reports and diagnostic activities, etc.

Various Predictive Maintenance techniques detect anomalies in equipment before those turn into system critical failure, allowing maintenance to be scheduled before the equipment actually breaks down. This increase equipment uptime, reduces overall maintenance costs and allows optimization of spare part inventory by enabling preventive maintenance based on the equipment's actual needs.

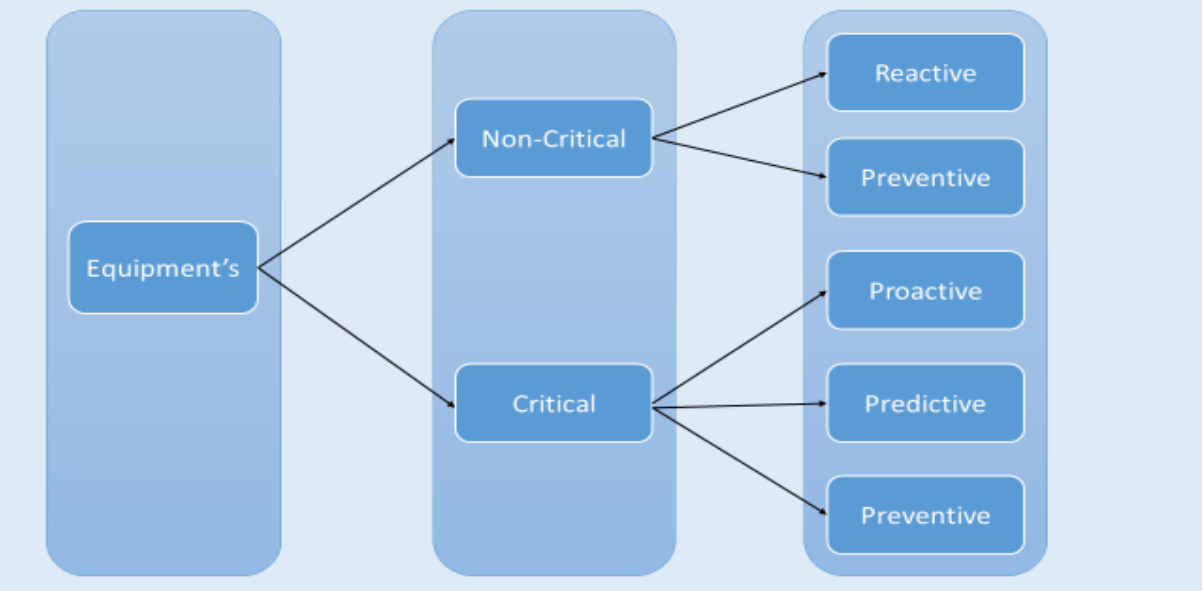
Now a days, Predictive maintenance is being done based on the analysis of data received from IT based Condition Monitoring System. Condition Monitoring System uses various sensors to provide meaningful insights of the current health of various devices and equipment in field and at Sub-stations. These sensors collect data to monitor various operating parameters such as temperature and oil level in Transformers and overloading of lines and transformers etc. It is suggested that DISCOMs may prepare a road map for adoption of such technologies at various voltage / equipment level with the approval of SERC/JERC.

The various types of predictive maintenance take condition based maintenance to the next level. The Predictive Maintenance of Critical equipment in the system need to be planned based on the sensor data and advanced analysis using AI predicting the possible failure of the equipment before it happen or to anticipate maintenance needs before they become urgent. The predictive maintenance may be initiated after receiving the report from detectors/sensors installed like Thermo-vision camera & partial discharge detector for detecting hot spots, partial discharge etc. Discoms may use thermography equipment and portable non-touch temperature measurement devices to identify the hotspots in joints in transformers, feeder pillars, connectors and lines etc. Periodic oil testing of transformer may also provide information regarding the health of transformer and helps in initiating corrective action to prevent failure. Drone fitted with thermal scanning cameras may also be used, if possible & feasible, for inspection of overhead critical sub transmission lines in urban areas.

1.5 REACTIVE /BREAK DOWN MAINTENANCE:

The Reactive Maintenance is also known as a breakdown/ repair maintenance if there is a damage/run-to-failure of an equipment. Other than natural calamity or Force - majeure conditions, majority of failure of an equipment is due to poor maintenance, excessive delays in maintenance, overloading, ignoring the condition monitoring signals and cause financial losses to the utilities. The reactive maintenance may be avoided by adopting the regular Preventive & Predictive maintenance practices by a utility.

1.6 PROCESS OF ADOPTING VARIOUS MAINTENANCE PRACTICES BY A UTILITY



The various equipment available in the system may be classified under Critical & Non-critical category and the schedule of Preventive, Proactive & predictive Maintenance should be prepared by Discoms for ensuring the healthy system to provide 24x7 power supply. An efficient network maintenance programme through proper planning, failure analysis and distribution efficiency improvements is essential to manage overall O&M of distribution utility.

Keeping in view the general layout of distribution system, the following equipment in the system may be classified under Critical & non-critical category based on criticality & time required to replace the network element / equipment:

(i) Critical Equipment

- Power Transformer and Sub-station major equipment including Switchgears & Protection system
- 33 kV, 11 kV & LT Lines / Cables
- Distribution Transformers
- HT Switchgears, RMUs and LT Circuit Breakers

(ii) Non-Critical Equipment

- Other equipment in system like Service lines, Meters, distribution Box which can be replaced immediately from store.

Many Utilities have installed SCADA/RT-DAS /DMS system for monitoring and control of the distribution system. In such cases, the monitoring of all possible parameters should be done through automated system.

1.7 DETAILS OF GENERAL FAULTS, PROBABLE CAUSES AND REMEDIAL ACTIVITIES TO BE TAKEN UP BY UTILITIES FOR MAJOR EQUIPMENT IN DISTRIBUTION SYSTEM

S. No.	Fault/Point of Concern	Probable Cause of Fault /Point of Concern	Remedial Action
1	Overhead Line/ Conductor Faults	1. Flashed /Punctured or broken insulators 2. Damaged jumper /Conductor 3. Fault due to Tree Contact 4. Faults due to Birds 5. Fault due to Cracked Pole 6. Improper Earthing 7. Unwanted wire b/w two phases 8. Improper sag between conductor and Guard wire 9. Higher loading of line	1. Flashed /Punctured or broken insulators checking and replacement. 2. Jumper repairing, either of same conductor size or next higher size of conductor size. 3. Plan to replace the cracked pole as soon as possible 4. Tree Pruning / Trimming by using Treepruner instrument. 5. Plan to reduce Faults due to Birds by installing bird repellent/ flapper.

S. No.	Fault/Point of Concern	Probable Cause of Fault /Point of Concern	Remedial Action
		beyond conductor capacity /overheating of joints & jumpers 10. External damages – Pole hit by a Vehicle, encroachments etc. 11. Improper Phase to Phase and Phase to earth clearance	6. Proper Earthing should be done 7. Plan for diverting load to nearby line or augmentation of line in case of overloading 8. Re-sagging of conductors
2	Under Ground Cable Faults	1. Insulation Degradation 2. Electrical Stress – due to untreated screen cut back during installation of cable termination, Lightening surges, Switching surge, Core Crossing above cut back area at cable termination, Application of high voltage during testing, etc. 3. Mechanical Stress due to Improper bending radius, Mechanical pressure /vibration & Improper cable supports 4. Thermal Stress due to Overloading, Fault current, High thermal resistivity of soil, improper electrical connections, Induced Sheath Current 5. Environmental stress due to UV exposure, Contaminants deposition on terminations, Pollutants reaction, etc. 6. External damage i. Water Ingression ii. Joint Failures iii. Cable fault due to excavation /	1. Minimize insulation failure by using proper meggering. 2. Usage of HS tape, water seals & end caps to prevent ingress of moisture. 3. Reduce joint failures by not using sub-standard joints kits and work done by qualified skilled jointers. 4. Plan to reduce external damage by proper patrolling. 5. Plan to reduce loading / burning of cables by proper load balancing. 6. Installation of cable markers on entire route of cable to avoid unnecessary digging 7. Ensure proper earthing at all end terminals 8. Diagnostic tools like Partial Discharge (PD), Tan delta, etc. may be used to detect and minimize insulation failure. 9. Cable and Joint specification should also be adopted in such a way to prevent water ingress in the cable like TRXLPE Cable and Resin Encapsulated Joints, etc. may be explored in area prone to water ingression in cables. 10. Usages of surge arrested at

S. No.	Fault/Point of Concern	Probable Cause of Fault /Point of Concern	Remedial Action
		digging on cable route 7. Joint & terminal failure due to poor quality of joint accessories and poor workmanship 8. Poor earthing of cable armour at all end terminals	proper places 11. Adopting standard installation practices 12. Condition based maintenance & diagnostics testing
3	Distribution Transformer Trippings / Interruptions	1. Defective Bushing: HV/LV & Oil Leakage 2. Condition of Breather & Conservator 3. High unbalancing current 4. Continuous overloading of DT 5. Frequent LT cable faults 6. Improper protection of both HT and LT side 7. Development of hot spots due to passage of time 8. Poor/defective earthing of neutral & body of DT and of LT feeders 9. Birds / Animal Electrocution 10. Poor maintenance of DT 11. High rating fuse used 12. Fault in cable chamber due to moisture ingress	1. HT and LT connections should be tight & properly insulated. 2. Proactive thermo-scanning 3. Earth value should be checked during Planned shutdown & earthing connections should be tightened 4. Earthing checked and provided new earthing where ever required. 5. Proactive patrolling, Drain valves should be sealed 6. Segregate multiple LT feeders that feed from one ACB. 7. Top fence covering in monkey/domestic animal prone Sub-station, provision of HT insulation caps. 8. Overhauling of the DT / replacement with new / repaired one. 9. Proper sealing of chamber to avoid moisture ingress 10. Reconditioning of silica gel and checking of oil level in conservation tank. 11. Insulation resistance measurement and Oil Test like BDV, Moisture Content, Acidity, IFT, color, resistivity should also be carried out at periodic level to assess the internal health of Transformer.

S. No.	Fault/Point of Concern	Probable Cause of Fault /Point of Concern	Remedial Action
			12. Ensure availability and functionality of suitable protective device at HT & LT side of transformer to avoid DT failure due to LT circuit fault.
4	Power Transformer Tripping	Differential Protection operation 1. Inter-turn fault/ Aging 2. LT joints & HT bushing failures 3. IED Failure 4. CTs wiring problem 5. CT Saturation 6. Fault at cable box before LV 7. Fault due to animal / birds 8. Multiple point earthing for CT secondary 9. Failure related to tap lid 10. External agent ingression at HV and LV cable boxes due to improper closing of cable boxes 11. LV cable damage 12. High resistance of CT secondary winding 13. Relay problem 14. Improper current or CT setting at relay 15. OLTC failure	1. Complete visual Inspection of power transformer. 2. Rectifying the root cause of breakdown 3. Stability test of power transformer to ensure differential relay operates during faults only. 4. Reconditioning of silica gel and checking of oil level in conservation tank.
	Oil Temperature indicator tripping / alarm	1. High temperature of oil due to heavy loading. 2. Relay mal-function. 3. Low intensity Inter turn fault. 4. Low IR in devices 5. Cooling fan and pump failure 6. Low IR in control cables	1. Checking of OTI meter & WTI meter for variation. 2. Check loading condition 3. Winding resistance of power transformer.

S. No.	Fault/Point of Concern	Probable Cause of Fault /Point of Concern	Remedial Action
		7. Water ingression inside device terminal boxes and Marshalling boxes 8. Oil level not maintained under OTI probes	
	Winding temperature indicator tripping /alarm	1. High temperature of winding due to heavy loading. 2. Relay mal-function. 3. Low intensity Inter turn fault. 4. Low IR in devices 5. Cooling fan and pump failure 6. Low IR in control cables 7. Water ingression inside device terminal boxes and Marshalling boxes 8. WTI CT issues 9. Oil level not maintained under WTI probes	1. Checking of OTI meter & WTI meter for variation 2. Check loading 3. Winding resistance of power transformer.
5	11 KV incomer tripping	1. Due to fault in 11 Bus system. 2. Fault near to substation or very high intensity of fault. 3. High breaker timer of outgoing breaker	1. Checking of tripping of any outgoing feeder along with intensity of fault 2. Check breaker timing of tripped breaker. 3. Checking for relay time coordination 4. Review of Relay coordination based on relay tripping
6	11 KV outgoing breaker tripping	1. Due to over loading. 2. Due to phase fault /earth fault	1. Check Relay's tripping parameters for analysis. 2. Line inspection is required before again charging. 3. Check gas pressure in case of gas breaker.
7	Failure of Lighting arrestor	1. Due to heavy voltage fluctuation. 2. Aging of lighting arrestors Surge counter, getting	1. Replace the faulty LA. 2. Check health of other installed LAs through suitable measures like measurement of insulation

S. No.	Fault/Point of Concern	Probable Cause of Fault /Point of Concern	Remedial Action
		opened 3.Improper or ineffective earthing of L/A 4. Insulation failure 5.Thermal effect due to high leakage current	resistance.
8	Low voltage at DC system	1. Due to charging problem. 2. Battery issues in existing system.	1. Check charger at location. 2. Impedance test of battery
9	DC leakage at substation	Earthing of any one of the terminal with ground.	Switch off AC supply to charger. Isolate DC supply at every section and check DC leakage in system and rectified the same.
10	Poor earthing at Grid substation.	Due to ageing / Soil condition & improper installation	1. Check earthing resistance at every pit of yards & neutral of transformer. 2. In case of poor earthing go for parallel earthing concept and connect it with old earthing Pit.

The Plants & equipment of Utilities are of varying ratings and ages and need proper upkeep by following appropriate maintenance schedules. Such schedules may be developed based on experiences/ best practices of the utilities in order to provide reliable power to consumers and in tune with the applicable regulations of the State Electricity Regulatory Commission keeping in view the age of infrastructure, availability of space, RoW issues & cost estimates, etc.

The Utilities may adopt the different levels of O&M Norms based on the automation in place like utilities having SCADA in place along with condition-based monitoring practices may follow predictive mode of maintenance, which will significantly reduce the number of physical site visits as well as O&M manpower. Discoms serving in densely populated urban areas may embrace online condition monitoring-based maintenance schedule to reduce O&M expenditure as well as equipment failure to enhance the reliability of the power supply. Combination of Physical & Online Condition based monitoring may be adopted by all utilities.

Technology intervention may lead to significant reduction in the frequency of physical inspection of equipment. Utilities should make a plan for adopting/scaling up of advanced technologies and induct/retain skilled manpower and put up for approval of SERCs. Utilities may also interact & take inputs from leading national & international utilities to align their operations adopting the technology & processes followed by the best in distribution business.

Chapter 2

O&M BENCHMARKING OF MAJOR EQUIPMENT IN 33/11 KV SUB-STATION

2.1 MAJOR EQUIPMENTS INSTALLED AT 33/11 KV SUBSTATION

1. Power transformer
2. Circuit Breaker
3. Current Transformer(CT)
4. Potential Transformer(PT)
5. Lightning (Surge) Arresters (LA)
6. Isolators & Earth switches
7. Battery bank & Battery chargers
8. 11 kV VCB Panels
9. 33 kV C&R Panels
10. Bus-Bar
11. APFC panels
12. ACDB (ac-distribution board)
13. Power and Control cable
14. Capacitor bank
15. Fire Fighting equipment
16. Sub-station Earthing

2.2 POWER TRANSFORMER

Power transformer is an important and most expensive equipment in a sub-station. The transformer's deterioration phenomena are related to electric, thermal, mechanical, chemical, environmental and combined stresses. Hence, failure of transformers could be due to insulation failure, or thermal failure, or mechanical failure or combination of these. Due to frequent system faults, over loading, environmental effect, unexpected continuous operating voltage and over voltage stresses of the system during the operation, many equipment fails much before their expected life span. There is no escape from normal long term ageing process but premature failure can be avoided by proper maintenance and health monitoring.

2.2.1 MAJOR OPERATING CONDITIONS FOR POWER TRANSFORMERS

In order to ensure that Power Transformers have long and trouble-free service, the adverse operating condition for transformers is generally avoided. The main operating conditions of a Power Transformer should be as under:

a) Operating temperature should be preferably less than 70°C (through Oil Temperature Indicator-OTI).

b) Operating the transformer generally not more than 2/3 of its maximum capacity (MVA).
c) Avoid Long duration overloading of transformer.
d) Heavy overloading is avoided by installation of Over Load Trimming Scheme (OLTS) to remove non-critical loads, during overloading of transformers.
e) Reduction in Short Circuit level by opening bus section breaker (where the SC level is reaching up to Circuit Breaker rating).
f) Reduction in fault clearance time by the protection system so that stress on transformer is minimal.
g) Providing surge arresters to take care of Transient Overvoltage (Lightening and Switching)
h) Use of tap changer to prevent Over fluxing of transformers
i) Parallel operation of transformer for reliability of Power Supply.
j) Integration of Winding temperature Indicator (WTI), Oil Temperature Indicator (OTI), Buchholz and other important transformer alarm with plant control system. (DCS, SCADA)
k) Commissioning of neutral grounding reactors for limiting the single phase to ground fault current, without losing the sensitivity of over current protection.
l) Maintaining proper oil level for the transformer tank
m) Measurement of cooling circuit control & OLTC supply for the transformer
n) Measurement of adequate body, core, and frame earthing resistance
o) Maintaining parallel operation for transformers with minimum voltage difference
p) Maintaining transformer from minor and profuse oil leakage
q) Ensuring proper closing of HV, LV & LV neutral cable boxes
r) Ensuring maintenance of proper canopies over all field devices throughout its service life
s) Maintaining the power circuit of outgoing feeders properly so that reduction in fault for outgoing feeders can be ensured
t) Breather quality should be maintained properly throughout its service life
u) Ensuring proper functioning for all cooling circuit fans and pumps
v) Usage of air cell type conservator to minimize the effect of oxidation and hydrolysis

2.2.2 MAJOR ALARMS/TRIPS USED IN POWER TRANSFORMERS

S. No.	Alarm / Tripping
1	Differential relay
2	Pressure ReleaseValve(PRV)
3	Oil Temperature Alarm(OTA)
4	Oil Temperature Trip(OTT)
5	Winding Temperature Alarm (WTA)
6	Winding Temperature Trip(WTA)
7	Low Oil Level Alarm(LOLA)
8	Buchholz Alarm (BA)
9	Buchholz Trip (BT)
10	Over Current Relay (O/C)
11	Earth Fault Relay (E/F)
12	Fire Protection System
13	Sudden Pressure Relay
14	Oil Surge Relay
15	High oil level alarm for main tank of conservator
16	Over fluxing alarm

2.2.3 BEST OPERATION & MAINTENANCE PRATICES

General Supervision of Power Transformer

1. **Dirt and Dust:** The external transformer surfaces shall be inspected regularly; and when required cleaned of dust, insects and other air borne dirt etc.
2. **Rust and Treatment:** A regular inspection is to be done on the external surface of the transformer tank and radiators.
3. **Mechanical Damage:** Checks must be carried out for mechanical damage to the fabrications and associated equipment. Particular attention should be

given to vulnerable areas such as radiators.

4. **Check out all Joints for Signs of Leakage:** All joints, both welded and gasketted, must be checked for signs of oil leakage. If there is any doubt of a leak, the area must be cleaned of oil, using a suitable solvent (methyl alcohol) and sprayed with liquid chalk.
5. **Check for Oil Level:** All oil levels associated with the equipment including oil conservatorand all oil filled bushings shall be checked. Also the oil in the oil seal should be maintained.
6. After completing all the checks, ensure that all materials or tools, used for maintenance work, have been removed. All clothes and other debris must be disposed of. The transformer compound should be left in a clean and tidy condition.
7. **Silica Gel Breather:** In open breathing transformer, the breather plays active role in maintaining the transformer dry by admitting dry air when transformer breathes. In transformers having air cell or diaphragm, the breather ensures dry air inside the air cell or above the diaphragm. The silica gel inside the breather becomes pink (or dark green in case of orange silica gel) from bottom to top over a period of time.
8. Periodic Checking the healthiness of transformer's associated devices like Surge arrester, bushings, WTI (Winding Temperature Indicator), OTI (Oil Temperature Indicator) & calibration of devices at regular interval
9. Arresting oil leakages, if any, by change of gaskets based on conditions.
10. Refurbishment / Replacement of oil, if chemical or electrical properties have violated limits.
11. Reconditioning of Earth pits based on test values.
12. Monitoring Insulation resistance of winding whenever Transformer is cut out for any reason / every year.
13. Replacement of defective transformer devices like MOG (Magnetic Oil gauge), WTI, OTI, PRD (Pressure relive device), OSR (OIL Surge relay) if found non-functional.
14. Replacement of transformer bushing based on absolute current measurement.
15. Water sealant can be used at the Mechanical relay control wiring covers like Buchholz, PRV, OSR, SPR and rain shed may be used at mechanical relays.

16. C & tan delta test should be carried out for windings and bushings.
17. Checking of proper blocking for all unused holes for field devices, marshalling box, cable boxes.
18. Sweep Frequency response Analysis (SFRA) of windings should be carried out.
19. Water accumulation over cable boxes, main tank and OLTC tank should be avoided.

2.2.4 MAJOR MAINTENANCE / INSPECTIONS PRACTICES TO BE ADOPTED FOR POWER TRANSFORMERS

a) UNMANNED SUB-STATION

Now a days, many of the utilities are monitoring the health and conditions of Sub-stations including Power Transformers through SCADA and out of these, many of the sub-stations are being operated Unmanned i.e. without any operator at the Sub-station and these S/Ss are being monitored and controlled remotely from SCADA Centre.

b) MANNED SUB-STATION

In case, the Sub-station is being operated manually and sub-stations operators are posted at the Sub-station in shifts for O&M of the Sub-station. The Sub-station operator is taking all the requisite parameters readings and notes them in a log book.

As many of the major parameters of Power Transformers are being logged automatically through SCADA in a 15minute interval in unmanned Sub-station hence, the periodicity of major inspection /maintenance of power transformers have been divided for Manned and Unmanned Sub-stations.

A) UN-MANNED SUB-STATION – SCADA PARAMETERS

SCADA PARAMETERS FOR O&M OF UN-MANNED SUB-STATION ALONG WITH THEIR FREQUENCY OF MONITORING (Including Power Transformer/OLTC/Circuit Breaker /Relays/ Fire Protection system /Battery /RTU etc.)

S.NO	BRIEF DESCRIPTION OF WORK	Frequency
1.	**Measured Values:-**	
a)	Active Power	24X7
b)	Reactive Power	24X7
c)	Load in each Phase (in Amp)	24X7
d)	Voltage of each phase	24X7
e)	Power Factor	24X7
f)	Max Demand on Feeder's	24X7
g)	Load through ACDB	24X7
2.	**Healthiness of Indication:-**	
a)	Breaker-ON/OFF/Intermediate Status	24X7
b)	Grid Status- Online/Offline Status	24X7
c)	Isolator Status- On/Off/Intermediate Status	24X7
d)	Isolator Feedback along with Monitoring/ Controlling	24X7
e)	Earth Switch Status	24X7
f)	Auto Changeover Switch Feedback Status	24X7 (Whenever Status Changes from field)
g)	Spring Charged/Discharged Status	24X7
h)	Main DC Fail Healthy/Unhealthy (Charger status , Battery status)	24X7
i)	OLTC Tap Position Indication(TPI)	24X7
j)	OLTC Tap Change in Progress	24X7 (Whenever Status Changes from field)
k)	OLTC Motor supply status	24X7
l)	OLTC position malfunction	24X7
m)	Eberle (Automatic Voltage Regulation Relay) Local/Remote	24X7
n)	Eberle (Automatic Voltage Regulation Relay) Manual/ Auto	24X7
o)	AC Fail	24X7
p)	Auto Trip	24X7
q)	Trip Circuit Healthy/Unhealthy	24X7

r)	Internal Relay Fault (IRF)	24X7
s)	SCADA local/Remote	24X7
t)	Winding Temperature Indicator (WTI)	24X7
u)	Oil Temperature Indicator (OTI)	24X7
v)	Battery Charger-Float/Boost Condition , AC supply of charger	24X7
w)	Low Battery Voltage Alarm	24X7
x)	DC Leakage-Battery Charger	24X7
y)	Charging and discharging current for battery bank and Temperature of battery cells	24X7
z)	Auto Operation of APFC Panel	24X7
aa)	Fire detection Alarm	24X7
ab)	Fire Protection System- Status-Monitoring (cylinder pressure, DC supply status, PNRV relay etc.)	24X7
ac)	PT MCB-Protection / PT MCB-Metering	24X7
	Forced Cooling status	24X7
2.	**Relay's /Intelligent Electronics Device Signal:-**	
a)	Overcurrent (O/C) Stage1	24X7
b)	Overcurrent (O/C) Stage2	24X7
c)	Earth Fault (EF) Stage 1	24X7
d)	Earth Fault (EF) Stage 2	24X7
e)	Line Differential Trip (LDR trip)	24X7
f)	PTR's Differential Trip	24X7
g)	Distance Relay (on I/C Line) Trip	24X7
h)	Distance Relay (Distance)	24X7
i)	Fault Current Level	24X7
j)	WTI Alarm/Trip	24X7
k)	OTI Alarm/Trip	24X7
l)	Pressure Release Valve (PRV) Trip	24X7
j)	Sudden PRV Trip	24X7
k)	Oil Surge Relay	24X7

l)	Buchholz Alarm/Trip	24X7
m)	Magnetic Oil Gauge (MOG)/Oil Level Low Alarm	24X7
n	SF6 Gas Pressure Low (66kv Circuit Breaker & GIS)	24X7
3.	**Distribution Management System (DMS)/11kV RMU**	
a)	Fault Passage Indicator (FPI) Monitoring	24X7
b)	Breaker Status-Open/Close	24X7
c)	Online Monitoring of DMS Status	24X7
d)	Gas Pressure low (RMU's)	24X7
e)	Close/Open Signal Feedback	24X7
f)	Load on each Phase monitoring	24X7
g)	Fault Current Level	24X7
h)	Auto Trip	24X7
i)	FPI EF & OC Trip	24X7
j)	FPI Reset Command	24X7
k)	Spring Charge/Discharge Condition	24X7
l)	Supervision of RTU communication with master	24X7
4	**Capacitor Bank**	
a)	Instantaneous current in all phases	24X7
b)	Instantaneous Voltage (Ph-Ph) (Ph-N)	24X7

B) MANNED SUB-STATION

MAJOR MAINTENANCE / INSPECTIONS PRACTICES FOR POWER TRANSFORMERS ALONG WITH THEIR PERIODICITY

S.NO.	ITEM TO BE INSPECTED	BRIEF DESCRIPTION OF WORK	FREQUENCY
1	Ambient Temp	Record the maximum daily ambient temperature.	Hourly
2	Winding/Oil Temp	Check that temp rise is reasonable. In case of any abnormal variation, check the cooling system of T/F. If the same is not found in order. Shut down the T/F for further investigation.	Hourly
3	Load/Voltage	Check against rated figures. In case of any variation, check the TPI.	Hourly
4	Oil level in transformer	Check against transformer oil level/ temperature. Top up with dry oil, if necessary.	Weekly
5	Oil level in bushings	Check for any oil leakage.	Weekly
6	Relief Vent diaphragm	Check for cracked or broken. Replace if necessary.	Weekly
7	For internal abnormal noise.	Check for any abnormal sound or excessive chattering. Shut down the T/F in case of abnormal noise, for further investigation.	Weekly
8	Heaters in Junction Box	Check for proper working, if provided. Replace, if found defective /damaged.	Weekly
9	External connection (Leads/Jumpers)	Check visually for tightness and sparking on jumpers, bushings etc. on complete darkness. Attend it, if required.	Weekly
10	Bus bar and cable boxes and cables	Check for any damage and signs of overheating at their joints. Check for overheating of back covers and attend, if found excessive heated.	Weekly
11	Dehydrating breather	Check for condition/colour of Silica gel. Recondition or replace as necessary.	Monthly
		Ensure for free air passage	Monthly
		Tight, lid of the breather for air tightness to avoid entry	Monthly
		Check oil level in oil cup and make up oil, if required.	Monthly
		Remove oil from dash pot and pour in fresh oil where required.	Monthly
12	Bushing and gaskets	Examine for cracks, Paint and dirt deposits and gap settings. Clean or replace it. Check gaskets	Yearly

S.NO.	ITEM TO BE INSPECTED	BRIEF DESCRIPTION OF WORK	FREQUENCY
		for leakage.	
13	Cooler fan, pump bearings, motors and operating mechanism	Lubricate bearings, check gear box. Examine Contacts, Check Manual control and interlocks. Replace burnt or worn out contacts or other parts.	Yearly
14	On load tap changer driving mechanism	Lubricate bearings, Check gear box oil level and examine contacts. Clean/Replace burnt or worn out contacts	Yearly
15	On load tap changer automatic control	Check all circuits independently. Check step by step operation including limit switches. Attend if found faulty.	Yearly
16	Insulation resistance	Check the I.R. values with 2.5KV rating meggar. Convert it at 70^0 C and compare the values with the value taken at the time of commissioning.	Yearly
17	Relays alarms, temperature alarm and their circuits	Examine relays and alarm contacts and their operation, fuses etc. Check for relays functioning clean or replace the contacts if required.	Yearly
18	Arcing Horns	Set the rods for alignment and for proper gap adjustment.	Yearly
19	Measuring / Protection CT's	Check for sparking and tightness of connection and oil level.	Yearly
20	Remote/ Manual Switch	Check for proper functioning	Yearly
21	Firefighting equipment	Examine them and ensure that these are in order.	Yearly
22	Bucholtz's relay	Note the oil level in the inspection glass of Bucholtz's relay.	Yearly
23	Oil in T/F and tapchanger	Check for dielectric strength. Dehydrate the oil, if necessary. Keep continuous record of test results.	Yearly
24	Ventilators	Check that air passages are free.	Yearly
25	Bucholtz's relay	Check proper operation by lowering the oil	Yearly
26	Forced cooling system	Megger testing of motors(pumps)	Yearly
27	Thermo Syphon Filters	Check moisture content	Yearly
28	Earth Resistance	Check for tightness of earth connections.	Yearly
		Measure earth resistance of the (a) T/F body, neutral and other body parts, (b) Keep proper record of test results. (Earth testing to be done	Yearly

S.NO.	ITEM TO BE INSPECTED	BRIEF DESCRIPTION OF WORK	FREQUENCY
		during driest part of the season)	
29	On load tap	Inspect all moving parts, contacts, brake shoes, motor etc. Clean, adjust or replace as required.	Yearly
30	Oil in T/F	Check acidity, PPM & BDV & compare with standard results.	Yearly
31	Oil in T/F	Check Tan delta, Furan analysis, IFT (Interfacial Tension) Sp. Resistively, sludge contents, DGA test, compare it with standard results.	Yearly
32	Oil filled bushing	Test oil for dielectric strength Dehydrate or replace the oil, if necessary.	Yearly
33	Cable box	Check for sealing arrangements for filling holes. Examine compound for cracks.	Yearly
34	Surge diverter and gaps	Examine for cracks and dirt deposits. Clean or replace if necessary.	Yearly
35	Gasket joints	Check for tightness of bolts to avoid uneven pressure. Replace damaged gasket.	Yearly
36	Pipe connections	Check oil pipes valves and plugs for tightness and proper functioning.	Yearly
37	Foundations	Check for cracks, if any and setting.	Yearly
38	Bushings	Test the bushings with a Hipet bushing tester and compare with previous figures.	Yearly
39	Temperature indication	Pockets holding thermo-meter should be checked. Oil to be replenished, if required.	Yearly
40	Dial type oil gauge	Check pointer for free operation. . Adjust, if required.	Yearly
41	Paint work	Should be inspected	Yearly
42	Conservator tank	Check for proper communication of the conservator with T/F tank by draining some oil through drain off valve and watching the oil in gauge glass to drop.	Yearly
		In case, the oil does not drop, investigate and remove the sludge or other obstructions after dis-assembling the tank.	Yearly
		Check for leakage of oil from glass side. Clean the inspection glass.	Yearly
43	PI & IR Value	Measurement of PI along with IR measurement	Yearly
44	Diverter switches for tap changer.	Check for worn out contacts. Filter oil irrespective of all test. Replace worn out parts.	Yearly or after 5,000 operations

S.NO.	ITEM TO BE INSPECTED	BRIEF DESCRIPTION OF WORK	FREQUENCY
45	Non-arcing selection switch of on load tap changer	General inspection. Replace worn out parts and filter the oil.	3 years or after 15,000 operations
46	Sweep frequency response Analysis	To measure the condition of winding , core and clamp structure etc.	During Overhauling
47	Overall inspection including lifting of core and coils		7 to 10 years
48	Major overhauls (complete) of transformers.		7 to 10 years
The major overhaul including lifting of core and coils of Power transformers may be based on overall health of the transformers like oil seepage/leakage, humming, IR value, PI value etc. In case all the tests results and physical condition of transformer is found to be good, the periodicity of item 47 & 48 may be selected accordingly.			
Insulation resistance measurement, tan δ of winding/bushings, winding resistance at all taps to be carried out once before expiry of warranty period and then to be continued as per schedule.			
Visual observation of transformers and Reactors by going round, should be made daily to check for any variations in noise, vibrations and any abnormality/leakages from cooler fans, oil pumps, radiators, valves etc.			

ON-LOAD TAP CHANGER - MAJOR MAINTENANCE / INSPECTIONS PRACTICES FOR ALONG WITH THEIR PERIODICITY (MANNED S/S)

Sr. no.	ITEM TO BE INSPECTED	BRIEF DESCRIPTION OF WORK	FREQUENCY
1	ON LOAD TAP CHANGER	Check leakage/seepage of oil from main tank to OLTC tank	WEEKLY
2		Oil leakage from OLTC.	WEEKLY
3		Silica gel breather	YEARLY
4		Oil in oil cup in silica gel breather	YEARLY
5		Vermin proofing of OSR to avoid moisture ingress	YEARLY
6		All unused wires are insulated	YEARLY
7		Prismatic oil gauge in OLTC conservator tank	YEARLY
8		OSR oil glasses.	YEARLY
9		Drain / filer valves	YEARLY
10		Cracks / any abnormality in barrier board	YEARLY
11		Step by Step operation of OLTC	YEARLY
12		Electrical end limit (both upper and lower)	YEARLY
13		Operation of OLTC	YEARLY

Sr. no.	ITEM TO BE INSPECTED	BRIEF DESCRIPTION OF WORK	FREQUENCY
14		Space heater / thermostat/illumination lamp in drive mechanism	YEARLY
15		Checking of OLTC Buchholz alarm /trip	YEARLY
16		OSR alarm/trip	YEARLY
17		Oil BDV for OLTC tank	YEARLY
18		Oil DGA	YEARLY
19		OSR trial operation	YEARLY
20		OLTC operation manual/auto/local/remote	YEARLY
21		OLTC drive mechanism cubicle	YEARLY
22		Diverter switch tank and barrier board	YEARLY
23		Fixed contacts in diverter switch	YEARLY
24		Moving contacts in diverter switch tank	YEARLY
25		Tightness of internal connections	YEARLY
26		Tap lead connection (for out tank OLTC only)	YEARLY
27		OSR connections	YEARLY
28		All gaskets joints	YEARLY
29		Transformer turn ratio / voltage ratio	5 years or after replacement of any primary part of OLTC
30		Winding resistance of HV winding on all taps	At the time of OLTC maintenance
31		Dynamic contact resistance measurement (DCRM) for health assessment of tap changer	5 years or after replacement of any primary part of OLTC
32		Checking of mechanical limit switch	At the time of OLTC maintenance
33		Inspection of energy accumulator for OLTC	At the time of OLTC maintenance

2.2.5 IT BASED CONDITION MONITORING OF POWER TRANSFORMER

Preventive maintenance is the key to keeping equipment healthy and in service. The most cost-effective maintenance approach is Condition-Based Maintenance (CBM) program which enhances the life of transformer and keeps it in service for longer time thus avoid the capital expenditure and secure revenue from sale of power from this system. Some of the benefits of the IT based Condition Maintenance are as follows:

- Provides advance information about health of equipment for planning a major maintenance /overhaul.
- Reduces maintenance cost
- Defers capital and maintenance expenditure
- Reduces forced outages of equipment
- Improves safety of operating personnel, reliability and quality of supply to customer
- Provides valuable information for life assessment of equipment for possible extension
- Helps in “Run-Refurbish-Replacement” decision

All Discoms are concerned to reduce the operation & maintenance cost of installed equipment and on-line condition monitoring system may help in this objective to take informed decision to prevent the failure of the vital equipment as the task of on-line monitoring is to provide focused, purposeful diagnosis information, so that remedial measures can be initiated for insipient faults. Under condition monitoring of power transformer, sensors are fitted on the transformer for collecting and sending the data to a data center through communication medium and data center has analysis software to estimate the extent of deterioration and effect of failure on real time basis and also suggest the immediate actions to be taken for enhancing the life of Transformer.

The following are main Transformer Parameters measured under on-line monitoring system:

- Gas-in-oil content
- Oil level in Buchholz relay
- Moisture in Oil
- Oil temperature, Hot spot
- Oil level
- Winding temperature
- Humidity
- Ambient temperature

- Oil Pressure
- Air temperature in cooler
- Operating conditions of Pumps & fans
- Power consumption of Motors /fans
- Voltage & Current of all 3 phases
- Active & Reactive Power
- Maximum loading & over loading of Transformer
- Over voltage , over current
- unbalance voltage /current
- OLTC control supply
- Condition of door locking for marshalling box, HV & LV cable boxes
- Average current drawn by OLTC motor during tap changing operation
- Average time for operation of OLTC motor during tap changing operation etc.

Transformer condition monitoring practices have evolved over a period of time. The condition of transformer may be judged by monitoring and trending transformer oil DGA & moisture, acidity, Tan delta and resistivity, number and severity of fault feed, overloading, age of transformer etc. This would also help in avoiding unforeseen failure of any Transformer, which could result in interruption of power supply.

It is important to minimize hazardous condition experienced in service life of transformer. The IT based condition monitoring practices, preventive maintenance schedule as well as condition based (predictive) maintenance practices would ensure trouble free life of transformer and optimal use of these assets. Hence, the Online monitoring of Power transformers at 33/11kV Substations should be adopted by discoms to monitor and record critical data like power transformer oil & winding temperature, tap information, oil level, transformer loading, etc. and to take the necessary actions as per the health report to prevent the failure of transformers hence improving the reliability of power supply to the consumers.

2.3 CIRCUIT BREAKERS:

A circuit breaker is an automatically-operated electrical switch designed to protect the electrical equipment /circuit from damage due to any fault in the system. Under fault conditions, current intensity increases multiple times the normal current flow, hence, the increased current is sensed by the relay of Circuit Breaker and then it energizes the tripping coil of breaker to isolate the system. Circuit breaker can be reset (either manually or automatically) to resume normal operation. Various types of Circuit Breakers are in operation in the country which includes Oil Circuit Breaker (OCB), Vacuum Circuit Breaker (VCB) & Gas (SF6) Circuit Breakers etc.

In the Vacuum circuit breaker, the arc quenching takes place in a vacuum medium while in oil circuit breaker, oil is used as arc quenching medium, The SF6, circuit-breakers use Sulphur hexafluoride gas as insulating and arc quenching medium. In VCB, the operation of switching on and closing of current carrying contacts and interrelated arc interruption takes place in a vacuum chamber of the breaker which is called a vacuum interrupter. VCBs are generally being used up to 33 KV level which SF6 breakers are being used in 66 KV & above voltage levels.

2.3.1 SCADA PARAMETERS – PARAMETERS MONITORED FOR CIRCUIT BREAKER THROUGH SCADA SYSTEM IN UNMANNED SUB-STATION

S.NO	ITEM TO BE INSPECTED	BRIEF DESCRIPTION OF WORK	FREQUENCY
1	Load	Status of load conditions on 3 phases, adjust relay Setting, if necessary.	24x7
2	Instantaneous current in all 3 phases	Status of Current conditions on 3 phases	24x7
3	Instantaneous Voltage in all 3 phases(Ph-PH) (Ph-N)	Status of Voltage conditions on 3 phases	24x7
4	Indicating and measuring instruments	Status for Checking, indicating and measuring instruments for correct reading and being in proper working order	24x7
5	Cabinet lights and heaters	Status of healthiness of cabinet heaters Replace burnt out lamps.	24x7
6	Power supplies and wiring/ DC Supply status	Status of all power control circuit switches	24x7
7	Heater & Thermostats status	Status of conditions of Heater & thermostats , replace if faulty	24x7

8	Breaker operating Status (Local/ Remote)	Status of the breaker operation (locally or in remote control operation0	24x7
9	Trip Relay Status		24x7
10	Trip Ckt status		24x7
11	Beaker Service Status		24x7
12	Spring Charge Status		24x7
13	SF6 Pressure status		24x7

2.3.2 VACUUM CIRCUIT BREAKER /SF6 BREAKER- MAJOR MAINTENANCE / INSPECTIONS PRACTICES TO BE ADOPTED ALONG WITH THEIR PERIODICITY (MANNED S/S)

Before starting maintenance work breaker should be isolated, disconnect auxiliary supply & discharge the springs by manual operation of the breaker.

S.NO	BRIEF DESCRIPTION OF WORK	Frequency
1.	General cleaning, dust cleaning & cleaning of pole assembly, examining the switchgear premises doors, circuit breaker etc. for general cleanness	Yearly
2.	All insulator should be cleaned with a non-shedding cloth	Yearly
3.	Cleaning lubricating & greasing (to prevent rusting)of operating mechanism parts	Yearly
4.	Check all nut & bolts for proper tightness	Yearly
5.	Check all indications	Yearly
6.	Check tripping alarm	Yearly
7.	Check Protection Healthiness of VCB's,SF6 Circuit Breaker, Check operation through remote ,local, manual& relay and conduct reduced voltage test for tripping	Yearly
8.	Check control connections, tighten all the connections	Yearly
9	Check CT connections for proper tightness	Yearly
10.	High voltage testing of breaker	Yearly
11.	Check electric charging of breaker	Yearly
12.	Checking the contact erosion	Yearly
13.	Check earthling of equipment	Yearly
14.	Check interlocks	Yearly
15.	Check the contactors, coils, switches etc for free movement	Yearly

16.	Check operation of thermostat for switching ON &OFF Heater.	Yearly
17.	Repaint the metal parts if the paint has faded out	Yearly
18.	Measure the closing time	Yearly
19.	Measure the opening time	Yearly
20.	Measurement of contact Resistance of each contact	Yearly
21.	Measurement of Resistance of closing coil	Yearly
22.	Measurement of Resistance of Tripping coil	Yearly
23.	Check contact travel.	Yearly
24.	Check – vacuum interrupter test in VCB,	Yearly
25.	Check Nomenclature on VCB (both in case of Indoor or Outdoor VCB's) and do correct nomenclature, if required	Yearly
26.	Check the tightness of structure bolt.	Yearly
27.	IR test to be carried out in open and close condition between top pole to earth, bottom pole to earth and between top and bottom pole	Yearly
28.	Inspection of metallic contacts in VCB	Yearly
29.	Gas pressure for SF6 type switchgear / vacuum for VCB	Yearly
30.	Gas quality for SF6 type CB (dew point, purity and SO2 content)	Yearly
31.	Heater & Thermostats status	Yearly
32.	Rack in rack out mechanism	Yearly
33.	Overhaul and checking the healthiness of main VCB and SF6 circuit breaker. The main checking points of this type of circuit breaker is due pint check and purity of SF6 gas, SF6 pressure test, leakage test, CRM, Timer, IR values, coil pick up voltage, tripping coil & closing coil resistance, trial tripping.	Yearly

2.3.3 OIL CIRCUIT BREAKER - MAJOR MAINTENANCE / INSPECTIONS PRACTICES TO BE ADOPTED ALONG WITH THEIR PERIODICITY (MANNED S/S)

S.No.	ITEM TO BE INSPECTED	BRIEF DESCRIPTION OF WORK	FREQUENCY
1	General cleanliness	Examine that switchgear premises doors, circuit breaker etc. for general cleanliness.	Yearly
2	Oil	Check oil leakage, if so level be also ascertained.	Weekly
3	Oil level and gauges	Check oil level in gauges of the tank/poles/oil filled bushing. Replenish oil if found below normal.	Weekly
4	Tank	Check for temperature and for any unusual noise and smell.	Weekly
5	Alarms and lamp indication circuit etc.	Test the alarm circuit for continuity and lighting circuit and earthing system.	Yearly
6	Load	Check for load conditions on 3 phases, adjust relay Setting, if necessary.	Daily
7	Indicating and measuring instruments	Check, indicating and measuring instruments for correct reading and being in proper working order	Daily
8	Auxiliary fuses	Check that auxiliary fuses are intact.	Yearly
9	Bushing or insulators	Check for chipped or broken insulator, excessive dirt film.	Yearly/ as & when required
10	Cabinet lights and heaters	Check cabinet heaters and see that they are in service during cold weather. Replace burnt out lamps.	Weekly
11	Power supplies and wiring	See that all power control circuit switches are closed	Weekly
12	Breathers and vents	Check for external obstructions to breathers and vents and condition of silica gel.	Weekly
13	Nuts, bolts & Jumpers etc.	Check whether nuts and bolts are tight and jumpers are properly connected.	Monthly
14	Drain plug	Check that drain plug is tight.	Monthly
15	Operation counter	Observe and record reading of operation counter.	Yearly
16	Local remote operation	Check that breaker can be operated locally and in remote control operation.	Yearly
17	Shutter mechanism and trolley alignment for 11KV breakers	To check for proper working of shutter mechanism and to verify the alignment of trolley.	Yearly
18	Manual operating device	Check that manual operating lever or jack is kept on hand and is in visible condition. See that breaker is closable with it.	Yearly

S.No.	ITEM TO BE INSPECTED	BRIEF DESCRIPTION OF WORK	FREQUENCY
19	Latch and Trip mechanism	Observe mechanism during general tripping operations to see that everything is in working order. Check pins, bearings and latch for wear, binding and misalignment. Clean and lubricate the moving parts. Check latch carefully to see that it is not becoming worn so as to unlatch from vibration or stick or fail to trip. Tighten bolts and screws.	Yearly
20	IR values	Check IR value in ON and OFF positions between contacts in off position. Check IR value of control cable with 500V megger.	Yearly
21	Earth resistance	Check earth resistance of body.	Yearly
22	Slow closing test	This test may be conducted and also check that all the three contacts are made simultaneously.	Yearly
23	Wiring connections	Check and tighten wiring connection at terminal points. Inspect wiring for open circuit, short circuit and damaged insulation.	Yearly
24	Aux. Switches	Check condition of contacts and refinish with fine file if burnt or corroded. Check contact springs, operating rods and levers. Check closing and operating position with respect to main contacts while breaker is slowly closed and opened manually.	Yearly
25	Control and protection chamber of 11KV switch	To check for alignment of front door opening/closing for loose fitting, loose wiring of opening in 11KV switchgear.	Yearly
26	11KV cable connections	Check for overheating and proper connection and insulation.	Yearly
27	Foundation	Check foundation for cracks and settings. Settings of the breaker tank may break bushings or cause misalignment of contacts or bindings of operating mechanism.	Yearly
28	Oil valves and plugs	Check condition of paint. Inspect oil valves and plugs. Flush out oil and clean the oil tank/quenching chambers.	Yearly
29	Oil levels and gauges	Clean dirty gauge glasses and connections into tank. Drain out and replace bushing oil if found dirty or discoloured.	Yearly
30	Panels and cabinets	Check air circuit breaker or other panels of insulating material for cracks and cleanliness. Check condition of enclosing cabinets including hinges, latches, locks door gaskets and paint.	Yearly

S.No.	ITEM TO BE INSPECTED	BRIEF DESCRIPTION OF WORK	FREQUENCY
31	Main terminals and ground connections	Tighten all nuts and ground connections. Refinish joint mating surface, if they have been overheated. Inspect ground cable to see that it is not loose or broken.	Yearly
32	Main contacts	Remove the tanks or drain out oil, so that the contacts can be inspected, dress contacts, if rough with a fine file. Check contacts voltage drop with millivolt meter after inspecting reasonable current. Frequency of contact maintenance should be based on numbers and severity of faults interrupted, Check adjustment of gap when required.	Yearly
33	Contact pressure spring	Check for loss of temperature damage or other deterioration.	Yearly
34	Flexible shunt	Check flexible shunts of contact hinges for overheating or damages. Tighten connections.	Yearly
35	Magnetic, air or oil blow out devices	Check arc-rupturing blow out coils, magnetic circuit arc chutes, de ion grids, oil blasts or other interrupters for proper operations.	Yearly
36	Operating rods shafts and cranks	Check for loose locknuts, set screws, keys, bearing bent rods or twisted shafts etc. clean moving parts of rust, dirt and accumulated grease and oil, wash out bearings, pivots and gears with chloromethane or other suitable cleaner and operate breaker several times to work out dirt and old lubricant. Lubricate with new grease or oil.	Yearly
37	Closing solenoid air cylinder, meter or spring	Observe mechanism during several operations to see that everything is in proper working order. Check solenoid plunger for sticking in guides. Check coil resistance and insulation resistance. Dismantle air cylinder and clean and lubricate. Check spring for proper tension and closing energy.	Yearly
38	Solenoid valves	Check for condition of valve, and refit as necessary. See that moving parts are free to operate. Check resistance and insulation resistance of solenoid coil.	Yearly
39	Operation counter	Check that the operation counter is properly registering the breaker operations.	Yearly
40	Position indicator	Check that position indicator is properly registering the breaker operations.	Yearly

S.No.	ITEM TO BE INSPECTED	BRIEF DESCRIPTION OF WORK	FREQUENCY
41	Mechanism cabinets	Check condition of metal and hardware. Repaint as necessary. See that door gaskets are tight and properly dust and vermin proof.	Yearly
42	Power supply and wiring	Inspect fuses of circuit breakers in all power and control supply circuits, check in insulation resistance of wiring with devices connected.	Yearly
43	Oil dielectric test and acidity test dependent on actual tripping	Check dielectric strength of the insulating oil in the main tanks and oil filled bushings. Oil should be filtered or replaced if dielectric strength is found to below 25 KV, or if there is a noticeable amount of carbon in suspension on the bottom of the tanks. Also check ratio and phase angle adjustments, the acidity of the oil.	Yearly
44	Operation	Some breakers particularly those carrying high values of current have a tendency to develop contact heating if left closed for long periods. Operating and closing the breakers several times at intervals, as system operation permit, may alleviate the heating by wiping the oxide from the contact surfaces, as well as demonstrate that the breaker is in operating condition.	Yearly
45	Spring Charging mechanism	Check the condition of Spring Charging mechanism & lubricate , if required	Yearly
46	Rack in & Rack Out Mechanism	Check conditions of Rack in and Rack out mechanism & lubricate if required	Yearly
47	Heater & thermostats	Check condition of Heater & thermostats	Yearly
45	Bushing current transformers and potential devices	Check tap setting and adjustments at terminal board to see that they agree with diagrams. Check insulations resistance of wiring with devices connected. Check of potential devices if changes have been made in secondary connection and burden. Tighten connections, including potential devices top into bushing.	Yearly
46	Testing of oil in oil filled bushings		Two years
47	Cleaning blast tube internally and checking clamping down nuts.		Two years
48	Overhaul and checking efficiency of main compressor. Complete overhaul of the O.C.B. (The period can be changed depending upon the lead cycle of the equipment and manufactures recommendations).		Once in two years

2.4 CURRENT TRANSFORMER (CT)

A current transformer (CT) is an instrument transformer designed to provide a current in its secondary winding proportional to the alternating current flowing in its primary. The current transformer works on the principle of variable flux. In the "ideal" current transformer, secondary current would be exactly equal (when multiplied by the turn's ratio) and opposite of the primary current. These are commonly used in metering and protection circuits in Sub-stations and fields.

Major Maintenance Activities for CT

Sr. no.	ITEM TO BE INSPECTED	BRIEF DESCRIPTION OFWORK	FREQUENCY
1	CURRENT TRANSFORMER	Visual Damages & Deterioration, if any	WEEKLY
2		Oil Leakage if any	WEEKLY
3		Oil Level in CT	YEARLY
4		Check condition of the Structure	YEARLY
5		All unused core are shorted in CT	YEARLY
6		All cables entry into CT is through cable gland	YEARLY
7		Check any abnormal sound with Ultra probe 15000 / any other new technology instrument	YEARLY
8		CT Bushing	YEARLY
9		Primary & Secondary Terminals winding	YEARLY
10		CT Junction Box	YEARLY
11		Oil Inspection Window	YEARLY
12		Primary Connections	YEARLY
13		Mounting Frames	YEARLY
14		Earthing CT/Frame/JB	YEARLY
15		JB Connections	YEARLY
16		Vermin Proofing of CT Junction Box/Sec Terminal	YEARLY
17		IR value of Primary to Earth	YEARLY
18		IR value of Secondary to Earth	YEARLY
19		IR Value of Primary to Secondary	YEARLY
20		Tan Delta	YEARLY
21		CT Turn Ratio	YEARLY
22		Body earth resistance	YEARLY

Sr. no.	ITEM TO BE INSPECTED	BRIEF DESCRIPTION OFWORK	FREQUENCY
		CT secondary wiring connection tightness	YEARLY
		CT secondary single point earthing	YEARLY
		Checking of condition of CT secondary terminal boxes	YEARLY
		Painting of body	YEARLY
		CT magnetic circuit	YEARLY
		Cleaning of insulators	YEARLY
		Checking of partial discharge, UHF, RFI & TEV signals	YEARLY
		CT Analysis	YEARLY

2.5 POTENTIAL TRANSFORMER (PT)

Voltage transformers (VT) or Potential transformers (PT) are another type of instrument transformer, used for metering and protection in high-voltage circuits. Typically the secondary of a voltage transformer is rated for 110 V at rated primary voltage, to match the input ratings of protective relays.

MAJOR MAINTENANCE ACTIVITIES FOR PT

S.No	ITEM TO BE INSPECTED	BRIEF DESCRIPTION OF WORK	FREQUENCY
1	POTENTIAL TRANSFORMER	Check any abnormal sound with ultrasonic detector	Weekly
2		Visual damages and deterioration if any	Weekly
3		Oil Level sight Glass	Yearly
4		Earthing PT/Frame/JB	Yearly
5		JB Connections	Yearly
6		Oil Leakage if any	Weekly
7		Check condition of fuses & that all fuses are intact	Weekly
8		PT Bushing	Yearly
9		PT Junction Box	Yearly

S.No	ITEM TO BE INSPECTED	BRIEF DESCRIPTION OF WORK	FREQUENCY
10		Secondary Connections	Yearly
11		IR value of Primary to Earth	Yearly
12		IR value of Secondary to Earth	Yearly
13		Oil Level in PT	Yearly
14		Vermin Proofing of PT Junction Box/Sec Terminal	Yearly
15		Secondary Terminals	Yearly
16		Primary Connections	Yearly
17		Mounting Frames	Yearly
18		IR Value of Primary to Secondary	Yearly
19		Correct Rating of PT Fuse, up to C&R Panel	Yearly
20		Check condition of the Structure	Yearly
21		Check all unused wires are insulated	Yearly
22		PT Analysis	3 Yrs.
23		C & ten Delta measurement	Yearly
24		Cleaning of Insulator	Yearly
25		Checking of partial discharge, UHF, RFI & TEV signals	Yearly
26		Turns ratio	Yearly
27		Painting of body	As required
28		Checking of condition of PT secondary terminal boxes	Yearly
29		PT secondary wiring connection tightness	Yearly

2.6 SURGE ARRESTER / LIGHTNING ARRESTER (LA)

Lightning is one of the most serious causes of over voltage. The typical lightning arrester also known as surge arrester has a high voltage terminal and a ground terminal to protect the equipment from Lightning and Surges. Surge Arrestors installed in the substation are intended to divert surges to earth and thus protect costly switchyard equipment. Proper insulation coordination is necessary for enhancing life span of costly substation equipment.

MAJOR MAINTENANCE ACTIVITIES FOR LA

Sr. no.	ITEM TO BE INSPECTED	BRIEF DESCRIPTION OF WORK	FREQUENCY
1	Surge Counter	Note and record operation indicator reading along with leakage current.	MONTHLY
2	Base & support	Usual inspection to detect cracking setting or shifting of base of supports.	MONTHLY
3	Surge Monitor	Check that surge monitor is properly connected and is in working order and shows a leakage current.	MONTHLY
4	Jumpers and clamps	Check jumpers and clamps for tightness.	YEARLY
5	Porcelain shells and insulators	Clean porcelain insulators and arrestor unit shells. Repair chipped spots on porcelain with lacquer such as red clay paint.	YEARLY
6	Grading rings	Check and tighten grading rings on high voltage arrestors.	YEARLY
7	Gaps	Check external gaps. Smooth off burnt spots and readjust spacing.	YEARLY
8	Weather sheds and hooks	See that weather sheds and hooks of oxide film arrestors are securely fastened in place, repaint if necessary.	YEARLY
9	Line and Ground connection	Check and tighten line and ground connections. Check ground lead for corrosion or damage below ground line. Check ground resistance. See that all leads are as short and direct as possible.	YEARLY
		Continuity of surge counters	YEARLY
10	Operation tests	To check the general working of lightening arrestors / Measurement of leakage or third harmonic current	YEARLY

2.7 LINE ISOLATORS & EARTH SWITCHES

Line Disconnectors / Isolators are off- line devices to disconnect the equipment from main circuit for maintenance / fault repair. The isolators have main current carrying arms and operating mechanism for connection and disconnection. The alignment of Isolator is very important for smooth operation. The limit switches, the healthiness of auxiliary contacts needs to be checked periodically. The main contacts are to be inspected and made smooth if any pitting marks seen. All moving parts are to be lubricated and tightened for smooth operation.

MAJOR MAINTENANCE ACTIVITIES FOR ISOLATORS

Sr. no.	ITEM TO BE INSPECTED	BRIEF DESCRIPTION OF WORK	FREQUENCY
1	Insulators	Check for cracked or broken porcelain and excessive dirt film and to undertake repair of chipped spots by painting with lacquer such as red clay paint.	YEARLY
2	Blades and contacts	Check that blades are properly seated in the contacts.	YEARLY
3	Blades and Latches and stops	Check that blade latches where provided are engaged.	YEARLY
4	Locks and interlocks	Electrical and mechanical interlock checking	YEARLY
5	Bolts, Nuts & Jumpers	Check bolts, nuts and jumpers for tightness. Apply petroleum jelly on male and female contacts.	YEARLY
6	I.R, value, earth resistance & CRM	Check IR value, earth resistance & CRM within limits Check that double earthing is provided.	YEARLY
7	Auxiliary & limit switches	Check condition of contacts and refinish with fine file if burnt or corroded. Check contact spring operating rod and lever. Check closing and opening position with respect to main switch contacts or travel or motor mechanism.	YEARLY
8	Manual operating Rod	To check for proper engagement of emergency operating handle and further its operation is smooth and satisfactory.	YEARLY
9	Opening Box mechanism	Isolator Operating mechanism Box physical condition, vermin proofing, interlocks, DC leakage	YEARLY

2.8 GAS INSULATED SUBSTATION (GIS)

Gas insulated substation (GIS) consist of various components i.e. Circuit breakers, Disconnections, Bus bars, Earth switches, Surge arresters etc. in the metal enclosure that is filled with SF6 gas at a certain pressure components. The enclosure is also equipped with sensors, monitors, indicators, alarms, and control devices that ensure the proper operation and safety of the switchgears. GIS can save up to 70-90% of space compared with air insulated substation. At medium voltage level, Hybrid GIS are also in use in which bus bar is solidly insulated in a compartment in place of SF6 Gas.

MAJOR MAINTENANCE ACTIVITIES FOR GIS SUBSTATION.

S.NO	BRIEF DESCRIPTION OF WORK	Frequency
1.	Physical Inspection of GIS /Hybrid GIS	
	a) Inspect for Physical damage and defects	Yearly
	b) Check working of all Indication	Yearly
	c) Check SF6 Gas Pressure.	Yearly
2.	Check the Cleanliness of outside area	Yearly
3.	Ensure Ring Core Type CT's and Proper connection of CT's Secondary Circuit.	Yearly
4.	Insulation Resistance Test of all wirings.	Yearly
5.	Function of Control and Interlocking.	Yearly
6.	Contact Resistance Test.	Yearly
7.	Timings Test for Circuit Breakers, Disconnector Switches, and Earth Switches (with contact travel and speed analysis.)	Yearly
8.	Function Test of Trip Free and anti-pump circuit.	Yearly
9.	Check Earthing of Equipments	Yearly
10.	Repaint the metal parts if the paint has faded out	Yearly
11.	Check Nomenclature on all GIS Components and do correct nomenclature, if required	Yearly

2.9 BATTERY BANK & BATTERY CHARGERS

In a substation, DC supply is very important as it is required for all protection system. Substations generally use Lead Acid batteries / Nickel-Cadmium batteries for DC supply. Now a days maintenance free batteries are also in use for substation applications. The Battery Chargers is also an essential part of Battery system. Battery charger is to be maintained for keeping the battery always charged and also to supply normal DC load for operation.

MAJOR MAINTENANCE ACTIVITIES FOR BATTERY SYSTEM

Sr. no.	ITEM TO BE INSPECTED	BRIEF DESCRIPTION OF WORK	FREQUENCY
1	Battery room and ventilation	See that battery room entrance doors are kept closed and that ventilation to outside air are open and air is circulated by running of the exhaust fan	DAILY
2	Dust cleaning	Dust cleaning for battery cells & Dust cleaning for charger	MONTHLY
3	Operation	Check charging rate -. Check and record pilot cell specific gravity, temperature and floating voltage	MONTHLY
4	Voltage at load bus and battery terminal	Check DC voltage at load bus and battery terminal AC supply for charger	MONTHLY
5	Bulb for dry rectifier element	Check for burnt/broken bulb and replace when necessary.	MONTHLY
6	Leakage test	Perform leakage test by lamp or voltmeter method.	MONTHLY
7	Cell Jars and covers	Check for cracked or leaking jars or covers and replace when necessary. Keep jars and covers clean.	MONTHLY
8	Plates	Inspect plates (in case of transparent containers only) carefully for signs of deterioration due to improper charging. Note quantity, colour and texture of sediment.	MONTHLY
9	Separators	See that the separators remain in place and are keeping the plates properly spaced(in case of transparent containers only)	MONTHLY
10	Electrolyte	Check electrolyte level and add distilled water when required.	MONTHLY

Sr. no.	ITEM TO BE INSPECTED	BRIEF DESCRIPTION OF WORK	FREQUENCY
11	Acid and distilled water storage	See that enough distilled water and acid are kept in storage to meet current needs. Check containers for cleanliness.	MONTHLY
12	Discharging and charging cycle	This is required to be carried out as prescribed by the manufacturer in order to prolong the life of the battery.	Half yearly /continuous by remote monitoring
13	Temperature of battery cells:	Checking of Temperature of battery cells:	Half yearly /continuous by remote monitoring
14	Base or rack	Inspect concretes base or wooden racks for deterioration. Repair and repaint with acid resistant paint as necessary.	YEARLY
15	Inter cell connectors and terminals	Clean acid corrosion from connectors and terminals should be lead coated. Tighten terminals and apply petroleum jelly for exposed surface.	YEARLY
16	Sink funnel and filters	See that the sink, funnels, fillers and other distilled water and acid handling facilities kept clean and in good useable conditions.	YEARLY
17	Water still	Check still for proper operation, adequacy and purity of distilled water delivered. Check that equipment is kept clean	YEARLY
18	Capacity discharge test	Capacity discharge test	YEARLY
19	Body earth resistance for charger	Check Body earth resistance for charger	YEARLY
20	Remote alarm circuit	Check Remote alarm circuit	YEARLY
21	Complete overhauling of the battery as per manufacturer's recommendations		As per battery conditions / as per manufacturer's recommendations

2.10 CONTROL & RELAY PANEL (33 KV & 11 KV)

33 KV relay & control panels are used to operate 33 KV circuit breakers. It also used to get all the monitoring information like breaker on /off status, spring charge, local remote status, trip circuit healthy information, DC & AC voltage related information etc. 33 KV control panels also include relays for protection & master trip relays also.11 kV Panel contains automatically-operated electrical switch designed to protect the 11 kV feeder from damage caused by faults. Circuit breaker can be reset (either manually or automatically) to resume normal operation.

MAJOR MAINTENANCE ACTIVITIES FOR C&R PANELS

S.NO	BRIEF DESCRIPTION OF WORK	Frequency
1	Check all indication lamps for working	MONTHLY
2	Check illumination lamp / power socket for working	MONTHLY
3	Vermin proofing of panel and door interlock switch	YEARLY
4	Check & ensure that L/R switch is at remote position.	YEARLY
5	Check rating of fuses/MCB.	YEARLY
6	Control Panel Interior.	YEARLY
7	Control Panel external surface.	YEARLY
8	Relay / Contactors with air blower (from distance).	YEARLY
9	All Control Connections.	YEARLY
10	Earthing Connection wherever provided.	YEARLY
11	Inter panel Coupling.	YEARLY
12	Multicore Cable Glands.	YEARLY
13	Check cubicle heater / thermostat for correct operation.	YEARLY
14	Dressing of wiring.	YEARLY
15	Check door bidding for dust proofing.	YEARLY
16	Check & ensure that all multicore cables are earthed atswitchyard side only.	YEARLY

S.NO	BRIEF DESCRIPTION OF WORK	Frequency
17	Check and ensure that relay healthy indication is glowing.	YEARLY
18	Check that all unused wires are insulated.	YEARLY
19	All Protection Connections and Space heater are in working condition & auto ON OFF	At the time of Protection checking
20	All Communication Connections.	At the time of Communication checking

2.11 EARTHING SYSTEM OF SUB-STATION

An effective earthing system in a sub-station is one of the most important work which is provided under and around the sub-station surface at a uniform potential and near zero or absolute earth potential as possible. This provision ensures that no human being in sub-station is subjected to a shock or injury on occurrence of a shortcircuit or development of other abnormal conditions in the equipment installed in the yard. Ground mat is provided below ground level. Earth electrodes are driven into ground at several points and are connected to grounding mat to form an earth mesh. All the structures, Transformers & other power equipment are connected to this mesh for effective earthing. The proper maintenance of the earthing is most important for safety purposes.

MAJOR MAINTENANCE ACTIVITIES FOR EARTHING SYSTEM

S.NO.	BRIEF DESCRIPTION OF WORK	FREQUENCY
1	Check All Earth pits	MONTHLY
2	Check All Earth connections at Earth pits.	HALF YEARLY
3	Check all equipments for double earthing	YEARLY
4	Check all earthing conductors for adequacy & proper tightness.	YEARLY
5	Check proper clamping of earthing pipe and earthing conductor.	YEARLY
6	Check numbering of all earth pits.	YEARLY
7	Check availability of Cast Iron lid for each earthing pit.	YEARLY
8	Check exposed portion of earth conductor for Galvanizing or painting	YEARLY
9	Check & ensure painting of Earth isolator box with Green colour for fast identification	YEARLY
10	Check that each multicore cable is grounded through cablegland.	YEARLY
11	Check and ensure that all power cables are earthed at one endonly	YEARLY
12	Check and ensure all multicore cables are earthed at switchyardend only or alternatively at one end only.	YEARLY

S.NO.	BRIEF DESCRIPTION OF WORK	FREQUENCY
13	Check and ensure that Substation building earth is connected to separate earth pit / pits and then the same is extended to mesh earthing in switchyard.	YEARLY
14	Check and ensure that individual Transformer neutral is connected to separate earth pit and then the same is extended to mesh earthing in switchyard.	YEARLY
15	All Earth connections at equipment mounting frames	YEARLY
16	All Earth pits resistance for Power / Distribution Transformer neutral	YEARLY
17	All Earth pits resistance for LAs	YEARLY
18	Resistance of earth mesh	YEARLY

Chapter 3

O&M BENCHMARKING OF DISTRIBUTION TRANSFORMERS

3.1 INTRODUCTION

Distribution Transformers carry a load, which varies from time to time during the day & night but generally capacity of these transformers are decided to cater for the maximum load during the day. However, often the average load on DT is far less than the peak load which occurs 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. BIS has issued the Indian Standards for Distribution Transformer (IS 1180) which stipulates the losses of Transformers at various levels.

The failure of Distribution Transformers leads to failure of Distribution system and subsequent outage which leads to financial loss in repair and replacement, loss of revenue and reduces quality and reliability of supplied power.

The operating conditions, particularly in rural India, like weather conditions, overloading, through or passing faults, inadequate protection, public interference, poor maintenance of LT and 11 kV lines often results in distribution transformer failure. Distribution transformers installed in rural areas form the bulk of these transformers. They are very much exposed to vulnerable weather conditions particularly lightning. These transformers feed lengthy Low Tension (LT) lines which are more prone to faults because of these atmospheric conditions.

Majority of the transformers have poor efficiency because of improper or unbalanced loading conditions. It is common practice to connect additional electrical load on these transformers on the basis of maximum demand recorded at some point of time or on the basis of assessed maximum demand without considering the seasonal variations and the actual diversity factor.

Un-authorized electrical connections also result in overloading. Wide variation in load and ambient temperature make undesired ingress of moisture, particularly in rural areas, which weakens the dielectric strength of transformer oil, forms sludge and deposits on the winding which on passage of time may obstruct the ducts in the winding provided for oil circulation. The routine maintenance of LT and 11 kV lines and protective equipment's associated with these transformers are also poor. Prolonged operation of distribution transformer under

abnormal operating conditions such as faults, overloading or unbalanced load deteriorate the insulating materials; ultimately leading to failure.

Following are some of the reasons for failure of distribution transformers in the country:

Major Reasons	Minor Reasons
• Insulation Failure • Damage to HT Coil • Damage to LT Coil • Damage to Core & Laminations • Failure to Tap Switch & Tap Arrangement • Water Ingress • Relay protection failure • External fault on LT side • Over voltage issues • Improper closing of HT & LT door, thereby allowing ingression of moisture and external agent • Inadequate oil level due to profuse oil leakage or pilferage • Improper homing of HT isolator • Rusting of whole body and conservator • Tap link board failure • Mal operation of HT or LT fuse • Inappropriate core and body earth resistance • High partial discharge for bushings and supporting insulators • High sludge content • Manufacturing defect • Core failure • Overloading • Accelerated ageing • Winding hotspot • Ingression of foreign object inside tank • Wrong protection grading at LT side • Insulation failure of cable at the cable terminations	• Oil Sample not Satisfactory • Lead connections cut off • Worn-out Bushing rods • Broken Bushings • Gasket Leakage • Welding Leakage • Leakage through Valves • Broken gauge glass • Broken vent diaphragm • Worn-out Breather • Loose connection at conductor points • Choking of radiator fins • Moisture ingression due to inadequate canopy arrangement • Deterioration of oil quality

Transformers have operating limits beyond which transformer failure can occur like overloading and other operational problems. In such adverse conditions there can be heavy damage to the transformer and it may cause intolerable interruption of service to customers and may also cause loss to public property & life due to accidents. Since the lead time for repair and replacement of transformers is usually quite high, hence proper quality, timely maintenance, and adhering to timely checks and maintenance schedule should be followed to avoid the failure of DTs. In case of failure of Distribution Transformers, the faulty transformer is to be replaced by a healthy transformer by the utilities within the specified time limit as per Rules / Regulations notified by the Govt/ SERCs. Initially, the faulty transformers are replaced immediately by healthy transformer and afterward the faulty transformer is repaired in the workshop to be used again in the field.

In order to ensure quality procurement along with higher energy efficiency requirements, some of the important points to be considered during procurement of Distribution transformers are highlighted below:

a) Distribution transformers are to be procured with Standard ratings as per IS. The maximum allowable losses at rated voltage and rated frequency permitted at 75°C for Distribution transformers can be chosen by the utility as per IS 1180 (as amended).

b) The above losses are maximum allowable and there would not be any positive tolerance.

c) As per the Electrical Transformers (Quality Control) Order, 2015 issued by Ministry of Heavy Industries and Public Enterprises, no person shall by himself or through any person on his behalf manufacture or store for sale, sell or distribute any electrical Transformers specified in the Schedule, which do not conform to the specified standards (i.e. IS 1180 Part-1, 2014) and do not bear Standard Mark of the Bureau of Indian Standards. Accordingly, ISI marking on the Distribution transformer is mandatory and the product should be manufactured in compliance with IS 1180 Part-1: (2014).

d) Additionally, Star rating by BEE is also mandatory on Distribution transformers.

3.2 REGULAR INSPECTIONS AND PERIODIC MAINTENANCE OF DT

The Regular inspections and periodic maintenance of Distribution transformers help to identify impending issues at the earlier stages to enable utilities to take necessary actions to prevent future problems.

- Distribution transformers must be regularly checked as an O&M practice especially for Overloading, damaged connectors, worn-out power cords, burning smell, loose plugs or misaligned parts to minimize system failures and fire hazards.
- It is paramount that the maintenance crew pays attention to applicable Standards (Like ISO 9001-2015/ISO-45001) to maintain a safe working environment for both the equipment and the maintenance staff.
- The proper exercise of the maintenance schedule should also be adopted by Discoms as it will lead to extension of life of Distribution Transformers, reduction in failure rate, enhanced reliability of power supply system and consumer satisfaction leading to an appreciable increase in revenue of the utilities. It is noted that some of utilities which give proper importance to this maintenance & repair aspects including training of its O & M staff are able to achieve less than 2 % DT failure rate in the country. For formulation of maintenance schedule, Data driven analytical approach should be adopted by Discoms. The Discoms should also have requisite mechanism to record and maintain transformer wise load, age and fault data and based on the data related to aging, loading and faults, Transformer should be prioritized for maintenance.

MAJOR MAINTENANCE PRACTICES FOR OIL FILLED DISTRIBUTION TRANSFORMERS:

S.NO	BRIEF DESCRIPTION OF WORK	FREQUENCY
1	Oil level in transformer	Yearly
2	Check that the colour of the silica gel in the breather is blue	Yearly
3	Check the breather for any cracks, holes, transparency and oil in the oil cup	Yearly
4	Check for any signs of arcing/pitting mark on Bus-bar & palm connector	Yearly
5	Ensure that there is no leakage of oil from gaskets, flanges, valves, radiators, bushings etc. Ensure oil level of conservator & cleaning of glass of conservator	Yearly
6	Check the healthiness and proper connections of LA	Yearly

7	Check out the conditions /joints of distribution cable /load cable, Tightness for all conductor joints	Yearly
8	Check that the bushing surface is clean.	Yearly
9	Check the bushings for any crack or any chipping of porcelain	Yearly
10	Check the earthing of the tank cover to tank	Yearly
11	Check the condition of neutral & transformer body grounding	Yearly
12	Ensure that the surface of radiator is clean	Yearly
13	Check the earthing of fencing (enclosure) with two separate earths	Yearly
14	Check the proper connections and working of smart/AMR meter /any other device like DTMU	As per requirement
15	Checking of all gasketed joints for proper tightening. All threaded joints like conservator cap and breather pipe to be secured using Teflon tape.	Yearly
16	Corrosion Protection If the transformer is located in a near drain or corrosive environment, apply appropriate corrosion protection measures to prevent tank and structural damage	Yearly
17	DT Oil Sampling to check the BDV	Yearly
18	Measurement of IR & PI	Yearly
19	Checking partial discharge for DTRs	Yearly
20	Checking of explosion vent pipe	Yearly
21	Checking of Earthing of DT's and its associated equipment's and Insulation resistance of DT	Yearly
22	Thermo scanning of Distribution Transformer before maintenance, if instrument is available	Yearly
23	Overall painting of body	As required

The following parameters of DT can be monitored remotely on daily basis in 15 minute time interval through smart DT meters:

- Loading
- Voltage profile
- Instantaneous /Max Current
- Power factor
- Monitoring of Oil temperature / Ambient temperature (if remote indicator is available)
- Oil level (if remote indicator is available)

3.3 DRY TYPE TRANSFORMER

Dry type transformer is another form of transformer which doesn't use oil as a coolant medium rather windings are kept in normal air in the enclosure. Opening are given in the enclosure which allows air to pass through it which cools the transformer. As per CEA safety regulations, only Dry type transformers are allowed inside residential/commercial buildings / basements. Dry type DT's are available for both Indoor & Out door installations.

3.3.1 MAINTENANCE SCHEDULE FOR DRY TYPE TRANSFORMER

S.No	BRIEF DESCRIPTION OF WORK	Frequency
1	a) Check for any crack/ flash mark on HV-LV bushings if any b) Check for dust on HV-LV bushing.	Yearly
2	Check for dust & rust on enclosure & HV-LV Cable box.	Yearly
3	a) Check for doors are properly closed or not. b) There should not be any open space at cable (HV& LV) inlet & earthing strip.	Yearly
5	a) Check for winding/setting for thermostat. b) Check for working for lamp	Yearly
7	Check for dust deposit over the core and coil assembly of transformer.	Quarterly
8	Enclosure should be earthed at two placed with separate earthing point.	Yearly
9	Neutral should be earthed at two placed with separate earthing point.	Yearly
11	Check the core looseness, Loose connection of live parts & vibration due to improper grouting of DT's in Foundation	Yearly
12	Check the rusting in enclosure & other part (Inside)	Yearly
13	Water accumulation in close proximity of Transformer Installation, it may be either by rainwater, pipe leakage & toilet area	Yearly
14	I.R value & Earth resistance	Yearly
15	Check temperature rise of winding temperature	Monthly
16	Check the cable opening. It should be completely sealed so no reptile should go inside the DT	Yearly
17	Tightness for all conductor joints	Yearly
18	Overall painting of body	As Required

3.3.2 PERFORMANCE MONITORING / REMOTE MONITORING OF DISTRIBUTION TRANSFORMERS THROUGH SMART / AMR METERS

Distribution Transformer being a vital element of the electric power distribution infrastructure, should be monitored regularly to prevent any potential faults as failure of the DT costs financial losses for discoms for repairing or replacement of failed DT.

As distribution transformers are installed in a large numbers and at scattered locations in urban as well as rural areas, their health monitoring through manual means is not at all practically possible. Hence, it is necessary to develop a system for remote monitoring of DTs and in this regard, the metering of Distribution transformers with AMR/smart meters and reading the meter data remotely will assist Utilities in the health/outage monitoring of DTs apart from DT-wise energy auditing and accounting. For this purpose, GPRS/GPS/IOT /RF based smart metering system may be installed on the transformer. The meter should measure, monitor and record different system parameters including those mentioned in the earlier section. The meter can continuously monitor the performance of the transformer and signal the control center through communication channels in case of abnormal behavior.

In urban area, large No. of Distribution transformers are equipped with communicable meters with AMR facility under RAPDRP and IPDS and are being read remotely at Data center for seamless energy accounting and auditing. However, a few issues have been observed in meter data availability for these DTs, mainly due to day to day operation and maintenance of AMR system of DT meters, mis-alignment or failure of modem, communication failures, non-restoration of DT metering system by the Utility staff / outsourced agency engaged in replacement of faulty Distribution transformers and the meter along-with communication equipment is not re-connected.

As of now, all the Distribution Transformers in rural area generally do not have Metering facility (or AMR/AMI) hence for such areas Smart Meters along with metering facility may be provided as per the time line issued by MOP. Under the Revamped Distribution Sector Scheme (RDSS) launched by the GoI in July 2021, it is envisaged to install 25 Crore Smart Meter in the country along with smart system meters on all Feeders and Distribution transformers within a specified time line for accurate Energy Audit and accounting .

Further, as the meter keeps record of different system parameters, transformer failure analysis can also be done and the cause of the transformer failure can be easily identified and analyzed by using AI/ML before taking decision on repairs/replacement.

To take the full advantages of already installed AMR/AMI meters, the utility should take care the operation and maintenance of AMR/AMI system of DT meters installed. This will enable seamless energy accounting and auditing without any manual intervention. Exception reports of DT metering data will also identify problems of overloading, light loading and unbalanced loading of Distribution transformers for taking further corrective actions and reduction in DT failure rates.

3.3.3 IOT BASED SOLUTION FOR TRANSFORMER OVERLOAD HANDLING AND LIFE EXTENSION

The Transformer failures generally occurs due to insulation failures. Overheating caused by overloading deteriorates the insulation life and causes early aging in transformers. Solutions like smart IOT may be adopted for controlling the temperature rise of transformer. The cooling fan can be installed for additional cooling of transformers which can be controlled via smart devices which can trigger based on the oil temperature rise. This solution can also help in mitigating the temporary seasonal overloading of transformers. This can be installed on pole mounted transformers and plinth mounted transformers also with structure.

A specialized algorithm feed in the controller keep check on temperature rise of DT and switches on first cooling fan at 65 degrees and second cooling fan at 70 degrees (configurable preset values). The controller gives command to upstream breaker for tripping for sustained overloading resulting in temperature rise to 90 degrees. Also data is stored in local memory and on web server for every ON and OFF operation along with temperature and date and time stamp for future analysis. Also alerts are generated when fan is nonfunctional and at high temperature rise threshold of 90 degrees. With alert message or email, the maintenance crew can be mobilized to check the loading and making alternate arrangement like mobile transformer installation or load shifting to other DT etc. to save the DT.

Apart from overloading, such solution are also being used now a days to monitor other transformer parameters like Oil Level and Lug Temperature etc. These solutions can trigger maintenance call to field crew if these parameters crosses the pre-defined threshold values.

Plinth mounted DT with auto cooling system

3.4 DISTRIBUTION TRANSFORMER MONITORING UNIT (DTMU)

Mainly voltage and current flowing through Distribution transformers can be monitored through DT meters, other critical parameters of distribution transformers like oil temperature, oil humidity, oil level etc. can be selected for online monitoring to avoid transformer failures and help take preventive actions to avert asset loss.

The Distribution Transformer Monitoring Unit (DTMU) is an intelligent device which monitors the identified parameters of the Distribution Transformers and communicate the same to the control center via some communication technology. The parameters like oil temperature, oil humidity, oil level etc. can be selected for online monitoring to avoid transformer failures and help take preventive actions to avert asset loss.

It will also help to take proactive actions to prevent such failures and issues. However, the add on module or unit should be easily mounted on a Distribution Transformer and it must aim at ensuring optimal/ least cost IT based solutions for new transformers and retrofitting in existing transformers. The followings points should be taken care for designing the features of DTMU:-

- The DTMU for the different categories of distribution transformers must be a simple, cost effective but robust device and should be able to monitor all parameters.
- The DTMU should be configurable for generating alarms based on pre-defined threshold values. The system shall either have an in built GPS/GPRS/IOT/RF modem or be made

compatible with existing meters to transmit these data to a Centralized Condition Monitoring Software. DTMU shall also have the capability to report any sudden loss of the sensors indicating a possible theft.

- DTMU may also have a built in module that can track the transformer, in case of theft. The unit should be designed to withstand ambient temperatures ranging from -10 degrees C up to 50 degrees Celsius.
- All the sensors (temperature measurement, level measurement etc.) should be robust pre-fabricated harnesses for easy installation and maintenance.

3.5 SMART SUBSTATION

The Smart Substation is an advanced version of the self-protected transformer. The internal protection devices in addition to the indicators and monitoring devices are installed at the sub-station for monitoring the internal condition / unmanned operation of the transformers / substation equipments. Smart Substations are need of the hour to increase reliability of supply and reduce losses in the system. Following are some of the important features of smart sub-station:-

1. Various sensors / devices are installed to monitor Voltage, Current, Load condition, power factor, Oil temperature of the transformer, temperature of the internal part, oil level indicator, humidity and operational condition of the protection devices etc.
2. DGA sensors and smart breathers are also installed for monitoring any incipient fault inside the transformers and moisture ingress.
3. Remote monitoring and operation by using GPRS/IOT / RF based system through standard protocol
4. Automatic Protection devices to protect the transformer from abnormal conditions like overload, over voltage, short circuit, internal short circuit, etc.
5. Energy metering system for Energy audit and automatic theft detection system.

3.6 RING MAIN UNIT (RMU's)

A ring main unit (RMU) is a metal enclosed set of switchgear used for providing ring-type distribution network system. It contains different types of configuration like 3 way, 4 ways etc. based on the requirement and field conditions to provide alternate feeds at various points of the network. RMUs may also be installed at distribution transformer level to provide alternate

path to the DT in case of power failure from main source. RMU is a completely sealed system with a stainless-steel tank, gas tight metal enclosure, containing all the live parts, load break switches, earth switch, the circuit breaker, busbar etc. inside the enclosure.

Type of RMUs

a) Based on location of application – Indoor, Outdoor
b) Based on number of ways – 3 W, 4 W, etc.
c) Based on automation – Manual, Motorised / FRTU

3.6.1 MAJOR MAINTENANCE ACTIVITIES FOR RMU

S.NO	BRIEF DESCRIPTION OFWORK	FREQUENCY
1	Check any damages are visible and rusting on RMU body.	HALF YEARLY
2	Physical damage to any parts and accessories of RMU.	HALF YEARLY
3	Accessories as per check list provided by manufacturer	HALF YEARLY
4	Inspection of SF6 gas pressure level in the RMU	YEARLY
5	Check operation of each isolator & circuit breaker for main switch on / off and earth switch on /off manually.	YEARLY
6	Check operation of all interlocks, e.g. front door should not open unless cable is earthed	YEARLY
7	Check healthiness of FPI in test mode for each isolator.	YEARLY
8	Cable & RMU Insulation Resistance Check by Megger	YEARLY
9	HI-POT test of RMU to ensure healthiness of interrupter unit	YEARLY
10	HI-POT test of RMU to ensure healthiness of bushings /insulators.	YEARLY
11	Working of VPIS (LEDs).	MONTHLY
12	Current transformer testing. a) Insulation resistance b) Polarity check c) Winding healthiness check –Lead resistance of current transformer d) Primary injection e) Insulation resistance test	As and when required as the status of CT may be monitored through remote monitoring
13	FPI Testing	YEARLY
14	Check operations of Isolator & breaker. a) Check control wiring connections. There should be	YEARLY

S.NO	BRIEF DESCRIPTION OFWORK	FREQUENCY
	no loose connection. b) Check electrical operations. c) Check the all mechanical interlocks with respect to doors. d) Relay setting should be checked.	
15	The cable should be tightened in cleat provided at lower side of the cable box in such a manner that there should be no stress on the cable itself & it should be held tightly.	YEARLY
16	a) Cable boots condition should be checked b) Cleaning the surfaces of the bushings. c) Cleaning the copper part of bushings. d) Clean the surfaces of the cable plugs.	YEARLY
17	Check the nomenclature/sign-writing on RMU.	YEARLY
18	Check the Plinth Condition of RMU	YEARLY
19	Earth switch contact resistance measured.	YEARLY
20	Check Partial Discharge Analyzer	YEARLY
21	Check connection of CBCT	YEARLY
22	Check sealing of all the holes / gaps.	YEARLY

3.7 FEEDER REMOTE TERMINAL UNIT (FRTU).

The Feeder Remote Terminal Unit (FRTU) is generally used for RMU automation. FRTU shall also be used for control of switching devices such as breaker; isolator switches etc. inside RMU panel from Master station(s). These FRTUs interfaced with the RMU's communication equipment. Usage of FRTU with proper control reduces the restoration time significantly. Self-healing for automatic restoration without human intervention may be implemented for decision making which will function independently with respect to communication with the SCADA head-end.

The FRTU panel also has Batteries, Modems/Routers and other accessories. FRTU generally have all accessories suitable for application for Distribution Automation system, and integration to SCADA Control Centre.

Major Maintenance Activities for FRTU.

S.NO	BRIEF DESCRIPTION OF WORK	FREQUENCY
1	a) Monitoring the FRTU-produced internal error messages b) Monitoring and checking the FRTU configuration and the status of all connected process signals c) Checking the current version of the configuration file d) Downloading or uploading the FRTU configuration file e) Checking and downloading revised software files for the FRTU CPU modules f) Uploading the archive files g) Communication of FRTU with master h) Lighting system of FRTU Control Panels. i) Communication of DI/DO. j) Door lock alarm integration with FRTU. k) Closing of unused TCP/IP ports and services	YEARLY
2	Battery and battery charger should capable for all FRTU required operation and Aux. supply to Modem & MFM and DC transducers etc.	YEARLY
3	Checking the protection of FRTU against reversed polarity, over current and under voltage conditions, to prevent the FRTU internal logic from being damaged.	YEARLY

S.NO	BRIEF DESCRIPTION OF WORK	FREQUENCY
4	Check the following a) MCB for each AC and DC supply. b) All intra panel wiring and cable to connect the Batteries. c) FRTU panel should be earthed to the existing system earthing d) FRTU Panel to RMU Panel wiring.	HALF YEARLY
5	Checking of FRTU panels, it shall be dust-proof with rodent protection.	HALF YEARLY
6	a) Checking the healthiness of DC Voltage to FRTU. b) Checking the healthiness of transducers for monitoring DC battery Voltage for RMU and FRTU Battery	YEARLY
7	Check the healthiness of FRTU Modem	YEARLY
8	Ensure the wiring shall be neatly secured in position and adequately supported	YEARLY
9	Check the Earthing of the frame of the system. Earth terminals should be connected to the earth bus.	YEARLY
10	Check the healthiness of Alarms in FRTU	YEARLY

3.8 LT AIR CIRCUIT BREAKER (LT ACBs)

Air Circuit Breaker (ACB) is an electrical device used to provide Overcurrent and short-circuit protection for electric circuits. These are usually used in low voltage applications. Air circuit operates in the air as an arc extinguishing medium, at a given atmospheric pressure. Their method of arc quenching control is entirely different from that of oil circuit-breakers. Air circuit breakers is durable, high-performing, easy to maintain and installed on LV Side of distribution transformer.

Air Circuit breakers generally have two pairs of contacts. The main pair of contacts (1) carries the current at normal load and these contacts are made of copper metal. The second pair (2) is the arcing contact and is made of carbon. When the circuit breaker is being opened, the main contacts open first. When the main contacts opened the arcing contacts are still in touch with each other as the current gets a parallel low resistive path through the arcing contact. During the opening of main contacts, there will not be any arcing in the main contact. The arcing is only initiated when finally the arcing contacts are separated and the arc is extinguished through a pre designed mechanism in ACB.

3.8.1 Major Maintenance Activities for ACB's

S.NO	BRIEF DESCRIPTION OF WORK	FREQUENCY
1	Visual Inspection a) Record operations counters b) Check circuit breaker panels and insulation material for cracks and cleanliness. c) Check the condition of enclosing cabinets including hinges, latches, locks, and door gaskets. d) Check for loose or broken frame ground connections. e) Check that all power and control circuit switches are closed and fuses are in place. f) Inspect wiring for damaged insulation. g) Checking and provide Missing ACB front cover h) Checking the usage of proper size Al Socket. i) Checking and providing Proper cleat & Clamp, if required. j) Checking Proper earthing of LT ACB Frame k) Checking the Crimping Work.	YEARLY
2	Preventive Maintenance a) Check the frame, panel, and cabinet condition of the paint and repaint as necessary. Tighten bolts to recommend specifications. Clean the exterior of the cabinet. b) Clean porcelain of bushings or insulators with water or a suitable cleaner. Repair chipped spots. Tighten bolts to recommended specifications. c) Perform bushing inspection for any carbon tracking, leaks, and cracks. d) Clean and repair chipped spots, remove and clean interphase barriers. e) Check main connections for loose or overheating terminals. f) Remove arc chutes so that the contacts can be inspected. Dress contacts, if rough, with a fine file. It is necessary to carefully remove only the projecting beads. Pits on a flat, smooth surface are not objectionable. g) Check contact springs for loss of temper, breaks, or rust deterioration. h) Check flexible shunts at contact hinges for overheating and fraying. Tighten connections to recommended specifications. i) Verify breaker fit and racking mechanism operation. j) Check operating rods, shafts, and bell cranks for loose locknuts, setscrews, keys, bearings, bent rods, or twisted shafts, etc. Clean moving parts of rust, dirt, and accumulated grease and oil. Wash	YEARLY

S.NO	BRIEF DESCRIPTION OF WORK	FREQUENCY
	out bearings, pivots, and gears with a suitable cleaner. Lubricate with new grease or oil with the type required by the application being used. In cold climates, it is important to use a lubricant that will not stiffen with cold. Wipe off excess lube. Enclosed dust-tight bearings should require less servicing. k) Observe the closing solenoid motor or spring during several closing operations to see that everything is in proper working order. Check the solenoid plunger for sticking in guides. l) Check close coil resistance with an ohmmeter and insulation resistance with an appropriate insulation tester. m) Observe the latch and trip mechanism during several tripping operations to see that everything is in working order. n) Check latch and trip assembly pins, bearings, and latches for wear, binding, and misalignment. o) Clean and lubricate latch and trip assembly. Check the latch carefully to see that it is not becoming worn so that it would unlatch from vibration or stick and fail to trip. Tighten bolts and screws to recommended specifications. p) Observe tripping operation during electrical operation. See that the full energy action of the plunger is obtained. Check the plunger for sticking-in guides. q) Inspect digital or electronic trip mechanisms for the power light and any possible error codes. r) Check the condition of auxiliary contacts and refinish them with a burnishing tool if burned or corroded. s) Check auxiliary contact springs, operating rods, and levers. Check the closing and opening position with respect to main contacts while the breaker is being slowly closed and opened manually. Certain auxiliary contacts used for special purposes may require adjustment for the closed position. t) See that the position indicator or semaphore is properly indicating the breaker position. Check operating rods or levers for loose parts.	
3	Manually operate the indoor and outdoor low voltage draw-out air circuit breaker, ‘CLOSE’ and ‘OPEN’ three times.	YEARLY
4	Complete timing tests for both indoor and outdoor circuit breakers. Test all trip functions available. This may include long-time pickup and delay, short-time pickup and delay instantaneous and ground-fault pickups.	YEARLY
5	Contact resistance test for both indoor and outdoor low-voltage draw-out air circuit breakers.	YEARLY

Chapter 4

O&M BENCHMARKING OF OVERHEAD LINES & CABLES

4.1 INTRODUCTION

The frequent failures of the overhead lines due to damage to the insulator, snapping of conductor, damages to electrical joints & earth joints etc which not only interrupts electricity supply but also results in revenue losses to the Discoms. Poor / inadequate maintenance of poles, span length, non-tension electrical joints, conductor spacing, line stay etc leads to the instability in the electrical and mechanical parameter of the line which reduce the life of the line.

4.1.1 Main Causes of Overhead Line faults

1. Flashed /Punctured or broken insulators
2. Damaged jumper/Conductor
3. Fault due to Tree Contact / foreign material fallen on lines line kites, flexes etc
4. Faults due to Birds
5. Fault due to Cracked Pole
6. Improper Earthing.
7. Improper clearances between phases and Phase & Neutral
8. Improper clearances with other HT/LT lines

4.1.2 Corrective & Preventive Action

1. Action for replacing Flashed /Punctured or broken insulators:
2. Action for Jumper Repairing
3. Action for Tree Pruning / Trimming and removal of foreign material
4. Action to reduce Faults due to Birds
5. Action to Replace Cracked Pole
6. Action for Proper Earthing.
7. Action for maintaining clearances within phases and Phase & neutral
8. Action for maintaining clearances with other HT/LT lines
9. Pole guard
10. Monitoring/Spreading awareness among people about the danger of flying kites near to power lines

4.2 NECESSARY CONDITIONS DURING O&M OF SUB-TRANSMISSION & DISTRIBUTION LINES

For maintaining the proper working of the line, the following Repair & maintenance practices may be adopted by the Discoms:

- The O&M personnel should ensure de-energization, isolation check with neon tester and properly grounding the network where the repair and maintenance activities are to be carried out.
- If there is any branch line within the working zone, it should be isolated and if there is any DT within the working zone, all DT's should OFF to avoid any back feeding from downstream.
- The Working personnel should ensure the availability of proper tools and accessories, safety apparels, spares and consumables required for carrying out the work.
- If double circuits exists on the same pole / tower then uses of RED and GREEN flags with respect to the charged and dead lines.
- Pole should be erected and maintained straight & stay set/wire should be fix at all pole where the line has deviated by more than 5° from End poles & Branch out/tee off pole etc. Suitable Muffing should be done on every pole as per the site condition. Higher strength poles may also be used where stay wire installation is not feasible due to various reasons like space constraint etc.
- Suitable conductor as per loading of the feeder should be thoroughly checked for any damage/cut mark before use.
- Earth connections should be properly tightened with all the metal part and guard wire. If any Joints have observed in the running portion of GI wire, should be remove. Earthing should be done on poles as per CEA regulations.
- Jumper should be same conductor and in case jumper length is more than 1 mt, then it should be supported by Insulator.
- Jumper may be sleeved with insulating material, if required, in the high bird flying areas to avoid the fault due to bird droppings.
- Anti-climbing devise & danger boards should be fixed properly on the Poles.
- Feeder identification may be done in case there is more than one circuit on the same pole. Identification tag should be fixed on poles.
- The poles should be check visually along with the condition of Pole base & alignment of pole. If the pole tilted, it should be straighten and if any bend occurred at the mid of the pole, it has to be changed & pole to be re-erected.
- The condition of Disc Insulator should be checked, if there is any crack / flash mark on the surface of the disc, disc should be changed. Similarly, during checking, if condition of strain clamp/pin insulator of disc insulator, any crack or flash mark on surface is noticed, it has to be change. The tightness of the fixing nuts may also be checked.

- All metal part should be painted by a suitable paint for increasing the durability of life span. Hot dipped galvanized /corrosion protective electroplated parts may also be used as per site requirement.
- In heavy wind areas, the metal parts of poles which are in close proximity of the jumpers, should be painted with insulating material to avert faults due to jumper swinging.
- On LT lines, suitable spacers should be provided in windy regions.
- Suitable properly grounded guarding wires shall be provided at road crossings.
- During visual inspection of bare conductor if any damage is noticed on the conductor, the damaged portion by same conductor should be replaced. If conductor is loose, the conductor to be re-sagged from section to section to maintain proper sagging. Intermediate poles, wherever necessary, may also be provided to avoid sagging.
- During visual inspection of Earthling, if any damaged is noticed on GI wire, it has to be erected with new complete earth electrode. If there is any binding joints observed at earth wire, the wire has to be changed.
- In the case of cable mounting on OH feeder, the cable should be mounted on pole structure through GI pipe/HDPE pipe and must be mounted with clamps of proper strength.
- Discoms should maintain the requisite maintenance & protective equipment like safety belt, hydraulic Bucket (Aerial Bucket) to avoid accidents required for maintenance of Lines.

4.2.1 NORMAL GROUND PATROLLING

It is a prevailing practice in discoms to plan and carry out pre-monsoon and post monsoon maintenance of Distribution network. As a practice, normally for an overhead network, HT lines should be attended twice in a year, i.e. before monsoon and after monsoon. The ground patrolling of lines should be conducted by line maintenance crew periodically. Periodicity will be decided on the basis of importance of the line, terrain condition, and proximity of the line to habitations, forests, gardens, water borne areas etc. and environmental impact on the line. However, pre-monsoon and post monsoon patrolling should be carried out necessarily.

During ground patrolling of the line, the patrolman should check for the following:-

- Location no; type of poles (PCC/Rail pole etc.), location address.
- Clearances of the line, both to ground and in air.
- Availability/ healthiness of all poles and their condition.

- Obstructions in the proximity of the line (within line corridor) like trees, branches, structures etc. location wise should be noted.
- Observing the condition of insulators, conductors, earth wire, jumpers, clamps, dampers, spacers etc., from ground level/nearest possible elevated level.
- Checking of Guarding system.
- Clearances on the Line crossings

4.2.2 SPECIAL PATROLLING OF THE LINES

A Special patrolling of the line should be done after any momentary / permanent tripping of the line on fault or for any defects. Defects noticed shall be rectified immediately if this can be attended while the line is live or at the earliest by availing shutdown. Proper planning of materials and manpower is required in order to carryout rectification under shutdown in minimum time to avoid/minimize interruption to the consumers.

4.2.3 BREAK DOWN MAINTENANCE

When a permanent/semi-permanent fault occurs on the line, the line may break down causing interruption of longer duration. The faults could be snapping of conductors, disconnection of jumpers, cross-arms/ pole twisting or pole collapse with or without damage to foundation. This may be due to various reasons like heavy wind due to storms, weakening of pole due to aging, accidents, thefts etc.

4.3 GENERAL MAINTENANCE ACTIVITIES OF OH LINES

- Check visually, the condition of Pole base & alignment of pole. If the pole tilted, should be straighten & rammed the pole base with brick bats after digging the earth around the pole base. If any bend occurred at the mid of the pole, has to be changed & pole to be erected as per drawing attached.
- Check visually the condition of existing stay
- Check the Condition & size of GI wire
- Check the Condition of Guy Insulator, if any damage or missing observed, should be fix/replaced.
- Check the conditions and earthing of Guarding wires.
- Check the Condition of tension screw, if any damage observed , it has to be changed otherwise to tighten the turn buckle ,if required
- Check the condition of anchor hook

- Check visually the Line Hardware
    - Condition of Disc Insulator, if there is any crack, flash mark on the surface of the disc,disc should to be changed.
    - Condition of strain clamp of disc insulator, If any crack or flash mark on surface, it hasto be change.
    - Condition of Pin insulator, if there be any flash mark on the insulator surface, it has tobe change otherwise check the tightness with the spindle.
    - Condition of Pin insulator spindle, if any damage or bend, to be change otherwise checkthe tightness of the fixing nuts
    - Condition of Top hamper; if any tilt observed at top hamper, it has to be straight or any damage occurred to the metal part, it is to be change, otherwise check the tightness of fixing nuts bolts
    - Condition of the V-arm. if any damage occurred on V-arm or on the fixing clamp, it is to be changed otherwise check the tightness of the fixing Nuts, bolts
    - Condition of channel-arm, if any damage occurred on channel-arm or on the fixing clamp, it is to be changed otherwise check the tightness of the fixing Nuts, bolts.
- Checking all metal parts on the pole of line for proper earthing.

4.3.1 VISUAL INSPECTION OF BARE CONDUCTOR

- If any damage occurred on the conductor, it is to be replaced by same conductor with sleeve joint.
- If there is any loose conductor, the conductor to be re-sagged from section to section.
- Also maintain the requisite spacing between the conductors.

4.3.2 INSPECTION OF ABC LINE

- Patrolling of AB cable feeder may be conducted to identify & removal of unauthorized tappings before starting of the work
- Check the earthing of Copper Screen of HT ABC along with messenger wire at starting & Endpoints to keep the conductive paths at zero potential/ Earth potential.
- Check the AB cable joints. AB cable should not be jointed temporarily. In case of emergency, proper joints must be made the next day. For jointing of Messenger wire, mid span joint sleeve should be used instead of binding wires.
- To ensure the availability of proper tools and accessories, safety apparels, spares and consumables required for carrying out the work.

- To ensure that AB cable should not be dragged on roads/ footpaths etc. It must be laid by use of rollers & pulleys. In case AB cable is laid through trees/ vegetation area, branches may be trimmed to avoid abrasion on AB cables.

4.4 MAJOR MAINTENANCE ACTIVITIES FOR 33 KV LINES

S. NO.	ITEM TO BE INSPECTED	BRIEF DESCRIPTION OF WORK	FREQUENCY
1	Poles- Steel/ Wood/ Cement	Damages/broken poles or for ground level erosion and corrosions where the pole is not capable of safely supporting its load.	Half yearly
2		Bowed or leaning poles due to improper guying or overloading.	Half yearly
3		Unauthorized attachments such as fencing, aerial wires etc.	Half yearly
4		Poles which are very much exposed to hitting /striking of animals and bumping and scrapping by vehicles.	Half yearly
5		If the pole Number plate is still distinct.	Half yearly
6		Check the condition of foundation and attend it, if necessary.	Half yearly
7		Examine if pole requires painting of in case of steel/wood poles.	Half yearly
8	Stays	Correct direction and proper angle of the stay.	Half yearly
9		Loose broken or any other damage done to stays.	Half yearly
10		Whether stay insulator is intact/whether stay is properly earthed.	Half yearly
11		If stay rods are corroded. Attend the same if required.	Half yearly
12	Cross arms and pole top steel works	If the cross-arms/clamps/knee has/have slipped.	Half yearly
13		Bending of cross arms due to uneven tension.	Half yearly
14		Excessive rusting of the cross arms bracings etc.	Half yearly
15		Cracked or splitting or the wooden cross-arms.	Half yearly
16		Loose or damaged bracings. Attend the same, if required.	Half yearly
17	Insulators	Broken or chipped porcelain flashover marks.	Half yearly
18		Tilted insulators	Half yearly
19		Excessive deposit of dust/salt/coal and other pollution clean the same.	Half yearly
20		Excessive rusting of fittings, replace the same, if required.	Half yearly

S. NO.	ITEM TO BE INSPECTED	BRIEF DESCRIPTION OF WORK	FREQUENCY
21	Conductor s and Earth wire	Examine, if securely tied to the insulator/pole/cross-arms	Half yearly
22		Proper sag, set right the same, if required.	Half yearly
23		Proximity of trees and other objects including building etc.	Half yearly
24		Sufficient clearance between conductors and earth wire and also from the ground	Half yearly
25		Sufficient clearance from other electric/telephone lines passing along below or above it.	Half yearly
26		Earth wire is properly supported	Half yearly
27		All the line guards are intact and installed where necessary	Half yearly
28		If joints in the jumpers and conductors appear all right	Half yearly
29		Broken conductors strands	Half yearly
30		Nicking near insulator neck/or near conductor clamps	Half yearly
31		Bindings wire has not become lose and open	Half yearly
32		Mid span joints have not cracked.	Half yearly
33		All joints and jumpers of aluminum conductors have proper clamps/jointing sleeves. Straight the same, if required.	Half yearly
34	Jumpers and other line accessories	Proper supporting and jointing two ends of the jumpers with suitable clamps.	Half yearly
35		Sufficient clearance between jumpers on the 3-phases	Half yearly
36		Sufficient clearance of jumpers from metal	Half yearly
37		Provision of proper insulation of jumpers	Half yearly
38		Signs of over-heating and burnings on jumpers and other fittings, Thermo scanning	Half yearly
39		Loose/defective clamps jointing sleeves, bolts and nuts, and other fittings.	Half yearly
40	Tree trimming and bird's nests etc.	Cut off the trees branches where necessary to maintain a minimum clearance of 1.8m on each side of the line	Half yearly
41		Remove all dead wood.	Half yearly
42		Remove all bird's nests. (once before the monsoons or earlier, if necessary)	Half yearly
43		Clean and examine insulators for cracks or flashover. Replace, where necessary.	Annually

S. NO.	ITEM TO BE INSPECTED	BRIEF DESCRIPTION OF WORK	FREQUENCY
44	Lightening arrestor	Perform impulse voltage spark over test and leakage current test to know the condition of the arrester; replace in case of unsatisfactory results.	Annually
45		Keep records of test results.	Annually
46		Check and tighten all line connection and earth leads	Annually
47	Earthing System	Replace all broken earth leads and tighten others. Measure earth resistance of various earths with earth. Tester. In case of low values, recondition them.	Annually

4.5 MAINTENANCE ACTIVITIES FOR 11 KV LINES

S. NO.	ITEM TO BE INSPECTED	BRIEF DESCRIPTION OF WORK	FREQUENCY
1	Poles (Steel, Wood Cement) Stays, Cross arms , Conductor, Insulator, Earthwire, Lightning arrestor, Earthing System	Same as recommended for 33KV lines above	Half yearly /Yearly
3	G.O. Switches/ DO Fuses	Evidence of over-heating burning, Corrosion / pitting on the switch contacts.	Half yearly
4		Broken or damaged insulators.	Half yearly
5		Proper and tight earth connections.	Half yearly
6		Fuse links for continuity, tightness of connections and correct rating.	Half yearly
7		Proper locking arrangement.	Half yearly
8		Proper alignment of switch contracts.	Half yearly
9		Proper and complete fitting of male contacts into the female ones.	Half yearly
10		Arcing horns are intact.	Half yearly
11	11 KV Cable and Cable boxes.	Check for the following:	
12		Proper supporting of the cable and the cable boxes.	Annually
13		Damaged insulators.	Annually
14		Tight and intact connections.	Annually
15		Proper earthing.	Annually

16		Overall condition of the cable and joint.	Annually
17	11 KV Cable and cable boxes	Clean and examine for damaged bushings	Annually
18		Check for compound level, if there is leakage.	Annually
19		Perform insulation resistance test, recondition or replace, where necessary.	Annually
20		Keep continuous records of insulation resistance.	Annually

4.6 GENERAL MAINTENANCE ACTIVITIES OF LT LINES

4.6.1 General Maintenance

- Check visually, the condition of Pole base & alignment of pole. If the pole is tilted, it should be straighten.
- Check the foundation of poles and do the cementing after digging the earth around the pole base.
- If any bend occurred at the mid of the pole, should be changed & new pole to be erected.
- Check visually the condition of existing stay and change if broken
- Check the Condition & size of GI wire.
- Check the Condition of Guy Insulator-if any damage observed or is missing, it should be fixed/replaced.
- Check the Condition of tension screw-if any damage observed, it has to be changed.Tighten the turn buckle, if required.
- Check the condition of anchor hook.
- Check visually the Line Hardware
  - ✓ Condition of Insulator-if there is any crack, flash mark on the surface of the insulator, it should be changed.
  - ✓ Condition of insulator spindle- if any damage or bend happened, it needs to be changed. Check the tightness of the fixing nuts.
  - ✓ Condition of the Double line X-arm. If any damage occurred on X-arm or on the fixing clamp, it has to be changed. Check the tightness of the fixing Nuts, bolts
- All metal parts to be painted for increasing the durability & life span of the same
- Visual inspection of bare conductor -if any damage occurred on the conductor, it to be replaced with the same conductor through sleeve joint & the nos. of joint is limited to maximum 2 per span
- Use of Line Spacer to avoid fall of snapped conductor to ground & also maintainingequal conductor spacing
- Visual inspection of Earthing should be carried out. If there is any joint

observed at earth wire, either the wire or the complete earth electrode has to be changed. Also, tighten all joints on earth set. Resistance value of earth shall be measured & it's value would be < 1 Ohm.

- Inspection of Joints – Jumpering should be done by same conductor & will be jointed by suitable C-wedge connector. Mid span joint has to be done by Suitable Sleeves.
- Cable mounting on OH feeder-The cable should be mounted on pole structure through pipes(GI/ DWC (Double Walled Corrugated)/ HDPE) and must be mounted with clamps/STP. Cable be taken upto top of line and jumper at cable end be through properly crimped lugs and fitted with C-wedge connector with line.
- During connection of service cable with the distribution box, the cable/conductor surface (after opening the insulation) should be cleaned properly and should apply anti corrosive grease before termination on distribution box.

6.4.2 MAINTENANCE ACTIVITIES FOR LT LINES

S.No.	ITEM TO BE INSPECTED	BRIEF DESCRIPTION OF WORK	FREQUENCY
1	Poles Stay Crossarm Conductor Insulator Connectors Cable Boxes etc.	Same as recommended for these items as above.	Annually
	LT Switch	**Check for the following:**	
2		If the switch with cover is intact.	Annually
3		If the cable/switch running hot.	Annually
4		Broken cut-outs.	Annually
5		Signs of over-heating/burning on contacts.	Annually
6		Proper size of fuse wire.	Annually
7		If the switch is properly earthed.	Annually
8		Safety from rain water etc.	Annually
9		Ensuring proper earthing of fuse boxes and LT neutral	Annually
10		Check lead on the LT circuit and replace the LT cable/LT switch by higher capacity one, where necessary.	Annually

S.No.	ITEM TO BE INSPECTED	BRIEF DESCRIPTION OF WORK	FREQUENCY
11		Replace the damaged LT Cable with new one of right capacity.	Annually
12		Examine the switch for smooth operation.	Annually
13		Replace the burnt/cracked cut-outs.	Annually
14		Recondition the switch contacts	Annually
15		Replace the old fuses with new ones of right capacity.	Annually
16		Tighten all connections.	Annually
17		Ensure that the inlet of the cable into the switch is plugged with plastic compound to avoid entry of rain water. Repair , where necessary.	Annually
18		Clean off the cob-web and other nests etc., from the inside of the switch.	Annually

4.7 UNDERGROUND CABLES

The code of practice for maintenance of underground cables shall be as specified in IS-1255 should be followed. However, the relevant texts from IS-1255 is reproduced here.

4.7.1 MAINTENANCE OF CABLE INSTALLATION

1.0 General - The maintenance of cable installation includes inspection, routine checking of current loading, maintenance and care of all cables and end terminations.

2.0 Inspection

2.1 Whenever the cables or joints are accessible as in manholes, ducts, distribution pillars, etc, periodical inspection should be made so that timely repairs can be made before the cables or joints actually cause interruption to service. The frequency of inspection should be determined by each electric supply undertaking from its own experience. Important heavily loaded lines will require more frequent attention than less important lines.

2.2 Cables laid direct in the ground are not accessible for routine inspection, but such cables are often exposed when the ground is excavated by other public utilities for installing or repairing their own properties. Preventive maintenance in the form of regular inspection of all digging operations by other utilities or persons, carried out in areas where electric cables exist is of utmost importance.

2.3 In a city where the roads are congested with services of other utilities, the likelihood of damage to electric cables is very high. The maintenance team shall patrol the various sections of the city and where it is found that cables are exposed, these should be examined thoroughly for any signs of damage: such as deformation or dents in the cable or damage to earthenware troughs or ducts.

12.0 Checking of Current Loading

3.1 The life of paper-insulated cables is considerably reduced through overloading. It is, therefore, essential to check the loads as frequently as possible to ensure that the cables are not loaded beyond the safe current-carrying capacities. The derating factors due to grouping of several cables, higher ambient ground temperature and higher thermal resistivity of soil, should not be neglected.

3.2 In the case of HV feeder cables emanating from sub-station, panel-mounted ammeters which are usually provided, should be read daily. In the case of medium voltage distribution cables emanating from distribution pillars, the loads are conveniently checked by 'clip-on" type portable ammeters. Distributor loads should be checked at intervals not exceeding three months.

4.0 Maintenance of Cables - Repairs of cables generally involve replacement of a section of the defective cable by a length of new cable and insertion of two straight joints. All repairs and new joints in connection with repairs should be made in the same manner as joints on new cables.

4.7.2 QUALITY OF MAINTENANCE & CROSS CHECKING

1. In order to improve the quality of maintenance, cross checking of maintenance activities should be done. Where maintenance work is done departmentally, at least 5 % of work may be cross checked by Division office and 2 % of maintenance work may be cross checked by Circle office. However, in cases where maintenance work is outsourced, the cross checking should be done before passing of bills of Contractor.

2. Rigorous monitoring as well as measures such as evaluation of feeder wise SAIFI and SAIDI must be worked out and discussed during the line staff meeting and feeder having lowest SAIFI/SAIDI and feeder with highest improvement in SAIFI/SAID during the

month may be appreciated in the meeting as well as should be put on Notice Board, declaring "Best feeder of the Month". Such activities encourages the good work and will motivate the staff.

3. In case of mesh network in urban areas, all the input points of DT should be considered as feeders and DT wise losses should be reported and discussed during monthly meetings.

4.8 LIVE WIRE / HOT LINE MAINTENANCE OF DISTRIBUTION LINES

By overseeing the major expansion of the distribution system and with growing expectations of consumer to get 24x7 uninterrupted power supply, every utility is looking forward to adopt the modern techniques of maintaining the sub transmission & distribution system to put at par with the global trend of maintenance techniques. Live-line / hotline maintenance involves maintenance, repair or replacement activity carried out on a live and operational line or switchyard apparatus using approved techniques and equipment. It is now a days one of the method of maintenance to ensure system integrity & system reliability to supply 24x7 power without any interruption. The adoption of live-line working technology will definitely reduce interruptions and increase the availability of the T&D system which is vital to generate more revenue. In the live-line / hotline maintenance, the maintenance of electrical line/equipment is taken up while the line/equipment is energized.

4.8.1 MAJOR BENEFITS OF LIVE-LINE WORKING:

- Substantial reduction in scheduled outages and reduction in interruptions/breakdowns
- Greater flexibility of maintenance management
- Uninterrupted and timely maintenance
- Increasing the reliability & efficiency of the system
- Timely attention to the routine maintenance curtailing huge breakdown expenses
- Optimize the generation facility
- Enhances the revenue of the utility
- More consumer satisfaction through maintaining continuity of service to customers
- Reduce planned outage maintenance

4.8.2 LIVE-LINE WORKING IN INDIA

Historically, live-line technologies in India are being taken up for transmission system of 220

KV and above, however, with the more awareness of consumers to get 24x7 uninterrupted power supply , the hot line maintenance is also being adopted at distribution level also. Although visual inspection of transmission and distribution lines provides flashover or broken insulators' data, the internal puncture phenomenon could not be recognised by such conventional methodology. A microprocessor-based Puncture Insulator Detector (PID) identifies all such invisible problems with computerised graphical output for every type of insulators such as porcelain, glass or polymer. This PID equipment is useful for different types of lines and switchyards. There are other live-line condition monitoring techniques available such as fault passage indicators for distribution lines and inspection of energised electrical joints and line conductors, etc.

In distribution sector , the distribution utility generally carry out tree trimming and breakdown maintenance activities. Hence, in case breakdown maintenance is converted to preventive maintenance, then live-line working will play a very important role . With the help of aerial work platform and rubber glove technique, all the uninterrupted maintenance activities on distribution lines like change of pin or disc insulators, hotspot rectification, conductor or jumper repairs, and tree trimming up to the extreme pole replacement in energised conditions can be taken up through hot line maintenance techniques.

4.8.3 LIVE-LINE WORKING METHODS

Hot-stick or distance technique consists of an insulated glass stick to protect the line worker from a grounded source while working on live lines. Generally, this technique is suitable and widely adopted up to 220 kV potential. Bare-hand technique permits linemen to be in direct contact with potential, being insulated from the grounded object. This live-line methodology is used above 132 kV level and up to 800 kV. Rubber glove or contact method is a technique in which the person is fully insulated from the ground through an insulated elevated platform and performs live-line work using approved insulating gloves and sleeves. This technique is useful only for distribution networks up to 33 kV.

Entire routine maintenance activities such as insulator replacement, on-load tightening of clamps and connectors, strengthening of dead-end joints, replacement of jumpers and mid-span joints, line conductor repairs, insulator hardware maintenance or replacement are possible by suitable hot-stick or bare-hand technique with appropriate live-line tools and equipment in live wire maintenance technique. To maximise the output of a live-line crew

working on lines, systematic application of vehicle mounted insulated aerial work platform is also being used as it will directly launch linemen on energised conductors and thus prevent the unnecessary task of climbing towers by linemen. Specially designed conductor trolleys for bare-hand technique are also helpful for linemen to work on energised conductors with increased safety and efficiency. With an advanced set-up of multiple scaffolding systems, live-line crews able to replace isolator switches and bus bar tubes in switchyards. Replacement of lightening arrester are now possible with the introduction of on-load temporary bypass switch.
In general, there are following methods are being used for safe live-line working :

- **Hot stick or Live Line Tool**

Hot sticks are used in live line work by having the worker remain at a specified distance from the live parts and carry out the work by means of an insulating stick. Tools can be attached to the stick, allowing work to be performed with the worker himself safely away from the live conductors.

- **Insulating Gloves or Rubber Gloves**

A live line worker is electrically protected by insulating gloves and other insulating equipment, and carries out the work in direct mechanical contact with live parts.

- **Barehand or Potential**

The barehanded approach has a live line worker performing the work in direct electric contact with live parts. Before contact, the worker's body is raised to the same electric potential as the live parts, and then held there by electric connection, while maintaining suitable isolation from the surroundings which are at different potentials, like the ground, other people or trees. Because the worker and the work are at the same potential, no current flows through the worker.

- **Unearthed or De-energised**

Some organizations additionally consider working on unearthed de-energised equipment to be another form of live-line working. This is because the line might become inadvertently charged (e.g. through a back-charged transformer, possibly as a result of an improperly connected, inadequately isolated emergency generator at a customer facility), or inductively coupled from an adjacent in-service line. To prevent this, the line is first grounded via a clamp known as a

bond or drain earth. Once this is in place, further work is not considered to be live-line working.

8.7.4 MAJOR HOTLINE MAINTENANCE WORKS IN DISTRIBUTION LINES AND SUBSTATIONS:

Some of the hotline maintenance operations that can be carried out for distribution system are as follows:

- Tightening/ replacement of clamps and connectors
- Replacement of defective pin and disc insulators
- Full load repairs of conductors and mid-span joints
- Maintenance /replacement of cross-arms , insulators and insulator supports
- Replacement, repairs and strengthening of jumpers
- Live line cleaning of pin and disc types insulators
- Un-interrupted tree trimming
- Changing of hardware components, spacers and dampers;
- Application of repair sleeves; maintenance and replacement of mid- span joints
- Replacement/Repair of damaged sections of the conductor
- Changing of poles
- Live-line washing
- Jumper online tightening and nut-bolt changing.
- Rectification on the switchyard bus, extension of main bus, connection of new bays and feeder, nut-bolt changing, isolator maintenance and replacement etc.

By following safe work procedures defined in various manuals, regulations and standards and use of pre-service equipment like hot-stick, rope and conductive suit tester, proper cleaning and conditioning of live-line tools and equipment and in-service leakage current monitors, etc., safety during live-line working should be fully achieved. Alternatively, risk of back feeding or accidently charged circuits, particularly in case of distribution systems, may be eliminated while performing live-line working.

4.8.5 DRONE BASED INSPECTION OF LINES

With advancement and acceptability of Drones, the inspection of critical lines / towers and other electrical equipment can be done through Drones. Drone Inspection based predictive maintenance analysis visualized through AI/ ML based platform are useful for Utility. Drones can also be utilized for asset mapping and fault detection of Distribution system and also to better track their maintenance activity. Drones can also be useful for accurate assessment of vegetation and encroachment along the route of the lines so as to take necessary actions accordingly.

Chapter 5

ASSET MANAGEMENT & INVENTORY MANAGEMENT

5.1 ASSET MANAGEMENT

Asset Management is an important activity in power distribution system planning, operation and maintenance. The network infrastructure comprising the distribution chain from the substation to the consumer premises has to reflect current best practices to meet the stress of fluctuating electricity demands. To this end, DISCOMs need to introduce asset data analytics as part of their strategy for predicting and analyzing faults, reducing downtime and rapid system restoration.

Asset data analytics uses risk-based analysis to manage performance, predict failures and control costs. It benchmarks asset performance and predicts how it is going to perform in the future. Apart from an analysis of the financial aspects of network asset performance, such as cost of downtime; there are technical, regulatory and socio-environmental aspects also such as power quality, reliability and carbon footprint. Asset wise data base for all the data required for data analytics should be available with DISCOMs in standard formats.

Innovations in Power Distribution automation and smart grid have resulted in the growth of intelligent devices communicating with the electrical network assets in real time and collecting vast amount of network data in the process. This data after analysis provide vital clues on the health of the electrical assets and operating conditions. A robust asset management helps plan power distribution network for profitable and sustainable operations. Efficient asset management maximizes asset value over its entire life cycle, maximizes ROI and optimizes network operations.

Accurate, timely and reliable asset information results in better decisions, leading to balancing cost, performance and risks associated with power distribution operations. Advanced asset analytics promises network efficiency improvement, asset optimization, loss minimization and carbon footprint reduction.

Substation asset analytics uses information collected from sensors/transformer monitoring

unit installed on Distribution Transformers and Fault passage current sensors installed on 11 KV feeders, in real time, and monitors any sign of overloading, short circuit or earth fault to ascertain possible fault conditions and location of impending fault. Early detection of an emerging fault provides operators with a better understanding of the vulnerable sections of the network and help them take preventive measures before major fault could occur.

By effective condition monitoring of distribution systems, the number and duration of the outages can be reduced drastically, thus saving the cost of maintenance and system restoration. This enables DISCOM improve network reliability, operate the network within acceptable limits and more consumer satisfaction.

Advanced asset analytics and preventive maintenance are being increasingly adopted by Distribution utilities across the globe for remote monitoring and real-time visualization of vital network assets of DISCOMs to manage their assets more productively, improving cost efficiency in network operations, increasing life expectancy of network assets and improving overall efficiency. All discoms should prepare a program for Health Monitoring of the critical components of their system and prepare a comprehensive annual program for preventive maintenance. Such program should be based on the data analysis to increase the reliability and quality of the power supply to the consumers.

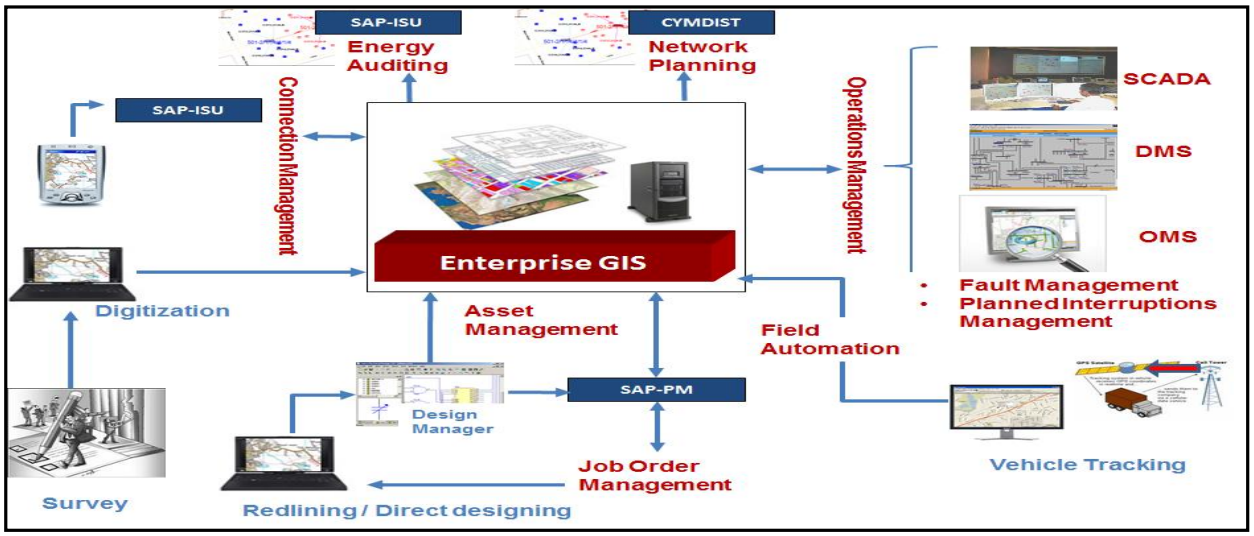
5.1.1 GEOGRAPHICAL INFORMATION SYSTEM (GIS- CONSUMER INDEXING & ASSET MAPPING)

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

- Geo coordinates controlled Asset record management.
- Network topology for operation service management.
- Consumer’s location and indexing with network and asset for service delivery.
- Field Crew movement and tracking for ease of services to the customers.

- Geo-fencing of the consumers for both commercial and maintenance operations, alongside vigilance activities
- Commercial operations and O&M staff tagged to the assets and consumers with each geo-location

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



5.2 INVENTORY MANAGEMENT

The goal of inventory management is to have the right products in the right place at the right time. This requires inventory visibility — knowing when to order, how much to order and where to store stock. It is the process of tracking and controlling assets, from acquisition to disposal. By using inventory management, utilities can have complete transparency into their inventory data, such as the quantity available, cost, and relevant supplier information, as well as knowing exactly what each asset is for and why it's been acquired. There should be well defined and documented processes related to all inventory operations viz., receiving, issuing, storage, verifications, meter management at meter stores, material scrapping etc.

Various Types of inventory management that can be followed by distribution utilities for better O&M are as follows:

Periodic inventory management: The periodic inventory system is a method of inventory valuation for financial reporting purposes in which a physical count of the inventory is performed at specific intervals. This accounting method takes inventory at the beginning of a period, adds new inventory purchases during the period and deducts issued / consumed / scrapped inventory.

Barcode inventory management: DISCOMs use barcode inventory management systems to assign a number to each product. They can associate several data points to the number, including the supplier, product dimensions, weight, and even variable data, such as how many are in stock.

RFID inventory management: RFID or radio frequency identification is a system that wirelessly transmits the identity of a product in the form of a unique serial number to track items and provide detailed product information. The warehouse management system based on RFID can improve efficiency, increase inventory visibility and ensure the rapid self-recording of receiving and delivery. In the RFID system, each equipment is tagged with unique ID and that ID should be part of Asset Change Management process and can be added in GIS for tacking of Equipment movement.

ABC Analysis - ABC analysis stands for Always Better Control Analysis. It is an inventory management technique where inventory items are classified into three categories: A, B, and C. The items in the A category of inventory are closely controlled as it consists of high-priced inventory, which may be less in number but are very expensive like Transformers, Cables, Panels, RMUs etc. The items in the B category are relatively less expensive than in the A category, and the number of items in the B category is moderate such as Joint, so the control level is also moderate. The C category consists of a high number of inventory items that require lesser investments, so the control level is minimum.

XYZ Analysis - XYZ analysis is a way to classify inventory items according to the variability of their demand or derived/forecasted consumption. XYZ analysis can be used to plan material requirements and inventory levels so that waste, production delays, or excessive inventory levels can be avoided.

- 1. X-goods - very low fluctuations: X-items are characterized by consistent sales over time. Future demand can be reliably forecast.
- 2. Y-goods - some fluctuations: Although demand for Y-items is not constant, the variability of demand can be predicted to some degree. This is usually because fluctuations in demand are caused by known factors, such as seasonality, product

life cycles, competitor actions, or economic factors. It is more difficult to accurately forecast demand.

- 3. Z-goods - the greatest variation: demand for Z-items can fluctuate widely or occur sporadically. There is no trend or predictable causal factors, making reliable demand forecasting impossible.

Economic Order Quantity (EOQ) method - Economic Order Quantity technique focuses on making a decision regarding how much quantity of inventory the company should order at any point in time and when they should place the order.

Minimum Safety Stocks method - The minimum safety stock is the inventory level that an organization maintains to avoid a stock-out situation. It is the level when we place the new order before the existing inventory is over.

Fast, Slow & Non-moving (FSN) method - FSN method of inventory control is very useful for controlling obsolescence. All the inventory items are not used in the same order; some are required frequently, while some are not required at all. So this method classifies inventory into three categories, fast-moving inventory, slow-moving inventory, and non-moving inventory. The order for new inventory takes place on the basis of the utilization of inventory. Control on non-moving inventory/slow moving/obsolete/damaged inventory is one of the focus area of inventory management. Periodic identification of slow moving and non-moving inventory and their review for utilization or disposal will control obsolescence and bring in efficiency.

First In, First Out (FIFO) - First in, first out (FIFO) is an inventory method that assumes the first goods purchased are the first goods sold. This means that older inventory will get shipped out before newer inventory and the prices or values of each piece of inventory represents the most accurate estimation. FIFO serves as both an accurate and easy way of calculating ending inventory value as well as a proper way to manage your inventory to save money and benefit your customers

5.3 ENTERPRISE RESOURCE PLANNING (ERP)

The profitability of the distribution sector is directly governed by the ‘meter-to-cash’ cycle and the total energy accounting process. Utilities require an ERP system to address the challenges that they face today. It includes the integration of connection services, revenue management and customer relationship management to streamline the entire process

chain. They require tools to identify operational bottlenecks, improve efficiency, enhance customer satisfaction and facilitate accurate energy audit. ERP solutions includes the Maintenance Management across network layers of Utility. It also enables focused maintenance practices mainly based on the condition monitoring of the assets. ERP is an asset for enabling the organization to run business smoother by unifying and protecting the information, automating processes and producing easy-to-understand trends. Below mentioned are some of the key benefits of ERP System:

1. **Efficiency:** An ERP System eliminates repetitive processes and greatly reduces the need to manually enter information. ERP system also streamline business processes and make it easier and more efficient.
2. **Forecasting:** Since the information within ERP is as accurate as possible, businesses can make realistic estimates and more effective forecasts. This will improve decision making through use of information and business analytics.
3. **Collaboration:** ERP software touches on almost every aspect of a business, thus naturally encouraging collaborative amongst different departments and employees.

4. **Scalability & Integrated Information:** To meet additional business requirements over a period, ERP system allows addition of new users and functions to grow from the initially implemented solution. Also, it brings an integrated platform with data consistency, accuracy, an ease of access for information in one place by stable, secure and integrated system for functions like Financials, Budgeting, HR & Payroll.
5. **Streamlined Processes & Cost Savings:** ERP increases efficiency and productivity by helping users to navigate through the complex processes, preventing data re-entry, and improving functions such as production, order completion and delivery. Also, it helps in achieving the better financial management and faster financial reconciliation for organization.

6. **Mobility:** An advantage of ERP System is having access to a centralized database from anywhere you work like Home, office etc.
7. **Reporting:** ERP software helps make reporting easier and more customizable with improved reporting capabilities.
8. **Enhanced Productivity:** Through streamlining of redundant processes by automation, optimum utilization of resources can be achieved thereby facilitating productive deployment of human resources allowing them to work on other projects and tasks.
9. **Regulatory Compliance:** Powerful ERP Systems will keep track of regulations within

the industry and monitor changes, which helps the organization to address governance and compliance requirements and reporting requirements.

10. **Enterprise Integration:** ERP enables integration of different functional & geographically dispersed regional offices/sub-stations through cross-functional, process-oriented and virtually integrated enterprise.
11. **Establishing Standard Business Processes and Practices:** ERP system plays a major role in establishing standard processes and practices within an organization. ERP System implementation and use will be an opportunity to improve business processes and adopt best business practices to derive maximum benefits out of it.
12. **Monitoring of Assets & Projects:** Efficient asset management of transmission network by effective monitoring, managing and maintenance of deployed assets. It also supports the organization through effective and integrated management for on-going projects.

Chapter 6

SAFETY MANAGEMENT

A Safety Management System provides organizations with a framework to improve employee safety and health, reduce workplace risks and create better, safer working conditions. The development and implementation of a comprehensive Safety Management System will support continual improvement and enables an organisation to develop and maintain a strong safety culture.

The formal and organization-wide approach to managing safety risk and guaranteeing the efficacy of safety risk controls is known as a safety management system (SMS). It consists of processes, practices, and policies for managing safety risks. In system safety and safety management, SMS presents an evolving process. It is a systematic procedure requiring DISCOMs to treat safety with the same importance as other fundamental business activities.

In this regard, ISO 45001:2018 is a standard that provides requirements for an occupational health and safety management system (OHSMS). This standard can be applied by distribution companies (DISCOMs) to improve their safety management practices. Some of the key requirements of ISO 45001:2018 are as given:

a) Hazard identification: DISCOMs must identify and assess the hazards that exist in their operations, including those associated with the distribution of electricity.

b) Risk assessment: DISCOMs must assess the risks associated with the identified hazards and develop appropriate controls to mitigate those risks.

c) Legal compliance: DISCOMs must comply with all applicable legal and regulatory requirements related to occupational health and safety.

d) Objectives and targets: DISCOMs must establish and monitor objectives and targets for improving their occupational health and safety performance.

e) Employee participation: DISCOMs must ensure that employees are involved in the development, implementation, and review of the OHSMS.

f) Training and competence: DISCOMs must ensure that employees are adequately trained and competent to carry out their work safely.

It is important to create system of safety competency mapping by DISCOMs to include class / field trainings and written/verbal competency tests with issuance of competency

certificates (for critical operations) for all resources (including vendor resources). The resources engaged in operations of distribution system have valid safety competency certificates.

g) Emergency preparedness and response: DISCOMs must have procedures in place to respond to emergencies and to minimize the impact of any incidents that may occur.

h) By implementing an OHSMS based on ISO 45001:2018, DISCOMs can demonstrate their commitment to safety management and ensure the health and safety of their employees and other stakeholders. This can also help to improve the overall performance and reputation of the DISCOM.

Further, Central Electricity Authority through various regulations viz. Central Electricity Authority (Technical Standards for Construction of Electrical Plants and Electric Lines) Regulations, 2022; Central Electricity Authority (Measures relating to Safety and Electric Supply) Regulations, 2010; Central Electricity Authority (Safety Requirements for Construction of Electric Plants and Electric Lines) Regulations, 2011 as amended from time to time, ensures the safety of electrical power system at all the times. Few of the CEA regulations provisions in this regard are enumerated below:

(1) The distribution utility shall make safety an integral part of work processes to ensure safety for employees including employees of contractor, sub-contractor as well as visitors.

(2) The distribution utility shall obtain accreditation of electric plants/ electric sub-stations with IS-18001 certification

(3) The distribution utility shall set up a sound and scientific safety management system which shall include -

(a) formulation of a written statement of policy in respect of safety and health of employees duly signed by owner, shall be displayed at the conspicuous places at the premises;

(b) defining and documenting responsibilities for all levels of functionaries to carry out safety related activities including responsibilities of the contractors;

(c) preparing detailed safety manual complying with the statutory requirements;

(d) establishing procedures to identify hazards that could give rise to the potential of injury, health impairment or death and measures to control impact of such hazards & establishing Standard Operating Procedure to deal with hazardous events;

(e) providing adequate human, physical and financial resources to implement the safety management system;

(f) providing safe working environment and evolving framework for occupational safety and health;

(g) providing and maintaining medical facilities;

(h) providing adequate training to all employees to keep them aware of safety related issues;

(i) establishing system for accident reporting, analysis, investigation and implementation of recommendations;

j) establishing system for proper communication, documentation and record management either in certified soft copy or hard copy form in relation to occupational safety and health;

(k) formulating emergency management plan for quickly and effectively dealing with probable emergencies that may arise on site as well as off- site;

(l) establishing methodology for internal and external audit of safety management system as per relevant Indian Standard;

(m) establishing system for periodic monitoring and review of the safety system by the management;

(n) overseeing the safety performance of contractors.

4. Safety officer- The Distribution utility shall appoint one qualified safety officer where the number of employees, including contract workers, exceeds two hundred and where the number of employees is less than two hundred, a suitable officer shall be designated as safety officer. The safety officer shall develop and organise safety training programmes at regular intervals in order to impart proper safety training and shall also create safety awareness among the employees.

Electrical Safety officer – The Distribution utility shall designate an Electrical Safety Officer for ensuring observance of safety measures specified in CEA (Measures relating

to Safety and Electric Supply) Regulations, 2010 in their organization for construction, operation and maintenance of power stations, sub-stations, transmission and distribution lines. ESO shall meet the qualifying criteria as mentioned in the regulations.

5. **Safety provisions relating to contractor.** - (a)The Distribution utility shall incorporate the safety provisions in the contract document which are required to be complied by the contractor's employees during execution of the contract to facilitate safe working during execution of the work.

(b) The contractor shall observe the safety requirements as laid down in the contract and in case of sub-contract, it shall be the responsibility of the main contractor that all safety requirements are followed by the employees and staff of the sub- contractor.

(c) The contractor shall be responsible for non-compliance of the safety measures, implications, injuries, fatalities and compensation arising out of such situations or incidents.

(d) In case of any accident, the contractor shall immediately submit a state of the same to the Owner and the safety officer, containing the details of the accident, any injury or casualities, extent of property damage and remedial action taken to prevent recurrence.

6. Medical facilities - The distribution utility shall provide medical facilities,- (a) where number of employees, including contract workers, working at one premises are fifty or less,-

(i) the services of a medical officer on retainer-ship basis, in his clinic shall be arranged and the said medical officer shall carry out the pre-employment as well as periodical medical examination and render medical assistance during any emergency;

(ii) there shall be a minimum of five persons trained in first-aid procedures amongst whom at least one shall always be available during the working hours;

(iii) a fully equipped first-aid box shall be maintained;

(b) where number of employees, including contract workers, working at one premises are between fifty-one and two hundred, then the distribution utility shall arrange for,-

(i) an occupational health centre having the facilities for health examination, diagnosis, treatment and maintenance of health records;

(ii) a part-time medical officer as overall in-charge of the said centre who shall visit the premises at least twice a week and whose services shall be readily available during medical emergencies;

(iii) one qualified and trained dresser-cum-compounder on duty throughout the working hours;

(iv) a fully equipped first aid box in all the departments;

(c) where number of employees, including contract workers, working at one premises are more than two hundred, then the distribution utility shall arrange for,- (i) an occupational health centre having the facilities for health examination, diagnosis, treatment and maintenance of health records;

7. Safety training and awareness.- (a) Regular safety training programmes to be conducted for employees shall include the following:- (i) general safety awareness; (ii) first aid; (iii) emergency procedures including shock treatment; (iv) use of personal protective equipment; (v) safely precautions while handling electro-mechanical equipment; (vi) use of different types of firefighting equipment; (vii) response in the event of emergencies including fire, flood, landslide, earthquake etc.; (viii) site specific hazards and the precautions as· well as response in respect of the same; (ix) ten hours training per year to each employee;

(b) The distribution utility shall ensure that adequate safety training is provided by the contractor to his employees.

(c) Safety promotional activities shall be organized periodically to create awareness and enthusiasm among the employees which shall include organizing safety day, safety week, fire safety day, fire safety week, safety competitions, posters, slogans, safety calendars and displays depicting possible consequences of unsafe acts and conditions.

Thus, by implementing the aforesaid key components of safety management, electricity distribution utilities can create a culture of safety and minimize the risk of accidents and injuries for their workers, customers and the public.

8. Electrical Accident: If any accident occurs in connection with the generation, transmission, distribution, supply or use of electricity, notice of the occurrence of such accident shall be reported to the Electrical Inspector. The utility shall send to the inspector a telegraphic report within 24 hours of knowledge of the occurrence of the fatal

accident and a report in writing in Form A within 48 hours of the knowledge of occurrence of fatal and all other accidents. The Appropriate Government may, if it thinks fit, require any Electrical Inspector, or any other person appointed by it in this behalf, to inquire and report the cause of accidents.

Chapter 7

ROLE AND RESPONSIBILITIES OF FIELD O&M STAFF

The above relation indicates a tentative number of employees for each DISCOM as per the number of consumers. Further, it is also noted that almost every DISCOM have about 90% of the total employees in O&M. However, on review of the standard practices, Manpower and operation norms of various DISCOMs, it is noted an absence of a uniform standard framework in various DISCOMs. To cope up with the changing sector dynamics that focus on changing conventional-renewable mix, higher digital penetration and enhanced customer centricity, the human resource requirement has also seen changes in terms of skill and competency requirements. Manpower requirements in a Discom will vary a great extent on the maturity curve at which a Discom is operating because the business requirements and corresponding staffing needs will be different at different levels.

Further, manpower deployment mix also needs standardization. While many DISCOMs show significant reliance on in-house staff with high proportion of workforce on DISCOM payroll, other DISCOMs have a larger focus on outsourced manpower which ranges from outsourcing of complete function such as meter reading or billing to deploying full time outsourced staff against specific positions. In addition to this, the relatively less expertise of existing workforce of Discoms in newly emerging areas like Smart Grid, smart metering, RE-integration, EV charging infrastructure and related challenges, real time demand based supply, etc., also has to be taken into consideration.

While the objective is to standardize the recommendations to the maximum possible extent, it is also pertinent to appreciate the level of incongruity among DISCOMs based on a number of parameters such as consumer mix, geographical spread, terrain, network infrastructure size, available capital etc.

However, in the below section, an effort has been made to delineate the roles and responsibilities of various teams for field O&M works at different levels in the DISCOM:

7.1 ROLE AND RESPONSIBILITIES OF FIELD MAINTENANCE TEAM

1. Each team may carry out work of maintenance on a designated day of week. The priority may be given to the higher rating critical equipments such as transformers, critical lines

etc. The number of maintenance day can be increased keeping in view the work load and maintenance requirement.

2. The check list for maintenance of major equipments shall be duly filled and signed by the team. The checklist may be developed as per the frequency mentioned for various equipments in the document.

3. Team shall prepare a report of maintenance, done on each equipment, material utilized and note down any major defects, which is to be attended such as Oil leakage, Oil doping, HT, LT stud/bushing replacement, MCCB replacement in 5/10/16 kVA transformer, joints, etc. The report shall be submitted to JE/DE of the sub division, who in turn may review the works of the division on every week.

4. Whenever any equipment such as transformer fails, the concern team under whose jurisdiction such transformer is situated, shall visit the location and identify the cause of failure of transformer or any other equipment.

5. The team has to ensure that such incidences are not repeated in future.

7.2 DUTIES AND RESPONSIBILITIES OF A DISTRIBUTION LINEMAN FOR O&M OF LINES

1. To survey all lines and report to his superiors any damages /repairing required variation from the original estimates.

2. To restore power supply in an area as quickly as possible or make arrangements for alternate power supply till power is restored.

3. To maintain LT, HT (Low tension, High tension) lines and equipment under his charge as per the schedule fixed up, as well as continuity of supply.

4. To rectify the fault by following instructions from superiors for such rectification.

5. To maintain distribution transformers/substations in his area of jurisdiction covering oil testing, checking of condition of breather, GO Switch operation, HT Fuses and LT side

protection, earthing of transformer body, neutral, etc.

6. To attend breakdown of HT and LT Lines in a time bound manner as per performance standards set by the State Electricity Regulatory Commission.

7. To replace damaged transformers in a time bound manner as per performance standards set by the State Electricity Regulatory Commission.

8. To make proper gradation of fuse in services and all other places where fuses are used.

9. To maintain a record showing the allocation of work every day and also record the progress of work against the allocation.

10. To supervise work under contract and see that all maintenance work is carried out as per maintenance schedule and as per standards.

11. To follow the code of safety rules and encourage the staff working under him to do the same.

12. To ensure security of Tools and Plants and safety appliances supplied to him and keep them in working order.

7.3 ROLE AND RESPONSIBILITIES OF SDO/JE OF SUB DIVISION

1. It shall be the duty of the concern SDO to ensure that required tools and tackles are made available to the team whenever they are sent for maintenance.

2. SDO shall prepare a team wise material planning well in advance for two months and submit to Division.

3. SDO shall make one JE as Nodal Officer at sub division level for monitoring and reporting of major/critical maintenance activities. Such Nodal JE of Sub division shall keep team wise record of various maintenance activities.

4. Nodal JE in consultation with SDO shall ensure that required material are issued to each team before scheduled day of maintenance.

5. SDO shall monitor team wise activity on weekly basis and shall take remedial measures/corrective actions to ensure that various maintenance activities are executed as per planning. SDO may be empowered to increase number of maintenance manpower days keeping in view the requirement & workload.

6. Team wise performance review may be taken by SDO once in month during line staff meeting and responsibility shall be fixed where higher failure due to lack of maintenance is observed.

7. SDO will have to maintain the record of major maintenance activities for each team & review with team leaders.

7.4 ROLE AND RESPONSIBILITIES OF JE AT DIVISION LEVEL

1. JE of each division shall be the nodal officer for monitoring the various maintenance activities.
2. He shall obtain the details of material requirement well in advance before two months and arrange for required material in consultation with EE.

3. JE shall submit the report of major maintenance activities executed as per prescribed format to circle office.

4. To have strict check on quality of maintenance, JE shall go for crosschecking of maintenance activities based on the report submitted by the team. Any discrepancies observed has to be brought to the notice of the Division head.

5. JE shall also attend those locations where major defects are observed by the field maintenance team. Some of the major defects could be replacing HV/LV stud/Bushing, cable/conductor hanging in the air at the ground level.

7.5 ROLE AND RESPONSIBILITIES OF DIVISION (EE)

1. Division head shall be primarily responsible for overall monitoring & material management in consultation with Circle head.

2. Division head shall also ensure that required tools like handy crimping tool, Meggar, Clamp on meters, etc. are allotted to each team.

3. EE shall review the ensure activity on fortnightly basis and shall take required remedial measures to ensure that maintenance is done as per planning.

4. Division shall ensure that any defects requires major repair, renovation, equipment lived its useful life, etc. are reported promptly to Corporate Office.

7.6 ROLE AND RESPONSIBILITIES OF CIRCLE (SE)

1. Circle head to ensure that proper stock of materials required for maintenance such as cable, conductor, Fuses, Lugs, Tape rolls, Transformer Breather, etc. must be maintained at division store. Some of the items which may be procured at decentralized level/Division level, it is to be ensured during the review meetings that the same has been procured and kept in store well in advance.

2. For centralized items procurement such as Power Transformers, Distribution Transformers, Testing Kits, etc. a material requisition is to be sent before two months in advance so as to take timely actions for availability of material.

3. A subdivision wise review of the said activities shall be taken during the monthly SDO meeting by circle heads. Any lethargy, discrepancies observed during the cross checking has to be dealt strictly.

Chapter 8

GUIDING PRINCIPLES FOR OPERATIONS & MAINTENANCE (O&M) EXPENSES OF DISTRIBUTION LICENSEES

8.1 INTRODUCTION

Operations and Maintenance (O&M) expenses for electricity distribution system is an essential part of financial planning of distribution companies (DISCOMs). It involves estimating and allocating funds for all the O&M activities judiciously to deliver 24x7 reliable & quality power supply to all the consumers along with meeting the performance parameters notified by SERCs.

O&M expenses include the expenses for salaries and wages of personnel required to maintain the distribution network, repair and maintenance expenses for up keeping and repairing of equipment, such as transformers, lines, poles, and wires etc., contracted services, and other costs associated with operating and maintaining the distribution business and associated infrastructure including various statutory /office expenses and levies etc. The O&M expenses can be grouped in following categories:

i. Employee Expenses
ii. Repair and Maintenance (R&M) Expenses
iii. Administrative and General (A&G) Expenses

Many factors such as infrastructure of network including number of Sub-stations, Distribution Transformers (DTs), line length, number of consumers, energy handled by the utility, consumer type & density, physical area of service, network spread, ageing of the network, overloading of the network, level of automation, hilly/plain area, change in tax rates and statutory levies such as license fee, minimum wages, pay revisions etc. have an impact on O&M expenses of a utility.

Different Electricity Regulatory Commissions prescribed different methodologies for recovery of O&M expenses. These methodologies are mostly based on past expenses. This document examines such methodologies and recommend a norm based hybrid methodology linking their O&M expenses with assets of the distribution licensee, and thus ensure better service to consumers.

8.2 PIE OF O&M EXPENSE IN DISCOM'S EXPENDITURE BASKET

	Maharashtra SEDCL	Tata Power, Delhi	Assam PDCL
Employee Expenses	73.4	63.6	78.0
R&M Expenses	16.0	22.6	16.0
A&G Expenses	10.6	13.8	6.0

It may be seen from the above that employee expense is a major part of total O&M expenses approved by SERCs. It may also be seen that employee expenses as percentage of total O&M expenses is less in Private DISCOMs than in Government owned DISCOMs due to various reasons including outsourcing of services and adoption of IT, automation etc.

8.3. REGULATORY PRACTICE FOLLOWED BY DISCOMS FOR O&M EXPENSES

Under the Regulatory regime, the respective Electricity Regulators approve the O&M expenses requirements for the next year/years based on the pre-defined formula/past expenses as well as the true-up of the O&M expenses for the past years.

To estimate the budget for O&M expenses, the distribution utilities (DISCOMs) identify all the operational and maintenance activities necessary to upkeep the distribution network functioning effectively to provide 24x7 reliable power to all consumers including SOP (Standards of Performance) requirements as notified by the respective SERC. This includes identifying areas that require maintenance, upgrading, or replacement of equipment, as well as anticipating any unexpected repair or replacement costs that may arise.

After identification of the requisite activities, the associated costs for each activity may be estimated including cost of labor, materials, IT services and any other expenses required for each activity, as well as accounting for any contingencies or unexpected expenses etc. After estimating the costs for all of the activities, DISCOMs can include the same in the annual plan for approval of SERC/JERC. The approved budget may undergo certain changes due to change demand, weather conditions, or other factors that affect the distribution business.

8.4. METHODS ADOPTED BY SERCS FOR DETERMINING O&M EXPENSES

The practices adopted by some of the SERCs for approving the O&M expenses are detailed at **Annexure-I**. Generally, SERCs are considering following methods for approving O&M expenses in Annual Revenue Requirement (ARR) of DISCOMs:-

i. O&M Expenses based on Distribution Asset /No of consumers etc.

Under this method, the O&M expenses of a DISCOM are derived by some SERCs on the basis of actual O&M expenses for last three (3) years based on per Network component expenses (like No of Substations (SS), DTs, Line/cable length etc.) or O&M expenses for past years based on per consumer expenses. The average of such past O&M expenses are considered as O&M expenses for the middle year and then the middle year expenses are escalated with year on year basis with the escalation factor considering CPI and/or WPI of respective years in a defined ratio for subsequent years up to the considered year.

ii. O&M Expenses based on average of last 3/5 years True up values or last year True up value:

Under this method, the Operation and Maintenance expenses of a Discom are derived by some SERCs on the basis of the average of the Trued-Up values for the last Three/Five years or based on True up value of only last year. The average of 3/5 Year O&M expenses are considered as O&M expenses for the middle year and then the middle year expenses are escalated with year on year basis with the escalation factor considering CPI and WPI of respective years in a defined ratio (60:40 or 55:45 or 30:70 etc) for subsequent years up to the considered year otherwise the last year True up value is escalated with escalation factor as above.

The formulas used for computation of various components of O&M expenses are as under:

Sl No	Heads	Formula
1	Employee Expenses	Employee expense are generally computed as per the following formula: $EMP_n = EMP_{n-1} \times (1+ \text{CPI inflation}) +$ one time expenses like arrears, pay commission etc Where:

		EMP_n: Employee expense for the nth year; EMP_{n-1}: Employee expense for the (n-1)th year; CPI inflation is the average of Consumer Price Index (CPI) for immediately preceding three Financial Years.
2	Repair and Maintenance Expense	**Case 1**: Repairs and Maintenance expense are calculated as per the following formula: $R\&M_n = R\&M_{n-1} \times (1 + \text{WPI inflation})$ Where: $R\&M_n$: Repairs & Maintenance expense for the nth year; $R\&M_{n-1}$: Repairs & Maintenance expense for the (n-1)th year; WPI inflation is the average of Wholesale Price Index (WPI) for immediately preceding three Financial Years. **OR** **Case 2**: Some SERCs computes the R&M charges based on Gross Fixed Assets (GFA) as: $R\&M_n = k * GFA_{n-1} * (1 + EF)$ Where GFA_{n-1} is the Gross Fixed Assets of (n-1)the year k is the factor governing the relationship of R&M expenses and GFA available with the discom and it is defined by SERCs per unit of Gross Fixed Assets(GFA).

		EF is the escalation factor defined by SERCs linked to CPI & WPI.
3	Administrative and General (A&G) Expense	A&G expense are being computed as per the following formula : $A\&G_n = A\&G_{n-1}$ x (1+ WPI inflation) + additional implications like legal charges and Statutory levies etc Where: $A\&G_n$: A&G expense for the nth year; $A\&G_{n-1}$: A&G expense for the (n-1)th year; WPI inflation is the average of Wholesale Price Index (WPI) for immediately preceding three Financial Years.

8.5. OBSERVATIONS

O&M Expense is critical component of Tariff determination. Inadequate O&M Expense will have direct bearing on network maintenance as well as services to the consumers. It may be noted that the SERCs approve the O&M expenses based on a normative formulas and in many cases, employee cost make a major part of O&M Expenses approved by SERCs leaving less budget for Repair & Maintenance of infrastructure. While examining the norms followed by different DISCOMs for O&M expenses, following broad observations have been noted:-

i. Generally, the heads for employee expenses and A&G expenses often had overlaps and were treated for benchmarking in a similar fashion. The methodologies for computation of A&G expenses & Employee expenses are similar. However, as these norms are based on past performance and are escalated with inflation, these methodologies do not account for improvements in efficiency from baseline. R&M expense is a distinct head with separate treatment in regulatory approval processes from the non- R&M heads.

ii. % of Employee Cost within total O&M Expenses for Private DISCOMs is below the all India average and State DISCOMs. Accordingly, there is a need for adopting automation /outsourcing services in State DISCOMs, so as to reduce the employee cost upto a reasonable level and a major part of O&M expenses may be used in repair & maintenance of distribution infrastructure.

iii. Across the states, there is significant variation in cost and diversity in O&M requirements across the DISCOMs and even within the DISCOMs, there is variation in O&M expenses depending upon the area and consumer mix.

iv. There are non-uniform practices of accounting of different expenditure in different heads by different utilities like. For example, some DISCOMs have meter readers on role (Employee cost) while other discoms have meter reading as outsourced (A&G Expenses). This shows a major non uniform practice among various SERCs.

v. Presently, many capital intensive works (e.g. smart meter implementation) are carried out in DISCOMs in TOTEX mode, where an external agency make the capital investment and DISCOMs have to pay monthly charges for the capital investment. However, there is no norm/practice to consider such recurring TOTEX expenses under O&M expenses of DISCOM.

8.6. RECOMMENDATIONS

8.6.1 Standardization of list of expenses under different heads

As explained above, there is no uniformity across DISCOMs in booking of expenditure under different heads namely Employee Expenses, Repair & Maintenance Expenses and Administrative & General Expenses. Generally, difference in treatment of following expenses have been observed:-

- **Outsourced employees**: The expenses for outsourced employees are booked by various DISCOMs either under Employee expenses or under A&G expenses. Considering that expenses for outsourced employees are in nature of employee expenses, it is recommended that the expenses for outsourced employees should be booked under Employee Expenses.
- **Training & Development Expenses**: There is need for adequate funds for training and development activities of the employee at all level so as to meet the new challenges in the sector. The training and development expenses may be booked under employees expenses.

Accordingly, suggested list of expenditure under different heads of O&M expenses could be as under:-

Employee Expenses	Administrative and General (A&G) Expense	Repair and Maintenance Expense
1) Basic Salary 2) Expenditure towards Contract of Service (Outsourced Employees) 3) Dearness Allowances (DA) 4) House Rent Allowances (HRA) 5) Conveyance Allowances 6) Leave Travel Allowances 7) Earned Leave Encashment 8) Medical Reimbursement/Expenses/Employee insurance expenses 9) Overtime Payment 10) Bonus/Ex-gratia Payment 11) Staff Welfare Expenses 12) Training and development Expenses 13) Payment under Workmen's Compensation Act 14) Provident Fund Contribution 15) Pension Payments 16) Gratuity Payments 17) Employee related insurance expenses 18) Other Allowances & Payments	1) Building Rent Rates & Taxes 2) Insurance 3) Telephone & Postage, etc. 4) Legal Charges, License fees, Petition filing fees & Audit Fees 5) Professional, Consultancy, & Technical Fees 6) Fees and Subscription 7) Printing, Stationary & Advertisement Expenses 8) Conveyance & Travel 9) Electricity & Water Charges 10) Safety & Security Expenses 11) Vehicle Running & Hiring Expenses 12) Expenditure of meetings / conference 13) Commissioning and Collection Charges 14) Expenses for contract for Service 15) Other Administrative Expenses 16) Other Scheme Expenses 17) Expenses on Building/Civil works / Hydraulic works/ vehicles.	1) Plant & Machinery maintenance expenses 2) Lines & Cable Network maintenance

8.6.2 Expenses incurred by DISCOMs under TOTEX model: Nowadays, smart metering installation is under implementation under TOTEX mode. Further, IT and OT services are also being hosted on cloud instead of 'On premise Servers' with monthly service charges instead of CAPEX expenses. Other expenses related to customer care center, cloud storage, demand forecasting, GIS mapping, Network analysis, annual technical support for SAP/HANA/Oracle software license, station monitoring system, Annual technical supports of SAP software Licensees, Vehicle tracking Systems, Radio Frequency Data Concentrator Unit (RF DCU), etc may also be in the nature of TOTEX.

It is recommended that expenditure on TOTEX/OPEX scheme shall be treated as separate head under ARR calculation and shall be reimbursed as per actual expenditure after prudence checked by concerned regulatory commission. As TOTEX expenses include OPEX expenses also, it should be ensured that no part of expenses claimed under TOTEX are claimed under O&M expenses.

8.6.3 METHODOLOGY FOR DETEMINATION OF O&M EXPENSES

Based on present regulatory practice, it has generally been observed that regulators have linked employee expenses and administrative & general expenses with either number of consumer or quantum of distribution assets, while repair and maintenance expenses are linked to gross fixed assets (GFA) of DISCOMs.

Generally, SERCs have adopted an approach wherein DISCOM's performance is evaluated /trued ups every year against its own performance in the past, resulting into no incentive for DISCOMs to improve its performance. Therefore, there is need for introducing a normative based approach for determination of O&M expenses of DISCOM, so that past approved expenditure does not become the only yardstick for determination of O&M expenses.

After examination of different models followed by Regulations, following hybrid approach for determination of O&M expenses **is recommended:**

A. Step 1: Business as usual with adjustment for efficiency improvement

In this step, the O&M expenses for DISCOM shall be computed for three components i.e. i) Employee expenses, ii) Repairs and Maintenance (R&M) expenses; and iii) Administrative and Generation (A&G) expenses. Each component of O&M expenses shall be allowed based on past trends, and inflation index after adjustment for efficiency improvement as decided by the Regulator.

Each component of above O&M expenses of a DISCOM can be derived on the basis of actual O&M expenses for last three/five (3/5) years based on per Network component expenses (like No of SS, DTs, Line/cable length etc) subject

to adjustment for best O&M practices in other DISCOMs. The average of such O&M expenses can be considered as O&M expenses for the middle year and then the middle year expenses are escalated with year on year basis with the escalation factor considering CPI and WPI of respective years in a defined ratio for subsequent years up to the considered year to arrive at base year figures for the control period.

Thereafter, O&M expenses for each year of the Control Period shall be computed based on the formula shown below:

$O\&M_n = EMP_n + R\&M_n + A\&G_n$

Where,

- $O\&M_n$ – Operation and Maintenance expense for the n^{th} year;
- EMP_n – Employee Costs for the n^{th} year;
- $R\&M_n$ – Repair and Maintenance Costs for the n^{th} year;
- $A\&G_n$ – Administrative and General Costs for the n^{th} year;

The above components shall be computed in the manner specified below:

EMP_n =	EMP_{n-1} x Estimated Number of Consumers for nth year x (1+CPI Inflation%-**X1**)
$R\&M_n$ =	K x (GFA_n +GFA_{n-1})/2 x (1+WPI Inflation-**X2**) +
$A\&G_n$ =	($A\&G_{n-1}$) x Estimated Number of Consumer for nth year x (1+WPI Inflation –**X3**)

Note:

EMP_{n-1} – Employee Costs/consumer for the $(n-1)^{th}$ year;

"K" is a constant specified by the Commission in %. Value of K for each year of the control period shall be determined by the Commission in the MYT order based on distribution licensee's filing, benchmarking of repair and maintenance expenses,approved repair and maintenance expenses vis-à-vis GFA approved by the Commission in past, age of the assets and any other factor considered appropriate by the Commission; The floor limit of factor K shall be considered as 2% - 4%.

GFA_{n-1} - Gross Fixed Asset = Closing GFA of the distribution licensee for the $n-1^{th}$ year as per audited books of account.

GFA_n – Estimated Gross Fixed Asset for the distribution licensee for the nth year based on approved CAPEX plan.

$A\&G_{n-1}$ – Administrative and General Costs/Consumer for the $(n-1)^{th}$ year;

CPI Inflation – is the point to point change in the Consumer Price Index (CPI) for Industrial Workers (all India) as per Labour Bureau, Government of India; in case CPI Inflation is negative, the escalation/change shall be 0%;

WPI Inflation – is the point to point change in the Wholesale Price Index (WPI) as per the Office of Economic Advisor of Government of India

X1,X2,X3- efficiency factors to be specified by the Commission. The efficiency factors shall be considered as 1-2% by the Commission. Further, the efficiency factor shall be considered as 0% if the consumer growth is more than 2%.

B. Step 2: Computation of O&M expenses as percentage of GFA

In this step, computation of O&M expenses will be carried out as percentage of GFA of DISCOM.

State-wise Gross Fixed Asset, O&M expenses and O&M expenses as % of Gross Fixed Asset during 2021-22 and 2022-23 available are at **Annexure-II**. All India average of O&M expenses as % of Gross Fixed Asset during 2021-22 and 2022-23 are 16.09% and 17.21% respectively. From Statistical analysis, it has been found that O&M expenses as a percentage of GFA lies between 13%-19% with 95% statistical confidence level with median of 14.70%. However, for hilly States and UTs, O&M cost as percentage of GFA is slightly higher (more than 20%).

In this step, O&M costs will be calculated at 15% (median) of the GFA for normal States/UT and 21% of GFA for hilly states. GFA based O&M expenses will give more flexibility to distribution licensee to optimize their expenses based on requirement and will also shift the focus of DISCOMs to invest in their network, and thus serve the consumers in better way**.** However, the Regulator may decide any other percentage based on their analysis.

C. Step 3: Hybrid Model:

In this step, the O&M expenses obtained as per Step-1 (Business as Usual) and as per Step-2 (GFA mode) will be compared for determination of O&M expenses by the Regulator. If the O&M expenses under Step-1 is less than O&M expenses under Step-2, then O&M expenses under Step-2 will be considered for determination of

O&M expenses by the Regulator. In other cases, O&M expenses as per Step-1 will be considered for determination of O&M expenses by the Regulator.

This hybrid model will ensure that distribution licensee will get atleast certain % of GFA as O&M expenses. As GFA of a distribution licensee depends on network capacity, therefore distribution licensee will be encouraged to invest in network upgradation, which in turn will help in better network availability and power availability to consumers.

8.6.4 Sharing of gains and losses: It is recommended that any gain or loss on account of difference between actual O&M expenses and expenses approved by the regulator during truing up may be shared with the consumers In line with the provisions in the Electricity (Second Amendment) Rules, 2023,. Accordingly, it is recommended that two third of the gains shall be passed on to the consumers in tariff and rest shall be retained by the distribution licensee and two third of the losses shall be borne by the distribution licensee and rest shall be borne by the consumers.

8.6.5 Pass through of uncontrollable expenses: It is recommended that there shall be provision for pass through of uncontrollable expenses including change in tax rates/regimes, new statutory levy & legal expenses unless barred, which is beyond control of the Distribution Licensee, and including expected one-time expenses such as implication of pay commission, Interim Relief, emergency response to natural calamities etc.

8.6.6 For a new deemed distribution licensee commencing operations during a Control Period, the O&M expenses shall be approved based on the proposal of such deemed distribution licensee in its petition for tariff determination.

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Annexure-I

Details of O&M calculation practices being adopted by some of the SERCs

Sr. No.	State	O&M Components	Norms and methodology
1.	Andhra Pradesh & Telangana	Employee expenses and A&G expenses	➢ Norms are set for Expenses per sub-station, per distribution network line length, per DT, per consumer. ➢ Norms are escalated year to year basis to arrive at the norms for the next financial year. ➢ These norms are multiplied by the number of sub-stations, line length, number of DTs and number of consumers to arrive at the employee and A&G expenses.
		R&M expenses	➢ % age of Gross Fixed assets (K factor is chosen based on the past data, presently-2.05% in AP , 1.01% in TSSPDCL and 1.19% for TSNPDCL)
2.	Bihar	Employee expenses	Norms are set for number of employees per 1000 consumers, Number of employees per sub-station & annual expenses per employees. Employee expenses at base year (EMPb)= (Number of employees per consumer x annual expenses per employee) + (No of employee per sub-station x annual expenses per employee) EMPn = (EMPb * CPI inflation) + Provision Where: EMPn : Employee expense for the year n CPI inflation: is the average increase in the Consumer

			Price Index (CPI) for immediately preceding three years Provision: Provision for expenses beyond control of the Distribution Licensee and expected one-time expenses
		A&G expenses	Norms are set A&G expenses per 1000 consumers, A&G expenses per employee. A&G expenses at base year (A&Gb) = (Expense/Employee* No. of employees) + (Number of consumers*Expenses/consumer). A&Gn = (A&Gb * WPI inflation) + Provision A&Gn: A&G expense for the year n WPI inflation: is the average increase in the Wholesale Price Index (WPI) for immediately preceding three years Provision: Cost for initiatives or other one-time expenses as proposed by the Distribution Licensee and validated by the Commission
		R&M expenses	➢ % age of Gross Fixed Assets based on the past data (presently 1.24% for NBPDCL and 1.71% for SBPDCL)
3.	Kerela	Employee expenses and A&G expenses	➢ Year wise norms specified for Expenses per consumer, Expenses per DT, Expenses per Length of HT line, Expenses per Length of LT line, Expenses per unit of sale ➢ The O&M expenses (Employee expenses and Administration &

			General expenses) for any year of the Control Period shall be allowed by multiplying the norms for that year with the actual number of consumers, distribution transformers, km of HT line and sales for the previous year
		R&M expenses	➢ % age of Opening Gross Fixed Assets. (presently 3%) ➢ Repair and Maintenance expenses for assets added during the year of the control period shall be allowed after prudence check by the Commission on a pro-rata basis
4.	Haryana	Employee expenses and A&G expenses	➢ EMPn (excluding terminal liabilities) + A&Gn = (EMPn-1+ A&Gn-1)*(INDXn/ INDXn-1) Where, INDXn – Inflation Factor to be used for indexing the Employee Cost and A&G cost. This will be a combination of the Consumer Price Index (CPI) and the Wholesale Price Index (WPI) for immediately preceding year.
		R&M expenses	➢ R&Mn = K * GFA * INDXn/ INDXn-1 Where, 'K' is a constant (expressed in %) governing the relationship between O&M costs and Gross Fixed Assets (GFA) for the nth year, where 'K' is a constant (expressed in %) governing the relationship between O&M costs and Gross Fixed Assets (GFA) for the nth year.
5.	Uttar Pradesh	Employee expenses	➢ EMPn= EMPn-1 × (1+ CPI inflation), Where: EMPn: Employee expense for the nth year; EMPn-1: Employee expense for the (n-1)th year; CPI inflation is the average of Consumer Price Index (CPI) for immediately preceding three Financial Years.

		A&G expenses	➢ A&Gn= A&Gn-1 (1+ WPI inflation) where WPI inflation is the average of Wholesale Price Index (WPI) for immediately preceding three Financial Years.
		R&M expenses	➢ R&Mn= R&Mn-1 (1+ WPI inflation) where WPI inflation is the average of Wholesale Price Index (WPI) for immediately preceding three Financial Years.
6.	Maharashtra	O&M expenses	➢ The Operation and Maintenance expenses are derived on the basis of the average of the Trued-up Operation and Maintenance expenses after adding/deducting the share of efficiency gains/losses, for the three Years ending March 31, 2019, excluding abnormal Operation and Maintenance expenses, if any, subject to prudence check by the Commission. ➢ These are escalated annually to arrive for the next year O&M expenses with 30% weightage to the average yearly inflation derived based on the monthly Wholesale Price Index of the respective past five financial years as per the Office of Economic Advisor of Government of India and 70% weightage to the average yearly inflation derived based on the monthly Consumer Price Index for Industrial Workers (all-India) of the past five financial years as per the Labour Bureau, Government of India, as reduced by an efficiency factor of 1% or as may be stipulated by the Commission from time to time, to arrive at the permissible Operation and Maintenance expenses for each year of the Control Period.

			➢ Provided further that the efficiency factor shall be considered as zero, in case there is an increase in the number of consumers including Open Access consumers connected to the Distribution Wires of at least 2 percent annually over the last 3 years.

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Annex-II

2021-22				
Serial No.	**State/UTs(Discom/Power Department)**	**Average Gross Fixed Asset (GFA) (Rs crore)**	**O&M Expense (Rs crore)**	**O&M Expense as % to Avg. GFA**
1	**Andhra Pradesh**			
2	APEPDCL			
3	APCPDCL			
4	APSPDCL			
5	**Arunachal Pradesh**			
6	Department of Power - Arunachal Pradesh		374.97	
7	**ASSAM**			
8	APDCL	8184.28	1182.23	14.45
9	**Bihar**			
10	NBPDCL	19490.28	840.24	4.31
11	SBPDCL	14595.24	1050.38	7.20
12	**Chattisgarh**			
13	CSPDCL	10670.51	1396.30	13.09
14	**Goa**			
15	Goa Electricity Department	1116.2	408.96	36.64
16	**GUJARAT**			
17	DGVCL	8124.43	740.19	9.11
18	MGVCL	6311.96	771.53	12.22
19	PGVCL	20449.93	1925.81	9.42
20	UGVCL	8747.33	909.89	10.40
21	**Haryana**			
22	DHBVNL	12252.24	1764.05	14.40
23	UHBVNL	9149.11	1905.94	20.83
24	**Himachal Pradesh**			
25	HPSEBL	7359.8	1889.63	25.68
26	**Jharkhand**			
27	JBVNL	10722.87	580.79	5.42
28	**Karnataka**			
29	BESCOM	17192.94	2371.38	13.79
30	CESCOM	3438.24	818.59	23.81
31	GESCOM	5139.14	908.53	17.68
32	HESCOM	10168.62	1283.83	12.63
33	MESCOM	3362.24	694.85	20.67
34	**Kerala**			
35	KSEBL	13698.88	2828.48	20.65
36	**Madhya Pradesh**			
37	MP East Discom	7479.99	1248.47	16.69
38	MP West Discom	4717.74	1300.33	27.56
39	MP Central Discom	8983.66	1249.18	13.91
40	**Maharashtra**			
41	MSEDCL	58183.97	8570.30	14.73

42	Adani Electricity Mumbai Ltd	8169.45	1440.76	17.64
43	BEST	2967.15	638.2	21.51
44	Tata Power Co.Ltd, Mumbai	3068.05	233.53	7.61
45	**Manipur**			
46	MSPDCL	756.5	85.36	11.28
47	**Meghalaya**			
48	MEPDCL	1008.8	181.79	18.02
49	**Mizoram**			
50	Department of Power - Mizoram	1422.11	214.59	15.09
51	**Nagaland**			
52	Department of Power - Nagaland			
53	**Odisha**			
54	TPCODL	6015.64	1048.76	17.43
55	TPNODL	3698.71	614.24	16.61
56	TPSODL	3339.05	582.3	17.44
57	TPWODL	5328.17	652.57	12.25
58	**PUNJAB**			
59	PSPCL	32039.81	4997.32	15.60
60	**Rajasthan**			
61	AVVNL	12302.79	1058.36	8.60
62	JdVVNL	11553.18	1121.09	9.70
63	JVVNL	16410.96	1394.98	8.50
64	**Sikkim**			
65	SPDCL			
66	**Tamil Nadu**			
67	TANGEDCO	67099	10312	15.37
68	**Telangana**			
69	TSNPDCL			
70	TSSPDCL			
71	**TRIPURA**			
72	TSECL	710.16	211.96	29.85
73	**Uttar Pradesh**			
74	DVVNL	10789.51	1178.56	10.92
75	MVVNL	9430.9	1264.54	13.41
76	PuVVNL	9791.78	1667.15	17.03
77	PVVNL	11021.6	1282.54	11.64
78	KESCO	852.32	244.92	28.74
79	NPCL	1428.01	80.91	5.67
80	**Uttarakhand**			
81	UPCL	5422.32	625.18	11.53
82	**West Bengal**			
83	WBSEDCL			
84	CESC			
85	**Union Territory**			
86	**Andaman & Nicobar Elect. Dept**	558.29	214.55	38.43
87	**Chandigarh Elect. Dept**	342.19	105.11	30.72
88	**DNH&DDPDCL**	622.4	38.58	6.20
89	**Delhi**			

90	BRPL	7419.95	1200.87	16.18
91	BYPL	3988.63	772.79	19.37
92	NDMC	1071.8	253.9	23.69
93	TPDDL	6480.7	820.26	12.66
94	**Jammu & Kashmir**			
95	JPDCL			
96	KPDCL			
97	**Ladakh, Electricity Dept.**			
98	**Lakshadweep Elect. Dept**	192.84	33.64	17.44
99	**Puducherry Elect. Dept**	992.08	137.99	13.91
	total	515834.45	71724.15	13.90

2022-23				
Serial No.	**State/UTs(Discom/Power Department)**	**Average Gross Fixed Asset (GFA) (Rs crore)**	**O&M Expense (Rs crore)**	**O&M Expense as % to Avg. GFA**
1	**Andhra Pradesh**			
2	APEPDCL			
3	APCPDCL			
4	APSPDCL			
5	**Arunachal Pradesh**			
6	Department of Power - Arunachal Pradesh		417	
7	**ASSAM**			
8	APDCL	9106.94	1274.87	14.00
9	**Bihar**			
10	NBPDCL	21519.485	939.2	4.36
11	SBPDCL	16049.79	1113.87	6.94
12	**Chattisgarh**			
13	CSPDCL	10819.25	1590.02	14.70
14	**Goa**			
15	Goa Electricity Department	1807.73	487.47	26.97
16	**GUJARAT**			
17	DGVCL	8973.24	705.08	7.86
18	MGVCL	6642.46	820.11	12.35
19	PGVCL	22056.25	1374.61	6.23
20	UGVCL	9487.89	892.63	9.41
21	**Haryana**			
22	DHBVNL	12893.28	1959.49	15.20
23	UHBVNL	9693.18	1607.35	16.58
24	**Himachal Pradesh**			
25	HPSEBL	8206.2	2578.55	31.42
26	**Jharkhand**			
27	JBVNL	11390.37	628.16	5.51
28	**Karnataka**			
29	BESCOM	19137.7	2832.17	14.80
30	CESCOM	4913.96	975.82	19.86
31	GESCOM	5331.42	1041.28	19.53
32	HESCOM	12139.71	1493.91	12.31
33	MESCOM	3760.98	817.52	21.74
34	**Kerala**			
35	KSEBL	14766.34	3345.05	22.65
36	**Madhya Pradesh**			
37	MP East Discom	7531.94	1316.92	17.48

38	MP West Discom	4717.74	1347.13	28.55
39	MP Central Discom	9148.58	1278.29	13.97
40	**Maharashtra**			
41	MSEDCL	58869.77	7845.63	13.33
42	Adani Electricity Mumbai Ltd	9047.335	1409.58	15.58
43	BEST	3067.92	635.33	20.71
44	Tata Power Co.Ltd, Mumbai	3232.48	260.51	8.06
45	**Manipur**			
46	MSPDCL	808.5	91.52	11.32
47	**Meghalaya**			
48	MEPDCL	1010.19	201.95	19.99
49	**Mizoram**			
50	Department of Power - Mizoram	1576.1	223.94	14.21
51	**Nagaland**			
52	Department of Power - Nagaland			
53	**Odisha**			
54	TPCODL	7323.37	1143.01	15.61
55	TPNODL	4543.97	688.46	15.15
56	TPSODL	3894.96	599.61	15.39
57	TPWODL	6065.81	737.25	12.15
58	**PUNJAB**			
59	PSPCL	33655.33	7123.53	21.17
60	**Rajasthan**			
61	AVVNL	11984	1455	12.14
62	JdVVNL	13090	1396	10.66
63	JVVNL	17641	1837	10.41
64	**Sikkim**			
65	SPDCL			
66	**Tamil Nadu**			
67	TANGEDCO	84855.52	11952.24	14.09
68	**Telangana**			
69	TSNPDCL			
70	TSSPDCL			
71	**TRIPURA**			
72	TSECL	742.65	222.53	29.96
73	**Uttar Pradesh**			
74	DVVNL	12830.41	1021.83	7.96
75	MVVNL	12024.34	1428.24	11.88
76	PuVVNL	11534.03	1703.34	14.77
77	PVVNL	11866.98	1307.02	11.01
78	KESCO	996.87	255.77	25.66
79	NPCL	1661.87	88.49	5.32
80	**Uttarakhand**			
81	UPCL	7664.14	681.87	8.90

82	**West Bengal**			
83	WBSEDCL			
84	CESC			
85	**Union Territory**			
86	**Andaman & Nicobar Elect. Dept**	515.02	230.3	44.72
87	**Chandigarh Elect. Dept**	311.43	115.68	37.14
88	**DNH&DDPDCL**	645.96	55.41	8.58
89	**Delhi**			
90	BRPL	7419.95	1200.87	16.18
91	BYPL	3988.63	772.79	19.37
92	NDMC	1071.8	253.9	23.69
93	TPDDL	6480.7	820.26	12.66
94	**Jammu & Kashmir**			
95	JPDCL			
96	KPDCL			
97	**Ladakh, Electricity Dept.**			
98	**Lakshadweep Elect. Dept**	197.91	38.58	19.49
99	**Puducherry Elect. Dept**	1031.94	157.33	15.25

Acronyms

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

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

ICT	Information & Communication Technology
LT	Low Tension
MDMS	Meter Data Management System
MSDE	Ministry of Skill Development Enterprise
MU	Million Unit
MW	Mega Watt
NABL	National Accreditation Board for Testing and Calibration Laboratory
NEF	National Electricity Fund
NSP	Network Service Provider
O&M	Operation and Maintenance
OFC	Optical Fibre Communication
OLTC	ON-Load Tap Changer
OMS	Outage Management System
PCS	Public Charging Stations
PFA	Power For All
PFC	Power Finance Corporation
PLC	Programmable Logic Controller
PMKVY	Pradhan Mantri Kaushal Vikash Yojana
PPP	Private Public Partnership
PSDF	Power System Development Fund
PV	Photo- Voltaic
RAPDRP	Restructured Accelerated Power Development and Reforms Program
RDSS	Revamped Distribution Sector Scheme

REC	Rural Electrification Corporation
RF	Radio Frequency
RMU	Ring Main Unit
RPO	Renewable Purchase Obligation
SAS	Substation Automation System
SAUBHAGYA	Pradhan Mantri Sahaj Bijli Har Ghar Yojana
SCADA	Supervisory Control and Data Acquisition
SERC	State Electricity Regulatory Commission
SLA	Service Level Agreement
SLD	Single Line Diagram
SLDC	State Load Dispatch Centre
SOP	Standard of Performance
T&D	Transmission and Distribution
TBCB	Tariff Based Competitive Bidding
ToD	Time of Day
TOTEX	Total Expenditure (Capex+ Opex)
UT	Union Territory