POWER TRANSMISSION CORPORTATION OF UTTARAKHAND LTD.

DRAFT

O&M MANUAL

PTCUL

PREFACE

Just like a human body every equipment has its own life to serve the purpose for which it is meant. A well maintained equipment not only serves its purpose efficiently, economically and quickly but also exceeds its expected life time. After formation of PTCUL as a State transmission utility to maintain, operate and run the State Grid of Uttarakhand as per Grid Code as well standard practices and procedures, the need of an O&M manual became essential. This Manual has been prepared for existing transmission network of PTCUL i.e. decade old Transmission lines, substations in plane and hilly terrain as well as new lines and substations added to the system to maintain balance of Load and Generation etc. There are two type of maintenance:

i) Preventive Maintenance
ii) Break down Maintenance

Preventive maintenance is a routine and regular maintenance to prevent future breakdown.

While framing this O&M manual for Substation and lines an attempt has been made to formulate proper guide lines, directions and instructions with suitable standard data and ratings, which will be helpful to field officers and staff for timely maintenance.

This O&M manual consists of two parts:-

Part – I deals with Preventative Maintenance of Substation Equipments and Protective Switchgears.

Part – II deals with Preventative Maintenance of Transmission Lines.

- The emphasis has been given to include the operation and maintenance procedures of new and modern technology for substation equipments and protective relays.

- The efforts have also been made that this manual shall be compatible with new state Grid code of Uttarakhand and also with relevant IS/IEC standards. A special topic of GIS systems being used for substations has also been incorporated.

- This manual covers preventive and normal breakdown maintenance and does not include the major repair works. The effort has been made to make the manual comprehensive and authentic. However suggestion for further improvement are always welcome.

Regulatory and statutory guidelines for carrying out Operation & Maintenance of transmission System.

(A) While carrying out operation & maintenance of transmission network, the regulations notified by Uttarakhand Electricity Regulatory Commission are also to be complied with. Terms & conditions for determination of Transmission tariff Regulation 2004 dated 25.08.2004 of UERC specifics regulations in respect of Transmission system availability and incentives, the relevant portions are given below:-

13. Target Availability for recovery of full transmission charges

(1) AC System : 98%

(2) HVDC bi-pole links and HVDC back-to-back stations : 95%

Notes

(a) Recovery of fixed charges below the level of target availability shall be on pro-rata basis. At zero availability, no transmission charges shall be payable.

25. Incentive

(1) The transmission licensee shall be entitled to incentive on achieving annual availability beyond the target availability as per regulation 13, in accordance with the following formula:

Incentive = Annual Transmission charges x [Annual availability – achieved target availability]/ Target availability

Provided that no incentive shall be payable above the availability of 99.75% for AC system and 95.5% for HVDC system.

Appendix -2

5. The transmission elements under outage due to following reasons not attributable to the transmission licensee shall be deemed to be available:

(a) Shut down of transmission licensee's transmission elements availed by other agency/ agencies for maintenance or construction of their transmission system.

(b) Manual tripping of transmission licensee's line due to over voltage and manual tripping of switched bus reactor as per the directions of SLDC/RLDC.

6. Outage time of transmission licensee's transmission elements for the following contingencies shall be excluded from the total time of the element under period of consideration.

(a) Outage of elements due to acts of God and force majeure events beyond the control of the transmission licensee. However, onus of satisfying the SLDC that element outage was due to aforesaid events and not due to design failure shall rest on the transmission licensee. A reasonable restoration time for the element shall be allowed by SLDC and any additional time taken by the transmission licensee for restoration of the element beyond the reasonable time shall be treated as outage time attributable to the transmission licensee SLDC may consult the transmission licensee or any expert for estimation of restoration time. Circuits restored through ERS (Emergency Restoration System) shall be considered as available.

(b) Outage caused by grid incident/ disturbance not attributable to the transmission licensee, e.g. faults in substation or bays owned by other agency causing outage of transmission licensee's elements, tripping of lines, ICTs, HVDC back-to-back stations etc. due to grid disturbance. However, if the element is not restored on receipt of direction from SLDC/RLDC while normalizing the system following grid incident/ disturbance within reasonable time, the element will be considered not available for whole period of outage and outage time shall be attributable to the transmission licensee.

7. if the outage of any element causes loss of generation of Central/ State Sector Station (s) then the outage period for that element should be deemed to be twice the actual outage period for the days (s) on which such loss of generation has taken place.

(B) UERC made some amendments in Appendix-2 of regulations of 2004 (Principal Regulations) and amendments were notified on 28.11.2008. The provisions of which are as under:-

2. In Appendix-2 of the Principal Regulations:

(1) at the end of clause (7), the following shall be added, namely:-

"(8) If the outage of any element causes power cut in the area of supply of the distribution licensee, then the outage period for that element shall be deemed to be twice the actual outage period for that day (s) on which such power cut has taken place.

(9) In case of delay in commissioning of transmission line beyond the scheduled date given while getting investment plan approved from the Commission, the line shall be deemed to be commissioned from such date and shall be considered to be unavailable due to forced outage for the purpose of calculating the overall availability of the transmission system."

Important Provisions of State Grid Code:-

(C) The Operation & Maintenance practices are also to be followed keeping in mind the provisions of State Grid Code notified by Uttarakhand Electricity Regulatory Commission. Some of the important relevant clauses of State Grid Code are as given under:-

3.5 Safety Standard

The applicable safety requirements for construction, operation and maintenance of electrical plants and electric lines shall be as per the Regulations notified by the Authority under clause (c) of Section 73 of the Act:

Provided that Indian Electricity Rules, 1956 and the prevailing guidelines of the Authority shall be considered until the Regulations are notified under clause (c) of section 73 of the Act by the Authority.

3.9.2 Fault Clearance Times

(1) The fault clearance time for primary protection schemes, when all equipments operate correctly, for a three phase fault (close to the bus-bars) on Users' equipment directly connected to IaSTS (Intra-State Transmission System) and for a three phase fault (close to the bus-bars) on IaSTS connected to Users' equipment, shall not be more than:

(i) 100 milliseconds for 800 kV class & 400 kV

(ii) 160 milliseconds for 220 kV & 132 kV/110 kV

(2) Back-up protection shall be provided for required isolation/ protection in the event of failure of the

primary protection systems provided to meet the above fault clearance time requirements. If a Generating unit is connected to the IaSTS directly, it shall be capable of withstanding the fault, until clearing of the fault by back-up protection on the IaSTS side.

4.1 Operating Policy

4.1.2 Overall operation of the State Grid shall be supervised form the State Load Despatch Centre (SLDC). The roles of SLDC shall be in accordance with the provisions of the Act.

4.1.5 The control rooms of the State Load Despatch Centre including Area Load Despatch Centres, Power Plants, substations of 132 kV and above and any other control centres of Transmission Licensees and Users shall be manned round-the-clock by qualified and adequately trained personnel.

4.2 System Security Aspects

4.2.2 No part of the State Grid shall be deliberately isolated from the rest of the State Grid, except (i) under an emergency and conditions in which such isolation would prevent a total grid collapse and/ or would enable early restoration of power supply, (ii) when serious damage to a costly equipment is imminent and such isolation would prevent it and (iii) when such isolation is specifically instructed by SLDC. Complete synchronization of Grid shall

be restored as soon as the conditions again permit it. The restoration process shall be supervised by SLDC, as per operating procedures separately formulated.

4.2.13 Users and Transmission Licensees shall provide automatic under frequency and df/dt reqlay-based load shedding/ islanding schemes in their respective

systems, wherever applicable, to arrest frequency decline that could result in a collapse/ disintegration of the State Grid, as per the plan separately finalized by the RPC and shall ensure its effective application to prevent cascade tripping of generating units in case of any contingency.

4.2.19 The State Constituents shall sent information/ data including disturbance recorder/ sequential event recorder output etc., to SLDC for purpose of analysis of any grid disturbance/ event. No State constituent shall block any

data/ information required by the SLDC for maintaining reliability and security of the grid and for analysis of an event.

4.2.20 All State Constituents shall make all possible efforts to ensure that the grid voltage always remains within the following operating range:

Voltage- (kV RMS)		
Nominal	**Maximum**	**Minimum**
400	420	360
220	245	200
132	145	120
66	73	60

5.4 Demarcation of responsibilities

5.4.12 The STU shall install special energy meters on all inter-connections between the State constituents and other identified points for recording of actual net

MWh interchanges and MVArh drawls. The type of meters to be installed, metering scheme, metering capability, testing and calibration requirements and the scheme for collection and dissemination of metered data shall be as per Regulations for Installation and Operation of Meters issued by the

Authority under section 54(2) (d) of the Act. All concerned entities (in whose premises the special energy meters are installed) shall fully co-operate with the STU/SLDC and extend the necessary assistance by taking weekly meter readings and transmitting them to the SLDC.

5.6 Reactive Power and Voltage Control

5.6.5 Switching in/ out of all 400 kV bus and line Reactors throughout the grid shall be carried out as per instructions of SLDC. Tap changing on all 400/220/132 kV ICTs shall also be done as per SLDCs instructions only.

INDEX

PART – I
O&M OF EHV SUBSTATIONS

PART – II
O&M OF EHV LINES

CHAPTER 1

PREVENTIVE MAINTENANCE PROCEDURES

1 INTRODUCTION

The proper maintenance of electrical system not only improves the reliability but also generate revenue for the electrical utilities. The old concept of break-down maintenance system, have not only resulted in unreliable supply but also have caused heavy monetary loss. 'Preventive Maintenance' or 'Periodic Maintenance' is very much relevant to keep the equipment continuously in service for desired output. This forms the base for 'Condition Based Maintenance' which helps in providing advance information about the health of the equipment for planning for major maintenance/overhauls.

Preventive maintenance procedures dealt in this chapter will help for timely corrective action and to maintain substation equipment without unplanned outage.

2. GENERAL INSTRUCTIONS FOR MAINTENANCE OF SWITCH YARD EQUIPMENT

(a) External Cleaning

The insulators of the transformer bushings/ circuit breaker / CT / CVT / isolator shall be cleaned from salt and dirt/dust deposition together with the cleaning of the other insulators in the substation. The time interval for this cleaning shall be based on the polluting atmosphere. For installations with higher atmospheric/saline pollution, cleaning frequency may be increased and and these may be suitably protected against pollution.

(b) Rust Protection

Some parts of the operating mechanism are made of steel and are surface treated against rust. In spite of the good rust protection, minor corrosion will occur after some years, especially when the breaker / isolator is standing in strong corrosive surroundings. The rust stains shall be sand papered away and new rust protection shall be painted or sprayed on. As rust protection, grease C or Tectyl 506 is recommended.

(c) Lubrication

For lubrication, the lubricants recommended by manufacturers shall primarily be used. This is especially important in cold climates with temperatures below - 25°C.

The bearings of the breaker and operating mechanism of isolator and breaker are to be lubricated with grease G although these normally do not need lubrication before the major overhauls. Plain bearings in mechanism details such as arms, links and link gears are also to be lubricated with grease G. These bearings shall be regularly lubricated with a few drops of' oil B. The teeth in the gear shall be lubricated with grease G. Dryness of driving mechanism may lead to maloperation and failure.

(d) Treatment of Contact Surfaces

The contacts of breaker / isolator / ground switch shall be treated according to the following directions:

- *Silvered contact surfaces:* Silvered contact surfaces shall be cleaned, if necessary, with a soft cloth and solvent (trichloro ethane). Steel brushing or grinding is not allowed.
- *Copper surface:* Copper surfaces shall be clean and oxide free. If necessary, they shall be cleaned with cloth and solvent (Trichloroethane) or steel brushing - After steel brushing, the surface shall always be cleaned of loose particles and dust.

- *Aluminium surfaces:* Aluminium contact surfaces shall be cleaned with steel brush or emery cloth. The surface is very thoroughly cleaned of particles and dust with a dry I cloth. After this, a thin layer of Vaseline is applied. This shall be done within 5 minutes after the cleaning. The joint shall be assembled within 15 minutes.

(e) Moving Contact Surfaces

- *Silvered:* Cleaned if necessary, with soft cloth and solvent (trichloro ethane). No steel brushing.
- *Non-silver coated:* Cleaned as silvered surfaces, can be steel brushed. After steel brushing they shall be thoroughly cleaned of loose particles and dust.
- *Lubrication:* Lubricant - Grease K is applied in a very thin layer on the surfaces of the male contact and the puffer cylinder. The superfluous grease is carefully removed.

3. TRANSFORMERS AND REACTORS

In order to provide long and trouble free service, it is important that a careful and regular supervision and maintenance of the transformer and its components is carried out. The frequency and extent of such a supervision and maintenance is dependent on the experience, climatic conditions, environment, service conditions, loading pattern etc. All work done on transformers should be recorded in history register for future reference. Efforts have been made to cover all important maintenance practices for transformers and reactors in this chapter with details of interpretation of test results.

I. General Supervision

(a) *Dirt and Dust*

The external transformer surfaces shall be inspected regularly; and when required cleaned of dust, insects and other airborne dirt. Transformers/ reactors installed near polluting industry/cement plants, etc., need special care and more frequent cleaning of the bushings and other components. All Marshalling Boxes and OLTC cubicle are to be kept properly closed so that there will not be entry of dust inside, which is difficult to clean.

(b) Rust and Treatment

A regular inspection is to be carried out of the external surface treatment of the transformer tank and radiators. Possible rust damages are removed and the surface treatment restored to original state by means of the primer and finish-paints of the transformer to minimize the risk of corrosion and its subsequent spreading. These checks also include looking for signs of oil leaks on gasket areas and welded areas containing oil. The touch-up paint as and when required as per site condition and re-painting is recommended once in five years. However transformers in coastal areas and more corrosive atmosphere may require more frequent painting.

(c) Check for any Signs of Mechanical Damage

Checks must be carried out for mechanical damage to the fabrications and associated equipment. Particular attention should be given to vulnerable areas such as radiators. If damage is seen on the equipment, a decision must be taken as to its seriousness. It may be necessary to take corrective actions such as the replacement of an item of equipment.

(d) *Check on all Joints for Signs of Leakage*

All joints, both welded and gasketed, must be checked for signs of oil leakage. If there is any doubt of a leak, the area must be cleaned of oil, using a suitable solvent (methyl alcohol) and sprayed with liquid chalk. This will promote the flow of the leak and give a good indication as to the exact location of the leak, if in fact there is one. If a leak is suspected on a gasket, the joint must be tightened until such time that it can be changed with a new gasket. If a leak is apparent at a welded joint once again clean the area and apply liquid chalk and allow to dry. This will highlight the point exactly if in fact there is a leak. It must be properly repaired with welding procedures when convenient. Prior to leaving the leak, it must be highlighted with a marker, or something similar, so it is not lost when permanent repair takes place.

Other areas commonly associated with oil leaks are drain plugs in radiators, valves in the oil management and cooling system and the gas and oil actuated relay.

(e) *Check for Oil Level*

It is good practice to check all oil levels associated with the equipment. This will incorporate the expansion vessel and all oil filled bushings. Also the oil in the oil seal should be maintained. Some bushings in transformers will be below the conservator oil level and some above. If there is leakage in bushing at the oil end, the level will be low or high depending upon the level of conservator. External leak on bushing will lead to indicate low oil level. This is to be observed accordingly and if there is leak, action is to be initiated immediately as bushing failure may lead to failure of entire transformer.

OLTC oil conservators are always kept at lower level compared to the main conservator tank so that OLTC oil will not mix with main tank oil. An increase in level of oil in OLTC conservator tank indicates internal leakage and action is to be taken accordingly. After energizing of the transforn1er, a certain settling may appear in sealing joints. This applies especially to sealing joints with plain gaskets that are not placed in grooves. These should therefore be re-tightened. For correct torque for tightening the bolt, the manufacturer's recommendations are to be followed.

(f) *Check on the Surrounding Areas*

Once all the checks are completed, a check should be made to ensure that all materials or tools, used for maintenance work, have been removed. All clothes and other debris must be disposed off. The transformer compound should be left in a clean and tidy condition.

II. Checks on Breathers

(a) *Checks on 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 should become pink from bottom to top over a period of time. Any de-colorization at top or sides indicates leakage in container and need to be attended immediately. In order to prevent severe deterioration of the silica gel, it is recommended that it is replaced when half to two thirds of the silica gel has become saturated and turned pink in colour. Failure to do so will severely retard the drying efficiency of the breather. The silica gel can be reactivated by heating it to 130°C-140°C in a ventilated oven until it has achieved the bright blue colour. Check that the oil level is correct in the oil cup at the breather base and fill oil if the level is found low.

Note: Do not exceed the temperature stated above otherwise the colour impregnation will be destroyed and the silica gel will turn black.

Immediately after re-activation the loose silica gel must be placed in a sealed container to prevent absorption of moisture on cooling. The silica gel should be stored in sealed condition until required for use.

Self indicating (blue) silica gel contains the dye cobalt chloride which has been classified carcinogenic by an European Commission directive and ia a banned substance because of its potential health hazards. In Europe the silica gel breathers are to be disposed in 'Class l' disposal locations for hazardous waste products or incinerated.

An alternative to the blue self-indicating silica gel is SILICA GEL ORANGE with an organic indicator. The colour changes from orange to light yellow as it absorbs moisture. The specifications of silica gel orange are as shown below:

Parameter		**Specification**
Adsorption capacity	RH 50% (min)	20
	RH 80% (min)	30
Appearance		Orange
Loss at heating up % (max)		4
Colour change	RH 50%	Light yellow
	RH 80%	Colourless or Slight yellow

In view of above use of blue silica-gel may be phased out.

(b) Drycol Breather Check (If Available)

Drycol breathers are provided in some transformers where air cell is not provided. It condenses the moisture inside the conservator and brings it out as water droplets. Silica gel breather will also be provided for these transformers. The following checks need to be carried out for drycol breathers:

Operation of counter reading: Check on a regular basis that the counter is functioning. Record the figures each time a check is made so that a progressive check is recorded.

Defrost current condition indicates that water is still being ejected from the breather

Press the test button and check that a defrost current is being indicated. Check that the two red neon lights are ON and the amber neon light is OFF.

Release the test button and check that the counter has advanced one count and that freeze current is indicated.

III Checks for Conservator

(a) *Visual Check for Conservator Oil Level*

The transformer oil conservator is provided with an oil-level indicator graduated from 0 to 1 or min to 6 or "low" to "full" with grading depending on the manufacturer. Normally the face of oil gauge or dial of Magnetic oil level Gauge (MOG) is marked at the *35°C* (or normal). These indications are relative to temperature of the operating equipment. The oil level indicated should be recorded along with top oil temperature.

If corrected oil level is normal, no additional action is required, whereas if it is above or below the normal level, it may be necessary to remove or add some oil. The correct oil-filling level is specified on an information plate that is placed on the transformer Rating plate panel. At an oil temperature of + *45°C*, the conservator should be half filled. If the level exceeds the "full" oil must be drained off. If the value is "low" or "min", oil must be filled in.

(b) *Leakage Testfor Air Cell*

Normally leakage test for air cell fitted inside the conservator is carried out before installing the conservator in its position or at the time of major overhaul. During service, the leakage in the cell or in the sealing of the conservator can be detected by the oil level in the prismatic oil level indicator, if provided, on the conservator. If there is no leakage, the prismatic oil level indicator will show "Full" oil level. However, in case of leakage, the oil level in the prismatic oil level gauge shall be lower than "Full" level.

For Releasing Air from Conservator Fitted with Air Cell

Pressurize the Air Cell up to the maximum pressure as specified by the manufacturer and open the air vent valves provided on the top of the conservator until oil starts coming out. Then close the valves. Release pressure from the Air Cell and refit breather.

For Releasing Air from Conservators Fitted with Diaphragm Type Air Sealing

Open the Air Release Valve provided on the top of the diaphragm and start filling oil into the conservator, preferably from the valve provided at the bottom of the conservator. Filling of oil from the oil filling valve at the bottom of the transformer tank is avoided because it may result in entry of air into the transformer which may get trapped in the winding and result in unnecessary accumulation of air in the Buchholz Relay at some later stage.

Continue filling oil into the conservator until it is full and oil starts coming out of the Air Release Valve. Close the Air Release Valve after ensuring that all the air has come out from the oil portion below the diaphragm.

Slowly drain the oil from the conservator until the oil level as indicated on the oil level gauge corresponds to the transfom1er oil temperature.

Before making the leakage test of air cell for the, transformer in service, oil should be drained out to the lower level of conservator. Apply pressure as specified by the manufacturers to inflate the air cell. Adjust the pressure after 6 hrs, if required. Check temperature and maintain the air cell at almost the same temperature for 24 hrs. If there is no loss of pressure during 24 hrs, it means the air cell is not having leak.

(c) *Caution*

Any heating process like welding, grinding etc. are not allowed on the assembled conservator fitted with air cell diaphragm as it is highly sensitive to heat.

IV. Check for Cubicle and Marshalling Kiosk and Valves

Marshalling Cubicle and Kiosk Check

The following need to be checked and ensured while inspecting and checking the Marshalling Boxes.

- Condition of paint
- Operation of door handles, Hinges
- Condition of door seal.
- Door switches
- Lights and heaters
- Thermostats
- Operation of heating and lighting switches
- Secure mounting of equipment
- Checking of tightness of cable terminations
- Checking of operation of contactors
- HRC fuses and their rating
- Operation of local alarm annunciation by pushing push buttons provided for lamp test, acknowledge, reset, system test, mute etc. to cover all system function.
- Source change over test check by putting off power sources alternatively.
- Check for plugs for dummy holes, glass windows and replacement, if found missing/ broken.

V. Checks for Auxiliaries

(a) *Cooling System*

The cooling surfaces of radiators shall be inspected regularly and when required cleaned of dust, insects, leaves or other air borne dirt. The cleaning is suitably carried out by means of water flushing at high pressure. Precaution should be taken to cover the fan-motor so that water may not go inside. Alternatively cleaning can be done with cleaning solution and cloth.

The fan-motors are provided with permanent - lubricated bearings and double sealing rings. The motor bearings are axially clamped with spring-washers. If the sound level of the fan increases, first tighten all mounting supports and in case any abnormal sound is noticed in fan motor, then action should be taken for repair! replacement.

(b) *Cooling System-Fans-Controls*

Fan controls are designed to operate both manually and automatically with set temperature. Manual, Control is to be turned 'ON' to operate cooling system for checking. Oil pumps need to be checked by observing their flow gauges. Measurement of pump current reveals any abnormality. Any significant imbalance of current between the terminals greater than 15-20% is indicative of the problem with the pump motor. Checking for correct rotation of fans and pumps to be ensured as reverse rotation may not provide desired result.

(c) *Calibration of OTI / WTI*

Temperature indicators in transformers are not only used for indication purpose they are used as protective device also. The accuracy of these devises is to be ensured for correct operation of alarm and tripping and also to prevent mal operation. The temperature bulb is to be removed from its well on the side/ top of transformer. Using a temperature controlled calibration instrument in oil bath the temperature of the bulb should be slowly raised in steps of *5°C* and observed for temperature reading. If the temperature deviation is more than ± 5°C compared to the standard thermometer reading, the thermometers are to be replaced with healthy one.

(d) *Checking of Cooler Control, Alarm and Trip Settings*

Setting of temperature should be as per approved scheme. Access the local winding/ oil temperature indicator and rotate the temperature indicator pointer slowly to the first stage cooling value (say 65°C). Check that the fans of those coolers set to first stage are operating. Continue rotating the pointer to the second stage cooling value (say 8O°C). Check that the fans of those coolers set to second stage are operating. Continue rotating the pointer to the alarm value (say 110°C). Check with the control room to ensure that the alarm signal has been received. Continue rotating the pointer to the trip value (say 125°C). Check with the control room to ensure that the trip signal has been received.

(e) *Gas Pressure Relay*

There are two types of gas pressure relays. The most common type is mounted at the transformer top body. Internal arcing in liquid filled electrical power equipment generates excessive gas pressures that can severely damage equipment and present extreme hazards to personnel. The gas pressure relay is intended to minimize the extent of damage by quickly operating and venting out the pressure. It will reset when the pressure becomes normal. A pointer is provided to indicate the operation of this relay and the relay is connected for tripping the transformer on operation. There will be oil spillage whenever the relay operates. Smaller transformers are provided with explosion vent where the diaphragm will rupture due to heavy internal pressure and releases the

pressure. The diaphragm needs to be replaced when it operates. There are some transformers fitted with sensitive sudden pressure relay, which operates on rate of change of differential pressure and trips the equipment.

(f) *Buchholz Relays*

The use of gas-operated relay as protection for oil-immersed transformers is based on the fact that faults as flashover, short-circuit and local overheating normally result in gas-generation. The gas-bubbles gathering in the gas-operated relay affect a float-controlled contact that gives an alarm signal.

For testing of the contact functions, buchholz relays are provided with a test knob on the cover. Unscrew the protective cap and press down the knob by hand. The spring loaded knob with a pin inside the relay actuates first the alarm device and then the tripping device. After testing, screw on the protective cap again.

Checking the operation of Buchholz relay in case of low oil level is carried out by closing step valve in both sides of the relay and draining of oil through oil drain valve provided in Buchholz relay. First alarm and then trip contact should operate to indicate healthiness.

To check the relay for oil surge, manufacturers recommendations for particular relays to be followed.

(g) *Bushings*

Bushings are most failure prone in any transformer/ reactor. Failure of bushings could lead to the fire in transformer and total damage. For uniform voltage distribution across capacitance graded bushings, bushing porcelains shall be cleaned from dust and dirt during shutdown maintenance. In areas where the air contains impurities as salt, cement dust, smoke or chemical substances, shorter intervals are required.

VI. Operational Checks and Inspection / Maintenance of Tap Changer

EHV Transformers are provided with tap changer to have voltage control. To enable operation of taps during service, On- Load Tap Changers (OLTC) are provided in EHV transformers. OLTCs may be located in either the high voltage winding or the low voltage winding, depending on the requirements of the user, the cost effectiveness of the application and tap changer availability. OLTC being a current interrupting device requires periodic inspection and maintenance. The frequency of inspection is based on time in service, range of use and number of operations.

(a) *Precautions*

This testing shall be carried out during shutdown period and all testing shall be done under total de-energisation condition. Ensure the isolation of transformer for high voltage and low voltage side with physical inspection of open condition of the concerned isolators/ disconnectors. In case tertiary is also connected, ensure the isolation of the same prior to commencement of testing

(b) *Tap Changer Hand Operation*

Check hand operation of the tap changer up and down the full range before electrical operation is attempted and that the handle interlock switch will not allow electrical operation while the handle is inserted. In addition where single phase tap changers are employed check their tap positions agree and are reached simultaneously at motor drive unit head. Continuity check should be done for any discontinuity during tap changing operation by connecting an analogue multi meter across HV and IV bushing in case of auto transformers and relevant winding in case of two winding transformers and change the tap positions from maximum to minimum.

(c) *Maintaining Circuit*

Check the maintaining circuit for correct sequence by hand winding unit half way through a tap and then remove the handle. Energize the drive motor and ensure that the motor continues to drive the tap changer in the same direction.

(d) ***Drive Motor***

With the tap changer in mid position check the direction of rotation and measure the start and running currents in both the raise and lower mode of operation and record their values.

Set the motor overload to 10% above running current

(e) ***Out of Step Relay***

Move one tap changer is in the three-phase bank to be one position out of step with other two. Check the tap changer faulty alarm is activated. Repeat for other two phases.

Hold the raise and lower push buttons in following a tap change to ensure it only moves one tap at a time hence checking the step by step relay.

(f) ***Tap Change Incomplete Alarm***

Check the operation of the tap changer incomplete alarm, including the flag relay, by winding the unit by hand half way through a tap change and monitoring their correct operation and time to operate.

(g) ***Remote Indication***

Check the remote indication and control facility is proved to the outgoing terminals of the marshalling kiosk.

(h) ***Tap Changer (Surge) Protective Relay***

Check the tripping function of the relay. Open the cover and press button "Trip". Check that all circuit breakers of transformer operate properly. Press push Button "Reset" close the cover and tighten it.

(i) ***Inspection and Maintenance of OLTCs***

Normally the temperature of the OLTC compartment may be few degrees Celsius less than the main tank. Any temperature approaching or above that of the main tank indicates an internal problem. Prior to opening the OLTC compartment, it should be inspected for external symptoms of potential problems. Such things as integrity of paint, weld leaks, oil seal integrity, pressure relief device and liquid level gauge are all items which should be inspected prior to entering the OLTC.

Following de-energisation, close all valves between oil conservator, transformer tank and tap-changer head, then lower the oil level in the diverter switch oil compartment by draining of oil for internal inspection. Upon opening the OLTC compartment, the door gasket should be inspected for signs of deterioration. The compartment floor should be inspected for debris that might indicate abnormal wear and sliding surfaces should be inspected for signs of excessive wear.

Finally, the tap selector compartment should be flushed with clean transformer oil and all carbonization, which may have been deposited, should be removed. Min BDV should be 50 kV and moisture content should be less than 20 PPM.

Dissolved Gas Analysis (DGA)

Transformer undergoes electrical, chemical and thermal stresses during its service life which may result in slow evolving incipient faults inside the transformer. The gases generated under abnormal electrical or thermal stresses are hydrogen (H_2), methane(CH_4), ethane(C_2H_6), ethylene (C_2H_4), acetylene (C_2H_2), carbon_monoxide (CO), carbon dioxide (CO_2), nitrogen (N_2) and oxygen (0_2) which get dissolved in oil. Collectively these gases are known as FAULT GASES, which are routinely detected and quantified at extremely low level, typically in parts per million (ppm) in dissolved Gas Analysis (DGA). Most commonly method used to determine the content of these gases in

oil is using a vacuum Gas Extraction apparatus/ Head Space Sampler and gas chromatograph.

DGA is a powerful diagnostic technique for detection of slow evolving faults inside the transformer by analyzing the gases generated during the fault which gets dissolved in the oil. For Dissolved Gas Analysis to be both useful and reliable, it is essential that sample taken for DGA should be representative of lot, no dissolved gas be lost during transportation and laboratory analysis be precise and accurate. Effective fault gas interpretation should basically tell us first of all, whether there is any incipient fault present in the transformer. If there is any problem, what kind of fault it is. Whether the fault is serious and the equipment needs to be taken out of service for further investigation.

DGA can identify deterioration of insulation oil and hot spots, partial discharge, and arcing. The health of oil is reflective of the health of the transformer itself. DGA analysis helps the user to identify the reason for gas formation and materials involved and indicate urgency of corrective action to be taken.

The evolution of individual gas concentrations and total dissolved combustible gas (TDCG) generation over time and the rate of change (based on IEC 60599 and IEEE C 57-104 standards) are the key indicators of a developing problem. Some of the recognized interpretation techniques are discussed below:

Individual Fault Gases Acceptable Limits

When no previous DGA history of Transformer is available, to ensure that a transformer is healthy or not, the DGA results are compared with the gassing characteristics exhibited by the majority of similar transformer or normal population. As the transformer ages and

gases are generated, the normal levels for 90% of a typical transformer population can determined. From these values and based on experience, acceptable limits or threshold levels have been determined as given in table (as per IEC 60599) below:-

Transformer Type	Fault Gases (in µl/l)						
	H_2	CH_4	C_2H_6	C_2H_4	C_2H_2	CO	CO_2
No OLTC	60-150	40-110	50-90	60-280	3-50	540-900	5100-13000
Communicating OLTC	75-150	35-130	50-70	110-250	80-270	400-850	5300-12000

The values listed in this table were obtained from specific networks. Values on other networks may not exactly indicate healthiness.

“Communicating OLTC” means that some oil and/or gas communication is possible between the OLTC compartment and the main tank or between the respective conservators. These gases may contaminate the oil in the main tank and affect the normal values in these types of equipment. “NO OLTC” refers to transformers not equipped with an OLTC, or equipped with an OLTC but not communicating with or leaking to the main tank.

However it is improper to apply threshold level concept without considering the rate of change of the gas concentration in Dissolved Gas Analysis. When an abnormal situation is indicated by above table, a testing schedule is devised with increased sampling frequency.

Total Dissolved Combustible Gas (TDCG) Limits

TDGC limits, PPI	Action
<or = 720	Satisfactory operation, Unless individual gas acceptance values are exceeded
721-1920	Normal ageing/slight decomposition, Trend to be established to see if any evolving incipient fault is present.
1921-4630	Significant decomposition, Immediate action to establish trend to see if fault is progressively becoming worse.
>4630	Substantial decomposition, Gassing rate and cause of gassing should be identified and appropriate corrective action such as removal from service may be taken.

TDCG includes all hydrocarbons, CO and H_2 and does not include CO_2 which is not a combustible gas.

Evaluation of Gases

The temperature at which the fault gas evolves is given in the table below:

Relationship with temperature
Methane CH_4>120^oC
Ethane (C_2H_6)>120^oC
Ethylene (C_2H_4)>150^oC
Acetylene (C_2H_2)>700^oC

Faults Associated with Different Gases

Oil Overheating	C_2H_4, C_2H_6,CH_4
Overheated Cellulose Traces of acetylene with smaller quantity of Hydrogen may be evolved. Large quantity of Carbon-Di-Oxide (CO_2) and Carbon Monoxide (CO) are evolved from overheated cellulose. Hydrocarbon gases such as Methane and Ethylene will be formed if the fault involved oil impregnated structure.	CO
Partial discharge in Oil (Corona) Ionization of high stressed area where gas/vapour filled voids are present or 'wet spot'produces Hydrogen and methane and small quantity of other hydrocarbons like ethane and ethylene. Comparable amounts of carbon mono-oxide and di-oxide may result due to discharges in cellulose.	H_2,CH_4
Arcing in Oil Large amount of Hydrogen and acetylene are produced with minor quantities of methane and ethylene in case of arcing between the leads, lead to coil and high stressed area. Small amounts of carbon mono-oxide and di-oxide may also be formed, if fault involves cellulose.	C_2H_2,H_2

It is to be understood that there is no definite interpretation method available, which can indicate the exact location and type of the! fault. The different interpretation methods only provide guidelines to make expert interpretation about the equipment. Apart from the DGA results various other factors are taken into consideration such as past history of the transformer, grid condition, loading patterns, voltage and frequency profile, etc.

4. CIRCUIT BREAKERS

Circuit breakers basically consists of two main parts, the interrupting chambers and the operating mechanism. The interrupting chambers normally do not require routine preventive maintenance other than cleaning but operating mechanism do require proper upkeep.

(a) Interrupting Chamber

Circuit breaker interrupting chamber is an enclosed unit mostly filled with oil or SF6 gas. Lower voltage Circuit breakers have vacuum interrupting chambers also. There is stress on the contacts during fault current interruption and damages may happen in arcing contacts or main contacts. The breaker interrupting chamber is recommended to be opened only based on condition monitoring tests or as per advice of the manufacturers.

(b) Operating Mechanisms

Normally circuit breakers have pneumatic, hydraulic and spring operating mechanisms. As operating force is required for closing and tripping of circuit breakers, there can be combination of these mechanisms in one circuit breaker. Since operating mechanisms have a number of moving parts, they need more maintenance such as

greasing, lubrication, cleaning, setting of limit switches, etc. Compressors/ oil pumps/ spring charging motors also require maintenance. Other maintenance on particular operating mechanism such as air compressor maintenance, nitrogen priming pressure checking in hydraulic mechanism, checking of over travel, checking of gaps in operating plunger of close/ trip coils etc. are to be carried out as the case may be and as specified by the manufacturers.

(c) SF_6 Gas

Most of the higher voltage circuit breakers adopt SF6 in interrupting chamber. The density of SF6 gas is about five times that of air and heat dissipation is also much more than air. At atmospheric pressure, dielectric strength of SF6 gas is about 2.4 times that of air and at about 3 kg/cm2 it is same as that of oil. As SF6 is Green House gas, it needs to be handled carefully and should not be let to the atmosphere.

(d) *Emptying and Re-filling of Gas*

The breaker is evacuated by means of the gas treatment equipment that purifies and also compresses the gas for storage, so that it can be reapplied. For economic and ecologic reasons, SF6 contained in electrical equipments, should not be vented into atmosphere. Prior to the gas removal, the quality of the SF6 gas should be tested.

Operational contamination should be absorbed with suitable filter unit provided in the gas handling plant. Such filters/ sieves should already be installed into the SF6 gas maintenance/handling unit. When SF6 is suctioned from a gas compartment, the gas is passed automatically through filters, which dry and purify the gas.

(e) ***Evacuation of SF6 Gas Circuit Breakers***

After maintenance/overhaul of the circuit breaker, it should be evacuated by vacuum PUI1l] before filling in the SF6 gas so that SF6 gas does not mix with ambient air and also humidity and dust particles are removed from the Breaker. With vacuum pump, a final vacuum must be reached less than 5 mbar.

5. PREVENTIVE MAINTENANCE OF CURRENT TRANSFORMERS

(a) Visual Inspection

Current transformers are normally filled with oil and have oil impregnated paper insulation for both primary and secondary winding. Careful inspection is to be made for any trace of oil leakages. Oil leakages are more prone through cemented joints or secondary terminal box due to improper sealing of terminal studs. As CTs have less oil quantity small leakage may lead to exposure of paper insulation and subsequent moisture absorption.

If bellows are provided in CTs, the position of bellow indicates either leakage of oil or expansion due to internal gas generation. Both the conditions are serious for the life of the CTs and immediate action to be initiated for rectification.

Visual inspection is also to be carried out on the healthiness of terminal connections, condition of porcelain, development of cracks, chippings, cleanliness of insulator surface etc.

(b) Maintenance of Gaskets

Marshalling boxes, CT terminal boxes are to be properly sealed to prevent any dust, rain water and insects. Door gaskets are to be changed periodically to give proper sealing. All door bolts/ latches are to be properly tightened and never left loose.

(c) Secondary Terminals Connections

Stud type terminals are preferred in Marshalling box cable terminals. This gives better grip even if more than one wire is connected to one terminal. But pin type terminals are also provided in some cases. Since tightness of wires may become loose due to vibration, climatic condition, it is required to check tightness of terminals periodically to avoid maloperation/ non-operation due to improper contacts. All terminals of unused CT secondary terminals are to be properly shorted to avoid development of abnormal voltage and subsequent failure of CTs. The tan δ test tap is to be properly earthed to avoid damage to insulation.

Primary Terminals

Thermovision scanning indicate proper connection of primary terminal. If thermovision is not carried out, physical checking of terminal connection is to be done with proper torque. All corona shields are to be provided and any damaged corona shield to be replaced with new one. As CT primary carries heavy current, any loose joint may lead to arcing and welding of terminal connectors.

6. CAPACITANCE VOLTAGE TRANSFORMERS/ POTENTIAL TRANSFORMERS/ CAPACITOR COUPLING

(a) Visual Inspection

The bel10ws provided in most of the CVTs are not visible from outside. CTs/ CVTs and CC are also oil fil1ed equipments and oil leak is to be observed. If oil leak is observed in anyone stack, the entire CVT is to be replaced. CVTs are tuned units and replacement of anyone stack is not recommended to avoid phase angle errors.

(b) Electro-Magnetic Unit

Electro-Magnetic Unit (EMU) of CVT houses the secondary transformer, Compensating reactor and ferro resonance suppression circuit. The colour of oil indicated through the gauge: glass gives some indication of the healthiness of the internal components. Any abnormal heating may also be observed through Thermovision scanning.

(c) Secondary Voltage

Deviation in secondary Voltage of CVT is clear indication of failure of capacitor elements. Necessary action to be taken to replace CVT if secondary voltage in anyone CVT is abnormal (may be +2V and -4V). Continuing the equipment in service beyond this stage may lead to failure/ bursting of CVTs.

(d) Other Maintenance

Maintenance of Marshalling box gaskets, tightening of secondary terminal connections and tightening of primary terminal connections, etc., are also to be ensured for healthy operation. It is to be ensured that al1 extra holes at Marshalling boxes are properly plugged and kept vermin proof. The anti-condensation heater and the thermostat are to be kept in working condition to keep inside of the panel dry.

7. DISCONNECTORS/ISOLATORS

Disconnectors have main current carrying arms and operating mechanism for connection and' disconnection. Being are off-line devices, they are normal1y air break type. Normally horizontal double break, Horizontal center break, Pantograph, Vertical break Disconnectors are in use for EHV isolations.

The alignment of Disconnectors is very important for smooth operation. The limit switches, the healthiness of auxiliary contacts needs to be checked periodical1y. The main contacts are to be inspected and made smooth if any pitting marks seen. The corona shields are to be kept smooth and shining and checked for tightness of fitting. Damaged

corona rings should be replaced. All moving parts are to be lubricated for smooth operation. The gear mechanism and motor normal1y do not require any maintenance and manufacturer's recommendation should be referred for maintenance of gears.

Earth Switches

The earth switch is a safety device and smooth operation is to be ensured by proper alignment. The earth blade contacts are to be cleaned properly for proper contact and contact resistance to be measured to ensure healthiness. The earth connection from blade to earth is to be carefully checked. All the joints to be tightened and flexible copper braid connections are provided and healthiness is to be ensured. All moving parts to be lubricated for smooth operation.

8. LIGHTING ARRESTER/SURGE ARRESTERS

Surge arresters are to be maintained to give protection to other connected switchyard equipments. Cleaning of porcelain insulators is very much required for uniform voltage distribution. Voltage grading rings are to be properly positioned and checked for tightness and any damaged rings to be replaced. Healthiness of surge monitors is to be checked and if found defective the same may either be replaced with healthy one or shorted to minimize earth resistance. Healthiness of earth connections to be checked as it plays a vital role on the operation of the surge arrester. Normally it is not recommended that if one stack fails it is replaced with healthy stack. It is always a good practice to change the entire arrester as the stressed stacks will start failing along with the new stack.

9. BATTERY AND BATTERY CHARGERS

Substations generally use Lead Acid batteries/for DC batteries for DC supply. More and more maintenance free batteries are now offered for substation applications which require less maintenance. As DC system is vital part of substation during emergency, upkeep of battery system is very important.

Cell containers are to be kept always clean to avoid surface leakage. Any leakage is to be attended immediately. Vaseline / white petroleum jelly is to be applied on battery terminal and inter-cell connectors, nuts and bolts to avoid sulphate deposit. The rubber seal at the base of the terminals and on cell lid is to be fitted properly and to be replaced if damaged. All connections are to be checked for tightness.

All vent plugs and level indicators to be maintained for healthiness. Maintaining level of electrolyte in flooded cells is of very important to avoid sulphation and permanent damage of the cells. Distilled water is to be added to make up to the level.

If VRLA battery is used, the battery room temperature is to be maintained using air conditioner as the temperature plays vital role on the performance of the battery.

(a) Battery Chargers

Battery charger is to be maintained for keeping the battery always charged and also to supply normal DC load for operation. If the charge / discharge ammeter does not show current on the charge side, then the float charger is not giving output. Defect should be located and corrected. In case of failure of float charger, the boost charger may be used as float charger as per design.

Charger panel is to be kept clean, free from dust and all terminals to be checked periodically for tightness. The battery maintenance and condition monitoring is to be carried out as per schedule to keep the DC system in healthy condition.

(b) BATTERY CAPACITY TESTING

This procedure describes the recommended practice of capacity testing by discharge in the battery. All testing should follow the safety requirements.

(c) INITIAL REQUIREMENTS

The following list gives the initial requirements for all battery capacity tests except otherwise noted.

(a) Equalize the battery if recommended by the manufacturer and then return it to float for a minimum of 72 h, but less than 30 days, prior to the start of the test.

(b) Check all battery connections and ensure that all connections are proper and clean.

(c) Record the specific gravity and float voltage of each cell just prior to the test.

(d) Record the electrolyte temperature of lO% or more of the cells to establish 31 average temperature.

(e) Record the battery terminal float voltage

(f) Take adequate precautions (such as isolating the battery to be tested from the batteries and critical loads) to ensure that a failure will not jeopardize other systems or equipment.

CHAPTER 2

MAIN AND AUXILIARY SUBSTATION EQUIPMENT: GENERAL TECHNICAL REQUIREMENTS

1. INTRODUCTION

The chapter briefly outlines the general technical requirements of the important equipment generally installed in EHV sub-stations.

2 CIRCUIT BREAKERS

Circuit Breaker is a switching device capable of making, carrying and breaking currents under normal circuit conditions and also making, carrying for a specified time breaking currents under short circuit conditions. Circuit breakers of the types indicated below are being presently used in India.

Table- 1

36 kV	- Minimum oil, Vacuum and Sulphur hexa fluoride (SF6)
72.5 kV	- Minimum oil, Air blast and Sulphur hexa fluoride (SF6)
145 kV and 245	- Minimum oil, Air blast and Sulphur hexa fluoride (SF6)
420 kV	- Minimum oil, Air blast and Sulphur hexa fluoride (SF6)
800 kV	- Sulphur hexa fluoride (SF6)

(a) Rated Operating Sequence (Duty Cycle)

The operating sequence denotes the sequence of Opening and Closing operation which the breaker can perform. The, operating mechanism experiences severe mechanical stresses during the auto re-closure duty. The circuit breaker should be able to perform the operating sequence as below.

(i) O-t-CO-T-CO
0 - Opening Operation
C - Closing Operation
CO - Closing followed by opening
t - 0.3 Sec. for rapid or auto re-closures T - 3 minutes

(ii) CO-t - CO where t = 15 sec. for circuit breaker not to be used for auto-reclosure

Table 2

Rated voltage (kV)	Rated short circuit breaking current (kA)	Rated normal current (Amp.)							
36	8	630							
	12.5	630		1250					
	16	630		1250	1600				
	25			1250	1600		2500		
	40			1250	1600		2500		
72.5	12.5		800	1250					
	16		800	1250					
	20			1250	1600	2000			
	31.5				1600	2000			
145	12.5		800	1250					
	20			1250	1600	2000			
	25			1250	1600	2000			
	31.5			1250	1600	2000			
	40				1600	2000		3150	
245	20			1250					
	31.5			1250	1600	2000			
	40				1600	2000		3150	
420	31.5				1600	2000			
	40				1600	2000		3150	
	50					2000		3150	4000
	63							3150	4000
800	40					2000		3150	

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

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

Pre-insertion resistor, if required shall normally have following values. However, precise value shall be decided based on transient over voltage studies.

420 kV	300-450 ohms
800 kV	300-400 ohms

(c) Operating Mechanism

The circuit breaker may be operated by anyone of the following operating mechanisms or a combination of them:

(a) Pneumatically operated mechanism

(b) Spring operated mechanism

(c) Hydraulically operated mechanism

3. DISCONNECT SWITCHES/ISOLATORS AND EARTHING SWITCHES

Disconnect switches are mechanical devices which provide in their open positions, isolating distances meeting the specified requirements. A disconnect switch can open and close a circuit when either a negligible current has to be broken or made or when no significant change in voltage across the terminals of each pole of the disconnect switch occurs. It can also carry currents under normal circuit conditions and carry for a specified time the short circuit currents. Disconnect switches are used for transfer of load from one bus to another and also to isolate equipment for maintenance.

The location of disconnect switches in substations affects not only the substation layouts but maintenance of the disconnect contacts also. In some substations, the disconnect switches are mounted at high positions. Although such substations occupy smaller areas, the maintenance of disconnect switches in such substations is more difficult and time consuming.

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

Various types of disconnect switches presently being used are given below:

36 kV	Horizontal Double Break
72.5 kV	Horizontal Double Break/ Center Break
145 kV	Horizontal Double Break/ Center Break
245 kV	Horizontal Double Break/ Center Break
420 kV	Horizontal Center Break/Pantograph, Double Break
800 kV	J Vertical Break

4. INSTRUMENT TRANSFORMERS

Instrument transformer is device used to transfer the current and voltage in the primary system to values suitable for the necessary instruments, meters, protective relays etc. They also serve the purpose of isolating the primary system from the secondary system.

Current transformer may be either of the bushing type or wound type. The bushing types are normally accommodated within the turret of main transformer and the wound types are invariably separately mounted. The location of the current transformer with respect to associated circuit breaker has an

important bearing upon the protection scheme as well as layout of substation.

The voltage transformer may be either of the electro-magnetic type or the capacitor type. The electro-magnetic type VTs are commonly used where higher accuracy is required as in the case of revenue metering. For other applications capacitor type is preferred particularly at voltages above 132 kV due to lower cost and it also serves the purpose of a coupling capacitor for the carrier equipment. For ground fault relaying, an additional core or a winding is required in the VTs which can be connected in open delta. The voltage transformers are connected on the feeder side of the circuit breaker. However, another set of voltage transformer is normally required on the bus-bars for synchronization.

Typical ratings for instrument transformers normally used are given below:

(a) Current Transformer

1	Nominal system voltage	765 kV	400 kV	220 kV	132 kV	66 kV	33 kV
2.	Highest system voltage	800 kV	420 kV	245 kV	145 kV	72.5 kV	36 kV
3.	Frequency	50 Hz	50 Hz	50 Hz	50 Hz	50 Hz	50 Hz
4.	Basic insulation level (kV peak)	2100	1425	1050	650	330	170
5.	Power frequency withstand strength	830	630	460	275	140	70
6.	Rated primary current	3000-2000-1000 A	2000-1000-500 A	800A/ 600A	800A/ 600A	400A/ 200A/	800A/ 400A/ 200A
7.	Rated burden for metering	20 VA	20 VA	20 VA	20 VA	20 VA	20 VA
8.	Rated short time current for 1 sec.	40kA	40 kA	40 kA	31.5 kA	31.5 kA	25 kA
9.	Secondary current amps.	1	1	1	1	1	1
10.	No. of cores	5	5	5	3	3	3
11.	Maximum temperature rise over design ambient temp	As per IEC : 60044-1					
12.	Type of insulation	Class A					
13.	Instrument safety factor	<10	<10	<10	<10	<10	<10	<10
14.	Class of accuracy (a) Metering Core (b)Protection Core	 0.2 3P	 0.2 3P	 0.2 3P	 0.2 3P	 0.2 3P	 0.2 3P	 0.2 3P

(b) Voltage Transformers

1.	Type	Single phase, oil filled, Natural oil cooled			
2.	Nominal system voltage	220 kV	132 kV	66 kV	33 kV
3.	Highest system voltage	245 kV	145 kV	72.5 kV	36 kV
4.	Insulation leve (a) Rated one min. Power Frequency withstand Voltage kV (rms) HV Terminal to earth	460	275	140	70
	(b) Impulse withstand voltage (1.2/50 micro sec. wave shape) kV (Peak)	1050	650	325	170
5.	Over voltage factor (a) Continuous (b) 30 sec.	 1.2 1.5	 1.2 1.5	 1.2 1.5	 1.2 1.5
6.	No. of secy. winding	Three	Three	Three	Three
7.	Voltage ratio	220 kV/ 3	132kV/3	66 kV/ 3	33 kV/ 3
		110 V/ 3	110 V/ 3	110 V/ 3	110 V/ 3
8.	Rated burden (not less than) (a) Core I (Metering) (b) Core II (Protection) (c) Core III (Open Delta	 100/50 VA 100/50VA 100/50 VA	 100/50VA 100/50VA 100/50VA	 100/50VA 100/50VA 100/50VA	 100/50VA 100/50VA 100/50VA
9.	Connection	Y/Y/open delta			
10.	Class of accuracy				
	(a) Core I (Metering)	0.2	0.2	0.2	0.2
	(b) Core II (Protection)	3P	3P	3P	3P
	(c) Core III (Open Delta)	3P	3P	3P	3P

(c) Capacitor Voltage Transformer

Voltage	765 kV	400 kV	220 kV	132 kV
Transformation ratio	765√ 3 kV 110/√3V	400√3 kV 110/√3V	220√3 kV 110/√3V	132√3 kV 110/√3V
No. of secondary winding	3	3	3	3
Voltage factor	1.2 Continuous & 1.5 for 30 seconds			
Rated capacitance	4400/8800 pF	4400 PF/8800 pF	4400 pF	4400 pF
Rated burden	50 VA	100 V A/50 VA	IOOVA/50 VA	100 V A/50 VA
Insulation Level (a) Rated one minute power frequency with stand voltage kV (rms)	830	630	460	275
(b) Impulse withstand voltage (1.2/50) micro second wowe shaped kV (Peak)	2100 1550	1425 1050	1050 -	650 -
(e) Switching Impulse withstand voltage (250/2500 Microv micro secs	1550	1050	-	-
Class of accuracy (a) Core I (Metoring) (b) Core 11(Protection) (e) Core III (open Delta)	0.2 3P 3P	0.2 3P 3P	0.2 3P 3P	0.2 3P 3P

5. TRANSFORMERS

General technical requirements of the transformers presently being used are given below:

33 kV Power Transformers

Three Phase Rating MV A	Voltage Ratio	Cooling
1.0	33/11	ONAN
1.6	33/11	ONAN
3.15	33/11	ONAN
4.0	33/11	ONAN
5.0	33/11	ONAN
6.3	33/11	ONAN
8.0	33/11	ONAN
10.0	33/11	ONAN

Vector Group: Dyll

66 kV Power Transformers

Three Phase Rating MV A	Voltage Ratio	Cooling
6.3	66/11	ONAN/ONAF
8.0	66/11	ONAN/ONAF
10.0	66/11	ONAN/ONAF
12.5	66/11	ONAN/ONAF
20.0	66/11	ONAN/ONAF

Vectcr Group: YyO

145 kV Power Transformers

Three Phase Rating MVA	Voltage Ratio	Impedance Voltage (Percent)	Cooling
Two Winding			
20	132/33	10	ONAN/ONAF
40	132/33	10	ONAN/ONAF

Vector Group: YNynO or YNdl1

245 kV Power Transformers

(A)Two Winding			
50	220/66 kV	12.5	ONAN/OF AF or ONAN/ODAF
100	220/66 kV	12.5	ONAN/OF AF or ONAN/ODAF ONAN/OFAF or ONAN/ODAF
100	220/33 kV	15.0	

(B) Interconnecting Auto Transformers			
35,50	220/33	10	ONAN/ONAF
50	220/132	10	ONAN/ONAF
100	220/1 32	12.5	ONAN/ONAF/OF AF Or ONAN/ONAF/ODAF
160	220/132	12.5	ONAN/ONAF/ODAF or ONAN/ONAF/ODAF
200	220/1 32	12.5	ONAN/ONAF/OF AF or ONAN/ONAF/ODAF

Vector Group: YNaodl1

Auto Transformers (420 kV voltage level) (Constant Percentage Impedance)

Three-Phase HV/IV/LV	**Voltage Ratio**	**Tapping Range percent**	**Per Cent**	**Impedance**	**Voltage**	**Cooling**
MVA			**HV-IV**	**HV-LV**	**IV-LV**	
100/1 00/33.3	400/132/33	+ 10% to -10% 16 steps of 1.25%	12.5	27	12	ONAN/ONAF
200/200/66.7	400/132/33	+10% to -10% 16 steps of 1.25%	12.5	36	22	ONAN/ONAF Or ONAN/ONAF
250/250/83.3	400/220/33	+10% to -10% 16 steps of 1.25%	12.5	45	30	ONAN/ONAF Or ONAN/ONAF
315/315/1 05	400/220/33	+10% to -10% 16 steps of 1.25%	12.5	45	30	ONAN/ONAF Or ONAN/ONAF
500/500/166.7	400/220/33	+10% to -10% 16 steps of 1.25%	12.5	45	30	ONAN/ONAF Or ONAN/ONAF
630/630/210	400/220/33	+ 10% to -10% 16 steps of 1.25%	12.5	45	30	ONAN/ONAF Or ONAN/ONAF

Vector Group: YNaodll

Auto Transformers (800 kV voltage level)

Ratings						
Three phase rating HV/IV/LV MVA	**Voltage Ratio kV**	**Tapping range (Percent)**	**Percent**	**Impedance**	**Voltage**	**Cooling**
			HV/IV	**HV/LV**	**IV/LV**	
315/315/105	765/220/33	+4.5% -7.5% 24 steps	12.5	40	25	ONAN/OFAF or ONAN ODAF or ODAF
630/630/210	765/400/33	-do-	12.5	60	40	-do-
750/750/250	-do-	-do-	-do-	-do-	-do-	-do-
1000/1 000/333.3	-do-	-do-	14.0	65	45	-do-
1500/1500/500	-do-	-do-	-do- tolerance	-do- ±10%	-do- ±15%	-do- ±15%

Vector Group: YNaodll

6 PROTECTION AGAINST LIGHTNING

A substation has to be shielded against direct lightning strokes either by provision of overhead shield wire/earthwire or spikes (masts).

Typical technical parameters adopted for surge arrestors are as follows:

Sl.No.	Item	765 kV	400 kV	220 kV	132 kV	66 kV
1.	System voltage kV	765	400	220	132	66
2	Highest system voltage kV	800	420	245	145	72.5
3.	Rated voltage Arrestor kV	624	390/360/336	198/216	120	60
4.	Nominal discharg current	20kA	----------10kA----------			
5.	Class	Class 5	Class 3	Class 3	Class 3	
6.	Pressure relief class	----------A----------				

7. INSULATORS

The creepage distances for the different pollution levels are provided according to the following table:

Pollution level	Creepage distance (mm/kV)
Light	16
Medium	20
Heavy	25
Very Heavy	31

For determining the creepage distance requirement, the highest line-to-line voltage of the system forms the basis.

The following types of insulators are normally used:

(A) Support Insulators:

(i) Cap and pin type
(ii) Solidcore type
(iii) Polycone type

(B) Strain Insulators:

(i) Disc insulators
(ii) Long rod porcelain insulators
(iii) Polymer insulators

8. PROTECTION

(A) Line Protection

(i) *400 kV Lines*

Generally two independent high speed main protection schemes called Main-I and Main-II with atleast one of them being carrier aided non-switched three zone distance protection are adopted. The other protection may be a phase segregated current differential (this may require digital communication) phase comparison, directional comparison type or a carrier aided non-switched distance protection. Further, if Main-I and Main II are both distance protection schemes, then they should be preferably of different type. However, they need not necessarily be of different make. Both the protections should be suitable for single and three phase tripping. In addition to the above following shall also be provided:

(i) Two stage over-voltage protection.
(ii) Auto reclose relay suitable for I ph/3 ph reclosure.
(iii) Sensitive IDMT directional Overcurrent E/F relay.

(ii) ***220 k V Lines***

There should be atleast one carrier aided non-switched three zone distance protection scheme. In addition to this another non-switched/switched distance scheme or directional over current and earth fault relays should be provided as back up. Main protection should be suitable for single and three phase tripping. Additionally, auto-reclose relay suitable for I ph/3 ph (with dead line charging and synchro check facility) reclosure shall be provided. In case of both line protections being Distance Protections, IDMT type E/F relay shall also be provided additionally.

(B) Bus bar Protection

Bus bar protection is required to be provided for high speed sensitive clearance of bus bar faults by tripping all the circuit breakers connected to faulty bus.

(C) Transformer Protection

Generally following protective and monitoring equipment for transformers of 400 kV and 220 kV class are provided:

(i) Transformer differential protection
(ii) Overfluxing protection
(iii) Restricted earth-fault protection
(iv) Back-up directional O/C + E/F protection on HV side
(v) Back-up directional O/C + E/F protection on LV side

(vi) Protection and monitors built in to Transformer (Buchholz relay, Winding and Oil Temperature Indicators, Oil Level Indicator, OLTC Oil Surge Relay and Pressure Relief Device)
(vii) Protection for tertiary winding
(viii) Overload alarm
(ix) Circulating current Differential Protection (Inter-turn phase fault)

(D) Local Breaker Back-up Protection

In the event of any circuit breaker failing to trip on receipt of trip command from protection relays, all circuit breakers connected to the bus section to which the faulty circuit breaker is connected are required to be tripped with minimum possible delay through LBB protection.

All protections need to be tested periodically for functional operation and record of testing should be provided in the substation for future records.

9. CLEARANCES

Minimum clearances required for substation upto 800 kV voltage level are as follows:

Highest system voltage (kV)	Basic Insulation level (kVp)	Switching impulse voltage (kVp)	Minimum clearances $		Sectional clearances (mm)
			Between Phase And Earth (mm)	Between Phases (mm)	
36	170	-	320	320	2800
72.5	325	-	630	630	3000
145	550 650	-	1100 1300	1100 1300	4000 4000
245	950 1050	-	1900 2100	1900 2100	4500 5000
420	1425	1050	3400*	-	6500
		(Ph-E) 1575 (Ph-Ph)	-	4200**	
800	2100	1550 (Ph-E) 2550 (Ph-Ph)	6400*	9400**	10300

* Based on Rod-structure air gap.
** Based on Rod-Conductor air gap.

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

10. Earthing

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

(a) The impedance to ground should be as low as possible. In the substations with high fault levels, it should not exceed 1 ohm and in the substations with low fault levels it should not exceed 5 ohms.

(b) The step and touch potentials should be within safe limits.

To meet these requirements, an earthing system comprising an earthing mat buried at a suitable depth below ground, supplemented with ground rods at suitable points is provided in the substation. The non-current-carrying parts of all the equipment in the substation and neutral of the transformer are connected to that earthing mat so as to ensure that under fault conditions, none of these parts is at a potential higher than that of the earthig mat. The ground rods are helpful in maintaining low value of resistance which is particularly important for installations with high system earth fault currents.

All substations should have provision for earthing the following:

(a) The neutral points of equipment in each separate system. There should be independent earth for the different systems. Each of these earthed points should be interconnected with the station earthing mat.

(b) Equipment framework and other non-current carrying parts.

(c) All extraneous metal framework not associated with equipment.

(d) Surge arresters: These should have independent earthing which should in turn be connected to the station grounding grid or earthmat.

Switchyard areas are usually covered with about 10 cm of gravel or crushed rock which increases the safety of personnel against shocks, prevents the spread of oil splashes and aids in weed control. This entails the provision of service roads for movement of vehicles required for carrying the equipment from the switchyard to service bay and back.

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

11. ***Fire Fighting System***

All substations should be equipped with fire fighting systems conforming to the requirements given in IS: 1646-1982 and Fire Protection Manual Part-I issued by Tariff Advisory Committee of Insurance Companies.

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

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

Although the replacement of bulk-oil and minimum oil circuit breakers by vacuum type and SF6 gas circuit breakers has reduced the risk of fires in electrical installations, considerable risk still exists on account of transformers, reactors, cables etc. which contain combustible insulating materials. It is therefore necessary to provide efficient Fire Protection Systems in the Electrical Installations. Fire Protection System consists of the following:

(i) Fire 'Prevention
(ii) Fire Detection & Annunciation
(iii) Fire Extinguishing

(i) *Fire Prevention*

Fire prevention is of utmost importance and should be given its due if risk of occurrence of fires has to be eliminated/minimized. The safety and preventive measures applicable for substations as recommended by the relevant authorities must be strictly followed while planning the substations.

All fire fighting equipment and system should be properly maintained. Regular mock drills should be conducted and sub station staff made aware of importance of fire protection and imparted training in proper use of the fire fighting equipment provided in substation *I* control room.

(ii) *Fire Detection and Annunciation*

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

(i) Ionization type
(ii) Smoke type
(iii) Photoelectric type
(iv) Bimetal type
(v) Linear heat Detection type/Quartzoid bulb type

(iii) *Fire Extinguishing*

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

(i) Hydrant System
(ii) High Velocity Water Spray System
(iii) Portable Fire Extinguishers

(iv) Fire Buckets.

(a) *Hydrant System*

This type of Fire Protection System is provided for Buildings.

The system consists of a network of laid MS Pipes fed from storage tank and water hydrant outlets provided at suitable locations. Fire fighting canvas pipes are provided in appropriate cabinets near the hydrants which can be accessed by breaking the glass of the storage unit. The canvas pipes are connected to the hydrants and water can be sprayed on the fire after opening the valve of the hydrant.

(b) *High Velocity Water (HVW) Spray System*

This type of Fire Protection System is provided for the following types of equipment:

(i) Power Transformers, both auto and multi-winding
(ii) Shunt Reactors

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

(c) *Portable Fire Extinguishers*

The portable fire extinguishers are strategically placed in the control room as well as the switched for easy accessibility and are used for extinguishing small fires or fires in a restricted area.

The following types of portable fire extinguishers are normally used.

(i) Chemical Foam type
(ii) Mechanical Foam type
(iii) Dry Powder cartridge type
(iv) Carbon Dioxide type.

Fire Buckets

These are specially fabricated buckets which filled with river sand and kept in the substation on stands. These buckets are provided with an additional handle on the side so that the sand can be easily sprayed on the fire.

These buckets are used for extinguishing fires on the ground.

Water Supplies

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

(i) One-hour pumping capacity of Hydrant System or 135 cum whichever is more
(ii) Half-an-hour water requirement for single largest risk covered by HVW Spray System.

Instrumentation and Control

HVW Spray System should include suitable instrumentation and necessary controls to make the system efficient and reliable. There should be local control panels for each of the pumps individually as also for the operation of deluge valve of the HVW Spray System. There should be a common control panel for the Jockey Pump and Air Compressors. Main annunciation panel should be provided in the control room with provision for repeating some annunciation from the pump house.

A diesel engine operated water pump is also provided for back-up in case electrically operated motor-pumps fail due to interruption in electricity supply.

Filtration/Hot Oil Circulation

- Connect bottom filter valve of tank to inlet point of filter machine.

- Connect top filter valve of tank to outlet of vacuum filter machine and start oil circulation

- The filter outlet temperature should be limited to 60 ~ 70^0 C.

- Continue filtration for 4 cycles whole oil should be circulated 4 times.

- Oil circuit should include a vacuum chamber in which oil drawn from the transformer is sprayed and the moisture and gases are released from the oil are extracted by the vacuum pump.

- Oil drawn from transformer is passed through a filter press before being admitted to the vacuum chamber to remove impurities.

- A minimum capacity of 6000 litres per hour is recommended for the circulation equipment.

- Cooler connection at inlet shall be kept closed to minimize loss of temperature during circulation. Outlet valve shall be kept open to allow expansion of oil inside the cooler.

- Coolers also shall be included in the hot oil circulation towards the end of the process.

- Drain the oil by simultaneously admitting dry air or nitrogen gas from the top. This is to avoid winding insulation coming in contact with moisture.

- Apply vacuum of 1.0 torr or better and maintain for 12 Hrs. (1 mm of Hg)

- Inject oil under vacuum upto a level of approximately half of the conservator.

- Repeat vacuum/hot oil circulation cycle till required dryness is obtained. The oil temperature shall not increased more than 75^0 C in any case.

- Normally 3 or 4 cycles of hot oil circulation and evacuation will be sufficient to obtain the required dryness for the insulation.

- Dryness of insulation is determined by measuring insulation resistance of transformer winding.

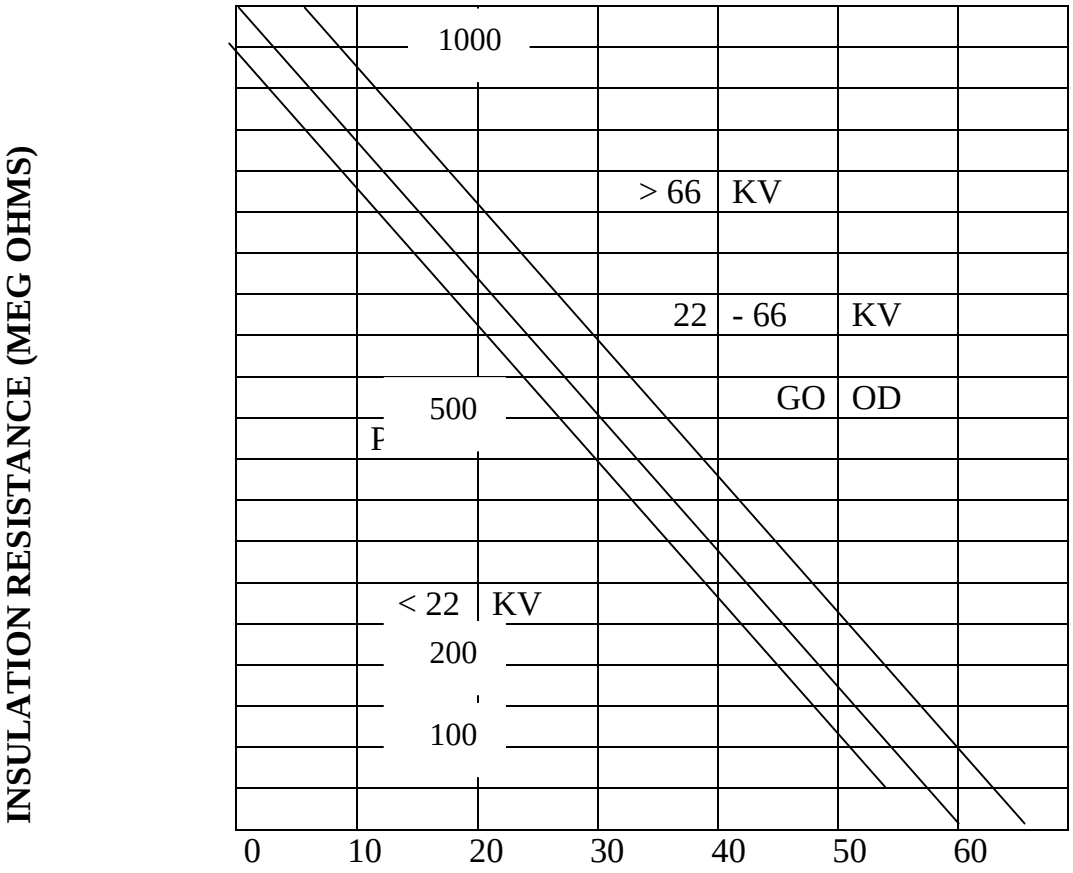
- Insulation resistance between each pair of windings and also between windings and earth shall be measured by using a 2000 V megger. Readings shall be comparable with the factory test results.

- Direct heating of transformer is not recommended for drying out at site.

- Oil samples shall be tested for moisture content, (below 20/15/10 ppm for 145/220/400 KV class respectively). Break down voltage (more than 60 KV at 2.5 mm gap). Resistivity ($\geq 10^{12}$ ohm meter) before final oil filling.

- Do not measure insulation resistance when the transformer is under vacuum.

Note : As the temperature of oil rises the megger value drops down upto minimum value and after remaining some hours at minimum value when it starts rising again then it should be understood as the circulation/filtration is complete.



Variation of Insulation Resistance with Temperature

Dielectric Strength of Insulating Oil (12.5mm dia. Spheres, 2.5 mm gap)

No.	Nominal Voltage of Transformer	Dielectric Strength of Insulating Oil (KV)
1.	145 KV class and above	More than 50
2.	72.5 KV class to less than 145 KV	More than 40
3.	Less than 72.5 KV class	More than 30

Acid Content of Insulating Oil (By neutralization)

No.	Judgment	Acid Content of Oil (mg KOH/g)
1.	Good	Less than 0.2
2.	Replace or do filtrations	0.3 ~ 0.5
3.	Replace immediately	Above 0.5

Resistivity of Insulating Oil

No.	Judgment	Resistivity of oil at 90^0 C (Ω - cm)
1.	Good	More than 0.1×10^{12}
2.	Fair	1×10^{11} to 0.1×10^{12}
3.	Poor	Less than 0.1×10^{11}

Water Content

No.	Nominal Voltage of Transformer	Water Content (ppm)
1.	145 KV class and above	20 ppm max.
2.	Below 145 KV class	40 ppm max.

Dielectric Dissipation Factor

No.	Nominal Voltage of Transformer	At 90^0 C, 40 ~ 60 Hz
1.	145 KV class and above	0.2 max.
2.	Below 145 KV class	1.0 max.

Oil Handling Capacity Rating of Filtering Machine

No.	Rating of T/F	Capacity of oil in T/F Kilo Litre	Oil handling Capacity of machine Ltr./hr
1.	5/8 MVA 33/11 KV	3/5	1000 Ltr/hr.
2.	20/40 MVA 132/33 KV	18/20	4000 Ltr/hr.
3.	100/160 MVA 220/132 KV	45/50	6000 Ltr/hr.
4.	240/315 MVA 400/220 KV	70/90	6000 Ltr/hr.

CHAPTER 3

MAINTENANCE SCHEDULES FOR EHV S/S EQUIPEMENTS

Maintenance schedules for various equipments of EHV Substation are given below:

A. TRANSFORMERS AND REACTORS

(i) Without Shut Down Activities

1	Checking of bushing oil level	M
2	Checking of oil level in conservator	M
3	Checking of oil level in OLTC conservator	M
4	Checking of leaks	M
5	Checking condition of silica gel in breather	M
6	Checking condition of silica get in breather	M
7	Checking of oil level in oil seal of breather	M
8	Testing of oil for DGA and other oil parameters	HY
9	Vibration measurements (for Shunt Reactors only)	2Y

(ii) Shut Down Activities

1	BDV, ppm of OlTC Diverter Switch compartment oil (Less frequently if operations are not more	Y
2	External cleaning of radiators	Y
3	Cleaning of all bushing (if required)	Y
4	Checking of auto starting of cooler pumps and fans	Y
5	Marshalling boxes of transformer/reactor and OLTC (i) Cleaning of marshalling boxes of transformer/reactor and OLTC (ii) Tightening of terminations (iii) Checking of contactors, space heaters, illumination, etc.	Y Y Y Y
6	Maintenance of OLTC driving mechanism	Y
7	Checking of all remote indications (WTI and Tap position indicator) and top up oil in pockets, if required	Y
8	Electrical checking/testing of pressure relief device, Buchholz realy, OLTC surge relay/checking of alarm/trip and checking /replacement of the gaskets of the terminal box	Y
9	Checking/testing of Buchholz relay by oil draining	Y
10	Frequency response analysis	SOS
11	Tan measurement for bushings	Y
12	Recovery voltage measurement	SOS
13	IR measurement of winding (Polarization Index and D.A.Ratio)	2Y
14	Tan measurement of Windings	2Y
15	Checking and cleaning of diverter contacts	2Y
16	Checking and calibration of OTI, WTI	2Y
17	Measurement of windings resistance at all tap positions	4Y
18	Filtration/degassing of main tank oil	SOS
19	Testing of bushing CTs	SOS
20	Filtration/replacement of oil of OLTC	SOS
21	Measurement of windings ratio	SOS
22	Checking of earthing connections	Y

M-monthly, QY-quarterly, Y-yearly, 2Y-once in 2years, 3Y-one in three years, 4Y-one in 4 years, SOS-as and when required.

Note

- Insulation resistance measurement, tan δ of winding/busing, winding resistance at all taps to be carried out once before expiry of warranty and then to be continued as per schedule.
- Vibration measurement for reactor to be carried out initially after 3 months and 6 months after commissioning and then to be continued as per schedule.

B. CIRCUIT BREAKERS

(i) Breaker Operation Checks

1	CB operating timings (Main, PIR, Aux.)	Y
2	Static contact resistance measurement	2Y
3	Dynamic contact resistance (DCRM), contact travel, contact speed, contact wipe, arcing contact length	2Y
4	Checking of pole discrepancy relay	Y
5	Functional checks, duty cycle operation including rapid re-closing (O-o.3s-CO)	Y
6	Checking of all operation lock=outs including SF_6 density monitor	Y
7	Checking of all interlocks	Y
8	Checking of pressure settings	Y
9	Cleaning of breaker interrupter, support insulators and grading capacitors	Y

(ii) Measurement/Testing

1	Checking of close/trip coil currents	Y
2	Checking of healthiness of operation counter	Y
3	Capacitance and tan δ measurement of grading capacitors	4Y

(iii) Control cabinet

1	Checking of tightness of all cable terminations in MB	Y
2	Checking of door sealing gaskets and replacement, if necessary	Y
3	Repainting of metallic surfaces	SOS
4	Checking of space heater (before monsoon)	Y

(iv) SF_6 Circuit Breakers

1	Checking of oil leaks from grading capacitors	M
2	SF6 gas leakage test	SOS
3	Dew point measurement of SF6 gas	3Y
4	Checking tightness of foundation bolts	Y

(v) Air Blast Circuit Breakers

1	Checking of oil leak from grading capacitors	M
2	Checking ofair compressor for oil level, oil quality, air filter, V-belt tension	QY
3	Maintenance of air dryers	HY
4	Functional checking of auto starting of air compressors and dryers	Y
5	Checking of air pressure drop during duty cycle operation	Y
6	Dew point measurement of operating air at the outlet of air dryer	Y
7	Checking of tightness of foundation bolts	Y
8	Air (pressure0 leakage check)	SOS
9	Overhauling of compressors	SOS

(vi) Minimum Oil Circuit Breakers

1	Checking of oil leak from grading capacitors	M
2	Checking for oil leakage/oil level and N2 pressure (if applicable)	M
3	Testing of oil for BDV	After 15 fault trips or yearly
4	Maintenance of breather and change of silica get	SOS

(vii) Vacuum Circuit Breakers

1	Cleaning of control cubicle and checking for loose connections	QY
2	Checking of ON/OFF indicators, spring charge indicator and checking manual and electrical operation	HY
3	Checking vacuum of interrupter by application of high voltage by disengaging with operating mechanism	Y
4	Checking erosion of contacts by erosion mark on operating rod or measurement of gap specified n closed position of contacts (wherever provide)	Y
5	Checking tightness of foundation bolts	Y
6	Replacement of vacuum interrupter	SOS

(viii) Hydraulic Operating Mechanism

1	Checking of oil level and replenishment/topping up, if necessary	M
2	Checking of oil leaks	M
3	Checking of oil pressure drop during duty cycle operation check	Y
4	Checking of auto-starting/stopping of oil pump, pressure switch settings,etc.	Y
5	Checking of healthiness of accumulator by checking the pre-charging pressure when building up pressure from zero	Y
6	Checking of operation of safety value	Y

(ix) Pneumatic Operating Mechanism

1	Checking of air compressor for oil level, oil quality, air filter, V-belt tension	QY
2	Maintenance of air dryer, if provided	HY
3	Functional checking of auto-starting of air compressors and dryers	Y
4	Checking of air pressure drop during duty cycle operation	Y
5	Overhauling of compressors	SOS

(x) Spring Operated Mechanism

1	Oil leakages from close and open dashpots, replace the same if leakage observed	Y
2	Greasing/lubrication of gears and various latches in the operating mechanism	Y
3	Checking of play of gaps in catch gears	Y
4	Maintenance of spring charging motors, cleaning of carbon brushes and contactors	Y
5	Replacement of oil in dashpot	SOS

C. CURRENT TRANSFORMERS

1	Checking of bellow expansion	M
2	Visual inspection of CT for oil leakage and crack in insulator, etc.	M
3	Thermovision scanning of CT	Y
4	Checking of oil leakage in terminal box	Y
5	Checking of primary connection strips, if provided externally	Y
6	N2 pressure checking	2Y
7	Measurement of Tan δ and capacitance	2Y*
8	I R measurement (DAR)	2Y
9	Checking of primary connection strips, if provided internally	SOS
10	Measurement of CT secondary resistance	SOS
11	Magnetization characteristics	SOS
12	CT ratio test	SOS
13	DGA and testing of other parameters of oil	SOS
14	Checking of burden on the secondary winding	SOS

* To be repeated before one year from commissioning and then a per schedule

(i) Marshalling Box

1	Checking of oil leakage in terminal box	M
2	Checking of healthiness of gaskets	Y
3	Checking of space heater and illumination	Y
4	Checking the tightness of all connections including earthing of PF terminal	Y
5	Cleaning of marshalling box and junction box	Y

D. POTENTIAL TRANSFORMERS/CAPACITANCE VOLTAGE TRANSFORMERS/COUPLING CAPACITORS

1	Checking of oil leaks	M
2	Measurement of voltage at Control room panel	HY
3	Visual checking of earthing HF point (in case it is not being used for PLCC)	Y
4	Checking for any breakage or cracks in cementing joint	Y
5	Cleaning of CVT capacitor stacks and tightness of terminal connections	Y
6	Theromovision Scanning of Capacitor stacks	Y
7	Capacitance and Tan δ measurement	3Y*
8	Testing of EMU tank oil for BDV (if oil found discolored)	SOS
9	Checking for rust and painting	

*** To be repeated before 1 year from commissioning and then as per schedule. This test is not possible to be conducted at site if isolation of neutral of intermediate PT is not possible at site.**

E. DISCONNECTORS/ISOLATORS AND EARTH SWITCHES

(i) Main Contacts

1	Cleaning and lubrication of main contacts, pins and bearings	Y
2	Checking of tightness of bolts, nuts and pins, etc.	Y
3	Cleaning of support insulators and checking of insulator cracks, if any	Y
4	Checking of interlocks	Y
5	Checking of earth connection of structure	Y
6	Operation check of isolators	Y
7	Checking of alignment	2Y
8	Main contact resistance measurement	2Y

(ii) Operating Mchanism

1	Checking and lubrication of linkages including transmission gears	Y
2	Checking and tightening of stopper bolts	Y
3	Cleaning of auxiliary switch contacts and greasing with silicon grease	Y
4	Lubrication of operating mechanism hinges, lock joints on levers, Bearings	Y
5	Checking of all mounting bolts for tightness	Y
6	Checking of healthiness of door gaskets	Y
7	Checking of earth connection of MOM box	Y
8	Checking of tightness of electrical connections	Y
9	Checking of space heaters and illumination	Y

(iii) Earth Switch

1	Checking and alignment of earthing blades	Y
2	Cleaning of contacts and lubrication	Y
3	Operation of earthing switch	Y
4	Checking of aluminum/copper flexible connectors	Y
5	Checking of earth connections of earth switch, structure and MOM box	Y
6	Checking of tightness of bolts, nuts and pins etc. and lubrication of pins and bearings	Y
7	Contact resistance measurement	2Y

F. SURGE ARRESTERS

1	Checking of leakage current (Third harmonic resistive current)	Y
2	Testing of counters and leakage current meters	Y
3	Cleaning of insulator	Y
4	Checking of earth connections between surge arrester, surge monitor and earth	Y
5	Measurement of capacitance and Tan δ and IR of each stack	SOS

G. BUS-BAR, JUMPERS, CONNECTORS, CLAMPS, SWITCHYARD ILLUMINATION, ETC.

1	Measurement of station earth resistance	Y
2	Cleaning of insulators	Y
3	Checking of insulators for cracks	Y
4	Thermovision scanning of all conductor joints, terminal connectors/clamps	Y
5	Checking of earthing connection of all structures	Y
5	Removal of hot spots	SOS
6	De-weeding of switchyard	SOS
7	Repainting, rust removal of all structures, equipments, etc.	SOS
8	Checking of switchyard lighting	SOS

H. CAPACITORS

1	Checking of leakage of oil	M
2	Unbalance in capacitors by checking open delta voltage	M
3	Physical checks, Tightness	Y
4	IR value	Y
5	Leakage current measurement	Y
6	Cleaning of insulators/bushings and tightening of connections	Y
7	Capacitance measurement of capacitor cells	Y
8	Checking of Protection relays for adopted setting	Y
9	Checking tightness of earth connection and foundation bolts	Y

I WAVE TRAPS

1	Tightness and cleanliness	Y
2	General inspection/cleaning of tuning unit	Y
3	Thermovision scanning of joints	Y
4	Cleaning of post insulators (if provided)	Y
5	Repair of bird guard	SOS

J. PROTECTION SYSTEMS

1	Testing of Dr/EL with time synchronization and unit	M
2	Calibration of tariff energy meters	-
3	Checking of voltage (in service) for relays	Y
4	Checking of DC logic circuits for trip and annunciations including timers by simulation	Y
5	Calibration of panel meters (Indicating/recording instruments along with the transducers)	SOS

(i) Distance Protection

1	Reach check for all 4/5 Zones*	Y
2	Times measurement	Y
3	Power swing blocking check	Y
4	Switch on the fault (SOTF) check	Y
5	Level detectors of pps.	Y
6	Fuse failure check	Y
7	Polarization check	Y
8	Negative phase sequence (NPS) detector check	Y
9	VT fuse failure check	Y

*** Includes Z1,Z2,Z3 and Z3 (reverse) or z 4 z 5 (reverse)**

Notes

- The above schedule for Distance relay is generic in nature and the manufacturer's maintenance instruction to be referred for any particular make of relay testing.
- As there are a number of different unit protections, the manufacturer's maintenance instruction to be referred for maintenance
- Whenever relays are tested on-line, proper isolation of the relay under test to be ensured
- The other protection to be healthy and in service before taking andy protection for on-line testing

(ii) Common Tests For Distance And Unit Protections

1	Trip contacts check	Y
2	Annunciation check	Y
3	Check for carrier send	Y
4	Auxiliary relays healthiness	Y
5	Over voltage relays	Y
6	Local breaker back-up	Y
7	STUB protection check	Y
8	Fault locator initiation check	Y
9	DR. EL initiation check	Y
10	Auto recluse check	Y
11	DC logic	Y
12	Reactor back up impedance	Y
13	Carrier send for remote trip	Y
14	Auxiliary relays (Buchholz, PRD, etc)	Y
15	Reactor differential protection	Y
16	REF protection	Y
17	DC logic	Y
18	Over fluxing relay	Y
19	Over load	Y
20	Directional over current	Y
21	LBB	Y
22	Auxiliary relays (Buchholz, PRV, etc.)	Y
23	Fuse failure check	Y
24	Transformer differential protn.	Y
25	Restricted earth fault	Y

(iii) Bus Bar Protection

1	Primary injection test	SOS
2	Protection stability and sensitivity checks	SOS
3	Relay and DC logic check	Y

(To be done whenever the protection AC circuits are disturbed like addition of new feeder)

(iv) Differential Relays

1	Pick up current at the fixed/selected setting	Y
2	Operation of high set element/instantaneous unit at the fixed/selected setting	Y
3	Operation of the relay at the selected restraint bias setting.	Y
4	Checking of 2nd harmonic current restraint feature	Y
5	Operation of alarm and trip contacts.	Y
6	Through current stability checks on the existing load.	Y

(v) Under Voltage Relay

1	Starting and pick up of the relay as per plug setting	Y
2	Relay operating time as per relay characteristic	Y
3	Operation of alarm and trip contacts	Y
4	Verification of input voltage on relay terminals	Y

(vi) Over Voltage Relay

1	Starting and pick up of the relay as per plug setting	Y
2	Relay operating time as per relay characteristic	Y
3	Operation of high set element/instantaneous unit at voltage setting, if applicable	Y
4	Operation of alarm and trip contacts	Y
5	Verification of input voltage on relay terminals	Y

(vii) Neutral Displacement Relay

1	Starting and pick up of the relay as per plug setting	Y
2	Relay operating time as per relay characteristic	Y
3	Operation of alarm and trip contacts	Y
4	Verification of continuity of input circuit (for RVT/NCT secondary circuit in case of capacitor banks, under shutdown).	Y
5	Verification of open delta voltage input by by-passing PT secondary supply one phase at a time (in case of 3 nos. single phase PT's).	Y

(viii) Over current And Earth Fault Relay

1	Starting and pick up of the relay as per plug setting	Y
2	Relay operating time as per relay characteristic	Y
3	Operation of high set element/instantaneous unit at current setting, if applicable.	Y
4	Operation of alarm and trip contacts	Y
5	Verification of input currents	Y
6	Verification of directional feature, if applicable.	Y

(ix) Under Frequency Relay

1	Pick up value of the relay at its settings by slowly decreasing the frequency from 50 Hz	Y
2	Drop off value of the relay at its settings by slowly increasing the frequency from pick up value	Y
3	Verification of df/dt feature of the relay, if applicable	Y
4	Operation of alarm and trip contacts	Y
5	Verification of input voltae on relay terminals	Y

(x) Over Fluxing Relay

1	Operating of over flux alarm as per relay setting by varying the voltage and frequency one at a time	Y
2	Operating of over flux trip features as applicable for the following; (i) IDMT characteristic (ii) Instantaneous element (iii) Fixed time setting	Y
3	Operation of alarm and trip contacts	Y
4	Verification of input voltage on relay terminals	Y

(xi) Local breaker back up protection, restricted earth fault (REF) and other instantaneous current operated relays

1	Pick up value of the relay at the selected setting	Y
2	Operating time of the relay	Y
3	Operation of alarm and trip contacts	Y
4	Verification of input currents	Y
5	Through current stability checks on the existing load in case of REF/circulating current differential protection.	Y

(xii) Fuse Failure Relays

1	(i) Remove main fuse of each phase voltage input to the distance protection scheme one by one in the relay panel (ii) Checking that the "VT Fuse Fail Alarm" is received. (iii) Checking that the distance protection does not operate	Y

(xiii) <u>MAINTENANCE OF NUMERICAL RELAYS (IED)</u>

All types of IEDs (Intelligent Electronic Devices) need not much routine maintenance after once properly installed, formatted and configured as per our requirements. In PTCUL normally there are ABB/SIEMENS/ALSTOM make IED/Numerical relays installed. It is therefore suggested that while commissioning these relays outmost care should be taken so that proper settings and binary inputs/binary outputs are correctly configured. Mostly REL/SIPROTEC/MICOM series relays are available, so their software should always be available with T&C wing.

However, the following problems may be encountered during operation of these relays for which the corrective action to be taken as below :

Problem	Corrective Action
- Relay in service/Run indication not glowing	Check the DC fuse of protection/ annunciation at relay. Replace it & check DC at back panels of relays.
- If DC supply of IED is OK and above problem persists.	Call T&C engineer/service engineer for replacement of relay.
- No display on the relay	Call T&C engineer/service engineer for rectifying fault or replace the relay
- Proper tripping/annunciation indicators not glowing or any mismatch	Call T&C engineer for checking binary inputs/outputs configurations with Laptop & relay software for making corrections.
- Relay malfunctioning or giving false trippings or no trippings	Call T&C engineer for checking the settings & time gradings from the relay front panel and make suitable changes required if any.

Note: For any other types of problems do not disturb the relays settings/formatting. Just call for T&C engineer or manufacturers Service Engineer.

.

Important : T&C Engineers must obtain the relevant software of the relays from the manufacturer of the company so that any change in relay setting, formatting and configuration can be done at site with the help of Laptop. Any change from the front panel of relays should be avoided.

K. PLCC SYSTEM

1	Checking of Return Loss	Y
2	Power supply measurements	Y
3	Transmitter checks	Y
4	Receiver checks	Y
5	Checks for Alarms	Y
6	Reflex Test	Y
7	LMU composite/Return loss	Y

L. TELEPHONE EXCHANGE

1	Maintenance of EPAX as per recommendations of the manufacturers	SOS

M. AIR CONDITIONING PLANT

(i) Compressors

1	Checking of belt tension. Alignment safety guard	M
2	Leakage checks for refrigerants and oil	M
3	Check oil level, top up if required	M
4	Checking of tightness of flywheel, bolted joints, leakages of oil etc.	QY
5	Checking of oil pressure switch. LP.HP, cut-out switches, solenoid valve, thermostat, Humidstat, etc.	Y

(ii) Condenser Unit

1	Checking for water leaks	M
2	Operation of inlet/outlet value	M
3	Checking of water pressure-inlet/lutlet and cleaning of side plates	HY
4	De-scaling of cooling water circuit	SOS

(iii) Water Treatment Plant

1	Cleaning of soft water tank and regenerationof chemicals	M
2	Checking operation of level switch	HY
3	Checking water quality	HY

(iv) Cooling Towers

1	Cleaning of sediment	M
2	Cleaning of nozzles for clogging	QY
3	Flow switch performance checking	QY

(v) Electrical Motors

1	Lubrication of moving parts	HY
2	Terminal connection checking	HY
3	Overhauling	SOS

(vi) LT Panels

1	Cleaning of bus bars, insulators, etc.	Y
2	Tightness of the connections	Y

(vii) Air Handling Units

1	Cleaning of suction air filters	QY
2	Checking of all interlocks	Y

N. BATTERIES AND DC DISTRIBUTION SYSTEM

1	Measurement of Specific gravity and voltage of cell	M
2	Checking electrolyte level and topping up with DM water, if required	M
3	Checking of Emergency DC lighting to control Room	M
4	Checking of any earth fault (If E/F relay not provided)	QY
5	Checking of electrical connections of charger panel and DCDB panels for tightness and cleanliness	Y
6	Checking of electrical connections for batteries and application of petroleum jelly on cell terminal, if required	Y
7	Checking control cards of charger and measurement of test point voltage values	Y
8	Battery impedance testing (Optional)	Y
9	Testing of DC E/F and under voltage relays	Y
10	IR measurement of charger transformer	Y
11	Discharge test of battery set	3Y

O. FIRE PROTECTIONS SYSTEM

(i) Compressor

1	Cleaning /replacement of air filter	M
2	Checking of compressor oil and replace, if necessary	QY
3	Maintenance and cleaning of compressor valves, gaskets, valve plates and replace, if necessary	QY
4	Operation check of low oil level switch	QY
5	Cleaning and checking for seating of the breather valve	QY
6	Cleaning of NRV/Hp tank	Y
7	General overhaul	SOS

(ii) Fire Alarm System

1	Sequence test for annunciation in control room panel	M
2	Smoke test	M
3	Cleaning	M
4	Battery electrolyte level checking	M

(iii) Diesel Engine

1	Checking of auto starting of diesel engine	M
2	Check oil level, top up if required	M
3	Checking/replacement of fuel oil/lube oil/air filter	Y

(iv) Jockey Pump

1	Check leakage and lubrication	M
2	Pump Overhauling	SOS

(v) V-Belt Drive

1	Checking of belt tightness	QY

(vi) Strainers

1	Cleaning of oil strainer	QY

(vii) Motors

1	Checking of terminal connection	HY

(viii) Pumps

1	Checking of operation of hydrant pumps sump pumps, jockey pumps.	M
2	Adjustments of glands for leakages and tightening of nuts and bolts	HY
3	Checking of alignment of pump set	Y
4	Replenishment of grease	SOS
5	Overhauling	SOS

(ix) Hydrant System

1	Checking of pressure of the hydrant system at the remotest end, auto-starting of pumps, diesel engine, etc.	Y

(x) Deluge System

1	Operations of deluge system, check outlet pressure, check alarm, and check starting of diesel /electrical pump.	Y

(i) Electrical Panels

1	Cleaning and tightening of terminals	Y

(xii) General

1	Greasing of all valves	HY
2	Painting of pipes, air lines, marshaling box	SOS

(xiii) Fire Extinguishers

1	Re-filling of fire extinguishers	SOS

P. <u>DIESEL GENERALTOR SET</u>

(i) Lubricating System

1	Check for oil leaks	M
2	Replacement of oil filter after recommended running hours	Y/SOS

(ii) Cooling System

1	Check for radiator air blocking and coolant level	M
2	Check for fan hub, drive pulley and water pump	Y

(iii) Air Intake System

1	Check for air leaks	M
2	Cleaning of air filters	HY
3	Replacement of Air cleaning element	Y

(iv) Fuel System

1	Check for Governor linkages, fuel transfer pump,fuel line connections	Y
2	Drain Sediments from fuel tank, change fuel filter and clean fuel tank breather	Y

(v) Main Generator

1	Check for air inlet restrictions	M
2	Checking for electrical connections for tightness	HY
3	Stator winding IR measurement	Y
4	Checking/cleaning of slip ring and its brushes	Y
5	Testing of protection/control relays and alarms	Y

(vi) Exhaust

1	Check for air leaks and exhaust restrictions	Y
2	Tight exhaust manifold and turbo charge cap screw	Y

(vii) General

1	Battery voltage and specific gravity measurement	M

Q. LT SWITCHGEAR, LT TRANSFORMER, LT PANEL, ETC.

(i) LT Panels

1	Cleaning of panels, bus bar insulators, etc.	Y
2	Relays testing	Y
3	Tightness of all electrical connections	Y
4	Checking of Indicating meters	Y
5	Check for change-over facility, if provided	Y
6	Check operation/Indications in Off-load condition of air CB	Y
7	Check spring charging of air CB	Y

(ii) LT Switch Gears

1	Functional checking (Trip,close,etc.) of 33/11 kV CBs.	Y
2	Measurement of operating timings	3Y
3	Cleaning of insulators and tightness of terminal connections of CBs. CTs. PTs, Isolators, etc.	Y
4	Alignment checking of isolators	Y

(iii) LT Transformers

1	Testing of oil BDV	Y
2	IR measurement	Y
3	Testing/checking of OTI, WTI and Buchholz (if provided)	Y
4	Checking of healthiness of pressure relief diaphragm	Y
5	Checking healthiness of Buchholz relay	Y
6	Checking tightness of earthing connections	Y

(A) GAS INSULATED SWITCHGEAR-SUBSTATION

1. INTRODUCTION

The main advantage of Gas Insulated Substation (GIS) is its high reliability and also compactness which has direct influence on land requirement, land cost, environmental considerations, etc. The initial equipment cost of GIS is usually higher than that of conventional Air Insulated Substation (AIS). The advantage and life cycle cost analysis are generally considered before deciding for GIS.

The land area required for a GIS substation is in the order of 10% to 20% of that for an AIS substation considering the switchgear bay. The saving in overall land area depends very much on the specific voltage level and the connection to transformers, reactors and incoming and outgoing lines. If the substation is connected to overhead lines, then space will have to be allocated for towers and droppers which might reduce the total land saving. Indoor and underground GIS is possible even in urban and highly populated areas which will allow building of the substation at the point of consumption which will bring about significant cost savings in the distribution network.

GIS also is considered for severe environment conditions, where saline pollution near coastal areas or industrial pollution requiring regular cleaning of insulators and corrosion of metallic components and electrical joints. GIS being totally enclosed units shall be immune to these severities. GIS is also adopted when substation is to be installed at very high altitudes or very low temperatures or seismic considerations and hydro stations.

2. MAINTENANCE OF GIS

I. Before taking up the maintenance of GIS, recommended safety rules from the manufacturer are required to be adhered to. Some of them are listed below but, it is recommended to integrate with recommendations of manufacturer of GIS.

(a) The maintenance programme and time based intervals specified/no. of operations whichever is earlier to form the basis of maintenance.

(b) Whenever maintenance is taken up, it is essential to:

- Employ the authorized personal

- Define and discuss in advance the maintenance to be performed and the relative hazards. Proper formatted record sheets to be prepared.
- Use parts only supplied by Original Equipment Manufacturers (OEM).
- It is necessary to identify the equipment which is required to be maintained. Ensure that it is in de-energized/degassed condition.
- It is essential to make sure that the equipment is earthed on all sides of the work- zone.
- The work-zone should be barricaded and operator should have necessary protective clothing and recommended safety devices.
- It is required to be ensured that necessary maintenance equipment such as slings, platforms, scaffoldings and electrical equipments/tools are in proper shape.

II. Conditions Monitoring of GIS

Generally GIS requires no or very little maintenance and monitoring the SF_6 gas pressure and quality is considered sufficient. For maintenance of the GIS, regular inspections, Routine scheduled maintenance and overhaul maintenance are specified by the manufactures. The maintenance to be carried out and their periodicity is indicated in the "Maintenance Schedule". Manufacturer's instructions are to be followed for special tests, if any, for that particular make of GIS substation.

III. SF_6 Gas

As SF_6 gas is used in all chambers of GIS the monitoring of pressure and quality is of the importance. As per IEC 62271-203/2003 the leakage rate from any single compartment of GIS to atmosphere and between compartments shall not exceed 0.5% per year for the service life of the equipment. The pressure inside a GIS may vary from the rated filling pressure level due to different service conditions. Pressure increase due to temperature and leakage between compartments may impose additional mechanical stresses. Pressure decrease due to leakage may reduce he insulation properties. Further the quality and dew point of Sf_6 gas should also be monitored as the property of SF_6 is related to it insulation quality.

(a) Partial Discharge Measurement

Electrical Ultra High Frequency (UHF) or Acoustic PD measurement techniques are being employed. Electrical UHF technique gives higher sensitivity and PD detection necessitates the installation of sensors inside the gas compartment during manufacture. Acoustic methods employ sensors which are fixed outside the enclosure. For both the methods the sensitivity depends on the distance between the defect and the sensor.

(b) UHF Partial Discharge Measurement

The partial discharge signals in the range 1000 MHz to 2 GHz can be detected in the time domain or frequency domain by means of installing sensors usually installed inside the chambers. Due to the complexity of the resonance pattern, the magnitude of the detected PD signal depends strongly on the location.

(c) Acoustic Partial Discharge Measurement

Acoustic signals are emitted from defects in a GIS mainly by the floating particles emitting a mechanical wave in the enclosure when they impinge on it. Discharges from the fixed defects create a pressure wave in the gas, which is then transferred to the enclosure. The resulting signal will depend on the source and the propagating path. As the enclosures are normally made of aluminium or steel, the damping of the signals is quite small.

Acoustic signals can be picked up by means of externally mounted sensors. The location of the defect can be found by searching for the acoustic signal with highest amplitude or time travel measurements with tow sensors. Bouncing particles producing discharges in the 5pC range can be detected with a high signal to noise ratio. Sensitivity decreases with distance because the acoustic signals are absorbed and attenuated as they propagate in the GIS. Acoustic measurement is immune to electromagnetic noise in the substation. The acoustic sensitivity to bounding particles is much higher than the sensitivity of any other method. PD measurement in a GIS installation is recommended once in 5 years.

In GIS substation some of the equipments like Bushings, Surge Arresters, Transformers shall be provided outside the GIS area. Condition monitoring of these equipment is to be carried out as followed for AIS substation equipment.

(B) SUBSTATION AUTOMATION

Open Systems

Benefits of open systems include longer expected system life, investment protection, upgradeability and expandability, and readily available third-party components.

An open system is a computer system that embodies supplier-independent standards so that software may be applied on many different platforms and can interoperate with other application on local and remote systems. An open system is an evolutionary means for a substation control system that is based on the use of non proprietary, standard software and hardware interfaces. Open systems enable future upgrades available from multiple suppliers at lower cost to be integrated with relative ease and low risk.

The concept of open systems applies to substation automation. It is important to learn about the different de jure (legal) and de facto (actual) standards and then apply them so as to eliminate proprietary approaches. An open systems approach allows the incremental upgrade of the automation system without the need for complete replacement as happened in the past with proprietary systems. There is no longer the need to rely on one supplier for complete implementation. Systems and IEDs from competing suppliers are able to interchange and share information. The benefits of open systems include longer expected system life, investment protection, upgradeability and expandability and readily available third-party components.

Levels of Integration and Automation

Substation integration and automation can be broken down into five levels. The lowest level is the power system equipment, such as power transformers and circuit breakers. The middles three levels are IED implementation, IED integration and substation automation applications. All electric utilities are implementing IEDs in their substations. The focus today is on the integration of the IEDs. Once this is done, the focus will shift to what automation applications should run at the substation level. The highest level is the utility enterprise, and there are multiple functional data paths from the substation to the utility enterprise.

Since substation integration and automation technology is fairly new, there are no industry standard definitions, except for the

definition of an IED. The industry definition of an IED is given below as well as definitions for substation integration and substation automation.

- *IED :* Any devise incorporating one or more processors with the capability to receive or send data/control from or to an external source (e.g. electronic multifunction meters, digital relays, controllers).

- *Substation integration :* Integration of protection, control and data acquisitions functions into a minimal number of platforms to reduce capital and operating costs, reduce panel and control room space, and eliminate redundant equipment and databases.

- *Substation automation :* Deployment of substation and feeder operating functions and applications ranging from supervisory control and data acquisition (SCADA) and alarm processing to integrated volt/var control in order to optimize the management of capital assets and enhance operation and maintenance (O&M) efficiencies with minimal human intervention.

Architecture Functional Data Paths

There are three primary functional data paths from the substation to the utility enterprise. The most common data path is conveying the operational data (e.g. volts, amps) to the utility's SCADA system every 2 to 4 s. this information is critical for the utility's dispatchers to monitor and control the power system. The most challenging data path is conveying the non operational data to the utility's data warehouse. The challenges associated with this data path include the characteristics of the data (waveforms rather than points) the periodicity of data transfer (not continuous, on demand) and the protocols used to obtain the data from the IEDs (not standard IED supplier's proprietary protocols). Another challenge is whether the data is pushed from the substation into the data warehouse, pulled from the data warehouse or both. The third data path is remote access to an IED by passing through or looping through the substation integration architecture and isolating a particular IED in the substation.

New Versus Existing Substations

The design of new substations has the advantage of starting with a blank sheet of paper. The new substation will typically have many IEDs for different functions and the majority of operational data for the SCADA system will come from these IEDs. The IEDs will be integrated with digital two-way communications. The small amount of direct input/output (hardwired) can be acquired using programmable logic controllers (PLCs). Typically thee are no conventional remote terminal units (RTUs) in new substations. The RTU functionally is addressed using IEDs, PLCs and an integration network using digital communications.

In existing substations, there are several alternative approaches depending on whether or not the substation has a conventional RTU installed. The utility has three choices for their existing conventional substation RTUs :

- Integrate RTU with IEDs : Many utilities have integrated IEDs with existing conventional RTUs, provided the RTUs support communications with downstream devices and support IED communication protocols. This integration approach works well for the operational data path but does not support the non operational and remote access data paths. The latter two data paths must be done outside of the conventional RTU.

- Integrate RTU as another substation IED : If the utility desires to keep its conventional RTU, the preferred approach is to integrate the RTU in the substation integration architecture as another IED. In this way, the RTU can be retired easily as the RTU hardwired direct input/output transitions to come primarily from the IEDs.

- Retire RTU and use IEDs and PLCs as with a new substation : The RTUs may be old and difficult to support and the substation automation project may be a good time to retire these older RTUs. The hardwired direct input/output from these RTUs would then come from the IEDs and PLCs as with a new substation.

Substation Automation Training Simulator

One of the challenges for electric utilities when implementing substation automation for the first time is to create "buy in" for the new technology within the utility. The more people know about a subject the more comfortable they feel and the better the chance they will use the technology. It is much easier and less stressful to learn about substation automation technology in a training environment away from the substation, than on a system installed in an energized substation. For these reasons, many utilities purchase a substation automation training simulator (SATS), which is an identical configuration to that installed in substations. The main difference is that the SATS included at least one of every kind of IED installed in all substations. In addition to training SATS is used for application development and testing of new IEDs.

Protocol Fundamentals

A communication protocol allows communication between two devices. The devices must have the same protocol (and version) implemented. Any protocol differences will result in communication errors. If the communication devices and protocols are from the same supplier, i.e., where a supplier has developed a unique protocol to utilize all the capabilities of the tow devices, it is unlikely the devices will have trouble communicating. By using a unique protocol of one supplier, a utility can maximize the device's functionality and see a greater return on its investment: however, the unique protocol will constrain the utility to one supplier for support and purchase of future devices.

If the communication devices are from the same supplier but the protocol is an industry-standard protocol supported by the device supplier, the devices should not have trouble communicating. The device supplier has designed its devices to operate with the standard protocol and communicate with other devices using the same protocol and version. By using a standard protocol, the utility may purchase equipment from any supplier that supports the protocol and, therefore, can comparison-shop for the best prices.

Protocol Considerations

There are two capabilities a utility considers for an IED. The primary capability of an IED is its standalone capabilities. Such as protecting the power system for a relay IED. The secondary capability of an IED is its integration capabilities, such as its physical interface (e.g., RS-232, RS-485, Ethernet) and its communication protocol (e.g., DNP3, Modbus, UCA2 MMS).

Utility Communication Architecture

The use of international protocol standards is now recognized throughout the electric utility industry as a key to successful integration of the various parts of the electric utility enterprise. One area addresses substation integration and automation protocol standardization efforts. These efforts have taken place within the framework provided by the Electric Power Research Institute's (EPRT's)UCA.

IEC 61850

The UCA2 substation automation work has been brought to IEC Technical Committee (TC) 57 Working Groups (WGs) 10,11, and 12, who are developing IEC 61850, the single worldwide standard for substation automation communications. IEC 61850 is based on UCA2 and European experience and provides additional functions such as substation configuration language and a digital interface to non conventional current and potential transformers.

Selecting the right supplier ensures that you stay informed about industry developments and trends and allows you to access new technologies with the least impact on your current operation.

Acronyms and Abbreviations	
DNP	Distributed network protocol
ECM	Equipment condition monitoring
EPRI	Electric Power Research Institute
GOMSFE	Generic object models for substation and feeder equipment
GPS	Global positioning system
ICCP	Inter-control center communications protocol
IEC	International Electro technical Commission
IED	Intelligent electronic device
IEEE	Institute of Electrical and Electronics Engineers, Inc.
I/O	Input/output
ISO	International Standards Organization
IT	Information technology
LAN	Local area network
Mb/s	Megabits per second
MMS	Manufacturing messaging specification
NIM	Network interface module
O&M	Operations and maintenance
PES	IEEE Power Engineering Society
PLC	Programmable logic controller
PSRC	IEEE PES Power Systems Relaying Committee
RF	Radio frequency
RFP	Request for proposal
RTU	Remote terminal unit
SA	Substation automation
SATS	Substation automation training simulator
SCADA	Supervisory control and data acquisition
TC	Technical committee
TCP/IP	Transmission control protocol and internet protocol
UCA	Utility communication architecture
VAR	Volt ampere reactive
WAN	Wide area network
WG	Working group

Annexure-A

FORMAT OF RECORD TO BE MAINTAINED AT EHV SUBSTATIONS

B. FORMAT OF RECORD TO BE MAINTANED AT EHV SUBSTATION

SHUT DOWN MAINTENANCE ACTIVITIES (SCHEDULED PLANNED / UNSHEDULED FORCED)
(FOR SUB-STATION / TL OFFICE)

SUB-STATION/TL OFFICE: **AMP FOR THE YEAR:**

SL. NO.	NAME OF LINE / ICT/BAY/ EQUIPMENT	DETAIL ACTIVITY	FREQUENCY M/TM/ 6M/Y	DATE	DURATION	REQUIRED FORMATS FILLED UP YES/NO	JOB COMPLETED (IN%)	SIGNATURE (MAINT ENGR)	SIGNATURE (S/S OR T/L IN CHARGE)

TRANSFORMERS & REACTORS-MONTHLY MAINTENANCE RECORD

Monthly Maintenance-Without shutdown Activity

MONTH……..

Sl. No.	Description of Activity	ICT-I	ICT-II	ICT-III	ICT-IV	BUS REACTOR	--LINE REACTOR	--LINE REACTOR	REMARKS & OBSERVATION
1.	Date of Commissioning								
2.	Make								
3.	Rating								
4.	Sl.No.								
5.	Bay Loc								
6.	Bushing Oil Level								
7.	Oil Level in Conservator								
8.	Oil level in OLTC Conservator								
9.	Manual Starting of Oil Pumps & Fans								
10.	Checking of Oil Leak								
11.	Oil level in breather oil seal								
12.	Condition of Silica Gel								
Signature of Maint Engineer					Signature of Substation-in-charge				

Note: No. of columns to be adjusted as per the population of Transformers & Reactors.

TRANSFORMERS & REACTORS - YEARLY MAINTENANCE RECORD

Dt. Of Commissioning …… Make…….Rating……. Sl. NO…… Bay Loc……

YEARLY MAINTENANCE – S/D Activity

SH MONTH ……. ACTUAL MONTH…… PTW NO……. DATE……

(I) AUTOSTARTING OF FANS AND PUMPS: DONE/NOT DONE
(II) MEASUREMENT OF BDV OF OLTC OIL

	R PHASE	**Y PHASE**	**B PHASE**	**PERMISSIBLE LIMITS**	**REMARKS AND OBSERVATION**
BDV (IN KV)					

(III) EXTERNAL CLEANING OF (I) RADIATORS
(II) ALL BUSHINGS

(IV) MAINTENANCE OF OLTC DRIVING MECHANISM

Sl. No.	**DESCRIPTION**	**STATUS**		**REMARKS**
		OK	**NOT OK**	
1.	VISUAL INSPECTION OF EQUIPMENT			
2.	HAND OPERATION ON ALL TAPS & HANDLE INTERLOCK SWITCH			
3.	OVERLOAD DEVICE OF DRIVING MOTOR			
4.	LOCAL & REMOTE OPERATION (ELECTRICAL) & L/R SWITCH			
5.	STEPPING RELAY IN REMOTE OPERATION			
6.	CORRECT OPERATION OF TAP POSITION INDICATOR			

(V) CHECKING OF REMOTE INDICATIONS OF WTI/REMOTE TAP INDICTION: OK/NOT OK

TRANSFORMERS & REACTORS - YEARLY MAINTENANCE RECORD

(VI) ALARM/TRIP TEST DATE……..

ALARAM TEST						TRIP TEST							
Main Buchholz	**OLTC Buchholz R/Y/B**	**WTI**	**OTI**	**PRD**	**MOG Low oil level**	**DIFF TRIP**	**O/C TRIP**	**Main Buclz**	**OLTC Buchholz R/Y/B**	**WTI**	**OTI**	**PRD**	**MOG Low oil level**

(VII) MARSHALING BOX – MAINTENANCE DATE……

Description	**Tightening of Terminations DONE/NOTE DONE**	**Cleaning DONE/NOTE DONE**	**Checking of contactors space Heater & illumination**
MB OF OLTC			
MB OF REACTOR			
MB OF NGR			
TB OF PRD			
TB OF BUCHHOLZ RELAY			
TB OF OIL SURGE RELAY			
TB OF SPR (IF PROVIDED)			
TB OF BUSHIG CT			

Signature of Maintenance Engineer …… Sig. Of substation In Charge……

(III) TAN δ MEASUREMENT FOR BUSHINGS

MAKE OF MEASURING EQUIPT ……
AMBIENT TEMP ……..^{O}C

Sl. NO.	Bushings	Capacitance				Tan				Remarks
		Pre-commg* Values		Measured Value		Pre-commg* Values		Measured Value		Measurement to be taken after cleaning
	Transformer Bushings 400 KV	C1	C2	C1	C2	Tan 1	Tan 2	Tan 1	Tan 2	TAN AT 20 DEG C= 0.007 (MAX)
	R Ø									
	Y Ø									
	B Ø									Rate of rise of Tan per year =0.001 Max.
	220 KV BUSHING									
	R Ø									
	Y Ø									Rate of rise of Capacitance value per year =+/-1%Max.
	B Ø									
	52 KV BUSHING									
	R Ø									Note:For Measurement of C1 values of the Busings, connection will be between HV and Test Tap and measurements in UST mode at 10.0 kV.
	Y Ø									
	B Ø									
	LINE REACTORS Bushings									
	R Ø									
	Y Ø									For measurement of C2 values of Bushings, connection will be between Test Tap and Ground and HV will be connected to guard. The measurement will be carried out in GSTg mode and test voltage will be 1.0 kV.
	B Ø									
	145 KV Neutral Bushing									
	NGR 145 KV Maiins-Comm.									

* Where Pre-commissioning values are ot available, Comparison with Previous year test results may be done

Signature of Maintenance Engineer……

Signature of Substation In Charge…….

CIRCUIT BREAKER – MONTHLY MAINTENANCE RECORD

Dt. Of Commissioning…….. MAKE…… RATING……. SL.NO…… Bay Loc……..

(A) MONTHLY MAINTENANCE – W S/D ACTIVITY

ACTIVITY	OBSERVTION & REMARI
a) Oil Leakage in Operating Mechanis	
b) Oil Level (Top up, if required)	
c) Air pressure / leakage in ABCB	
d) Oil level in MOCB	
e) Oil Leaks from Grading Capacitors	

Signature of Maintenance Engineer……

CURRENT TRANSFORMER – MAINTENANCE RECORD

Dt. Of Commissioning…… MAKE……. RATING/Type…… Sl. NO. …….. Bay loc……

(A) MONTHLY MAINTENANCE –W/SD Activity

Visual inspection of CT for oil leakage and crake in insulators ……

Checking of bellow for expansion …….

MARSHALLING / SECONDARY TERMINAL BOX

Check for any oil leakage from Secondary Terminal BOX ……

Checking of healthiness of gaskets ……

Signature of Maintenance Engineer…… Signature of Substation In Charge……

CURRENT TRANSFORMER – YEARLY MAINTENANCE RECORD

Dt. Of Commissioning…… MAKE……. RATING/Type…… Sl. NO. …….. Bay loc……

(i) MARSHALLING BOX

(I) Cleaning of MB……..

(II) Checking the tightness of all electrical connections including earthig of MB……

(III) Cleaning and tightness of CT secondary termrinals and checking healthiness of sec terminal busing …….

(IV) Checking of Space Heater..& Illumination…….

(ii) Thermovision Scanning of CT & Top Dome

Kit Load:

	Ambient Temp.	Scanned Temp. R Phase	Scanned Temp. Y Phase	Scanned temp. B Phase	Remarks
CT Tank					
Top Dome					

Signature of Maintenance Engineer…… Signature of Substation In Charge……

CAPACITOR VOLTAGE TRANSFORMER – MAINTENANCE RECORD

Dt. Of Commissioning…… MAKE……. RATING/Type…… Sl. NO. …….. Bay loc……

A. MONTHLY MAINTENANCE –W/SD

(i) Checking of Oil Leaks

B. 3 MONTHLY MAINTENANCE

(i) Measurement of voltage at switchyard MB (in volts)

CORE No.	CONNECTION	VALUE IN VOLTS		
		R PHASE	Y PHASE	B PHASE
CORE -1	PHASE-N			
CORE -2	PHASE-N			
CORE -3	PHASE-N			

C. YEARLY MAINTENANCE

(I) Visual Checking of Earthing of HF Point – (IN CASE IT IS NOT USED FOR PLCC)

(II) Checking of any breakage of cracks in HF bushing.

(III) Cleaning of CVT Capacitor Stacks and tightness of terminal connections.

(IV) Thermovision Scanning of Capacitor Stacks

Camera used Ambient Temperature

	R-Phase	Y- Phase	B-Phase	Remarks
Top Stack				
Middle Stack				
Bottom Stack				
EMU Tank				

(v) Checking of Neutral Earthing in CVT MB And Tightness of All connections

(vi) Cleaning of Marshalling Box & Junction Box

(vii) Checking of Space heater & illumination

(viii) Checking healthiness of all gaskets

DISCONNECTING SWITCHES/ISOLAORS AND EARTH SWITCHES – MAINTENANCE RECORD

Dt. Of Commissioning …… MAKE ……..

RATING/Type…….. Sl.No…….. bay Loc…….

(A) YEARLY MAINTENANCE –S/D Activity PTW NO…….DATE……

(i) OPERATING MECHANISM

(a) Maintenance of linkages including transmission gears-

(b) Maintenance of Stopper bolts-

(c) Cleaning of Aux. switch contacts & Greasing with Silicon Grease-

(d) Checking of Electrical/Mechanical Interlock with E/S & CB-

(e) Lubrication of operating Mechanism hinges, Lock Joints – on Levers. Bearings.

(d) Checking & Tightening of all the mounting bolts

(ii) MAIN CONTACTS

(a) Cleaning and Lubrication of Main Contacts

(b) Alignment

(c) Tightening of Bolts & Nuts, Pins Etc.

(d) Cleaning of Support Insulators and check for cracks in insulators, if any

(e) Checking of interlocks

(iii) MARSHALLING BOXES OF ISOLATORS AND EARTH SWITCHES

(b) Checking of space heater & illumination

(c) Checking of healthiness of Rubber Gaskets

(d) Visual Check of auxiliary contacts

(e) Cleaning and tightness of all terminations

(iv) EARTH SWITCH

(a) Checking and Alignment of Earthing Blades

(b) Cleaning of Contacts

(c) Operation of Earth Switch

(d) Checking of Aluminum/Copper flexible conductor:

(e) Checking of earth connections of structure & MOM box.

SURGE ARRESTER – MAINTENANCE RECORD

Dt. Of Commissioning …… MAKE ……..

RATING/Type…….. Sl.No…….. Bay Loc…….

(A) YEARLY MAINTENANCE

(a) Checking Of Leakage by Current Analyser (mA) after cleaning the porcelain surface.

PHASE	TOTAL CURRENT	3RD HARMONIC RESISTIVE CURRENT (13 R) In μ A	REMARKS
R			13R=500 μ A Max. for Gapless Type Arresters
Y			13R=1000 μ A Max. for Gapped Type Arresters
B			

(b) Testing by Surge Monitor kit - Counter and meter tests

(c) Cleaning of LA Insulators

Signature of Maintenance Engineer…… Signature of Substation In Charge……

BUSBAR AND BUS POST INSULATOR – MAINTENANCE RECORD

YEARLY MAINTENANCE OF BUS BAR & BPI

SL.NO.	ACTIVITY	SCHEDULED DATE/ACTUAL DONE ON DATE	MEASURED VALUE	REMARKS
1.	Measurement of station earth resistance			
2.	Thermovision scanning of all conductor joints and terminal cnnectors/clamps			As per enclosed formate given in this document separately
3.	Cleaning of Insulators		Done/Not Done	
4.	Checking of Insulators for cracks		Done/Not Done	

Signature of Maintenance Engineer…… Signature of Substation In Charge……

MAINTENANCE RECORD OF WAVE TRAP

YEARLY MAINTENANCE OF BUS BAR & BPI

SL.NO.	ACTIVITY	SCHEDULED DATE	ACTUAL DONE ON DATE	REMARKS
1.	Tightness and cleanliness			
2.	General Inspection/Cleaning of tuning unit			

Signature of Maintenance Engineer…… Signature of Substation In Charge……

YEARLY MAINTENANCE FORMATE FOR SUB-STATION ILLUMINATION SYST EM

DATE OF MAINTENANCE: **MTC.DONE BY:** **MTC.DATE:**
PTW NO: **DATE:** **132KV/220 KV/400KV S/YARD**

SL.NO.	JOB DESCRIPTION	REMARKS & OBSERVATION	DATE	SIGNATURE
1.	Check healthiness of light fittings in all circuits in the station bldg. PH and DGS bldg. Repair, replace as required			
2.	Check if all switchyard fittings are in working condition (…….nos. as per list). Repair, replace as required.			
3.	Check lighting panel, receptacle panel tightening of terminals.			
4.	Check OUTPUT SUPPLY after fuse in receptacle panel			

Signature of Maintenance Engineer…… Signature of Substation In Charge……

MONTHLY MAINTENANCE FORMAT FOR SUB-STATION AIR CONDITIONG SYSTEM

DATE OF MAINTENANCE: **MTC.DONE BY:** **MTC.DATE:**
PTW NO: **DATE:** **AC UNIT NO:**

SL.NO.	EQUIPMENTS	JOB DESCRIPTION	REMARKS
A	UNIT RUNNING		
1.	Compressor:	-Check operation of loading by adjusting thermostats -Put back to original setting	
2.	Filters: Fine filter (Outlet of AHU) Course Filter (Inlet of AHU	-Measure pressure drop using Monometer	
3.	Pan Humidifier 1&2	-Check healthiness of heaters. -Check operation of float switch by draining water. (Switch Off power before check).	
4.	Air heaters AHU	Check heater operation by Ampere check.	
B	UNIT WHEN STOPPED		
1.	All Compressors	-Check oil level in sight glass -Checking of belt tension, alignment, safety guard -Leakage checks for refrigerants and oil -Checking of tightness of flywheel, bolted joints, leakages of oil etc.	
2.	All control panels	-Check for loose contact if any. Tighten where necessary. -Clean inside -Check all the heaters inside Control Panel working.	
3.	CONDENSER UNIT	-Checking of water pressure-inlet/outlet & cleaning of side plates -Checking for water leaks -Operation of outlet/inlet valve	

Signature :
Name :
Designation :
Date :

Signature :
Name :
Designation :
Date :

MAINTENANCE FORMATE FOR BATTERY SETS

SUB-STATION :
DATE OF INSPECTION :
BATTERY SET : I/II VOLTAGE : 24/48/110/220 VOLTS MONTH :
BATTERY VOLTAGE : ----------VOLT

(A) MONTHLY MAINTENANCE FORMAT – Bank - A

- Checking of electrolyte level and topping up with DM water, if any
- Checking of emergency DC lighting to control Rook

(SWITCH OFF CHARGER TO NOTE TOTAL BATTERY VOLTAGE EXCEPT 24 V BATTERY OF HVDC STATION)

The cell voltage should be less than 2.16 and Specific Gravity 1195+/-10 at 27 degC

Cell NO.	Battery Voltage	SP. Gravity	Cell Temp ^{o}C	Cell No.	Battery Voltage	Sp. Gravity	Cell Temp ^{o}C
1.				29.			
2.				30.			
3.				31.			
4.				32.			
5.				33.			
6.				34.			
7.				35.			
8.				36.			
9.				37.			
10.				38.			
11.				39.			
12.				40.			
13.				41.			
14.				42.			
15.				43.			
16.				44.			
17.				45.			
18.				46.			
19.				47.			
20.				48.			
21.				49.			
22.				50.			
23.				51.			
24.				52.			
25.				53.			
26.				54.			
27.				55.			
28.				56.			

Checking of any Earth fault in D.C. System Wherever F/F relays are not provided

Signature :
Name :

Signature :
Name :

MONTHLY MAINTENANCE FORMAT FOR SUB-STATION FIRE FIGHTING SYSTEM

SUB-STATION : **DATE OF MAINTENANCE :**
PTW NO : **DATE :**

S.NO.	EQUIPMENTS	JOB DESCRIPTION	REMARKS & OBSERVATION
	Operate Fire fighting Hydrant pump (MOTOR DRIVEN) by Pump Start Device (PSD).	Run for five minutes -Check forsmooth operation with slight leakage from shaft seal. (it is a healthy indiction)S	
	Operate Fire fighting Hydrant pump (Diesel Engine driven) by Pump Start Device (PSD).	-DO-	
	Operate Fire fighting Deluge pump (Diesel Engine driven) by Pump Start Device (PSD).	-DO-	
	Pump House	-Run the sump pit to drain water if required	
	Hydrant pump Deluge Pump Jokey Pump-1 Jokey Pump-2	- Clean all motors, pumps and other equipment in the Pump House. - Clean the floor and ceiling. -Check that all valves are in correct position and locked by padlock or strap.	
	COMPRESSOR		
	JOCKEY PUMP		
	DIESEL ENGINE		

Signature of Maintenance Engineer…… Signature of Substation In Charge……

YEARLY MAINTENANCE FORMATE FOR SUB-STATION FOR FIRE ALARAM SYSTEM

SUB-STATION : **DATE OF MAINTENANCE :** **MTC.DONE BY :**

PTW NO : **DATE :**

01. Check for operation of fire alarm system installed at various location by Agarbati or some smoke device
02. Check for alarm in the control panel.
03. Check the condition of battery.
04. Check for cleanliness.

S.NO.	TYPE	LOCATION	QUANTITY	REMARKS&OBSERVATION	DATE	SIGNATURE

Signature of Maintenance Engineer…… Signature of Substation In Charge……

MONTHLY MAINTENANCE FORMAT FOR SUB-STATION DG SET

DG SET BI : DATE OF MAINTENANCE : MTC.DONE BY :
DG SET CAPACITY : PTW NO/DATE : RUNNING HOURS OF DG SET :

S.NO.	EQUIPMENT	JOB DESCRIPTION	REMARKS & OBSERVATION
A	LUBRICATING SYSTEM	CHECK-for leaks -hydraulit-governor oil level CHECKS :- For –radiator air blocking -hose and connections -coolant level	
B	COOLING SYSTEM		
C	AIR INTAKE SYSTEM	CLEAN- Crankcase Breather -OR change Air Cleaner Element	
D	FUEL SYSTEM	-Fuel Transfer Pump -fuel lines connections DRAIN-Sediments from Fuel Tank CHANGE-Fuel Filter as per manufacturers' recommendations or yearly whichever is earlier CLEAN- Fuel Tank Breather	
E	EXHAUST	Torque:- Tight Exhaust Manifold & Turbocharger Cap screws, If leaks found	
F	MAIN GENERATOR	-Protections, Control & Alarms, Instrumentations -Remote/Local; Auto Start/Stop operation -Tightness of Power & Control cable connections -Stator winding IR/Resistance measurements -Checking/Cleaning of slip ring and its brushes	

Signature of Maintenance Engineer…… Signature of Substation In Charge……

MONTHLY MAINTENANCE FORMAT FOR SUB-STATION DG SET

DG SET BI : **DATE OF MAINTENANCE :** **MTC.DONE BY :**
DG SET CAPACITY : **PTW NO/DATE :** **RUNNING HOURS OF DG SET :**

S.NO.	EQUIPMENT	JOB DESCRIPTION	REMARKS & OBSERVATION
A	LUBRICATING SYSTEM	CHECK-for leaks -Bypass Filter -Engine Oil -Hydraulic Oil	
B	COOLING SYSTEM	CHECKS: for -Fan hub, Drive pulley and water pump	
C	AIR INTAKE SYSTEM	CLEAN- Crankcase Breather -OR change Air Cleaner Element	
D	FUEL SYSTEM	-Fuel Transfer Pump -fuel lines connections DRAIN-Sediments from Fuel Tank CHANGE-Fuel Filter as per manufacturers' recommendations or yearly whichever is earlier CLEAN- Fuel Tank Breather	
E	EXHAUST	Torque:- Tight Exhaust Manifold & Turbocharger Cap screws, If leaks found	
F	MAIN GENERATOR	-Protections, Control & Alarms, Instrumentations -Remote/Local; Auto Start/Stop operation -Tightness of Power & Control cable connections -Stator winding IR/Resistance measurements -Checking/Cleaning of slip ring and its brushes	

Signature of Maintenance Engineer…… Signature of Substation In Charge……

PLCC EQUIPMENT MAINTENANCE RECORD

Dt. Of commissioning……. Make/Moder…….Cab.Sl.No.

Nem of Line/Direction……

(A) YEARLY MAINTENANCE – S/D ACTIVITY PTW NO…….Date……..

(a) General Cleaning of Cabinets.

(b) Checking of healthiness of Ventilation Fans in Cabinet.

(c) Level Measurements

SR.NO.	MAINTENANCE	TEST POINTS (T.P) WHERE MESUREMENTS TO BE DONE	SPEECH Tx….Rx….	PROTECTION-1 Tx….Rx….	PROTECTION-2 Tx….Rx….
1.	POWER SUPPLY MEASUREMENTS				
2.	INPUT VOLTAGES				
3.	STABILISED DC VOLTAGES				
4.	TRANSMITTER CHECKS				
5.	FM OSCILLATOR-Frequency measurement				
6.	AM OSCILLATOR- Time measurement				
7.	OUTPUR LEVEL MEASUREMENT				
8.	RECEIVER CHECKS				
9.	Receiver level FM				
10.	Receiver level AM				
11.	ALARM CHECKS				
	Check Alarm contacts with Buzzer/Ohm meter after inserting test plug “IN POSITION”				
12.	TRANSMISSION OF PROTN. CODE CODE I CODE II CODE III				
13.	RECEIPT OF PROTN. CODE CODE I CODE II CODE III				
14.	LOOP TEST/REFLEX TEST				

Note: This is only a guide line. The format to be modified as per actual PLCC system available at Site.

Sig. Testing Engr. Sig. Station In-charge

PREVENTIVE MAINTENANCE RECORD FOR PROTECTION SYSTEM

MONTHLY PREVENTIVE MAINTENANCE RECORD – GENERAL

SN	ACTIVITY	APR	MAY	JUNE	JULY	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR
1.	Testing of Disturbance Recorder for test prints Feeder I Feeder II And so on												
2.	Testing of Even Logger (Min tow events to be checked												

Sig. of Maint. / Testing Engr. Sig. of sub Station In-Charge

CHAPTER 4

Standard acceptable technical values

1.1	Fresh Transformer oil before filling in Transformer		
	Parameters	**Standard Values (Acceptable range)**	**Source**
	(a) Appearance	Clear and transparent and free from suspended matter or sediments	IS 335 – 1993
	(b) Density at 29.5^0 C	0.89 g/cm^3 (Max)	IS 335 – 1993
	(c) Kinematic Viscosity at 27^0 C at 40^0 C, Max	27 cSt (Max) under consideration	IS 335 – 1993
	(d) Interfacial Tension (IFT) 27^0 C	0.04 N/m (Min)	IS 335 – 1993
	(e) Flash point, Pensky marten (Closed)	140 ^{0} C (Min)	IS 335 – 1993
	(f) Pour point	- 6^0 C (Max)	IS 335 – 1993
	(g) Acidity (Neutralisation Value)		
	(i) Total acidity	0.03 mg KOH/ g (Max)	IS 335 – 1993
	(ii) Inorganic acidity/ alkalinity	Nil	IS 335 – 1993
	(h) Corrosive Sulphur	Non – Corrosive	IS 335 – 1993
	(i) Di-electric strength (Breakdown voltage)		
	(i) New unfiltered oil	30 kV, rms (Min)	IS 335 – 1993
	(ii) After filtration	60 kV, rms (Min)	IS 335 – 1993
	(j) Dielectric Dissipation Factor (Tan) DDF at 90^0 C	0.002 (Max)	IS 335 – 1993
	(k) Specific Resistance (Resistivity)		
	(i) at 90^0 C	$35*10^{12}$ Ω –cm (min)	IS 335 – 1993
	(ii) at 27^0 C	$1500*10^{12}$ Ω –cm (min)	IS 335 – 1993
	(l) Oxidation stability		
	(i) Neutralization value after oxidation	0.40 mg KOH/g (Max)	IS 335 – 1993
	(ii) Total Sludge after Oxidation	0.10% by weight (Max)	IS 335 – 1993
	(m) Ageing Characteristics after Acceleration ageing (open breaker method with copper catalyst)		
	(i) Specific Resistance (Resistivity)		
	at 27^0 C	$2.5*10^{12}$ Ω –cm (min)	IS 335 – 1993
	at 90^0 C	$0.2*10^{12}$ Ω –cm (min)	IS 335 – 1993
	(ii) Dielectric Dissipation Factor (Tan delta) at 90^0 C	0.2 (Max)	IS 335 – 1993
	(iii) Total Acidity	0.05 mg KOH/ g (Max)	IS 335 – 1993
	(iv) Total Sludge	0.05% by weight (Max)	IS 335 – 1993
	(iv) Total Sulphur	0.15% (Max)	IEC 60296-2003
	(n) Water content of new unfiltered oil	50 ppm (Max)	IS 335 – 1993
	(o) S. K. Value	4 to 8% by mass (Max)	IEC – 60296, 2003
	(q) Presence of Oxidation Inhibitor	Oil shall not contain antioxidant additives. Value of 0.05% by mass (Max) shall be treated as absence of	IS 335 – 1993

		DBPC – Phenolic type inhibitor	
	(r) PCB content (Polychlorinated Bipheyls)	Not detectable 0.1 mg/kg (Max)	IEC – 60296, 2003
	(s) Dissolved Gas Analysis (DGA)	Not applicable	IS 335 – 1993
	(t) 2 – furfural (Furan Analysis, Test method – IEC 61198:1993)	0.1 mg/kg (Max)	IEC – 60296, 2003
	(u) Furfural (Aging criteria for oil immersed Power Transformer)	Warning Trouble 1.5 ppm 15 ppm	CIGRE DOC. No. 227 Life Management Technique for Power Transformer Page – 107
	(v) Total Furan Content	250 parts per billion (ppb)	Transformer Diagnostic USBR, june 2003, Page 15
	Additional Requirement for inhibited oil		
	Inhibitor content (Antioxidation additive content) DBPC (Ditertiary Butyl Paracersol) DBP (Ditertiary Butly Phenol)	Minimum 0.08 % by mass and maximum 0.4% by mass	Inhibitor content determination (Test Mehod:IS – 13631) IEC – 60296, 2003
		Minimum 0.15 % by mass and maximum 0.3% by mass	Nynas and shell Inhibited oil

1.2	**Transformer oil for in-service Transformer**			
	Oil Parameters	At the time of first Charging.	During O&M	
	(a) Appearance	Clear, free from sediment and suspended matter	Clear without visible contamination	IS 1866 - 2000
	(b) Break Down Voltage (BDV) (GAP – 2.5 mm) min	40 kV for < 72.5 kV 50 kV for 72.5 to 170 kV 60 kV for > 170 kV	30 kV for < 72.5 kV 40 kV for 72.5 to 170 kV 50 kV for > 170 kV	IS 1866 - 2000
	(c) Water content (Moisture) (Max)	20 ppm for < 72.5 kV 15 ppm for 72.5 to 170 kV 10 ppm for > 170 kV	No free moisture for<72.5 kV 40 ppm for 72.5 to 170 kV 20 ppm for > 170 kV	IS 1866 - 2000
	(d) Acidity (Neutralization value (Max)	0.03 mg KOH/g	0.3 mg KOH/g	IS 1866 - 2000
	(e) Sediment & Sludge (Max)	0.01% by mass	0.02 by mass	IS 1866 - 2000
	(f) Resistivity			
	(i) Resistivity at 20^0 C (Min)		$1*10^{12}$ Ohm-cm	IS 1866 - 2000
	(ii) Resistivity at 90^0 C (Min)	$6*10^{12}$ Ohm-cm	$0.1*10^{12}$ Ohm-cm	IS 1866 - 2000
	(g) Dielectric Dissipation factor at 90^0C and 40-60 Hz (Tan Delta/ power factor) (Max)	0.015 for < 170 kV 0.01 for ε170 kV	1.0 for <170 kV 0.2 for 170 kV	IS 1866 - 2000
	(h) Inter Facial Tension (IFT) AT 27^0 C (Min)	35 mN/m	15 mN/ m	IS 1866 - 2000
	(i) Flash Point (Min)	140^0C	Max decrease of 15^0C from initial value	IS 1866 - 2000

	(j) Density at 29.5^{0}C (Max)	0.89 g/cm3	Not Essential	IS 1866 - 2000
	(k) Kinematic Viscosity at 27^{0}C (Max)	27 cSt	Not Essential	IS 1866 - 2000
	(l) Pour point (Max)	-6^{0}C	Not Essential	IS 1866 - 2000
	(m) Oxidation stability of uninhibited old			
	(i) Neutralization value (Max)	0.4 mg KOH/g	Not Essential	IS 1866 - 2000
	(ii) Sludge (Max)	0.1% by mass	Not Essential	IS 1866 - 2000
	Additional requirement for inhibited oil			
	(n) Oxidation Stability of inhibited oil	Minimum 0.08% by mass and maximum 0.4% by mass	Not Essential	IEC 60296, 2003

1.3	**Dissolved Gas Analysis (DGA)**		
	Typical rates of gas increase for power transformers	Values in milliliters per day	IEC: 60599-1999 See note Below
	Hydrogen (H_2)	<5	
	Methane (CH_4)	<2	
	Ethane (C_2H_6)	<2	
	Ethylene (C_2H_4)	<2	
	Acetylene ((C_2H_2)	<0.1	
	Carbon Monoxide (CO)	<50	
	Carbon dioxide (CO_2)	<200	
	Equation to calculate the rate of gas increase as per IEC: 60599 – 1999 Rate – $(Y_2-Y_1)m/\{>(d2 – d1)\}$ m1/ day Where Y_1 = is the reference analysis Y_2 = is the last analysis (Y_2-Y_1) – is the increase in micro litre per litre. M = is the mass of oil, in kilograms P = is the mass density, in kilograms per cubic metre. d_2 = is the date for Y_1 d1 = is the date for Y_2		
1.4	**Transformers/ Reactors**		
	Ten Delta for bushing at 20^{0}C	0.007	IEC – 60137
	Capacitance for Bushing	-5% to +10% Variation	
	Contact Resistance of Bushing	10 Micro – Ohm/Connector	NGC, UK Recommendation
	Ten Delta for Windings at 20^{0}C	0.007	IEEC/C57.12.90.1999
	Ten Delta for Windings at 20^{0}C (Power factor)	0.005	Transformer Diagnostic USBR, June 2003
	Rate of Rise of Tan Delta (Bushing & Winding)	0.001 Per year (Max)	
	Magnetizing current test (Excitation	If the excitation current is less than 50 milli amperes (mA), the difference between the two higher currents	Transformer Diagnostic USBR, June 2003

	current test)	should be less than 10%. If the excitation current more than 50 mA, the difference should be less than 5%. In general, if there is an internal problem, these differences will be greater.		
	Magnetic Balance Test (Three Phase)	Value of supply voltage (230 V AC) in one phase is equal to sum voltage induced in other two phase. When supply voltage in middle limb, voltage induced in outer limbs should equal and roughly half of the supply voltage.		
	Winding resistance Transformer and Reactor (Resistance converted to 75^0C)	± %5 difference between phases or from Factory tests.		
	Voltage Ratio of Transformer (All Taps)	± %5 difference from Factory tests.		
	Insulation Value (Thumb Rule/ Empirical Formula)	Min insulation values for one minute resistance measurement for transformers may be determined by using the following formuls: R = CE/ √kVA Where R = Insulation resistance, in MΩ C= 1.5 for oil filled transformers at 20^0C, assuming that the transformer's insulating oil is dry, acid free, and sludge free. = 30.0 for un-tanked oil impregnated transformers. E – Voltages rating, in V, of one of the single phase windings (ph – to ph for delta connected and ph – to neutral for wye connected transformers) kVA = Rated capacity of the winding under test (If the winding under test is three-phase and the three individual windings are being tested as one, the rated capacity of three-phase winding is used.		
	IR Value of Winding (Min)	Rated Voltage Class of winding	Min desired IR value at 1 minute at 30^0C (Mega ohm)	
		11 kV	300	
		33 kV	400	
		66 kV & above	500	
	Polarization index (Ratio of IR values at 10 min to 1 min)	Polarization index	Insulation Condition	
		Less that 1	Dangerous	
		1.0-1.1	Poor	
		1.1-1.25	Questionable	
		1.25- 2.0	Fair	
		2.0-4.0	Good	
		Above 4.0	Good	
	CORE INSULATION TEST Min (Between CL and CC +G with tank grounded)	1000K Ohms at 2.5/3.5 kV DC for 1 min		
	Transformer Neutral Resistance Value	Below 1 ohm		
	Turret/ Neutral Resistance Value	±3%		IS – 2705
	Vibration level for Reactors	200 Microns (Peak to Peak) 60 Microns (Average)		
	Sweep Frequency Response Analysis Test (20 Hz to 2	In general, changes of +/- 3 dB (or more) in following frequency range may indicate following faults: Frequency Range		Euro – Double Client Committee Transformer Diagnostic

	MHz)	Probable Fault 5Hz to 2 KHz Shorted turns, open circuit, residual magnetism or core movement 50 Hz to 20 KHz Bulk movement of windings relative to each other 500 Hz to 2 MHz Deformation within a winding 25 Hz to 10 MHz Problems with winding leads and/ or test lead placement.			USBR, June 2003
	Moisture measurement of winding (RVM Measurement)	IEEE Std. 62-1995			
	Insulation condition	% Moisture by dry weight in paper (Wp)	% Water saturation of oil ( )		CIGRE DOC No. 227. Life management Technique for Power Transformer Page 119
	Dry (at commissioning)	0.5- 1.0%	<5%		
	Normal in operation	<2%			
	Wet	2-4%	6-20%		
	Extremely wet	>4.5%	>30%		
	Degree of polymerization (DP)	New insulation	1,000 DP to 1,400 DP		EPRI's Guidelines for the life Extension of Substations, 2002 Update, Chapter 3, Table 7 DP Values for Estimating Remaining paper life.
		60% to 66% life remaining	500 DP		
		30% life remaining	300 DP		
		0 life remaining	200 DP		
1.5	**CIRCUIT BREAKERS**				
	Dew Point of SF_6 Gas	Dew point values as per Annexure – II			
	Dew Point of operating air	+45^{0}C at Atmospheric Pressure			
	(A) CB Operating timing	400 kV	220 kV	132 kV	IEC-62271-100 (2001)
	(a) Closing time (Max)	150 ms	150 ms	150 ms	
	(b) Trip time (Max)	25 ms	35 ms	45 ms	IEC-62271-100
	(c) Close/Trip time pole discrepancy at rated operating pressure	50 ms 3.33 ms	5.0 ms 3.33 ms	5.0 ms 3.33 ms	2001
	- Phase to Phase (Max) close open	2.5 ms	2.5 ms	2.5 ms	IEC-62271-100 (2001)
	-Break to Break (Max) of same phase	35 ms 300 ms	35 ms 300 ms	35 ms 300 ms	
	(d) CO time (min)	±5 ms ±3ms	±5 ms ±3ms	±5 ms ±3ms	With simultaneous close & trip command.
	(e) Trip delay time for DCRM test (CO operation) – Minimum				
	(f) Deviation from standard timings as per GTP of manufactures – close open				

	(B) Travel of operating rod	ABB CGL BHEL Alstom (Imported)	200 mm 230 mm 130 mm 184 mm	IEC-62271-100 (2001)
	(C) PIR time - BHEL make - CGL make - ABB mak - NGEF make - M&G make - TELK make - Alstom make (HVDC) -ABB make (HVDC)	400 kV 12-16 ms 8-12 ms 8-10 ms 8-12 ms 8-12 ms 8-12 ms 8-12 ms 8-12 ms		Manufactures Recommendations.
	(D) PIR operating time prior to opening of main contacts (ABB, CGL, NGEF make CBs)	5 ms (Min) at rated pressure		
	(E) PIR and main contacts overlap time (BHEL, M&G, ABB (imported make CBs)	5 ms (Min) at rated pressure		
	(F) Tan delta of grading capacitors	0.007		Since temperature correction factor for Tan Delta depends on make, type and also again conditions, the correction factors for different types/ makes are different. Hence no standard temperature error factors can be applied
	(G) Rate of rise in Tan dalta	0.001 per year (max)		
	(H) Capacitance of grading capacitors	Within ±5% of the rated value		
	(I) Contact Resistance of CB (in Micro-Ohm)	400 kV 220 kV 132 kV 150 100 100		
	(J) Contact Resistance of CB terminal connector	10 Micro-Ohm per connector		NGC, UK Recommendations
	(K) Evacuation level before SF6 gas filling	5mbar (min)		
	(L) N2 leakage rate from N2 accumulator	3 bar per year (max)		
	(M) IR VALUE			
	1. Phase – Earth 2. Across open contacts 3. Control cables	1000 M-Ohm (Min) by 5.0/10.0 kV megger 1000 M-Ohm (Min) by 5.0/10.0 kV megger 50 M-Ohm (Min) by 0.5 kV megger.		
	(N) PRESSURE SWITCH SETTINGS - SF6 gas pressure switches	Within ±0.1 Bar of set value.		

	- Operating air pressure switches - Operating oil pressure switches	Within ±0.1 Bar of set value Within ±0.1 Bar of set value	
	(O) BDV of oil used for MOCB - At the time of filling -During O&M	 40 kV at 2.5 MM GAP (Min) 20 kV at 2.5 MM GAP (Min)	 Manufactures Recommendations
1.6	**CURRENT TRANSFORMERS**		
	(A) IR Value -Primary – Earth -Secondary – Earth -Control Cables	1000 M –OHM (Min) 50 M-OHM (Min) 50 M-OHM (Min)	by 5.0/10.0 kV Megger by 0.5 kV Megger by 0.5 kV Megger
	Tan delta value	0.007	Since temperature correction factor for Tan – Delta depends on make, type and also ageing conditions, the correction factors for different types/ makes are different. Hence, no standard temperature error factors can be applied.
	Rate of rise in Tan Delta	0.001 per year (max)	
	(B) Monitoring of Tan delta • Upto 0.007 (rise @ 0.001) • 0.007 to 0.011 • 0.011	- Yearly monitoring - Half yearly monitoring - Replace the CT	
	Terminal connector contact resistance	10 Micro-Ohm per connector	NGC, UK Recommendations
	CT ratio errors	±3% protection cores ±1% metering cores	IS – 2705 - do-
		Pressure: 0.10 kg/cm^2; 0.20 kg/cm^2; 0.30 kg/cm^2; 0.40 kg/cm^2; 0.50 kg/cm^2 Oil level: 10 mm; 30 mm; 50 mm; 70 mm; 90 mm	
1.7	**CAPACITIVE VOLTAGE TRANSFORMERS**		
	(A) Tan Dalta	0.007	Since temperature correction factor for Tan – Delta depends on make, type and also ageing conditions, the correction factors for different types/ makes are different. Hence, no standard temperature error factors can be applied.
	(B) Rate of rise in Tan Delta	0.001 per year (max)	
	(C) Change in Tan from pre commissioning value	Measurement Value — Measurement Frequency Upto +0.002 - Three yearly +0.002 to +0.003 - Yearly Above +0.003 - alarming	

	(D) Capacitance	Within ±5% of pre commissioning value		
	(E) Contact resistance of terminal connector.	10 Micro-OHM per connector		NGC, UK recommendations
	(F) Change in capacitance from pre commissioning value	Measurement Value Measurement Frequency Upto ±2% - Three yearly ±2% to ±3 - Yearly Above ±6% - alarming (needs replacement)		
		1000 M-OHM (Min) by 5.0/10.0 kV Megger 50 M-OHM (Min) by 0.5 kV Megger 50 M-OHM (Min) by 0.5 kV Megger		
	(G) Drift in secondary Voltage (to be measurement in 0.2/0.5 class multimeter)			
		Condition Frequency	Measurement	
	Upto ±0.5 volts ±0.5 to ±0.8 volts ±0.8 to ±1.2 volts ±1.2 to ±2.0 volts above +2.0 volts -0.8 to -4.0 volts less than -4.0 volts	Healthy To be monitored Close monitoring Close monitoring Alarming Close monitoring Alarming	Six month 03 monthly monthly 15 days replacement 15 days replacement	
	(H) EMU tank oil parameters BDV (Min) Moisture content (Max) Resistivity at 90^0C Acidity IFT at 27^0C Tan delta at 90^0C Flash Point	 30 kV (GAP 2.5 MM) 35 PPM $0.1*10^{12}$ OHM-CM 0.5 mg KOH gm (Max) 0.018 N/M (Min) 1.0 Max 125^0C (Min)		IS- 1866
	(I) CVT voltage ratio errors	±5% protection cores ±5% metering cores		IEEE/C93.1.1990 IEC 186
1.8	**DISCONNECTING SWITCHES**			
	(A) Contact resistance (B) Contact resistance of terminal connector (C) IR Value - Phase – Earth - Across Open Contacts - Control cables	300 Micro – Ohm (Max) 10 Micro-Ohm per connector 1000 M-Ohm (Min) by 5.0/10.0 kV megger 1000 M-Ohm (Min) by 5.0/10.0 kV megger 50 M-Ohm (Min) by 5.0 kV megger		NGC, UK recommendations
1.9	**SURGE ARESTER**			
	(A) Third Harmonic Resistive Current (THRC) – for all makes Elpro/ Alstom / Oblum/ CGL - For new Las - For Las in services	• Upto 30 Micro – Ohm • (Upto 150 Micro – Ohm) – Normal • (150 to 350 Micro-Ohm) – to be tested for insulation test & if value found low - to be removed from service. • Beyond 350 Micro Ohm (Gapless type) - to be removed from service • Beyond 350 Micro Ohm (Gapless type) - to be removed from service		
	(B) IR Value	1000 Mega-Ohm (Min)		

1.10	**MICELLANEOUS**		
	(A) Station Earth Resistance	1.0 Ohm (Max)	IEEE/C37.010.1979
	(B) Thermovision Scanning - Temp upto 15^{0}C (above ambient) - Temp above 15-50^{0}C (above ambient) - Temp above 50^{0}C (above ambient	- Normal - Alert - To be immediately attended.	
	(C) Therminal Connectors	10 Micro-Ohm per connector	NGC, UK recommendations,
	(D) IR Values - All Electrical Motors. - Control Cables - LT Transformer - LT Switchgears	50 M-Ohm (Min) by 0.5 kV megger 50 M-Ohm (Min) by 0.5 kV megger 100 M-Ohm (Min) by megger 100 M-Ohm (Min) by 0.5 kV megger	IS 900
1.11	**BATTERIES**		
	(A) Terminal connector resistance	10 Micro-Ohm ±20%	ANSI/IEEE/450-1987
	(B) Specific Gravity	1200 ± 5GM/L at 27^{0}C	
1.12	**DG SET**		
	(A) Winding IR value (B) Stator winding resistance	50 M-Ohm Within ± 10% of STD value	

DEW POINT OF SF6 GAS

Sl. No.	Make of CB	Dew Point at rated pressure	Dew point at Atmospheric Pressure (Limit)	Remarks
1	BHEL	-15^{0}C	-36^{0}C	At the time of commissioning
		-7^{0}C		During O&M
		-5^{0}C		Critical
2	M&G		-39^{0}C	At the time of commissioning
			-32^{0}C	During O&M
3	CGL	-15^{0}C	-35^{0}C	At the time of commissioning
		-10^{0}C	-31^{0}C	During O&M
4	ABB	-15^{0}C	-35^{0}C	At the time of commissioning
		-5^{0}C	-26^{0}C	During O&M
5	NGEF	-15^{0}C	-36^{0}C	At the time of commissioning
		-7^{0}C	-29^{0}C	During O&M
		-5^{0}C	-27^{0}C	Critical
6	For all make	-15^{0}C	-35^{0}C	To be followed for substations having ambient temperature less than 0^{0}C

Annexure-B

ESSENTIAL REGISTERS TO BE MAINTAINED AT EACH SUBSTATION

SL. NO.	Particulars	Register No.
1.	Index of registers	1
2.	Plant History Register	2
3.	Operation and Maintenance manual	3
4.	Shift Arrangement Register	4
5.	Attendance Register	5
6.	Testing Register	6
7.	Defect Register	7
8.	Daily Energy Account Register	8
9.	Shut down Form Register	9
10.	Tripping Register-Primary System	10
11.	Stoppage Register	11
12.	Authorization Register	12
13.	Instruction Register	13.
14.	Inspection Register	14
15.	Rostering Register	15
16. (a)	Message Register-Control	16(a)
16 (b)	Message Register-Local	16(b)
17.	Maximum/Minimum Load Register	17
18.	Carrier Fault Register	18
18.	Compressor Reading Register	19
19.	LA’s Surge Counter Reading Register	20
20.	Daily Log Sheet	21

INSTRUCTIONS FOR MAINTENANCE OF ESSENTIAL REGISTERS:

1. INDEX REGISTER:

Sl. No. of Register	Details of register	Remark
1	2	3

2. PLANT HISTORY REGISTER:

Sl. No.	Technical specification of Equipment/plant	History (specified events in the life of equipment)	Remark
1	2	3	4

3. OPERATION AND MAINTENANCE MANUALS

4. SHIFT ARRANGEMENT:

Date Groups	1	2	3	4	5	6	7	30	31	Remarks
A	R	N	N	N	R	ABCD Details Shifts,		E	E	
B	E	E	E	E	E					
C	M	M	M	M	M	R-Rest, N-Night		M	M	
D	N	G	G	R	N	M-Morning E-Evening G- General		N G	N G	

5. ATTENDANCE REGISTER:

Attendance register should be maintained to have a proper watch for the staff of general shift and maintenance staff posted at each Grid Sub-Station.

6. TESTING REGISTER:

Sl. No.	Date	Name of equipment	Details of Test	Test Result	Signature of J.E./A.E
1	2	3	4	5	6

7. DEFECT REGISTER:

Date & Time	Defect observed	Noted by	Compliance for removal of defect with details	Signature of J.E./A.E.
1	2	3	4	5

8. DAILY ENERGY ACCOUNT REGISTER:

Sl. No.	Voltage	Name of Feeder/transformers	IMPORT					EXPORT					Calculation of Losses
			Last Day reading at 24.00 hrs	Present reading at 24.00 hrs	Diff.	MF	Nett. Energy in MWH	Last Day reading at 24.00 hrs	Present reading at 24.00 hrs	Diff.	MF	Nett. Energy in MWH	(A) Total Import (MWH) (B) Total Export (MWH) A-B x 100 % Losses = A
1	2	3	4	5	6	7	8	9	10	11	12	13	14

Counter Signature JE (T&C)/AE (T&C) **Signature of J.E. (M)/A.E. (M)**

9. SHUT-DOWN/WORK PERMITS FORM REGISTER:

This should be maintained to keep the records of all the shut-downs in prescribed proformas.

10. TRIPPING REGISTER (PRIMARY SYSTEM):

Sl. No.	No. o f Breaker & feeder	Date & time of tripping	Date/Time of closing	Flags at this end		Flags at other end		If any other breaker at this or other end also tripped (if yes, flags may also be noted0	Signature of J.E,/A.E	Fault analysis of tripping & remarks, if any
				Control Panel	Relay Panel	Control Panel	Relay Panel			
1	2	3	4	5	6	7	8	9	10	11

11. STOPPAGE REGISTER:

Sl. No.	Tripping		Breakdown	Shutdown	Rostering	Total effective duration of failure of Supply		Total effective availability of Supply		Signature of S.S.O./J.E.
	From To Duration	Flags & Reasons	From To Duration reason	From To Duration reason	From To Duration	Including Rostering	Excluding Rostering	Hrs.	Month	
	2	3	4	5	6	7	8	9	10	11

12. AUTHORISATION REGISTER:

Sl. No.	Name of person authorized	Name of work for which authorized	Dated signature of person authorized for work	Dated signature of authority who has authorized	Remarks
1	2	3	4	5	6

13. INSTRUCTION REGISTER:

Date	Details of instructions	By whom instructions given	Note By	Compliance with dated Signature
1	2	3	4	5

14. INSPECTION REGISTER:

Date	Inspecting Officer	Observation	Signature	Noted by	Compliance with dated Signature
1	2	3	4	5	6

15. ROSTERING PROGRAMME REGISTER:

Date	Rostering Programme	Received from	Code No. if any	Communicated to	Remarks	Noted by
1	2	3	4	5	6	7

16. MESSAGE REGISTER:

Date & Time	Code/Message No.		From	To	Detail of Message	Action taken	Remarks JE/SSO in shift
	Receiving End	Sending End					
1	2	3	4	5	6	7	8

17. MAXIMUM/MINIMUM LOAD REGISTER:

Sl.No.	Name of feeder/ Transformer	Rated load	Maximum Load recorded		Volt & time of Max. Load	Date & time	Max. Simultaneous Load		Load Shedding at the time of max. load		Signature of SSO/JE
			MW	Amp.			MW	Amp.	MW	Amp.	
	2	3	4	5	6	7	8	9	10	11	12

18. CARRIER FAULT REGISTER:

Date & time	Name /No. of channel being defective	Time of Occurrence of fault	Nature of fault	Signature of T&C staff noting the fault	Date & time of removing of fault
1	2	3	4	5	6

19. COMPRESSOR READING REGISTER:

Time of start	Compressor No.1		Final Pressure	Reading of Hour meter		Duration of running	Any other details	Signature SSO/JE
	Initial pressure	Time of closing		Starting	Closing			
1	2	3	4	5	6	7	8	9

20. LA's SURGE COUNTER READING REGISTER:

Sl No	Date	Time	Reading of counter			Reading of Ammeter			Signature of JE/SSO
			R	Y	B	R	Y	B	
1	2	3	4	5	6	7	8	9	10

21. DAILY LOG SHEET – As per Substation requirement

MAINTENANCE PROCEDURES OF EHV TRANSMISSION LINES

CHAPTER 1

MAINTENANCE PROCEDURES OF EHV TRANSMISSION LINES

A INTRODUCTION

1. Today, PTCUL is operating and maintaining transmission lines of Voltage class upto EHV 400 KV, AC. These lines criss-cross the entire length and breadth of Uttarakhand State and power is transmitted on these lines to the remotest comer. A very high degree of availability is therefore required which consequently makes break down maintenance of these elements paramount importance.

2. Generally, the following types of breakdowns are required to be attended to:

(i) Tower collapse including foundation failure
(ii) Cross-arms failure of tower
(iii) Earth wire failure
(iv) Jumper failure
(v) Conductor snapping and breakages
(vi) Insulator failure
(vii) Reduction in clearance due to swing / Falling and growth of tree and branches
(viii) Hardware failure

3. Although there are minor/major modification in the design of Towers ranging from 66 KV to 400 KV to take care of various parameters like number of Sub-conductors in a bundle, statutory clearances, live metal clearances, angle of shield and so on, the essential principle of break down maintenance of all Towers/line material remain basically the same as described below:

B ACTIVITIES PERFORMED FOR ATTENDING THE FAULTY LINE

After declaration that the line is faulty, following activities are carried out.

1. Locating the Fault

A number of methods are now available to pin point with a great deal of accuracy the location of a fault along the line. After having done so, the shift incharge is required to inform all concerned.

2. Patrolling and Scheduling

Patrolling is carried out and a schedule is prepared for the restoration of the line at the earliest taking into account various factors like importance of the line (evacuation line, link line,, grid strengthening, etc.), availability of ERS, restoration on normal towers depending on the availability of spare towers and damage to the foundations, and so on. It must be mentioned here in this connection that there cannot be a hard and fast rule or even a thumb rule to determine the restoration time of a broken down line. It all depends on factors mentioned above as also many other reasons.

After getting a message of location of breakdown, a Assistant Engineer shall immediately visit the site and inspect the following:

- List out the approach to the location and the activities to be done to clear the approach for truck, tractor and light vehicles.
- Inspection of the spot and list out the activities to be done to clear the site from bushes and other hindrances for easy handling of T&P and material required.
- Inspection of the failed part of the line and list out the materials and T&P required for the job.
- If some stays and deadman are to be provided the pit digging works shall be marked immediately and pit digging started.

After this but before leaving the site, he shall start approach clearance work and site clearance work immediately so that site is cleared for working as soon as gang, T&P and material reaches site. Similarly, unskilled man power required shall be arranged for the future work there itself. Before starting, list of persons shall be prepared, sub gangs formed activity-wise and their transportation arrangement to the site done. The scope of above activities will widen as per the nature of break down and controlling officer will be the best judge for planning. First aid and seasonal medical drugs shall available for the maintenance of health of the workers. There should always be some vehicle available at work spot to meet any accidental exigencies and this shall be covered in the planning. Sufficient potable water arrangement and tents etc., shall be available at site depending upon the nature of work. Sufficient discharging local, earthing sets shall be taken to site after due inspection for their perfectness. Site camps for the convenience of the workers can be arranged in local Gram Panchayat halls etc. as per the facility available.

C GENERAL SAFETY PRECAUTIONS

1. Objective

When work is to be carried out on lines with one circuit de-energized, it is necessary to provide safe working conditions to enable that work to be carried on the de-energized circuit. This is also applicable for all twin / Quad bundle conductor lines whether single circuit or double circuit.

2. Scope

The Safety Instruction sets down the procedure to be adopted when carrying out maintenance on a de-energized circuit of a EHV transmission line. It does not provide for work on live circuits.

3. Definitions

Terms printed in Bold are Defined Safety Rule Terms, and those printed in Italic are specific definitions, which only apply to this Safety Instruction.

- *Earth End Clamp* - The End Clamp of an Additional Earth which is to be connected to tower members, cross-arm members or a suitable earth spike driven into the ground at ground potential.

- *Line End Clamp* - The End Clamp of an Additional Earth, which is to be connected with conductor or jumper.

- *Earth Lead* - A lead made of aluminium strands protected with a transparent cover
  for connection between the Line End Clamp and the Earth End Clamp.

- *Socket* - The sliding socket for holding and operating the *Line End Clamp, which*
  is a part of a *Telescopic Pole or Bridging Pole*.

- *Earthing Pole* - An insulated pole with a Socket, which is to be used for tightening
  the Line End Clamps on to conductors or jumpers while maintaining Safe
  Electrical Clearance.

- *Pole Extension* - A suitable length of extended pole which is to be connected with
  the Earthing pole for achieving the *Safe Electrical Distance* when connecting *Line*
  End Clamps to conductors or jumpers.

- *Trailing Earth* - An earth of sufficient length of earth lead suitable for connection between conductor and the tower when lowering or raising conductors. This can be in the form of additional earth.

- *Bridging Pole* - A short insulated pole with a Socket which is used for applying and tightening Bridging Earths. First part of earthing pole can be used as bridging pole.

- *Bridging Earth* - An earth used for bridging across insulator strings or when a conductor is to be cut or jointed. An additional earth with line and clamp on both ends can be used as bridging earth.

- *Working Phases* - The conductor phases on which linesmen will carry out work.

- *Field Equipment Earth* - Approved connections for bonding items of field and access equipment such as scaffold, hydraulic platforms, mobile cranes, winches etc. to earth. The earths are' colored orange to identify them from Additional Earths and are not included on an Earthing Schedule. They shall have a minimum cross sectional area of 35 mm2 copper equivalent. An additional earth can be used in the form of field equipment earth.

4. Dangers

The main dangers when working on transmission lines are :

- The possibility of personnel making mistakes, identification of the circuit on which it is safe to work with the one that is still energized.
- Infringing Safety Clearance before Additional Earths are applied.
- Inadequate precautions to exclude any induced voltages present on the conductors or fittings.

5. General Precautions to be taken before Climbing or Working on Transmission Towers or working on Conductors

These general safety precautions are to be taken in addition to the normal safety precautions, are detailed below:

- One responsible officer (Supervisor/Engineer) should always be present at the site of work.

- The "CIRCUIT UNDER SHUT DOWN" as per PTW should be identified at the working location(s) with the help of a circuit plate or any other reliable method.

- All linesmen who work on the transmission towers, conductors or fittings, shall wear and make use of all safety belts/hamesses and other safety equipment provided for their protection.

- One green flag shall be attached at the Anti climbing device level. One green flag shall be attached at each conductor cross-arm level. All these green flags shall be attached to the side of the tower that supports the circuit under shutdown.

- Six red flags should be attached in the center line of the tower at cross-arm level to identify the danger zone of the live circuit.

- The above green and red flags should be attached to all towers on which linesman are likely to climb.

- **Additional Earths** shall be carried on to the tower in gunny/suitable bags to avoid any damage to the **Additional Earths**. Alternatively the **Additional Earths** can be carried manually by the linesmen on their shoulders.

- **Safe Electrical Clearance** shall be maintained by all linesmen until all the **Additional Earths** are correctly connected to conductors or jumpers of circuits under shutdown.
- All Earth End clamps of all **Additional Earths** at the point where the lineman is standing or sitting in order to apply the **Additional Earths**, shall be connected to the tower / cross-arm member.

- After connection of the Earth End clamps with the tower / cross-arm members, all *Line End Clamp* shall be connected to conductor or jumper from the point where lineman is sitting or standing.

- The Earthing Pole I Bridging Pole shall be kept suitably on the tower after connection of the Line End 'Clamps until disconnection of all **Additional Earths**.

- If during working on conductors, jumpers, insulators or fittings, an *Earth End Clamp or Line End Clamp* of an **Additional Earth** becomes disconnected for any reason, linesmen must shift away from tower / cross-arm members to maintain Safe *Electrical Clearance*. He must not touch the disconnected end of the **Additional Earth** and should maintain Safe Electrical Distance from the disconnected end of the Additional Earth. In such a case, an extra **Additional Earth** shall be fitted in parallel with the faulty earth. Then the disconnected Additional Earth shall be removed, by the use of the *Earthing Pole*.

- After completing the work, all tools, plant and men shall be removed from the conductors and fittings. The last linesman shall remove the Line End Clamps from the conductors / jumpers sitting or standing at the point of connection of these **Additional Earths** to the tower / cross-arm side. After this, the Earth End Clamps shall be removed. This procedure shall be repeated for the disconnection of all other **Additional Earths**.

- On completion of work, the **Additional Earths** shall be carried to the ground from the tower in gunny / suitable bags to avoid any damage to the **Additional Earths**. To avoid damage, no Additional Earths should be thrown from the tower.

- While coming down from the tower, the linesmen will remove the red flags and the green flags.
- The number spare Additional Earth should be carried to the working tower to provide a spare in case of any contingencies.

- Isolation of Line Reactors: To reduce induced voltage on dead circuit of Transmission lines, isolate Line Reactors at both ends of line (wherever provided) in the dead circuit. This shall be done before closing earth switch at line ends of dead circuit.

D STEPS TO BE TAKEN IN CASE OF TOWER COLLAPSE

When there is a collapse of towers of a line, the line trips but the indications are insufficient to indicate that it is the collapse of towers. An attempt is made to charge the line. If the line trips again then patrolling of the line is carried out. If it is known that there is a collapse of the towers on the line, then following steps are resorted to:

- Visual inspection of the affected site is carried out to assess the extent of damage caused and material requirement for restoring the line.

- Permit to work is applied for carrying out work on the affected section and line is suitably earthed.

- The section of the line which is affected is divided into two categories- completely damaged and partially damaged. Both of these are made free of conductors and earth wires by disconnecting these from the clamps and insulators.

- The site is made clear of all damaged material.

- If the foundation is intact and the stubs are damaged above the ground level, then the damaged portion of stub is to be cut and extension piece is to be provided with the help of fish plate or cleat and the same foundation is utilized for erection of the tower.

- If the foundation is damaged, then location for the foundation shall be marked studying the profile.

- Once the location is finalized, pit marking is done and then excavation of the pin carried out using JCBs.

- For partially damaged towers, the damaged/sheared members are removed arrangement is made of these members by local fabrication or from spares.

- The conductors and the earth wires are held with connecting clamps on both sides of tower. Stays are provided at the cut points of the section and repairs to the conductor and the earth wire are carried out by conventional methods. It should I ensured that the conductors do not rest on the hard strata and suitable wooden cushions are used. The conductor and the earth wire should not be under any load!

- For stub setting quick setting cement of sufficient hardness shall be used.

- In the meantime, tower material shall be kept ready at the site by stacking properly. Proper inspection of position of conductor and earthwire of all the phases shall be done before starting the tower erection.

- After tower erection is complete insulators are hoisted. Then the conductors and earth wire stringing is carried out. In case cut point is damaged, then fresh stringing may be required.

- Earthing shall be done immediately after stub setting but before starting to erection.

- After completion of the final works, the permit to work shall be cancelled removal of all men and material from site.

- The line can now be charged.

E INSULATOR REPLACEMENT

1. Bundle Conductor (Twin/Quad) Transmission Line

T &P Generally Required

Sl. No.	Description of T &P	Qty.
1.	Walkie Talkies	2 Nos.
2.	Suspension insulator changing rig	1 No.
3.	Snatch Block and 15 mm diameter polypropylene rope	I No.
4.	D - Shackle - 3 ton	8 Nos.
5.	D - Shackle - 2 ton	2 Nos.
6.	Wire slings with soft eyes 5.5 m long, 14 mm dia., 4.5 ton capacity	2 Nos.
7.	Fiber slings Red - 5 ton, 0.5 meter long	3 Nos.
8.	Ratchet hoists 3 ton	2 Nos.
9.	Come along clamps (Klein Chicago type) 10-16 mm	2 Nos.
10.	Cross-arm fixer plate	1 No.
11.	Ratchet Hoist 750 kg	2 Nos.
12.	Insulator lifting plate	1 No.
13.	Lashings	Few Numbers
14.	Insulator sack	1 No.
15.	Aluminium ladder	1 No.
16.	Earthing set as per earthing schedule	1 Set
17.	Items as per safety procedure	

2. Safety

- Before commencing work, transmission line Maintenance Engineer will check that

PTW of the line has been obtained and the line has been shut down, isolated and earthed as per Safety Instructions mentioned in above.

- Ensure that all staff have and make use of Personal Protective Equipment (e.g., helmets, safety belts etc.)

- Ensure that all staff climbing the transmission tower have been trained in climbing techniques and are competent to carry out the work.

- Check the site for general Safety - Power lines, road or rail crossing or other obstructions.

3. Procedure

(a) For Outer Insulator String

- Attach snatch block to suitable point on a tower.

- Raise aluminium ladder to cross-arm to be worked on and attach it between cross arm and conductors.

- Check integrity of all fittings, pins and bolts on insulator strings to be worked on.

- Remove corona rings from bottom end of insulator set.

- Raise line end yoke plate adapter, cross-arm fixer plate, D shackles, 2 number ratchet hoist, 2 number 5.5m wire slings and fiber slings to cross-arm temporarily securing them.

- Attach cross-arm fixer plate to end of cross-arm - using span set and D shackles.
  (when changing out side insulators).

- Attach suspension insulator yoke plate adaptors over line end yoke plate.

- Attach 5.5m wire bonds to cross-arm fixer plate using 3 ton D shackles.

- Attach 3 ton Ratchet Hoist to wire bonds using 3 ton D - shackles.

- Attach 3 ton Ratchet Hoist to yoke plate adapter bracket.

- Take a small amount of load to tension the wire rope slings.

- Attach insulator sack to the 2 number 14 mm wire rope slings using karabiners so that the sack supports the insulators when they become slack.

- Attach insulator lifting plate around insulator two below the one to be replaced and secure to the main support wire bonds via I meter span sets and wire rope come along clamps and the 750 kg pull lifts using 2 ton D shackles.

- Move the come along clamps up the steel wire ropes to take out any slack in the span sets and pull lifts.

- Take up tension on the 3 ton ratchet hoists that are connected to the 5.5 m long wire bonds until insulator string starts to become slack.

- Place insulator sack under defective insulators.

- Using the 2 number 750 kg ratchet hoists take the weight of insulators until the faulty unit can be removed.

- Remove the defective insulator and replace with the new ensuring that the security clip is correctly located in the insulator cap.

- Gently release the two 750 kg ratchet hoists.
- Gently release the two 3 ton ratchet hoists to transfer the load back insulator string.

- Remove all T & P from Tower.

(b) For Inner Insulator String

Repeat the above except attach the 2 number 5.5 m long wire bonds to cross-arm (tower body end) adjacent to the insulator suspension point, using 0.5 m 5 tonne span sets and 3 ton D shackles.

Man Power required	-	3 Nos. technicians
	-	4 Nos. others
Time for activity	-	2 hours

4. Bundle Conductor (Twin) Transmission Line - Replacement of Suspension Insulator
T &P Generally Required

Sl. No.	Description of T&P	Qty.
1.	Walkie Talkies.	2 Nos.
2.	One meter fibre round sling (5 T red).	2 Nos.
3.	Two meter fibre round sling (5 T).	3 Nos.
4.	3 ton pull lift (roller chain type).	1 No.
5.	450 mm Lifting Shoe (3T).	1 No.
6.	3 ton shackle	3 Nos.
7.	Insulator lifting plate.	1 No.
8.	750 kg pull lift (roller chain type).	2 Nos.
9.	Folding ladder (fiber glass / AI) - 4.5m long.	1 No.
10.	Earthing set as per earthing schedule scheme - 1	1 Set.
11.	Items as per safety procedure.	

Method

- Attach one meter fiber sling around the end of the cross-arm at a suitable location.
- Connect a two meter fiber sling to the one around the arm with a 3 ton shackle.

- Connect a 3 ton pull lift to the 2m fiber sling and conductor lifting shoe.
- Position conductor lifting shoe under conductor and operate the pull lift until the insulators become slack.
- Place the insulator lifting plate under the insulator 2 units below the broken one.
- Attach 1 meter fiber sling around the end of cross-arm at suitable location.
- Attach 750 kg Pull lifts to both ends of fibre round slings.
- If required, attach fibre round slings to insulator lifting plate.
- Operate the 750 kg Pull lifts until the weight of the insulators has been taken.
- Now replace the defective insulator.
- Reverse the procedure to transfer the load back onto the insulator string.
- Clear down the tower.

Man Power required - 2 Nos. technicians
- 2 Nos. others

Time for activity - 2 Hrs.

5. Replacement of Tension Insulator - Procedure

T &P Generally Required

Sl. No.	Description of T&P	Qty.
1.	**Snatch Block** and 15 mm diameter endless polypropylene rope	1 No.
2.	Tension Insulator changing rig	1 No.
3.	12 meter long 16 mm diameter wire bond with soft eyes both ends	1 No.
4.	5.25 metre long 14 mm dia. wire bond with soft eyes both ends	1 No.
5.	Insulator sack	1 No.
6.	D - Shackle - 6 Ton	2 Nos
7.	D - Shackle - 3 Ton	2 Nos
8.	Ratchet hoists 6 ton	1 No.
9.	Ratchet hoists 1.5 ton	1 No.
10.	Lashings	Few Numbers
11.	Earthing set as per Earthing Schedule	1 set
12.	Items as per safety procedure	

Procedure

- Attach snatch block, complete with sash line to suitable point on tower.

- Check integrity of all fittings, pins and bolts on insulator strings to be worked on

- Remove corona rings and temporarily tie onto conductors.

- Raise tension insulator changing lowering rig, D shackles, ratchet hoists and the slings to cross-arm temporarily securing them.

- Attach both adapter plates to the yoke plates for the insulator string in which the insulators are to be changed.

- Feed 1 number 5.25m long 14 mm diameter wire bond through one side of insulator sack. Feed the 12m 16 mm diameter wire bond through the other side of sack. And raise to cross-arm. Connect the 1.5 ton ratchet hoist to the 14 mm wire bond so that the hook on hoist is inside sack.

- Connect the 12m long wire sling to the yoke plate adapter plate at the cross-arm and using a 6 ton D shackle. This wire sling has already been threaded through the sack, feed the free end around to cross-arm. Attach 6 ton ratchet hoist to the sling and anchor back to cross-arm using 6 ton D- shackle.

- Connect the 6 ton ratchet hoist and the 16 mm wire bond between the two adapter plates either side of the insulator string to be worked on using 6 ton D shackle.

- Using the 6 ton ratchet hoist, take up the load on the insulator string.

- Using the 1 number 750 kg ratchet hoist simultaneously, release the tension in the insulator string until insulators are resting in the sack. Remove faulty insulator and replace ensuring that the insulator security retaining clips (W pins) are securely fastened.

- Gently release the 750 kg. Ratchet hoists.

- Gently release the 6 ton . Ratchet hoist until load is transferred back to the insulator string

Remove all T&P

Man Power required	- 3 Nos. technicians
	- 3 Nos. others
Time for activity	- 3 Hrs.

6. CATCHING OFF / HOLDING TWIN/QUAD CONDUCTORS AT SUSPENSION TOWER

T &P Generally Required

SI. No.	Description of T&P	Qty.
1	Snatch Block and 15 mm diameter polypropylene endless rope	1 No.
2	Walkie talkies	2 Nos.
3	200 meters 14 mm diameter wire rope with soft eye at one end and taper fused the other end	4 Nos.
4	Ground anchors/ deadmen and 14 mm diameter 10 meter long wire bond with soft eyes	4 Nos.
5	Wire rope shortners of capacity 7 ton for 14 mm wire rope	4 Nos.
6	Come along clamps for Bersimis conductor	4 Nos.
7	Spacer yoke plate	1 No.
8	D - shackles - 3 ton capacity	8 Nos.
9	Fiber Slings Red - 5 ton, 0.5m long	2 Nos.
10	Conductor Running Blocks (7.5 ton)	4 Nos.
11	Ratchet Hoists capacity 4.5 ton	4 Nos.
12	Ratchet Hoists capacity 3.5 ton	2 Nos.
13	Wire rope slings 14 mm 5.5m long with soft eyes	2 Nos.
14	D - shackles capacity 5 ton	8 Nos.
15	Aluminium ladder	1 No.
16	Earthing set as per earthing schedule	1 Set.

7. REPAIRING OF TWIN CONDUCTOR AT GROUND OF 400KV LINE, - TENSION TOWER

T&P Generally Required

SI. No.	Description of T &P	Qty.
1.	H.F. Chokes	2 Nos.
2.	Earthing Leads	6 Nos.
3.	Snatch block 5 T capacity	5 Nos.
4.,	Sling 3m long I8mm size	6 Nos.
5.	Steel rope 12mm114m	400m
6.	D-Shackle heavy duty 5T capacity	8 Nos.
7.	Four sheave pulley block l0t capacity	2 Nos.
8	Stay wire for ancker 100m. long.	2 Nos.
9.	Rail piece	2 Nos.
10.	Sling 10m Long I8mm size	2 Nos.
II.	Especially fabricated sag plate	I No.
12.	Equalizer pulley l0t capacity ,With shilling 20m long I8mm size	I No.
13.	Come along clamp	2+2 (extra)
14.	Crow bar 250 x 5 cm	10 Nos.
IS.	Lineman safety belt	4 Nos.
16.	prop line rope I8 mm size 100m length	1 Set.
17.	Ring Spanner 7/16 x 9/16'	4 Nos.
IS.	D-Spanner 7/16 x 9/16	4 Nos.
19.	Plier S"	4 Nos.
20.	Screw Driver	4 Nos.
21.	V-Bolts 3/4" size/IS mm size	10 Nos.
22.	Hammer 141bs.l5 kg	2 Nos.
23.	Polypropylene rope 12mm 100 m length for hand line	4 Nos.
24.	Steel pulley single sheave 6" size/IS cm size	4 Nos.
25.	Tommey	2 Nos.
26	Polypropylene rope I8mm 100m length	2 Nos.
27.	Hydraulic compression machine 100 t capacity along with die	1+1 (extra)
2S.	Hexa frame with blades	1 No.
29.	Safety halmet	S Nos.
30.	First aid box	1 No.
31.	Steel roller	4 Nos.
32.	Ground rollers	4 Nos.
33.	Double arial rollers	10 Nos.
34.	Steel measuring tape 15 m	1 No.

Procedure

After arranging shut down on the line, the permit to work is issued to an authorized supervisor of the line. The maintenance crew alongwith authorized supervisor reaching site of work need observe the following steps for carrying out the job of repairing of conductor:

- Temporary earths should be provided on both sides of the section of line through High Frequency Choke (H.F. Chokes) wherein damaged conductor is required to be repaired.
- It should be checked up if there are any line crossings in that span in which lowering of conductor is to be done. Permits on these lines should also be arranged and lowering of these lines should be done simultaneously.

- Three linemen who can do the work on the conductor should climb up the tower alongwith hand line / rope.

- Corona control rings, jumpers of bundled conductor will be opened from the conductor side which is to be lowered.

- Specially fabricated sag plate is hoisted to the cross-arm with the help of hand line and fitted with yoke plate.

- Four sheeve pully block with Equiliser puny and long sling is lifted to the cross- arm and fitted with sag plate.

- One Linemen goes to the conductor with 2nd hand line for lifting the cum-along clamp and D-Shackles. These clamps are then fitted by lineman thereafter comes back to the cross-arm.

- Load of the conductor is taken on the four sheave pully block by tightening the same with the help of two way/three way rope puny block. With this, conductors get loosened from ending cones and thus spared from yoke plate.

- By loosening the two way/three way rope puny block smoothly, conductor is lowered to the ground.

- The crimping/bolted type repair sleeve can also be used for repair of the conductor for attending to emergencies. In this case, there is no necessity to bring down the conductor on ground and the Lineman can fit it at the affected point by climbing on the conductor. In case the damage is on longer section, even two or three repair sleeves may be used to tide over the crises. However, where the damage of strands of conductor is too much, compression joint may be provided by bringing the conductor at ground. Temporary repair case also be done by providing preformed armour rods.

- After repair of conductor and checking of ending cone and straight through joint etc. in that span, conductor is lifted by tightening the two way/three way rope pully block and refit the ending cones.
- Then one lineman goes on the conductor and after opening the cum-along clamps of both sides, the same brought down on the ground with the help of hand line.

- Then spare 4 sleeve puny block and equiliser puny etc. from sag plate for bringing it down on the ground with the help of hand line.

- Spare the sag plate from yoke plate for bringing it down on the ground.

- Refit the jumpers and corona control rings.

- After the work of repair of damaged conductor is over, all the staff is asked to climb down. The temporary earths and H.F. Chokes etc. are got removed and permit to work got cancelled for re-energisation.

Note: The T&P required to carry out above repairing job varies as per the nature of the voltage level from 66KV to 400KV but principle remains same.

Man Power required 25-30 Nos
Time of activity 10 hours

Note: (a) Mild steel rod fitted with 4 sheave pully block with rope should be used so that the 4 sheave pully block works smoothly so that it does not turn/rotate.
(b) Duster cloth etc. may be used up on the conductor before using cum-along clamp to avoid the damage of conductor.
(c) Before pulling of conductor it must be loosened from suspension points on two towers.

8. PROCEDURE FOR REPAIRING OF CONDUCTOR AT GROUND OF 400KV LINE, - SUSPENSION TOWER

T &P Generally Required

Sl.No.	Description of T&P	Qty.
1.	H.F. Chokes	2 Nos.
2.	Earthing leads	6 Nos.
3.	Snatch block 5t capacity	6 Nos.
4.	Sling 3 m. long 10mm size	6 Nos.
5.	Steel rope 10/12/14 mm size	100m.
6.	D-Shackle Heavy Duty	6 Nos.
7.	Pulling & lifting machine 5t capacity	1 No.
S.	Hanger especially made	1 No.

9.	V-Clamp 3/4"/IS mm. size.	4 Nos.
10.	Polyproplene rope I8mm size 100m. length	2 Nos.
11.	Polyproplene rope 12mm size 100 m. length	3 Nos.
12.	Polyproplene rope I8mm size 6' 12 m long	4 Nos.
13.	Ring spanner 7/16 x 9/16 as per requirement	4 Nos.
14.	D-Spanner 7/16 x 9/16 as per requirement	
15.	Lineman safety belt	4 Nos.
16.	Plier S"/20 cm.	4 Nos.
17.	Screw driver	4 Nos.
IS.	Crow Bar 250 x 5 cm	6 Nos.
19.	Steel pully single sheave size 6"/15 cm.	3 Nos.
20.	First aid box	1 No.
21.	Safety helmet	S Nos.
22.	Steel rollers	4 Nos.
23.	Hydraulic compression machine 100 t capacity alongwtih die.	1+1 (extra)
24.	Hexa frame with blades	1 No.

Procedure

After arranging shut down on the line, the permit to work is got issued to an authorized supervisor of the line. The maintenance crew alongwith the authorized supervisor reaching the site of work need to observe the following steps for carrying out the job of repairing of conductor:

(i), (ii) and (iii) As Per procedure for repair of conductor in case of 400 KV line (Angle Tower) as mentioned in the above said para.

(iv) Corona control rings, grading rings and arcing horns are removed and kept on the tower cross-arm.

(v) With the help of hand line, two Nos. snatch blocks of 5 ton capacity, slings, D-shackles, especially fabricated hanger alongwith steel rope size 10 mm etc. are sent on cross-arm and fixed.

(vi) Load of bundled conductors is taken on the hanger by operating the pulling and lifting machine (trifer) of 5 Ton capacity of heavy duty turn buckle of 10 T capacity or four sheave pully block capacity l0t.

(vii) The disc insulator string is made free from the conductor. The bundled conductor alongwith hanger is brought down to the ground on rollers slowly by operating the pulling and lifting machine (trifer).

(viii) The repair of conductor is done as per damages on the conductor as under

Man Power required 20-25 Nos.
Time of activity 8 hours

9. JOINTING PROCEDURE

Wherever jointing of conductor is required, it is done with the help of compression type mid span joints. 15. The complete joint consists of a steel sleeve for the central core and a much longer aluminium sleeve for the overall aluminium conductor. The plugs are used for sealing the holes in the aluminium sleeve after hot paste filler has been injected in it. The steps involved in the making of compression joints on the conductor are as follows:

- The conductor is brought down on the ground as discussed previously.
- The conductor is inspected for its damage and cut for taking suitable action.
- Aluminium compression sleeve is made to slip over one conductor end and slide back the same along the conductor.
- Using a Hacksaw blade the aluminium strands from each side of conductor are cut exposing the steel core a little more than the length of steel compression sleeve
- Steel compression sleeve is inserted in the steel core of conductor (both sides) making sure that the ends of steel core touch each other in the middle of the sleeve
- The steel sleeve is compressed over its entire length making the first compression at the centre and working out towards the end allowing dies to always over lap the previous position.
- The distance from the centre of the steel joint equivalent to half the length of aluminium sleeve is measured and marked on the conductor, to help in centring the aluminium sleeve over the steel joint.
- Aluminium sleeve is slipped up over the steel joints and is centered as per earlier marking. HV filler compound/grease (or as per conductor/hardware manufacturer's recommendations) is injected through holes provided in aluminium sleeve with the help of inject pump. The plugs (aluminium strands etc.)are inserted in the filler holes. Finally aluminium sleeve is compressed. The first compression is made from the point of compression zone marked on the aluminium sleeve which is generally outside the length of the compressed steel sleeve. Thereafter the compression is made over the length of aluminium sleeve by completing first on one side and then the other side.

Methods Employed to Overcome Failure of Jumpers

- Periodical tightening of jumper joint nut bolts
- Providing steel nut bolts
- Use of only standard and quality material
- P.G. clamps joints shall be avoided and shall be replaced with crimped joints
- To avoid insulator string failure due to lightning proper shielding angle shall be maintained and footing earth resistance shall be as minimum as required

- Hardware shall be maintained in good condition to avoid string failure
- All precautions to avoid conductor breaking or snapping shall be taken
- Never keep provision to develop air gaps due to reduced contact pressure and reduction in contact area
- Periodic jumper joints temperature measurement with Thermovision camera is essential
- Regular interval patrolling and enquiries with nearby dwellers for hot spots and sparking shall be enquired into.

10 REPAIR OF FAILED EARTH WIRE

Procedure

T &P Generally Required

SI.No.	Description of T &P	Qty.
1.	Cartridge firing tool	1 No.
2.	Cartridges.	SNos.
3.	Piece of Earth wire of same size (2,S m)	1 No.
4.	Light weight trolley with brake.	1 No.
S.	Wedges 9 2 Nos. for DIE joint & 3 Nos. for Mid span compression joint)	3 Nos.
6.	Wire Brush.	1 No.
7.	Grease	Small qty.
8.	Hammer (1 kg.).	1 No.
9.	Hydraulic compressor Machine	I No.
10.	Items as per safety procedure.	

a) Breakage of Earth-wire at Dead End

In case of breakage of earth-wire at dead-end, a piece of earth-wire of about 30 meter length is cut near the broken end of the earth-wire. Another piece of new earth-wire of proper length is cut so that when it is joined with the existing earth-wire the earth-wire can be easily connected to the dead-end. This piece of new earth wire is joined to the existing earth wire using a mid span joint. Similarly dead-end joint is provided at the other end. The mid-span joint and the dead-end joint is done using hydraulic compressor machine. The earth-wire is taken up with the help of winch and hooked to the tension clamp.

b) Breakage of Earth-wire near Suspension Clamp

For damage of earth-wire near suspension clamp the earth-wire is made free from the towers on both the sides of the tower where it is damaged. This is done to facilitate provision of mid span joints to the earth wire on ground. For this, the earth-wire in cut upon 30 meters from both the broken ends of the earth-wire. A piece of new earth-wire of length 60 meters is now joined with the existing earth-wire. Mid-span joints are provided using hydraulic compressor machine of 100 ton capacity. The earth-wire, then, taken up with the help of winch and hooked to the tower with the suspension clamps.

This is possible only where the site conditions are very favorable for simple working. If the ground conditions are not favorable and the span lengths are varying much it becomes very necessary to make the earth-wire free from all of the towers and one of the nearest dead end. The earth wire is required to be taken on the earth-wire rollers on the towers where it has been made free. After repairs of the earth-wire as described above the earth-wire is hooked to the dead-end with the help of winch and clamping is done after removing the rollers. This is only possible when the measurements of the earth-wire cutting and the new earth-wire are very accurate otherwise sagging will be different and working will be very difficult.

c) Breakage of Earth-wire within Span

In this case, when the earth-wire breaks it does not fall on the ground but it gets wound on the conductors. The first job therefore becomes to make the earth-wire free from the conductors and to bring it on the ground to be inspected for damages. If no damage is observed then a piece of 15 meters in cut from the both the broken ends and a new earth-wire of the length of 30 meters is connected to the existing earth-wire by providing two mid-span joints. The joints are made as per the standard procedure described above.

Whenever in mid span a few strands of the earth-wire and damaged bridling for that portion is needed to be done, a small piece of the earth-wire is tied alongside the portion of the running earth-wire where strands are found damaged and the two of the piece are tied to the running earth-wire with the help of Bulldog grips.

Note: In case of breakage of earth wire on 400 KV double circuit lines the procedures are the same except that the earth-wire is taken up very vigilantly and slowly so that the clearance from the other circuit is not reduced any time.

Precautions

So long as the earth-wire is on the rollers the persons handling the earth-wire do not get electric shock. However, while removing the earth-wire from the rollers if it is not earthed from both the sides of the rollers the person handling the earth wire may get electric shock. Hence, while handling the earth wire it must be properly earthed from both the ends.

11. PREVENTIVE MAINTENANCE OF TOWER FOUNDATION

Problems in tower foundations

- Land slide
- Sinking of hill
- Soil erosion

Protection measures

- Injection of cement slurry
- Crate work
- Provide retaining wall
- Compaction of soils

Any defect in foundation noticed in time can be rectified in time, with or without outage. The failures are of following types:

(a) Due to design deficiency
(b) Due to construction deficiency
(c) Due to ageing and lack of O&M

The design deficiency is mainly caused due to unworkable design including bar bending schedule etc. The construction deficiency include improper laying of concrete and the form work, disproportionate concrete mix, poor back filling, improper classification of soil and the selection of type of footing, insufficient curing etc. The ageing of stub and concrete will take place in saline area.

12 MAINTENANCE OF EARTHING OF TRANSMISSION LINES

The earthing system of the transmission towers playa major role during normal working as well as during abnormal working of transmission lines. Earthing system of transmission line comprises of towers, earthwire, jumpers, earthing bonds, individual earthing electrodes of the tower and connections thereof.

Monitoring the Earth Resistance Values

As per IE Rules, tower footing resistance should be measured every year and record thereof maintained for proper monitoring. After monitoring, if the values are found more than the required, then the tower body connecting contacts shall be cleaned and provided with cold galvanizing and tightened if possible.

If the values are not improved even after this, then the electrodes shall be by placing low resistivity material around the electrodes as mentioned in ISS.

13 TREE CUTTING/TRIMMING

Introduction

Transmission lines are erected for transmitting huge electrical power economically from generating stations to the distant thickly populated and industrial areas where it is not possible or economical to establish generating stations. The power is transmitted at High Voltage (HV) or Extra High Voltage (EHV). The lines carrying the power at Extra High Voltage, the voltage 66 KV and above viz. 66 KV, 100 KV, 132 KV. 220 KV, 400 KV on AC transmission and 500 KV HVDC are termed as the transmitting lines. The transmission lines generally pass through the lands of revenue, urban and forest authorities. There are enormous trees in these lands coming in the right of way (ROW) of the lines. For the reasons mentioned below and for maintaining the right of way as per IS 5613 tree-cutting is required to be done. It is not economical to divert transmission lines to avoid tree-cutting interfering the ROW. Thus, tree-cutting is essential during the line construction activity and also during maintenance of the lines.

Reasons for Tree-cutting

(i) To facilitate the work of preliminary survey, check survey and marking of tower position;
(ii) To facilitate the work of stub setting;
(iii) To facilitate the work of tower erection in some areas;
(iv) To avoid damage to the-conductor and earth wire during stringing and to have economical and speedy work; and
(v) To clear the right of way as per IS. 5613 before commissioning the lines.

Reasons for Tree-cutting during Maintenance of Lines

(i) To avoid tripping on the transmission lines

The trees have moisture in them and because of deep roots in the soil they provide path for current which happens to flow when the branches of the trees come near the lines. As the distance between the trees and lines reduces there happens electrical break-down through the air because of grounding by the trees. Sometimes the branches of the trees touch the lines. For such incidences protection is provided on the lines and those are operated to avoid future damage. Until the protection operates, dangerous step and touch potentials are developed around the base of the trees which is hazardous to the persons and animals passing nearby. At the time of break-down very big spark-over takes place with cracking sound.

Tripping on the transmission lines is not desirable as they carry huge power and it may affect other transmission lines, power stations and substations in the grid.

Every year, number of trippings are experienced on the transmission lines due to less electrical clearance between tree branches and the lines. This is hazardous, and affects the power supply.

(ii) To facilitate easy and economical maintenance of work such as rehabilitation of fallen towers, stringing snapped conductors and broken earthwires.

(iii) To facilitate movement of vehicles and equipments during maintenance.

(iv) To avoid causing fire to dried trees,

(v) To avoid accidents to persons during tree cutting for other reasons. It has been observed that while cutting trees by the owners of the trees because of not following proper procedure have experienced accidents. Sometimes wood thieves have fallen prey to it.

(vi) To avoid development of dangerous step and touch potentials at the base of the trees due to leakage of current from the line to the tree.

(vii) To avoid bad effects of electrostatic and electro-magnetic fields created by transmission lines on the life and on the growth of the trees and their hazards to human life.

Tree Clearance

(i) The trees falling in the right of way must be cleared.

(ii) The trimming/cutting of tree branches under the conductors is to be got done in order to ensure proper clearance.

(iii) The practical experience shows that the branches of trees coming within permissible clearance from the conductor their leaves changes shape and colour and they are found dehydrated. This may be due to leakage current.

This effect can be utilized by the patrolling staff to judge whether tree branches are entering in the undesired clearance zone of the line and further tripping can be avoided by timely chopping the branches.

CHAPTER 2

SCHEDULE, NORMS & FORMATS FOR PATROLLING AND MAINTENANCE OF TRANSMISSION LINES

1. INTRODUCTION :- As per policy of the different Power Transmission Corporation, O&M documents are to be prepared and reviewed ones in four years to incorporate the feed back of the regions in carrying out the maintenance activities. Accordingly, O&M document on schedule or patrolling and maintenance and norms, format for patrolling and maintenance are prepared.

2 NORMS:-

2.1 **Ground Patrolling Norms :-** Based on the feedback on requirement of ground patrolling and effective use of manpower, the terrains has been divided in to three categories and the frequency of patrolling is advised as under :-

a.	Normal terrain	6 month (pre monsoon & post monsoon)
b.	Vulnerable terrain	3 month
c.	Most Vulnerable terrain	Monthly

Criteria for normal terrain :- Normal terrain, which does not require any special consideration on account of natural reasons, theft or insurgency. In normal terrain, tower patrolling (one pre monsoon & other post monsoon) are to be planned.

Pre monsoon patrolling :- the patrolling/rectification programme for pre monsoon patrolling must be prepared in such a way that the defects noticed during this patrolling are attended atleast 15 days prior to monsoon arrival date.

Post monsoon patrolling :- Post monsoon patrolling may be planned immediately after the monsoon and should be completed within 60 days. Required maintenance/rectifications should be completed in next one month.

High wind velocity area :- some area of various lines fall under high wind velocity zone and are prone to tower collapse particularly during the month of April to June. In such areas, post monsoon patrolling should be completed by the end of December and required maintenance/rectification including replacement of missing tower parts are to be completed on priority latest by the end of February to withstand the spate of hail storm/windstorm.

Criteria for vulnerable terrain :-

i. Forest, hills, hill slopes containing tall trees on uphill slides.
ii. Affected by natural reasons i.e. pollution/flood/land slides etc.
iii. Theft Prone
iv. Power line (132 KV and above)/Railway line/highway/Major river crossing locations
v. Areas prone to mining/blasting near transmission line

Criteria for most vulnerable terrain :-

i. Critical land sliding
ii. Insurgency/terrorist prone area based on previous experience
iii. Change of river course
iv. Repeated thefts

2.2 **Rusting of tower parts:-** Recently, it has been observed that at some places, rusting of tower parts/stubs have taken place due to direct contact of wet soil with tower parts. Therefore, it is essential to ensure that the mandatory clearance from top of the coping of each leg and present ground level is to be maintained. In case, the present ground level is above the coping level, the height of the chimney may be raised after concurrence of Zonal General Manager (O&M).

2.3 **Ground patrolling after line faults:-** Emergency ground patrolling of the line is to be carried out for +/-5% towers both sides of the faulty tower indicated by online fault locator to trace the fault and take corrective action. If off line, faulty locator is available at either end. The same should be utilized for the faulty line testing to pin point the defective location.

1.1 **Norms for tower top patrolling:-** Tower top patrolling of the lines may be planned to find the untraceable faults during line patrolling and in stretches having component failure history.

1.2 **Norms for Thermovision scanning:-** Thermovision scanning of the lines may be carried out on need basis. Thermovision scanning of highly loaded lines (normal power flow-above 120% of SIL rating) may be carried out on sample basis (10% of the tension towers) every year. Based on the findings, further activity of thermovision scanning may be decided. In case of hot spot, tightening of jumpers/bolted joints may be carried out.

1.3 **Norms for punctured Insulators Detection:-** Norms for frequency of online punctured insulator detection is also advised from critical lines/critical locations to the lines facing frequent insulator problem. The activity may be planned accordingly.

1.4 **Check list for ground patrolling:-** General checklist for ground patrolling (attached at Annexure-II) is prepared for use as guideline for ground patrolling. During patrolling, various points may be checked as per the checklist and the defects if any may be noted for further recording in log book of line defects (format-II).

MAINTENANCE SCHEDULES OF TRANSMISSION LINES

SL. No.	Name of the activity	Frequency	Nature
A.	Inspection of towers after climbing the tower 1. Frequent tripping of line on line faults and fault is untraceable during ground patrolling	On need basis	Non S/D
B.	Thermo-vision scanning of highly loaded lines (normal, power flow-above 120% of SIL rating) on sample basis (10% of the tension towers-Jumpers)	Annually	Non S/D
C.	Punctured Insulator Detection in Insulator failure prone stretches	On need basis	Non S/D
D.	Attending of defects		
1.	Foundation-backfilling/Soil removal	Immediately	Non S/D
2.	Attending of crack of chimney	Immediately	Non S/D
3.	Attending of damage to revetment/retaining walls	Immediately	Non S/D
4.	Replacement of Danger/number/Phase/Circuit plate	Within 3 months	Non S/D
5.	Replacement of missing/ damaged tower members	Immediately	Non S/D
6.	Cutting of trees which do not require S/D	Immediately	Non S/D
7.	Cutting of trees which require S/D	Immediately	Non S/D
8.	Replacement of broken/damaged insulator in normal area-(three or less per tring)	Yearly	HLM or S/D
9.	Replacement of broken/damaged insulator in normal area- (more than three/string)	Immediately	S/D
10.	Replacement of broken/damaged insulator in polluted area- (tow/string)	Immediately	HLM or S/D
11.	Cleaning of insulators in polluted area a. Critical/heavy pollution b. Normal/light pollution	 Half yearly or less as per site requirement Yearly	 S/D S/D
12.	Attending of failed spacer-dampers/spacers A Causing conductor damage B Hanging/ dislocated spacer-dampers	 Half yearly Yearly	 HLM or S/D
13.	Attending of hot spots	Immediately	Non S/D
14.	Tightening of B&N/ Anchor bolts	Immediately	Non S/D or HLM
15.	Re-fixing of vibration dampers of conductor/Earth-wire	Yearly	S/D or HLM
16.	Replacement of damaged corona rings/arcing horns	Yearly during AMP	S/D or HLM
17.	Attending of damage to tower earthing	Immediately	Non S/D
18.	Replacement re-fixing of damaged/missing copper	Immediately	Non S/D

* HLM= Hot Line Maintenance

CHAPTER 3

IMPORTANT PARAMETERS AND DATA USED IN TRANSMISSION LINES

A. MECHANICAL PARAMETERS

1. Wind Speed

Based on the wind speed map of India the entire country has been divided into six wind zones below in Table No. 1 with maximum wind speed of 55 m/sec and minimum wind speed of 33 m/sec as per IS:802 (Part I/Sec I) - 1995.

Table 1

Wind zone	Basic wind speed (m/sec)
1	33
2	39
3	44
4	47
5	50
6	55

2. Maximum Temperature of Conductor/Earth Wire

For optimal current capacity in the conductor the maximum temperature in the ACSR conductor is 75° C (85° C may be considered for higher thermal rating of the line) in any part of the country. For All Aluminum Alloy Conductor (AAAC) the corresponding temperature has been permitted to be 85° C. The maximum temperature for earthwire is 53° C.

3. Span

(a) **Design span** - Normal design spans for various voltage transmission lines considered are given in Table 2.

Table 2

Voltage (KV)	Normal design spans (m)
800	400,450
400	400
220	335,350,375
132	315,325,335
110	315,325,335
66	240,250,275
500 HVDC	400

(b) **Wind span** - The wind span is the sum of two half spans adjacent to the support under consideration. For plain terrain this equals to the normal ruling span.

(c) **Weight span** - The weight span is the horizontal distance between the lowest points of the conductors on the two adjacent spans. For design of towers the following weight spans are generally considered.

800 KV and 400 KV Lines

		Permissible Weight Span (m)			
Terrain/tower type		Normal condition		Broken wire condition	
		Max.	Min.	Max.	Min.
(a)	Plain Terrain				
	Suspension	600	200	360	100
	Small/Medium Angle	600	0	360	-200
	Large Angle	600	0	360	300
(b)	Hilly Terrain				
	Suspension	600	200	360	100
	Small/Medium/Large Angle	1000	-1000	600	-600

220 KV Lines

(a)	Plain Terrain				
	Suspension	525	200	315	100
	Small/Medium Angle	525	0	315	-200
	Large Angle	525	0	315	-300
(b)	Hilly Terrain				
	Suspension	525	200	315	100
	Small/Medium/Large Angle	1000	-1000	600	-600

132 KV Lines

(a)	Plain Terrain				
	Suspension	488	195	195	104
	Small/Medium Angle	488	0	195	.200
	Large Angle	488	0	195	.300
(b)	Hilly Terrain				
	Suspension	488	208	192	104
	Smal1/Medium/Large Angle	960	-960	576	-576

66 KV Lines

(a)	Plain Terrain				
	Suspension	375	163	150	75
	Small/Medium Angle	375	0	150	-150
	Angle				
(b)	Hilly Terrain				
	Suspension	375	163	150	75
	Smal1/Medium/Large Angle	750	-750	450	-450

B ELECTRICAL PARAMETERS

1. Current carrying Capacity

(i) Normally for continuous operation the transmission lines unused on various voltages are designed to carry or transmit maximum power loads at the designed maximum conductor temperature of 65^0 as follows

At 132 KV with 'Panther' ACSR =75 MVA
At 220 KV with 'Zebra' ACSR = 200 MVA
At 400 KV with 'Moose' ACSR = 500 MVA

(ii) ACSR Conductor current Rating as per IS: 398 (Par-II-19510

Cod Name	**Calculated resistance at 20^0 oms/km**	**No. of Wires**		**Dia of Conductor (mm)**	**Approx current carrying capacity**		**Approx cost of conductor kg/km**			**Approx. Ultimate Tensile strength (kg)**
		AI	**Steel**		**At 40^0 ambient temp(A)**	**At 45^0 ambient tem (A)**	**Total**	**AI**	**Steel**	
Dog	0.2745	61	7	14.15	324	300	394	288	106	3290
Panther	0.1375	30	7	21.00	520	482	976	586	390	9127
Zebra	0.0620	54	7	28.62	795	736	1623	1185	483	13316
Deer	0.06786	30	7	29.89	806	747	1977	1188	789	13230
Moose	0.05517	54	7	31.77	900	835	2002	1463	539	16250

2. EHV Line load ability

The line loadability for EHV lines of 400 KV, 220 KV and 132 KV lines with ACSR conductors as indicated above shall vary with length of lines. As summarized in the table below-

Line voltage/No. of Circuit		**Line loadability in MW for line Length of Approximate calculated values of**			
		450 Kms	**200 Kms**	**100 Kms**	**50 Kms**
(A)	**SINGLE CIRCUIT**				
(i)	400 KV (with Twin Moose)	511	766	1022	1533
(ii)	220 KV (with Zebra Moose)	125	187	250	375
(iii)	132 KV (with Panther Moose)	45	67	90	135
(B)	**DOUBLE CIRCUIT**				
(i)	400 KV (with Twin Moose)	1038	1552	2076	311
(ii)	220 KV (with Moose)	271	406	542	813
(iii)	220 KV (with Zebra)	266	399	532	798
(iv)	132KV (with Panther)	96	144	192	288

However, the limiting factor for line loadability is Thermal Rating of conductor or SIL whichever is lower.

3. Thermal Rating of Line

The current capacity of ;Moose', 'Zebra' and 'Panther' ACSR conductor at 47.5^0 C Ambient Temperature for maximum conductor temperature of 75^0 C considering wind of 2.2 Km/hour is given in the following table. The corresponding Thermal Rating of the above conductors in MVA as well as in MW (assuming power factor of 0.8 lagging) for 400 KV, 220 KV and 132 KV transmission lines is also mentioned in the following table:-

Line Voltage	Code name of conductor	Current carrying capacity for one ckt in amp.	Corresponding Thermal Rating for			
			Single Circuit		Double Circuit	
			MVA	MW	MVA	MW
400 KV	Twin 'Moose'	2x604	670	536	1340	1072
220 KV	'Moose' ACSR	604	230	184	460	368
220 KV	'Zebra' ACSR	554	211	169	422	338
132 KV	'Panther' ACSR	371	85	68	170	136

4. Electrical Clearances

The electrical design of a tower involves fixation of external insulation i.e., air clearance and insulator string length to cater to different electrical over voltages. For systems upto and including 245 KV the insulation is determined from the power frequency voltage and lightning impulse requirement whereas for systems above 245 KV, the power frequency and switching impulse voltages are the governing criteria. The other factors which affect the electrical insulation are climatic conditions, altitude, relative humidity, pollution etc.

5. Air Clearances

The air clearances applicable to transmission lines are categorized as minimum ground clearance, phase to grounded metal clearance, phase to phase clearance, clearance between power conductor and groundwire (mid span clearance), clearance between power lines crossing each other, power lines crossing tele-communication lines, railway tracks, roads, lakes etc.

The various aforesaid clearances as generally adopted are as follows:

6. Minimum Ground Clearance

The minimum clearance above ground as per sub rule 4 of Rule 77 of I.E. Rules 1956 (latest revision) for AC system and for 500 KV HVDC system as adopted in India are as given in Table.

Highest System Voltage (KV)	72.5	145	245	420	500 HVDC	800
Minimum ground clearance(mm)	5500	6100	7000	8840	12500	15500

To the above clearance, an additional clearance of 150 mm is added to provide for uneven ground prof1le and possible sagging error.

7. Minimum Clearance above Rivers/Lakes

In case of accessible frozen rivers/lakes, the minimum clearance above frozen rivers/lakes should be equal to the minimum ground clearance.

The minimum clearance of power conductor over the highest flood level in case of non navigable rivers shall be as given in Table.

Highest system Voltage (KV)	**Minimum clearance above highest flood level (mm)**
72.5	3650
145	4300
245	5100
420	6400
500 HVDC	10650
800	13200

8. Clearance between Conductor and Groundwire "At Midspan"

The minimum mid-span clearance for different voltage rating lines is given in Table.

Highest System Voltage (KV)	72.5	145	245	420	800	500 HVDC
Minimum mid span clearance (mm)	3000	6100	8500	9000	12400	8500

9. Clearances at Power Line Crossings

Power Lines Crossings Each Other

The minimum electrical clearances between the lowest power conductor of crossing line over the crossed line as per Rule 87 of IE Rule 1956 (latest edition) is given in Table.

Highest System voltage Rating of crossed line (KV)	**72.5**	**145**	**245**	**420**	**800**	**500 HVDC**
Highest voltage Rating of crossing line (KV)	Minimum electrical clearance (mm)					
72.5	2440	3050	4580	5490	7940	6790
145	3050	3050	4580	5490	7940	6790
245	4580	4580	4580	5490	7940	6790
420	5490	5490	5490	5490	7940	6790
800	7940	7940	7940	7940	7940	7940
500 HVDC	6790	6790	6790	6790	7940	6790

Power Lines Crossing Communication Lines

The minimum clearances to be maintained between power lines and communication lines as per "Code of Practice for Protection of Telecommunication Line Crossings with Overhead Power Lines" as given in *Table.*

Highest System Voltage (KV)	72.5	145	245	420	800	500 HYDC
Min. clearance between power conductor crossing telecommunication line (mm)	2440	2750	3050	4480	7900	6860

10. Power Line Crossing Railway Tracks

The minimum vertical clearance between the lowest conductor of a power line crossing the railway track as per "Regulations for Power Line Crossings of Railway Tracks 1987" shall be as follows:

Highest Voltage (KV)	Minimum Clearance (mm)	
	Above Rail Track	Above Crane
72.5	14,100	2,000
145	14,600	2,500
245	15,400	3,500
420	17,900	6,000
800	23,400	11,500
500 HVDC	19,300	7,250

11. Clearances to Ground, Buildings and Power Lines Running along/across the roads as per IE Rules 1956 (latest edition)

The minimum clearances as given in IE Rules 1956 (latest edition) are reproduced in Table.

Nominal System Voltage	66 KV	132 KV	220 KV	400 KV	500 KV HVDC	800 KV
Clearance	(Minimum Value in m)					
(i) Clearance to Ground						
Across Street	6.1	6.1	7.0	8.80	12.40	15.50
Along Street	6.1	6.1	7.0	8.80	12.40	15.50
Other areas	5.5	6.1	7.0	8.80	12.40	15.50
(ii) Clearance to Buildings						
Vertical (*) –from highest object	4.0	4.6	5.5$	7.30	11.59	10.90
Horizontal (+) –from nearest point	2.3	2.9	3.80$	5.6	10.98	9.20

$: Should not cross over/near buildings.

** : Vertical clearance to be obtained at maximum still air final sags (at maximum temperature or ice coated conductor at zero degree Celsius.*

+ : Horizontal clearance to be obtained at worst load condition with maximum deflected conductor position including that of insulator string if any.

Note : For 800 KV minimum clearance to ground as 15.50 m has been considered as per environmental criteria notified by Govt. of India in February2003.

12. Insulators / Insulation

The following type of insulator strings are generally used on Transmission lines.

Sl. No.	Type of string	Size of the disc Dia/spacing (mm)	EM strength of insulator disc (KN)	No. of discs.
	66 KV			
1.	Single "T" suspension string	255x145	45	5
2.	Single suspension pilot string	255x145	45	5
3.	Double suspension string	255x145	45	2x5
4.	Single tension string	255x145	45	6
5.	Double tension string	255x145	45	2x6
	132 KV			
1.	Single "I" suspension string	255x145	45	9
2.	Single suspension pilot string	255x145	45	9
3.	Double suspension string	255x145	45	2x9
4.	Single tension string	255x145	70	10
5.	Double tension string	255x145	70	2x10
	220 KV			
1.	Single "I" suspension string	255x145	70	13 or 14
2.	Single suspension pilot string	255x145	70	13 or 14
3.	Double suspension string	255x145	70	2x14
4.	Single tension string	255x145	120	14 or 15
5.	Double tension string	255x145	120	2x15
	400 KV			
1.	Single "I" suspension string	255/280 x145	120	1x23
2.	Single suspension pilot string	255/280 x145	120	1x2
3.	Single "V" suspension string	255x145	90	2x23
4.	Double "I" suspension string	255/280 x145	120	2x24
5.	Single tension string	280x170 or 255x170	120	1x24
6.	Double tension string	280x170 or 255x170	160	2x23
	500 HVDC			
1	Double 'V'	280x170	210	4x35
	800 KV			
1	Double 'V'	320x170	210	4x38

13. Right of Way Requirement

The transmission line corridor requirement for different voltage lines is as follows:

Voltage level (KV)	Corridor requirement (m)
66	18
110	22
132	27
220	35
400	52
500 HVDC	52
80	85

14. Important Mechanical Data of various Conductors

SI. No.	Code	Strands		Ultimate strength (kg)	Overall dia (cm)	Total sectional area sq. cm	Unit Wt. Kg/m
		AI No./mm	Steel No./mm				
1	Dog-*	6/4.72	7/1.570	3,305	1.415	1.185	0.3940
2.	Leopard	6/3.283	7/1.753	4,140	1.585	1.485	0.4935
3.	Tiger	30/2.362	7/2.362	5,800	1.650	1.622	0.6060
4.	Wo1f-*	30/2.590	7/2.590	6,867	1.813	1.949	0.7260
5.	Panther *	30/3.000	7/3.000	9,144	2.100	2.615	0.9740
6.	Bear	30/3.353	7/3.353	11,330	2.350	3.262	1.2195
7.	Goat	30/3.708	7/3.708	13,800	2.600	4.000	1.4915
8.	Sheep	30/3.980	7/3.980	15,900	2.793	4.620	1.7260
9.	Kundah	42/3.595	7/1.960	9,054	2.688	4.252	1.2180
10.	Zebra-*	54/3.180	7/3.180	13,289	2.862	4.845	1.6210
11.	Deer	30/4.267	7/4.267	18,200	2.984	5.300	1. 9800
12.	Camel	54/3.353	7/3.353	14,760	3.020	5.382	1.8100
13.	Drake	26/4.4424	7/3.454	14,175	2.814	4.684	1.6280
14.	Moose@	54/3.530	7/3.530	16,438	3.177	5.970	2.0040
15.	Redwing	30/3.920	19/2.350	15,690	2.746	4.452	1.6460
16.	Bersimis	42/4.570	7/2.540	15,734	3.510	7.252	2.1850
17.	Curlew	54/3.510	7/3.510	16,850	3.162	5.915	1.9760

** : IS – 398(2)-1996 (upto 220 KV)*
@ : IS – 398(5)-1992 (upto 400 KV)

15. Data on some other earthwires and OPGW (Optical Ground Wire) is given in Table.

SI.No.	Stranding No/dia. (mm)	Weight per metre (kg)	Overall Diameter (mm)	Total area Sectional (Sq mm)
	Earthwire			
	a) Normal			
	earthwire			
I.	7/3.15	0.428	9.45	54.552
2.	7/3.50	0.523	10.50	67.348
3.	7/3.66	0.538	10.98	73.646
4.	7/4.00	0.690	12.00	87.965
5.	19/3.15	1.163	15.75	148.069
6.	19/3.50	1.436	17.50	182.801
7.	19/3.66	1.570	18.30	199.897
8.	19/4.00	1.875	20.00	238.761
	b) Special			
	earthwire			
9.	16/2.86 Al	1.005	18.12	194.6
	Alloy			
	19/2.48 Steel			
	c) O.P.G.W.			
10.	13/2.34mm	0.468	12.5	83
	AS+12/9.3I1m			
	/3 Al extruded			
	tubes			
11.	7/3.80mm	0.5238	12.58	92.58
	AS +12/811m11			
	(tube)			
12.	1/5+8/3.2	0.458	11.40	71.41
	Optical Fibre			
	Glass			

16. As per State Grid code of Uttarakhand the operating range to be maintained at different grid voltage level is given in Table.

VOLTAGE – (kV RMS		
Nominal	**Maximum**	**Minimum**
400	**420**	**360**
220	**245**	**200**
132	**145**	**120**
66	**73**	**60**

Annexure-A

CHECK LIST FOR GROUND PATROLLING

SL. No.	Particular
1.	Mandatory clearance between coping level & ground level
2.	Soil Erosion
3.	Defect in Foundation/chimney
4.	Defect in Pipe/CP earthing system
5.	Missing Danger Plate
6.	Missing Number Plate
7.	Missing Phase Plate
8.	Missing Anti Climbing Device (ACD)
9.	Missing/Damaged/rusting tower parts if any, Part no. & quantity
10.	Missing bolts/Dummy holes
11.	Trees around base
12.	Broken insulators (Circuit No.)/Phase
A	One disc/String
B	Two disc/String
C	Three disc/String
13.	Pollution on insulators, if any (Bird excretal/Vehicular/Industrial/Coastal etc.
14.	Dislocated/damaged Vibration Damper/Special Damper in forward span (Ckt. No.)/ Phase
15.	Damaged conductor hardware fittings in forward span (Ckt. No.)/ Phase
16.	Damaged conductor in forward span (Ckt. No.)/ Phase
17.	Trees in forwarded span clearances
18.	Missing copper bond
19.	Missing/loose Vibration Damper for Earthwire
20.	Foreign Material on tower etc.
21.	New Building/power line/railway line new construction in forward span clearances
22.	Any other abnormality observed i.e. uneven settlement of foundation, crack in revetment etc.

Annexure-B
Format-I

Monthly Patrolling Programme

OFFICE Subdivison

Programme month :

Sl. No.	Name of Line man/Jr. Engineer	Date		Section/locations assigned	Remarks (ref notes)
		From	To		
Name of Line :					
Name of Line :					
Name of Line :					
Details of previous month patrolling target which could not be accomplished :					

Signature of line In-charge

Note:

1. Programme to be sent form Division to General Manager (O&M) Office with monthly report

   If previous month's patrolling targets not completed, reason and rescheduling dated to be mentioned.

Format-II

Summary of Line defects

(Prepared for attending the faults and to be retained in Division office)

Circle		Division	Name of line	Total locations		

SL. No.	Loc. No.	Date of detection of fault	Nature of defect	Date of attending the defect	Remarks

	Executive Engineer	Assistant Engineer	Junior Engineer
Signature			
Name			
Designation			

Format-III

LOG BOOK OF LINE DEFECT

Circle	Division	Line	Loc. No.	Type of tower	Type of Foundation	Village	Police station	Distt.

Description of defects													
SL.. NO	Patrolling/ rectification date	Foundation	Tower	Insulator	Hardware fittings	Conductor	Conductor accessories	Earth wire	E/W accessories	Infringement to electrical clearances	Any other Information /defect noticed	Remarks	Signature/ Name / Designation

Format-IV

SUMMARY OF LINE DEFECTS FOR THE MONTHS OF ……

(to be submitted to General Manager (O&M) Office)

Circle		**Division**		**Section patrolled during the month**	
Line				From	To
Total Length					

Sl. No.	**Nature of defect**	**No. of defects pending at the beginning of month**	**No of additional defects noticed during the month**	**Cum. Defects**	**No. of defects attended during the month**	**Balance defects to be attend**	**Planned date of liquidation of defects**	**Remarks**

	Executive Engineer	**Assistant Engineer**	**Junior Engineer**
Signature			
Name			
Designation			

Format-V

TOWER CLIMBING PATROLLING REPORT (NON OUTAGE)

Substation	Name of line	Patrolling date	Loc no	Type of tower

Bolts loose Y/N		First section [ ]	Upper section [ ]	Cross arm [ ]	
Tower members above bottom cross arm level		All secure [ ]	Missing [ ]	Nos. [ ]	
Missing bolts/Dummy holes		Yes [ ]	No [ ]	Quantity [ ]	
Earth wire fittings	Cub bond	Good [ ]	Rusty [ ]	Need replacement [ ]	
	Sus. Clamp	Good [ ]	Rusty [ ]	Need replacement [ ]	
Circuit	Single/double	1	11		
		Inner Limb	Outer Limb	Inner	Outer limb
Flashed over/cracked Insulators	Left/top				
	Middle/middle				
	Right/bottom				
Hardware fittings including split pins	Left/top				
	Middle/middle				
	Right/bottom				
Presence of pollution	Yes [ ]	No [ ]	Source of pollution- (Industrial/Vehicular/Bird excreta/any other)		
Comments					

	Assistant Engineer	Junior Engineer	Lineman
Signature			
Name			
Designation			

Format-VI

LINE DECLARED FAULTY INSPECTION REPORT

Region	Name of line		Patrolling date				
Fault locator reading	End-A		End-B				

Sl. No.	Location No.	Phase	Description of Fault

	Assistant Engineer	Junior Engineer	Lineman
Signature			
Name			
Designation			

Format-VII

INSPECTION REPORT FOR MAJOR MAINTENANCE/BREAKDOWN WORKS

Substation	Name of line	Patrolling date					Loc no				Type of tower

Type Of Maintenance	Description		Status
Insulator Replacement	1.	Whether IR value of insulators checked in stores and is more than 2000 mega-ohm	Yes/No
	2.	Check all bols & pins for their correct sizes, all nuts, lock nuts, washers and split pins are fitted correctly.	
	3.	Check conductor clamps to ensure that all nuts and spring washers are fitted and keeper has no signs of cracking	
Collapse of tower/conductor replacement	1.	Check point no. 1,2,3 &4 above for Insulator replacement	
	2.	Check damper positions are correct	
	3.	From tower, visually check spacers in adjacent spans	
	4.	Check ADC, step bolts, correct plates and no damaged steel work.	
	5.	Ensure that there are no missing tower parts and blank holes	
	6.	Record evidence of disaster in neighboring areas	

	Assistant Engineer	Junior Engineer	Lineman
Signature			
Name			
Designation			

Format-VIII

LIVE LINE PUNCTURE INSULATOR DETECTION

Subdivision	Name of line	Activity date				

Sl. No.	Loc No.	Circuit (I/II)	Phase (R/Y/B) (Top Middle/Bottom) (Left Middle/Right)	String I V (Inner/Outer) Double Tension (left/right) Q-Tension (Left-(top/bottom), Right- (Top/Bottom)	No of Puncture insulator discs	Positions of punctured insulator from line side

	Assistant Engineer	Junior Engineer	Lineman
Signature			
Name			
Designation			