Operation and Maintenance Manual

POWER TRANSMISSION CORPORTATION OF UTTARAKHAND LTD.

CENTRAL BOARD OF IRRIGATION AND POWER

POWER TRANSMISSION CORPORTATION OF UTTARAKHAND LTD.

PTCUL

POWER TRANSMISSION CORPORATION OF UTTARANCHAL LIMITED

Operation & Maintenance Manual

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Acknowledgement

PTCUL (Power Transmission Corporation of Uttarakhand Limited) is the power transmission utility of state of Uttarakhand which provides the pathway for power within the State of Uttarakhand. It owns, builds, maintains and operates the high-voltage electric transmission system within in Uttarakhand.

PTCUL has made significant progress in the recent past under the dynamic leadership of Shri Atul Agarwal, Managing Director, PTCUL by his new initiatives and dynamism.

PTCUL has made wonderful strides for development of power sector in Uttarakhand. The Power Transmission availability in 2018-19 has increased from 99.14% to 99.38% which is higher than UERC prescribed standards (98%) and also Transmission losses for 2018-2019 are 1.27%, against losses of 1.39% in 2017-2018 which is much lesser then National standards (2% to 2.5%).

Apart from above, Shri Atul Agarwal as part of his excellent initiative for accentuating of knowledge of professionals has taken a lead to get the existing technical documents revised/updated.

Central Board of Irrigation and Power (CBIP) expresses its deep gratitude to Shri Atul Agarwal, Managing Director, PTCUL for posing faith in entrusting the job for revision and updation of O&M Manual for Transmission Lines prepared by PTCUL to CBIP.

The CBIP has retained the basic structure of the existing manual prepared by PTCUL. The chapters have been suitably revised and updated now. Moreover, keeping in view the innovations and technological developments in the power system, we have included the following relevant details in this manual for the benefit of the professionals:

- Operation Procedures for 400kV, 220kV and 132kV switchyard added in this Manual.
- General understanding on relay indication added
- List of Daily check list added.
- Maintenance procedure for Substation equipments - check list for all equipment's revised

In order to prepare the revised manual lots of related documents have been referred and advice of renowned experts in transmission such as Shri S.K. Ray Mohapatra, Chairman of CBIP's Expert Group on Substations and Chief Engineer, Central Electricity Authority and Shri P.B. Mehta, Member of CBIP's Expert Group on Substations, Member CIGRE NSC C4 and Former Design Engineer GETCO and has been sought on the subject. We convey our sincere gratitude to the above experts for their valuable support in updating this publication.

We are surer that information given in this revised manual will be useful to the professionals of PTCUL and this manual will ultimately help in further increasing the performance of PTCUL.

It will be a matter of great pleasure for CBIP to help in such endeavors of PTCUL in future.

Dr. G.P. Patel
Secretary
Central Board of Irrigation and Power

July 2020

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 Operation & Maintenance (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. Breakdown Maintenance is the rectification work done after occurrence of some fault (other than failure of equipment)

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 implementing timely maintenance.

This maintenance manual consists of Three parts:-

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

Part – II : Deals with Preventative Maintenance of Transmission Lines.

Part – III : Deals with different formats used in O&M of Substation and 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 suggestions for further improvement are always welcome.

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POWER TRANSMISSION CORPORATION
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Operation & Maintenance Manual

Section - I

OPERATION HANDBOOK

OPERATION PROCEDURE FOR 400 KV SWICHYARD

1.1 PROCEDURE FOR ISOLATION OF 400 kV LINE FOR MAINTENANCE WORK

1) Obtain requisition form for Line Clear Permit (LCP) duly signed by maintenance engineer.
2) Check that the asked shutdown is approved by concerned authorities from Load Dispatch Centre.
3) Inform LDC & Operating personnel of opposite ends before switching OFF line breaker
4) In case of interstate lines obtain the code from LDC before switching OFF the breaker
5) In consultation with opposite end personnel ,Switch OFF the breaker from receiving end & then switch OFF the CB from sending end.(However CB may Auto trip on Remote End through carrier signal if set such.)
6) In the switchyard physically check that all three poles of CB are opened.
7) Check the Indication Lamp, Semaphore etc on Control panel confirming of opening of CB If operated though SCADA confirm the same on SLD of SCADA
8) Hand gloves should be used for the operation of isolators/earth switch while local operation.
9) Open all bus isolators & line isolator from both the ends.
10) Check the resetting of CT SWITCHING RELAY & PT SELECTION relay
11) Check the Indication Lamp, Semaphore for opening of Isolators on control panel. Check the indication on schematic of SCADA confirming the open position.
12) In switchyard ,physically check that the position of all the poles of all isolators are in fully opened condition
13) After confirming opening of isolators at both ends, close Earthing Switch at both the ends.
14) LCP should be obtained from opposite end.
15) Necessary entry should be made in LCP book & it should be issued to maintenance engineer for carrying out the work.
16) Necessary painted board with marking of “LCP ISSUED & MEN AT WORK” should be hanged on the control panel of isolated line.
17) Isolated bay should be cordoned with the help of manila rope for safety measure.

Special Care: While providing the local earthing to any equipment, connect the clamp of wire side of earthing rod to the ground first and then connect the clamp of rod to the equipment

1.2 PROCEDURE FOR RESTORATION OF 400KV LINE AFTER COMPLETION OF MAINT. WORK

1) For restoring the 400kv line after completion of work, get all forms of LCPs returned duly signed by respective maintenance engineer confirming all men and materials are removed from line.
2) The rope which was used to cordon the isolated bay should be removed.
3) Ensure that no local/loose earthing is provided in the yard.
4) Hand gloves should be used for local operation of isolators/earth switch
5) Open earthing switch
6) Return LCP to the opposite end.
7) Before closing the Isolators ensure that all the three poles of CBs are open
8) Close Line isolator in consultation with opposite end.
9) Close the bus isolator & check the operation of CT SWITCHING & PT SELECTION relay.
10) Check the Indication Lamp, Semaphore etc on control panel and schematic on SCADA for confirmation of close position of Isolators and open position of ES
11) Inform LDC regarding the charging of line.
12) In case of interstate lines take code from LDC for charging of line.
13) Study the voltage condition at either ends & charge the line from sending end & synchronize the line from receiving end with the help of synchronizing trolley.
14) The lines which are connected with power station should always be charged on dead line from s/s end & synchronizing will be done from power station end.
15) Procedure for SYNCHRONISING receiving end (DEAD LINE CHARGING)
    - ✓ For carrying out dead line charging put Syn. Bypass selector switch on “BYPASS” position on Bus coupler panel & sync selector switch on “ON” position provided on feeder panel in old panels. In case of new panel put Syn. Selector Switch on “BYPASS” position in feeder panel
    - ✓ Switch ON the line breaker.
    - ✓ In the switchyard, Confirm that all the three poles of breaker are closed.
    - ✓ Check voltage of all the three phases.
    - ✓ Put Sync Bypass selector switch back on “ON” position in Bus Coupler panel & sync selector switch on “OFF” position in feeder panel in case of old panel.
    - ✓ In case of new panel put Syn. Selector Switch on “OFF” position in feeder panel (at SYNCHRONISING)
    - ✓ Connect synchronizing trolley to control panel by inserting plug in the sync Socket of control panel.
    - ✓ Put Sync Bypass selector on “ON” position in bus coupler panel & Syn selector switch on “ON” position in feeder panel in case of old panel.
    - ✓ In case of new panel put Syn. Selector Switch on “CHECK” position in feeder panel.
    - ✓ Incoming (Line) & running (Bus) voltage & frequency will appear on the sync Trolley.
    - ✓ Put synchro scope switch on “ON” position
    - ✓ Pointer of synchro scope will revolve in clockwise direction and it will remain fixed in centre (dark zone area) & “SYNCHRONIZATION IN LIMIT” lamp will glow.
    - ✓ At that particular instant close the breaker.

- ✓ Check indication, semaphore for closing of breaker.
- ✓ In the switchyard, Confirm that all the three poles of breaker are closed.
- ✓ Check current in all three phases.
- ✓ Put sync selector switch in “OFF” condition & remove synchronising trolley.

1.3 PROCEDURE FOR RESTORATION OF 400 KV LINE AFTER FAULT TRIPPING.

When 400 kv line trips on fault following procedure should adopted to normalize / put back line in service:

1) Annunciator will operate & will give audible alarm. Accept the Annunciator to silent the alarm.
2) Note down all the facia window's indications and time of incident.
3) Check whether line has Auto reclosed .This can be seen from the current & CB position.
4) If current is less than the normal current (i.e. Line charging current), it means only opposite end CB has tripped.
5) If it is showing a normal current then CB at both ends are auto reclosed successfully.
6) If there is no current ,means CB have tripped and on lockout at both the ends
7) Note down relay indications / fault locator readings / counter readings of this end.
8) Collect facia / relay indications / fault locator readings / counter readings from the opposite end.
9) Inform the In charge of substation and higher officer/opposite end officers as per procedure.
10) Reset all relays & facia at this end & get it confirmed that at opposite end.
11) Analyse the fault by studying the relay indications of local end & opposite end.
12) Carry out the inspection in the yard for any abnormality in the bay.
13) Similarly instruct to carry out yard inspection at opposite end.
14) If there is a phase to phase fault then breaker will trip and on lock out.
15) In case of single phase sustained fault auto reclose will not be successful and &breaker will trip on lock out.
16) For above both the conditions line patrolling work should be carried out by maintenance in charge before charging the line.
17) After inspection of yard, line patrolling & attending the fault, Dead line charging / synchronizing procedure should be carried out as outlined above.
18) If Line is tripped due to over voltage, line charging should be carried out in consultation with LDC.
19) Disturbance recorder / event logger chart should be studied properly for the correct operation of relay & breaker.
20) If auto reclosure fails to operate, in case of a single phase fault, line can be test charge with consultation of LDC.
21) Finally message should be conveyed to all the officers as per the procedures of the PTCUL.

1.4 PROCEDURE TO SWITCH OFF 400KV LINE DUE TO HIGH VOLTAGE

Following procedure should be adopted to switch OFF the 400kv line due to high voltage under the instruction of LDC.

1. Contact opposite end and get voltage level.
2. See local end voltage and compare with opposite end.
3. Always switch OFF breaker from sending end first and then switch OFF the breaker from opposite end. (However the breaker at opposite end will auto trip on Direct trip command.)

1.5 PROCEDURE FOR ISOLATION AND RESTORATION OF 400KV TRANSFORMER BAY FOR MAINTENANCE WORK

1) Obtain the Requisition form for LCP duly signed by maintenance engineer.
2) Ensure that outage of the proposed Transformer is confirmed by LDC.
3) Inform LDC about the commencing of shutdown.
4) Switch OFF the CB of LV side first & then switch OFF the CB of HV side.
5) In the switchyard check that all three poles of HV & LV Breakers are opened.
6) Check Lamp indication, Semaphore and schematic position of SCADA confirming the opening of CB of HV & LV of Transformer.
7) Local operation of Isolator and ES (if any) shall be carried out with the use of Hand gloves.
8) Open bus side & Transformer isolators on both (HV & LV) side.
9) Check the resetting of CT SWITCHING RELAY& PT SELECTION relay on both side.
10) Check Lamp indication, Semaphore and schematic of SCADA for confirmation of opening of Isolators.
11) Close the Earth switch (ES) provided on Isolator on Transformer side (400kv) and ES on LV (220kV) side, if LV Isolator is without ES provide local earthing.
12) Isolated bay should be cordoned with the help of manila rope for safety measure.
13) LCP should be given to maintenance engineer for carrying out maintenance work with necessary entries in the LCP book.
14) Board showing “LCP ISSUED & MEN AT WORK” should be hanged on control panels of both side.
15) For restoring 400kv ICT after completion of work get LCP returned duly signed by maintenance engineer confirming removal of all men and materials.
16) The rope used for cordoning isolated ICT bay should be removed.
17) Open earthing switch provided on 400kv & 220kV side & remove local earthing provided if any.
18) ! BEFORE CLOSING THE ISOLATOR ENSURE THAT ALL THREE POLES OF BREAKER ARE OPEN.
19) Close Transformer side isolators on both the sides.
20) Close the bus isolator on both the sides & check the operation of CT SWITCHING &PT SELECTION relay on HV & LV sides.
21) Check Lamp indication, Semaphore schematic on SCADA confirming for closing of Isolators and opening of ES.
22) Inform LDC for charging of ICT
23) First close HV side CB & then close LV side CB.
24) Check that all three poles of HV & LV Breakers are closed.
25) Check the currents in all three phases of HV& LV sides.

1.6 PROCEDURE FOR RESTORATION OF 400KV ICT/TRANSFORMER AFTER TRIPPING

1) Accept the facia.
2) Note down the facia and relays from control and relay panel.
3) Inform the SLDC and officials of PTCUL regarding the tripping of ICT/Transformer with facia and relays.
4) Analyze the fault by studying the relays.
5) Inspect the ICT/Transformer & its bay equipments.
6) Try to find out the cause of tripping.
7) If back up relay is operated due to reflected fault of feeder(on downside) and no abnormality is found in the switchyard then one test charge can be taken with the permission of SLDC.
8) If it stands OK then current in all three phases should be checked on HV and LV side.
9) If the transformer tripped on “Buchholz / Differential relay” test charge should not be taken before testing of transformer and investigation.
10) Gases from the Buchholz should be collected for detailed analysis.
11) Charging of transformer should be avoided unless satisfactory cause of tripping (that ensure the healthiness of transformer) is found.
12) When ICT/ transformer trips on differential protection due to failure of HV/LV side equipment like LA /CT ,the faulty equipment should be replaced after which the transformer can be taken into service of course after carrying out necessary stability test.
13) When ICT trips on “ NDR” relay following checking should be carried out before test charging ICT
    - Check 33kv Tertiary bus for the electrocuting of birds or animals etc
    - Check the healthiness of 33kv PT
    - Check the healthiness of 33kv Surge Arrestor.

14) When ICT /Transformer trips on “REF” relay, testing of transformer (including measurement of Winding Resistance) should carried out before charging.
15) When transformer trips on WTI/OTI even though respective temperature is low then the healthiness of thermometer & mercury switch should be checked.
16) Official message should be conveyed to all respective authorities of PTCUL with a copy to SLDC.
17) After attending the problem, the Transformer can be taken into service by adopting the procedure outlined above in “ISOLATION & RESTORATION OF 400KV ICT”

1.7 PROCEDURE FOR ISOLATION AND RESTORATION OF 400kV BUS REACTOR FOR MAINTENANCE WORK

1) Obtain the Requisition form for LCP duly signed by maintenance engineer.
2) Ensure that outage of proposed Bus reactor is confirmed by SLDC.
3) Inform SLDC.
4) Switch OFF the CB for Reactor.
5) Check in the switchyard that all three poles of CB are opened.
6) Check the Lamp indication, Semaphore in Control panel and schematic of SCADA confirming the opening of Breaker.
7) Hand gloves should be used for the local operation of isolators/ES.
8) Open bus isolator & reactor isolator and close the ES on reactor isolator.
9) Check the resetting of CT SWITCHING RELAY & PT SELECTION relay.
10) Check the Indication of Lamp, Semaphore on control panel and schematic of SCADA confirming the opening of Isolators/closing of ES
11) Isolated bay area should be cordoned by manila rope for safety.
12) LCP should be given to maintenance engineer for carrying out maintenance work with necessary entries in the LCP book.
13) Necessary board with marking of “LCP ISSUED & MEN AT WORK” should be hanged on the control panel.
14) For restoring Bus reactor after completion of work, get LCP returned duly signed by maintenance engineer with confirmation that all persons and materials are removed from working site.
15) The rope used for cordoning isolated bay should be removed.
16) Open ES provided on reactor isolator and remove local earthing provided if any.
17) ! BEFORE CLOSING THE ISOLATOR ENSURE THAT ALL THREE POLES OF BREAKER ARE OPEN and close the Reactor Isolator and then bus Isolator.
18) Check the operation of CT SWITCHING & PT SELECTION relay.
19) Check the Lamp indication, Semaphore on control panel and schematic on SCADA confirming the closing of Isolator.
20) Inform the SLDC about restoring back the reactor into circuit.
21) Close the CB if the system voltage permits.
22) In the switchyard check that all three poles of the CB are closed.
23) Check the currents of Bus reactor in all three phases.

1.8 PROCEDURE FOR RESTORATION OF 400kV BUS REACTOR AFTER FAULT TRIPPING

1) Accept the facia.
2) Note down the facia and relays from control and relay panel.
3) Inform the SLDC and respective authorities of PTCUL regarding the tripping of Bus reactor with facia and relays.
4) Analyze the fault by studying the relay.
5) Inspect the Reactor & Reactor bay equipments.
6) Try to find out the cause of tripping.
7) If the Reactor tripped on "Buchholz / Differential relay/PRV /REF, test charge cannot be taken without testing the Reactor.
8) Gases from the Buchholz should be collected for detailed analysis.
9) When Reactor trips without any relay & facia, it might be tripped on Back up impedance relay due to failure of PT supply, so check PT fuses of above relay. In such case after attending the problem, Reactor can be taken into service by adopting the procedure outlined in "ISOLATION & RESTORATION OF 400KV BUS/Line REACTOR"

1.9 PROCEDURE FOR SHUTDOWN OF ONE OF THE TWO 400KV MAIN BUS FOR MAINTANCE WORK

1) Ensure that confirmation of outage of mentioned 400kV bus is received from SLDC well in advance.
2) Inform SLDC regarding the starting of 400kv Bus outage.
3) List out the number of feeders/equipments to be transferred from one bus to another bus.
4) Put the switch of 400 kV Bus bar protection scheme in “OUT” position.
5) Hand gloves should be used for the local operation of isolators/ES.
6) Close that the other bus isolator of feeder whose load is to be transferred and confirm the operation of CT SWITCHING RELAY.
7) Bus no. 1 & 2 inter connected / bus wire faulty facia will appear on control panel.
8) Open the bus isolator of main bus whose outage is to be taken.
9) Check the resetting of CT SWITCHING/ PT SELECTION relay of Bus under outage and operation of PT SELECTION relay where load is transferred.
10) Bus no. 1 & 2 inter connection/Bus wire faulty facia can be reset now.
11) Above operations are to be carried out for all feeders/equipments one by one till the complete load of one bus is transferred to another bus.
12) While carrying out this operations observe the current on Bus coupler panel, if it is found high then keep both Bus isolators of one of the feeder in closed position & open that bus isolator (bus bar under outage) at last BEFORE OPENING OF B/C BREAKER ONLY .
13) Do not open bus isolator connected to the bus which is under outage before confirming the operation of CT SWITCHING relay of other bus where load is to be transferred.
14) ! ENSURE THAT ALL FEEDER/ICT/REACTOR BUS ISOLATOR CONNECTED TO THE BUS UNDER SHUTDOWN ARE OPENED.
15) Finally switch OFF 400 kV Bus coupler Circuit breaker.
16) Open the Isolators for the bus no. 1 & 2 of bus coupler bay.
17) Put the switch of Bus Bar Protection scheme at IN position.
18) Close the ES at both ends of Bus under shutdown or local earth may be provided.
19) Now LCP can be issued to maintenance engineer to carry out required Maint. Work.

1.10 PROCEDURE FOR RESTORATION OF 400KV MAIN BUS AFTER MAINT WORK-TRANSFERRING LOAD BACK TO NORMAL i.e. ON BOTH THE MAIN BUS

1) Get all the LCPs returned (with confirmation that all the persons and materials are removed from work place) from maintenance engineer for normalizing both the Bus, after completion of shutdown of one of the main bus.
2) Inform SLDC regarding taking both Bus into service.
3) 400kV bus being very important item to be taken care from power reliability and safety viewpoints, Switchyard inspection should be carried out to confirm that nothing is left out at bus to be charged.
4) List out the feeders/Equipments to be transferred to normalize the load position.
5) Put the switch of 400 kV Bus bar Protection scheme at “OUT” position.
6) Remove local earthing if provided and Open ES provided at both the end of bus.
7) Close the main bus no. 1 & 2 isolator of Bus Coupler Bay.
8) Put Sync Bypass selector switch on “BYPASS” position & Syn selector switch on” ON” position in B/C panel in case of old panels .In case of new panels put Synchro selector switch on “BYPASS” position.
9) Switch ON the B/C CB.
10) Put Bypass selector switch on “ON” position & Syn selector switch on “OFF” position in B/C panel in case of old panels and in case of new panels put Synchro selector switch on “OFF” position.
11) Close the bus isolator of one of the feeder normally fed by the bus which was under outage.
12) Bus no. 1 / 2 inter connection / bus wire faulty facia will appear on control panel.
13) Check the operation of CT SWITCHING RELAY.
14) For the same feeder, open the bus isolators connected to bus where the load was transferred.
15) Check the resetting of CT SWITCHING RELAY/ PT SELECTION relay & operation of PT SELECTION relay of the bus under outage.
16) Bus 1 / 2 inter connection facia can be now reset on control panel.
17) Above operations are to be carried out for all the feeders/bay one by one till the original condition of both the bus bars are restored.
18) While carrying out this operations observe the current on Bus coupler panel, if it is found high then keep both Bus isolator of one of the feeder in closed position & open that bus isolator connected to bus where the load was transferred earlier while taking shutdown.
19) Reset all relays and facia appeared on control & Busbar relay panel.
20) Put the switch of 400 kv Busbar Protection Scheme at “IN” position.

1.11 PROCEDURE FOR RESTORATION OF 400KV BUSBAR SCHEME AFTER OPERATION OF BUSBAR PROTECTION SCHEME

Following procedure should be adopted to normalize the busbars when separated out due to operation of bus bar protection scheme:

1) Accept all the facia of feeders/equipments connected with the tripped bus.
2) Note down all the facia / relay indications /counter readings of all the tripped feeders/equipments.
3) Collect all facia / relay indications / counter readings from the opposite end of tripped lines if any.
4) Inform respective officers of PTCUL and SLDC regarding operation of bus bar protection scheme with exact time and all the relay indication/facia etc
5) Reset all facia and relays at both the ends.
6) Check whether breaker at both (or all) the ends tripped correctly or not.
7) Carry out the switch-yard observation and isolate faulty equipments of the tripped bus.
8) ! ENSURE THAT ALL THE THREE POLES OF ALL THE CBs CONNECTED TO THE FAULTY BUS ARE IN OFF POSITION.
9) After isolating the faulty equipment from the bus, start the procedure to normalize the bus in consultation with SLDC.
10) Put Sync selector switch at "ON" position & Sync Bypass switch at BYPASS" position in Bus Coupler panel in case of old panel. In case of new panel put synchro selector switch at "BYPASS " position
11) Switch ON the Bus coupler breaker.
12) Take all the feeders/ ICT/Reactor in to service one by one in consultation with SLDC as per procedure outlined above.
13) Ensure while taking bays into service, load on BC should not exceed. If found high, keep both Bus isolator of one of the feeder in closed position & open the bus isolator (which is not needed).
14) After normalization convey message to SLDC.

1.12 PROCEDURE FOR TRANSFERRING LOAD OF 400KV FEEDER EQUIPMENT FROM MAIN BUS TO TRANSFER BUS THROUGH TBC

1) Ensure that proposed transfer of load of particular feeder/equipment to TBC is confirmed by SLDC.
2) Ensure physically that all the three poles of CB for TBC are in open condition.
3) ! Do remember to use Hand gloves while operation of isolators/ES
4) Close Transfer Bus Isolator of TBC bay and check the corresponding Lamp & semaphore indication and schematic on SCADA for confirmation of operation.
5) Close the Transfer Bus Isolator of feeder/ equipment whose load is to be transferred and confirm all indications on control panel and SCADA.
6) Check the operation of CT SWITCHING relay.
7) Close the Main Bus isolator of TBC bay (bus with which feeder /equipment is originally connected.) and confirm the indication on control panel/SCADA.
8) Check the operation of CT SWITCHING relay & PT SELECTION relay.
9) Put NIT switch (transfer switch) at “I” position.
10) Switch ON the TBC Breaker.
11) In the switchyard ensure that all three poles of TBC Breaker are closed and also confirm the respective indications on Control Panel/SCADA.
12) Put NIT switch at “T” position.
13) Switch OFF the feeder/equipment CB and confirm the respective indications on panel/SCADA.
14) In the switchyard, ensure that all three poles of feeder/equipment Breaker are opened.
15) Load of particular feeder is transferred on TBC bay which can be confirmed with the meter readings of that bay and TBC bay.
16) Open the equipment side/line side isolator of that particular bay. For which shutdown is to be taken and ensure the proper indications on panel/SCADA.
17) Open the Main Bus isolator of that particular bay and confirm the indications on panel/SCADA.
18) Check the resetting of CT SWITCHING relay.
19) ! ENSURE THAT PT SELECTION RELAY MUST REMAIN OPERATED.
20) Put a board on operating handle at the control panel with clear painted writing “LOAD ON TRANSFER BUS”.
21) In case of Line and shutdown is only for switchyard ,let suitable caution board be put on Control panel as well as in switchyard at the operating handle of equipment/line side Isolator showing- **LINE SIDE END OF ISOLATOR IS LIVE”**

1.13 PROCEDURE FOR TRANSFERRING THE LOAD OF 400KV FEEDER / EQUIPMENT BACK FROM TRANSFER BUS TO MAIN BUS

1) In switchyard physically ensure that ALL THREE POLES OF CB OF THAT PARTICULAR BAY ARE OPENED.
2) ! BE CAUTIOUS THAT LINE SIDE END OF Line ISOLATOR IS LIVE.
3) ! Do remember to use Hand gloves for the operation of isolators.
4) Close the Main Bus isolator of the particular bay which is connected to TBC and confirm the respective indications on control panel/SCADA.
5) Check the operation of CT SWITCHING relay.
6) Close the Line/equipment side isolator of the particular bay and check the respective indications on panel/SCADA.
7) Put NIT switch at “I” position.
8) Switch ON the CB of that particular bay and confirm the respective indications on panel/SCADA.
9) In the switchyard ensure that all three poles of that CB are closed.
10) Put NIT switch at “N” position and Switch OFF the breaker of TBC bay.
11) In the switchyard ensure that all three poles of breaker of TBC are opened.
12) Check the respective Lamp and semaphore indication on control panel and on schematic of SCADA.
13) Check that all meters confirm about the transfer of load from Transfer bus to Main bus.
14) Open the main bus isolator of TBC bay and confirm the respective indications on panel/SCADA.
15) Check the resetting of CT SWITCHING relay& PT SELECTION relay.
16) Open the Transfer bus isolator of TBC bay and confirm the respective indications on control panel/SCADA.
17) Check the resetting of CT SWITCHING relay.
18) Remove the board showing “LOAD ON TRANSFER BUS” from the control panel.
19) Inform SLDC regarding the transfer of load.

2. OPERATION PROCEDURE FOR 220 KV SWICHYARD

2.1 OPERATION PROCEDURE FOR ISOLATION OF 220KV LINES FOR MAINTANCE WORK

1) Obtain the Requisition form for LCP duly signed by maintenance engineer.
2) Ensure that outage of proposed line is confirmed by SLD.
3) Inform SLDC & opposite ends before switching OFF line breaker.
4) In case of interstate line obtain the code from SLDC before switching OFF the CB.
5) In consultation with opposite end switch OFF the CB of receiving end & then switch OFF the CB of sending end.
6) Confirm that all the poles of CB are opened by observing in switchyard.
7) Confirm the respective Lamp and Semaphore indications on control panel and on SCADA schematic.
8) Do remember to use Hand gloves for the operation of isolators/earth switch(ES)
9) Open bus & line isolator from both the ends and confirm the respective indications (Lamp and Semaphore) on control panel/SCADA schematic
10) In case of two or more bus system, check the resetting of CT SWITCHING RELAY & PT SELECTION relay.
11) After confirming opening of isolators at both ends, provide Earthings at both the ends.
12) Obtain Line Clear Permit (LCP) from opposite end and make necessary entry in LCP book/log register(s) and issue LCP to Maint Engineer.
13) Hang a board “LCP ISSUED & PERSONS AT WORK” on one of the operating handle of control panel of isolated line.
14) Isolated bay should be cordoned with the help of manila rope as a measure of safety.

2.2 PROCEDURE FOR RESTORATION OF 220KV LINE AFTER COMPLETION OF MAINTENANCE WORK

1) Get all LCPs returned duly signed by maintenance engineers/ opposite end with a confirmation regarding persons and materials are removed form line to be charged.
2) Remove the rope which was used to cordon the entire isolated bay.
3) Ensure that no external earthing is provided on any of equipment under shutdown.
4) Return LCP to opposite end.
5) Do remember to use Hand gloves for the operation of Isolators/ES.
6) Open earthing switch of this side and get it opened from opposite end.
7) ! BEFORE CLOSING THE ISOLATOR ENSURE THAT ALL THREE POLES OF CB ARE OPEN.
8) Close line isolator in consultation with opposite end.
9) Close the bus isolator & check the operation of CT SWITCHING & PT SELECTION relay (in case of two main bus system).
10) Check the respective indications (Lamp and Semaphore or mimic schematic) on Control panel/SCADA which confirms the closing of Isolator and opening of ES.
11) Inform SLDC regarding the charging of line.
12) In case of interstate lines take code from SLDC for charging of line.
13) The lines which are connected with power station should always be charged on dead line from s/s end & synchronizing will be done from power station end.
14) SYNCHRONISING PROCEDURE/DEAD LINE CHARGING
    - For carrying out dead line charging put Syn. Bypass selector switch at “BYPASS” position on Bus coupler panel & Sync selector switch at “ON “ position provided on feeder panel in old panels.
    - In case of new panel put Syn. Selector Switch at “BYPASS” position in feeder panel.
    - Switch ON the line CB and confirm that all the poles are closed.
    - Check voltage on voltmeter of line panel.

<u>For synchronising follow the below procedure</u>

- Put Sync Bypass selector switch back at “ON” position in Bus Coupler panel & sync selector switch at “OFF “position in feeder panel in case of old panel. In case of new panel put Syn. Selector Switch at” OFF” position in feeder panel
- Connect synchronizing trolley to control panel by inserting plug in the syn. Socket of control panel.
- Put Sync Bypass selector at “ON” position in bus coupler panel & Sync selector switch at “ON” position in feeder panel in case of old panel. In case of new panel put Syn. Selector Switch at ‘CHECK” position in feeder panel.
- Incoming (Line) & running (Bus) voltage & frequency will appear on the syn.Trolley.
- Put synchroscope switch on “ON” position
- Pointer of synchroscope will revolve in clockwise direction and it will remain fixed in center (dark zone area) & “SYNCHRONIZATION IN LIMIT” lamp will glow at that particular instant close the CB.
- Check all respective indications on Panel/SCADA.

- Confirm that all the three poles of breaker are closed by observing in switchyard.
- Check current in all three phases.
- Put synchronising switch at" OFF "condition & remove synchronising trolley.

2.3 PROCEDURE FOR RESTORATION OF 220 KV LINE AFTER FAULT TRIPPING.

1) Accept the Annunciator to silent the alarm/hooter sound.
2) Note down facia / relay indications / fault locator readings / counter readings of this end.
3) Collect facia / relay indications / fault locator readings / counter readings from the opposite end.
4) Inform all the respective officers of PTCUL (this end/opposite end) and SLDC regarding the tripping of line with time and all indications/facia.
5) Reset all relays & facia at your end & get it same at opposite end.
6) Analyze the fault by studying the relay indications of local end & opposite end.
7) Carry out the inspection in the switch yard for any abnormality in the entire bay area (all equipments)
8) Similarly instruct to carry out yard inspection at opposite end.
9) For a single L-G (line to ground) fault if no abnormality is found in the switchyard of any side, a test charge can be taken in consultation with SLDC.
10) For a phase to phase fault after inspection of yard and line patrolling & attending the fault, Dead line charging/ synchronizing procedure should be carried out as outlined above.

2.4 PROCEDURE FOR ISOLATION AND RESTORATION OF 220KV TRANSFORMER FOR MAINTENANCE WORK

1) Obtain Requisition form for LCP duly signed by maintenance Engineer.
2) Ensure that outage of proposed transformer is confirmed by SLDC.
3) Inform SLDC regarding this shutdown.
4) Switch OFF the CB of LV side first & then switch OFF CB of HV side.
5) In the switchyard check that all three poles of HV & LV Breakers are opened.
6) Check respective indications (Lamp Semaphore, mimic) on control panel/SCADA schematic confirming opening of Breaker of HV & LV sides.
7) Do remember to use Hand gloves for the operation of isolators/ES.
8) Open Bus & Transformer isolators on both side (HV & LV) of transformer.
9) Check the resetting of CT SWITCHING RELAY& PT SELECTION relay on 220kv side if two main bus scheme is installed.
10) Check respective indications on control panel/SCADA mimic confirming the opening of Isolator and closing of ES (if exists).
11) Provide local earthing on both HV & LV side if required.
12) Isolated bay should be cordoned with the help of manila rope for safety measure.
13) Issue LCP to maintenance engineer for carrying out maintenance work.
14) Make sure necessary entries in the LCP book/log sheet is made.
15) Hang the board painted with "LCP ISSUED & PERSONS AT WORK" on both side (HV &LV) control panels.
16) For restoring transformer after completion of work get (all) LCP(s) returned duly signed by Maint engineer confirming that all persons and materials are removed from the transformer and bay equipments to be charged.
17) The rope used for cordoning isolated Transformer bay should be removed.
18) Remove local earthing from HV & LV side.
19) ! BEFORE CLOSING THE ISOLATOR ENSURE THAT ALL THREE POLES OF BOTH CBs ARE OPEN.
20) Close Transformer isolators on both the sides.
21) Close the bus isolator & check the operation of CT SWITCHING & PT SELECTION relay on HV side (if it is two main bus scheme).
22) Check respective indications (Lamp, Semaphore) on control panel and SCADA schematic confirming the closing of Isolators and opening of ES.
23) Close HV CB, then LV CB.
24) Inform SLDC regarding charging of transformer.
25) In the switch yard check that all three poles of HV & LV Breakers are closed.
26) Check the currents in all three phases of HV& LV sides.
27) Inform all respective officers of PTCUL regarding charging of transformer.

2.5 PROCEDURE FOR RESTORATION OF TRANSFORMER AFTER FAULT TRIPPING

1) Accept the facia.
2) Note down the facia and relays from control and relay panel of both the sides (HV & LV).
3) Inform the SLDC and respective officers of PTCUL regarding the tripping of Transformer with facia and relays.
4) Inspect the Transformer & its bay equipments for any abnormality.
5) Try to analyze the fault by studying the relays' indications and try to find out the cause of tripping.
6) If back up relay is operated due to reflected fault of feeder and no abnormality is found in the switchyard then one test trial of charging can be taken with the permission of SLDC.
7) If it stands OK then current in all three phases should be checked on HV and LV side.
8) If the transformer trips on "Buchholz / Differential relay" trial for charge should not be taken before testing of transformer.
9) Gases from the Buchholz should be collected for detailed analysis.
10) Unless satisfactory cause of tripping is found, charging of transformer should not be done.
11) When transformer trips on differential protection due to failure of HV/LV side LA / CT, same should be replaced & the transformer can be taken into service after carrying out necessary stability and other tests.
12) When Transformer trips on "REF" relay, testing of transformer including measurement of Winding resistance should carried out before charging.
13) When transformer trips on WTI/OTI even though there is a low temperature, check the healthiness of thermometer & mercury switch and control circuit.
14) Finally a message should be conveyed to all the officers of PTCUL with a copy to SLDC.
15) After attending the problem, the Transformer can be taken into service by adopting the procedure outlined above in "ISOLATION & RESTORATION OF 220KV TRANSFORMER"

2.6 PROCEDURE FOR ISOLATION OF ONE 220KV MAIN BUS BYTRANSFERRING LOAD ON ANOTHER MAIN BUS

1) Ensure that prior confirmation of outage of 220kV Bus is obtained from SLDC well in advance.
2) Inform SLDC regarding the 220kV Bus outage.
3) List out the feeders/equipments to be transferred from one bus to another bus.
4) Put the switch of 220 kV Bus bar protection scheme at “OUT” position.
5) ! Do remember to use Hand gloves for the operation of isolators/ES.
6) Close the bus isolator of feeder where the load is to be transferred and confirm the operation of CT SWITCHING RELAY.
7) “Bus no. 1 & 2 inter connected / bus wire faulty” facia will appear on control panel.
8) Open the bus isolator of main bus whose outage is to be taken.
9) Check the resetting of CT SWITCHING/ PT SELECTION relay of Bus under outage and operation of PT SELECTION relay where load is transferred.
10) “Bus no. 1 & 2 inter connected/Bus wire faulty” facia can be reset now.
11) Check the respective indications (Lamp and semaphore) on panel /SCADA.
12) Above operations are to be carried out for all the bays one by one till the complete load of one bus is transferred to another bus.
13) While carrying out this operations observe the current on Bus coupler panel, if it is found high then keep both Bus isolator of that particular feeder in closed position & open the bus isolator (for which bus under outage) at last BEFORE OPENING OF B/C CB ONLY .
14) Do not open bus isolator of the bus which is under outage before confirming the operation of CT switching relay of other bus where load is to be transferred.
15) ! CONFIRM THAT ALL THE ISOLATORS OF BUS UNDER SHUTDOWN ARE OPENED FOR ALL THE RESPECTIVE BAYS.
16) Finally switch OFF CB OF 220 kV Bus coupler.
17) Open the bus no. 1 & 2 isolators of bus coupler bay.
18) Now the bus whose shutdown is arranged is idle.
19) Put switch of bus bar protection scheme at “IN” position.
20) Close earthswitch at both ends of bus for safe working and confirm the indications on panel/SCADA.
21) Issue LCP (with necessary entries into the LCP register) maintenance engineer for carrying out bus maintenance work.

2.7 PROCEDURE FOR RESTORATION OF 220KV MAIN BUS BY TRANSFERRING LOAD BACK TO ORIGINAL MAIN BUS

1) Get all LCPs returned duly signed by concerned engineer(s) confirming that all persons, materials and local earthings are removed from the working site.
2) Inform LDC for taking Bus into service.
3) Confirm again through switchyard observation regarding removal of local earthing and confirm that all the poles are opened for CB of 220kV Bus coupler.
4) List out the bays to be transferred back to normal bus.
5) Put the switch of 220V BBP scheme at “OUT” position.
6) Open the Bus Earth switch provided at one or both ends of the bus under shutdown.
7) Close the main bus no. 1 & 2 isolator of bus coupler bay.
8) Put Bypass selector switch at” BYPASS” position & Sync selector switch at” ON” position on B/C panel in case of old panels .In case of new panel put Synchro selector switch at “BYPASS” position .
9) Switch ON the CB of 220kV B/C bay.
10) Put Bypass selector switch at “ON” position & Sync selector switch at “OFF” position on B/C panel in case of old panel. In case of new panel put Synchro selector switch at “OFF” position. Now both the bus are charged.
11) Close the bus isolator of one of the bay for the bus which was under shutdown.
12) “Bus no. 1 / 2 inter connected /bus wire faulty” facia will appear on control panel,
13) Check the operation of CT SWITCHING RELAY.
14) Open the bus isolators of the same bay for the bus on which the load was transferred.
15) Check the resetting CT SWITCHING RELAY/ PT SELECTION relay & operation of PT SELECTION relay of the bus under outage.
16) “Bus 1/2 inter connected/ /bus wire faulty” facia can now be reset.
17) Above operations are to be carried out for all the bays one by one till the original loading condition of both the bus is achieved.
18) While carrying out these operations observe the current on Bus coupler panel, if found high, keep both Bus isolator of that particular bay in closed position & open the bus isolator of side from where load is to be transferred.
19) Reset all relays and facia appeared on CRP of any bay & Busbar Protection panel.
20) Put the switch of 220 kV Busbar Protection (BBP) scheme at “IN” position.
21) Inform all respective officers of PTCUL and SLDC about the normalization of bus after the shutdown.

2.8 PROCEDURE FOR RESTORATION BUS POSITION AFTER OPERATION OF 220KV BUSBAR PROTECTION RELAY

Following procedure should be adopted to normalize the bus loadings when separated out due to operation of bus bar protection scheme:

1) Accept all the facia of the bays connected with the tripped bus.
2) Note down all the facia / relay indications /counter readings of all the tripped feeders/equipments.
3) Collect all facia / relay indications / counter readings from the opposite end of tripped lines.
4) Inform all respective officers of PTCUL and SLDC regarding operation of bus bar protection scheme with exact time.
5) Reset all facia and relays at both the ends.
6) Check whether CB at this end and any opposite end tripped correctly or not.
7) Carry out the switch-yard observation and isolate faulty equipments of the tripped zone of bus.
8) ! ENSURE THAT ALL THE THREE POLES OF ALL THE CBs CONNECTED TO THE FAULTY BUS ARE IN OFF POSITION.
9) After isolating the faulty equipment from the bus, start the procedure to transfer the bus loading in consultation with SLDC.
10) Put Synchro selector switch at “ON” position & Sync Bypass switch at “BYPASS” position on Bus Coupler panel in case of old panel. In case of new panel put synchro selector switch at “BYPASS” position.
11) Switch ON the CB of Bus Coupler bay.
12) After charging the bus, start taking all healthy bays one by one in service from both the ends in consultation with SLDC as per respective procedure outlined above.
13) Ensure that load on BC bay does not exceed during the above operation of taking bays into service.
14) If in case of high current, keep both Bus isolator of a particular bay in closed position & open the isolator of bus which required being isolated.
15) Thus both the bus can be normalized which were separated by operation of bus bar protection (BBP) Relay.
16) Convey message to all respective officers of PTCUL and SLDC

2.9 PROCEDURE FOR TRANSFERRING LOAD OF 220KV FEEDER / EQUIPMENT FROM MAIN BUS TO TRANSFER BUS THROUGH TBC BAY

1) Ensure that proposed transfer of load of particular bay to Transfer Bus is confirmed by SLDC.
2) By observing in the switchyard, ensure that all three poles of CB of TBC Bay are opened.
3) Do remember to use Hand gloves for the operation of isolators.
4) Close the Isolator of TBC bay for the bus with which particular bay is connected and confirm the indications (Lamp, semaphore) on panel/SCADA.
5) Check the operation of CT SWITCHING relay & PT SELECTION relay.
6) Close the Isolator connected to Transfer bus of TBC bay and check the respective indications on panel/SCADA.
7) Close the Isolator connected to Transfer bus for particular bay and check the respective indications on panel/SCADA.
8) Check the operation of CT SWITCHING relay.
9) "Bus -1/2 &Transfer Bus interconnected" facia will appear on B/C panel.
10) Put NIT switch at "I" position.
11) Switch ON the CB of TBC Bay and check the respective indications on panel/SCADA and confirm that all the poles of CB are closed.
12) Put NIT switch at "T" position.
13) Switch OFF the CB of a particular bay under consideration.
14) In the switchyard, ensure that all three poles of CB are opened and check the respective indications on panel/SCADA.
15) Now the load of the particular bay under consideration is transferred on the Transfer Bus. Start the isolating that bay.
16) Open the Equipment /Line isolator of particular bay and check the respective indications on panel/SCADA.
17) Open the Main Bus Isolator of particular bay and check the respective indications on panel/SCADA.
18) Check the resetting of CT SWITCHING relay.
19) "Bus –1/2 & Transfer Bus interconnected" facia can now be reset on B/C panel.
20) ! ENSURE THAT PT SELECTION RELAY MUST REMAIN OPERATED IN PARICULAR BAY & TBC PANEL.
21) Hang the board painted with "LOAD ON TRANSFER BUS" on the control panel.
22) In case of Line bay, BE CAUTIOUS THAT LINE SIDE END OF ISOLATOR WILL REMAIN LIVE.

NOTE: This is a Typical Procedure. However it may Change from Station To Station. Please Follow the Procedure as per Actual Scheme Drawing.

2.10 PROCEDURE FOR TRANSFERING THE LOAD OF 220KVFEEDER / EQUIPMENT BACK FROM TRANSFER BUS TOMAIN BUS

1) OBSERVE IN THE SWITCHYARD TO ENSURE THAT ALL THREE POLES OF CB OF PARTICULAR BAY UNDER REFERENCE ARE OPENED.
2) IN CASE OF LINE BAY, BE CAUTIOUS THAT LINE SIDE END OF ISOLATOR IS LIVE.
3) ! Do remember to use Hand gloves for the operation of isolators.
4) Close the isolator of particular bay connected to Main bus with which TBC is connected. Check the respective indications (Lamp, Semaphore) on panel/SCADA.
5) Check the operation of CT SWITCHING relay.
6) Close the Line /Equipment isolator of the particular bay and check the respective indications on panel/SCADA.
7) “Bus –1/2 & Transfer Bus interconnected” facia will be appeared on B/C panel.
8) Put NIT switch at “I” position.
9) Switch ON the CB of particular bay and check the respective indications on panel/SCADA.
10) Observe in the switchyard to ensure that all three poles of that CB of particular bay are closed.
11) Put NIT switch at “N” position.
12) Switch OFF the CB of TBC bay and check the respective indications on panel/SCADA and physical condition of all the poles are open.
13) Now load is transferred from Transfer Bus to Main breaker of particular bay.
14) Open the Isolator of particular bay connected with Transfer Bus and confirm the respective indications on panel/SCADA.
15) Check the resetting of CT SWITCHING relay.
16) “Bus –1/2 & Transfer Bus interconnected” facia can now be reset on B/C panel.
17) Open the Main bus Isolator of TBC bay and check the respective indications on panel/SCADA.
18) Check the resetting of CT SWITCHING relay & PT SELECTION relay.
19) Open the Isolator of TBC bay connected with Transfer bus and check the respective indications on panel/SCADA.
20) Remove the board hung with painted “LOAD ON TRANSFER BUS” from the control panel.
21) Inform SLDC and all respective officers of PTCUL regarding the transfer of load.

NOTE: THIS IS A TYPICAL PROCEDURE. HOWEVER IT MAY CHANGE FROM STATION TO STATION. PLEASE FOLLOW THE PROCEDURE AS PER ACTUAL SCHEME DRAWING.

SPECIAL NOTE:
IF 220KV BUS REACTOR BAY EXISTS IN ANY SUBSTATION, PROCEDURE FOR ISOLATION AND RESTORATION SHALL BE AS PER THE SAME GIVEN FOR 400KV BUS REACTOR BAY.

3. OPERATION PROCEDURERS FOR 132KV SWITCHYARD

3.1 PROCEDURE FOR ISOLATION OF 132KV LINE

1) Obtain the Requisition form for LCP duly signed by maintenance engineer.
2) Ensure that outage of proposed line is confirmed by SLDC.
3) Inform SLDC & opposite end operating personnel.
4) In consultation with opposite end personnel, let CB of receiving end be switched OFF and after it switch OFF the CB of sending end.
5) Observe in the switchyard to check that all three poles of CB are opened.
6) Check the respective indications (Lamp, Semaphore) at panel/SCADA confirming of opening of CB.
7) ! Do remember to use Hand gloves for the operation of isolators/earth-switch.
8) Open bus & line isolator from both the ends.
9) Close the ES or provide Earthings at both the ends on line side end of isolator.
10) Check the respective indications on panel/SCADA.
11) Obtain the LCP from opposite end and issue LCP to concerned Maint. Engineer. Make necessary entry in LCP/log registers.
12) Hang a board on Control panel of isolated line painted with “LCP ISSUED & PERSONS AT WORK”.
13) Isolated bay should be cordoned with the manila rope for safety measure.

3.2 PROCEDURE FOR RESTORATION OF 132KV LINE AFTER COMPLETION OF MAINT. WORK

1) Get all LCPs returned duly signed by maintenance Engineers/ opposite end with confirmation that persons, material and local earthing are removed from particular line.
2) Remove the rope which was used to cordon the isolated bay.
3) Ensure by observing in switchyard that no loose earthing is still provided.
4) ! Do remember to use Hand gloves for the operation of isolators/ earth switch.
5) Open earthing switch of this end and Return LCP to opposite end and get the ES of opposite end opened.
6) ! ENSURE THAT ALL THREE POLES OF CB ARE OPEN.
7) In consultation with opposite end operating personnel, Close Line isolator and then close bus isolator at both the ends.
8) Close the CB from sending end first and then close the CB of receiving end.
9) Check in the switchyard that all three poles of breaker are closed.
10) Check the respective all indication (lamp, semaphore etc) on panel/SCADA to confirm the status of all equipments.
11) Check that Ammeter is showing current in all three phases.
12) Inform SLDC and respective officers of PTCUL regarding the restoration of 132 KV Line with exact time.(e.g. Line AAAAA is charged from xxx end at 16-25 hrs stood OK , parallel at station YYY at 16-28 hrs stood OK)

3.3 PROEDURE FOR RESTORATION OF 132KV LINE AFTER FAULT TRIPPING

When 132 kV line trips on fault following procedure should adopted to normalize / put back it in to service:

1) Annunciator will operate & give audible sound Accept the Annunciator to silent the sound.
2) Note down facia / relay indications / fault locator readings / counter readings of this end.
3) Enquire whether CB at opposite end has tripped.
4) If operated, Collect facia / relay indications from the opposite end.
5) Inform the respective officials of PTCUL and SLDC regarding the tripping of 132 KV line with timings.
6) Reset all relays & facia at this end & get it opened at opposite end.
7) Analyze the fault by studying the relay indications of both ends.
8) Carry out the inspection in the switchyard to check any abnormality in the bay equipments.
9) Similarly get it report of the same at opposite end.
10) If it is tripped on single phase fault (L-G) and no abnormality is found at nay end then test trial for charging the line can be done in consultation with opposite end and SLDC.
11) Close the CB from sending end first, wait for 2-3 minute and hold good then close CB of receiving end.
12) Check Ammeter readings (currents) in all three phases of 132 KV line.
13) If line tripped on L-L or LLG, LLL it should be declared as Permanent Fault (PF).
14) Isolation of line for attending fault shall be done as per the procedure described above in this manual and issue LCP to respective engineer.
15) After competition of rectification work on line, get all LCP returned.
16) Restore the line as per the procedure outline above in this manual.
17) Inform SLDC and respective official of PTCUL about restoration of 132 KV Line with exact time.

3.4 PROCEDURE FOR ISOLATION AND RESTORATION OF 132 KV TRANSFORMER BAY FOR MAINTENANCE WORK

1) Obtain the Requisition form for LCP duly signed by maintenance engineer.
2) Ensure that outage of proposed transformer is confirmed by SLDC.
3) Inform SLDC.
4) Switch OFF the CB of LV side first & then that of HV side.
5) Observe in the yard to check that all three poles of CBs opened.
6) Check the respective indications (Lamp, semaphore) on panel/SCADA confirming opening of CBs.
7) ! Do remember to use Hand gloves for the operation of isolators/ES.
8) Open Transformer side and bus Isolators on both side of transformer.
9) Check the respective indications on panel/SCADA.
10) Close ES if available or provide local earthing on HV & LV side of transformer.
11) Isolated bay should be cordoned with the manila rope as a safety measure.
12) Issue LCP to maintenance engineer for carrying out maintenance work with necessary entries in the LCP/log register.
13) Hang a board painted with “LCP ISSUED & PERSONS AT WORK” on control panel of each side.
14) For restoring transformer after completion of work, get LCP returned duly signed by maintenance engineer confirming that all persons, materials and local earth are removed from working site.
15) Remove the rope used for cordoning isolated transformer bay.
16) Open the ES and/or Remove local earthing from each side.
17) ! ENSURE THAT ALL THREE POLES OF CBs ARE OPEN.
18) Close Isolator on Transformer side for both the sides.
19) Check respective indications on Panel/SCADA ensuring the status.
20) Close CB on HV side after 2-3 minute close CB on LV side.
21) Check that all the three phases of CBs are closed and confirm the status of all respective indications on Panel/SCADA.
22) Check that all three phases show almost balanced currents as per routine loadings.
23) Inform SLDC and all respective officers of PTCUL regarding charging of Transformer.

3.5 PROCEDURE FOR RESTORATION OF TRANSFORMER BAY AFTER FAULT TRIPPING

1) Accept the facia.
2) Note down the facia and relays each side of transformer.
3) Inform the SLDC and all respective officers of PTCUL regarding the tripping of Transformer with facia and relays and time of tripping.
4) Try to analyze the fault by studying the relays.
5) Inspect the Transformer bay complete to check any abnormality
6) Try to find out the cause of tripping.
7) If back up relay is operated due to reflected fault of feeder and no abnormality is found in the yard then one test trial for charging can be taken with the permission of SLDC.
8) If it stands OK then current in all three phases should be checked on HV and LV side.
9) If the transformer trips on "Buchholz / Differential relay/PRV/REF (if provided) it should not be charged before testing of transformer and instruction of inchage engineer.
10) For carrying out testing/rectification work follow the procedure for isolation of Transformer outlined above in this manual.
11) If transformer tripped on buchholz, check oil level in conservator, if found low topping of oil should be carried out.
12) Gases from the Buchholz should be collected for detailed analysis.
13) Unless satisfactory cause of tripping is found, charging of transformer should not be done.
14) When transformer trips on differential protection due to failure of HV/LV side LA / CT, same should be replaced & the transformer can be taken into service after carrying out necessary stability test.
15) When Transformer trips on "REF" relay, testing of transformer including measurement of Winding resistance should carried out and after clear finding of cause and rectification thereof the transformer should be charged.
16) When transformer trips on WTI/OTI even though there is a low temperature then check the healthiness of thermometer, mercury switch and control circuit.
17) After satisfactory testing of transformer by testing personnel charging procedure can be commenced.
18) Restore the transformer as per procedure outlined above in this manual
19) Inform SLDC and all respective officers of PTCUL regarding restoration of transformer.

3.6 PROCEDURE FOR ISOLATION OF 132 KV SINGLE BUS

1) Obtain Requisition Form for LCP duly signed by maintenance engineer.
2) Ensure that outage of proposed 132 KV Bus is confirmed by SLDC.
3) Inform SLDC and operating personnel of opposite ends stating loading on 132 KV lines, load on transformer and Load of downward bus if affected by this bus shutdown.
4) Switch OFF CB of transformer connected with this 132 KV Bus from LV side and then open CB of HV side.
5) Do remember to use Hand gloves for operation of isolator.
6) Open the Isolator on bus side and transformer side of Transformer bay for both HV and LV. Confirm the respective indications (Lamp, semaphore) on Panel/SCADA.
7) Check in the yard that all three poles of breaker are opened.
8) Switch OFF CB of one of the 132 KV line from receiving end fist then sending end in consultation with personnel of opposite end. Check the respective indications on panel/SCADA to ensure status.
9) Check that all three poles of breaker are opened.
10) Similarly switch off all 132kV lines connected to this bus under shutdown.
11) Open the Line side from opposite end and Line side and Bus side isolator of this end.Check the status of Isolators with respective indications on Panel/SCADA.
12) Close ES on Line side Isolator for all the lines and check the status with respective indications on Panel/SCADA.
13) Open Isolator of 132 KV PT and check voltmeter for zero bus voltage.Check status with indications on Panel/SCADA.
14) Provide earthing on 132 kV bus at either end.
15) Issue LCP to the maintenance engineer for carrying out maintenance of 132 KV Bus.

3.7 PROCEDURE FOR RESTORATION OF 132 KV SINGLE BUS AFTER MAINTENANCE WORK

1) Get LCP returned from Maintenance Engineer with confirmation on removal of persons, materials and local earhting from working site.
2) Open ES or Remove earthing provided on 132 KV lines and transformer or other bay location.
3) Do remember to use Hand gloves for operation of isolator and earthswitch.
4) Close Isolator of 132 kV PT and check the respective indications (lamp, semaphore) on Panel/SCADA.
5) Take one of the 132kV lines (which serves as Incoming line in normal conditions) into service as per procedure outlined above in this manual, thus 132kV bus will be charged.
6) Check the PT voltages on all the three phases.
7) Take 132kV Transformer bay into service as per the procedure described above in this manual.
8) Similarly take all the lines connected to the bus under shutdown into service one by one.
9) Take all the Transformers connected to this bus in to service one by one.
10) Convey message to all respective officials of PTCUL and SLDC regarding restoration of 132kV bus.

SPECIAL NOTE: THE SUB-STATION WHERE THE 132Kv SIDE SWITCHING SCHEME IS TWO BUS OR TWO BUS WITH TRANSFER BUS, THE OPERATION OF BAY ISOLATION AND RESTORATION WILL BE AS PER THE RESPECTIVE PROCEDURE OF THE 220KV BAYS DESCRIBED HEREIN ABOVE.

4. SAMPLE LIST OF RELAY INDICATIONS

DISTANCE PROTECTION SCHEME (OLD STATIC RELAY)

(E. E. Co. / ALSTHOM / ALSTOM /AREVA)

A): MM3V

FLAG DESCRIPTION
30 A R Ph to GROUND FAULT
30 B Y Ph to GROUND FAULT
30 C B Ph to GROUND FAULT
30 AB R -Y Phase to Phase FAULT
30 BC Y- B Phase to Phase FAULT
30 CA B- R Phase to Phase FAULT
30 G ZONE – 1
30 H ZONE – 2
30 J ZONE – 3
85 X 1 CARRIER SEND
85 X 2 CARRIER RECEIVED
186A/B A/R LOCK OUT

B): QUADRA MHO

LED DESCRIPTION
a R Ph FAULT
b Y Ph FAULT
c B Ph FAULT
Z 2 ZONE 2
Z 3 ZONE 3
AIDED CARRIER AIDED TRIP
SOTF SWITCH ON TO FAULT TRIP
V Fail PT FUSE FAIL ALARM
P POWER SWING OPERATED

C): MICRO MHO

LED DESCRIPTION
a R Ph FAULT
b Y Ph FAULT
c B Ph FAULT
N GROUND FAULT
Z 1 ZONE 1 OPERATED
Z 2 ZONE 2 OPERATED
Z 3 ZONE 3 OPERATED
AIDED CARRIER AIDED TRIP
SOTF SWITCH ON TO FAULT TRIP
V Fail P T FUSE FAIL ALARM
P POWER SWING OPERATED

D): OPTIMHO
TEXT DESCRIPTION
A R Ph FAULT
B Y Ph FAULT
C B Ph FAULT
N GROUND FAULT
Z1 ZONE 1 OPERATED
Z 2 ZONE 2 OPERATED
Z 3 ZONE 3 OPERATED
AIDED CARRIER AIDED TRIP
ABC SWITCH ON TO FAULT TRIP
V Fail PT FUSE FAIL ALARM
PSB POWER SWING OPERATED

E): EPAC
TEXT DESCRIPTION
A R Ph FAULT
B Y Ph FAULT
C B Ph FAULT
N GROUND FAULT
Z 1 ZONE 1 OPERATED
Z 2 ZONE 2 OPERATED
Z 3 ZONE 3 OPERATED
AIDED CARRIER AIDED TRIP
ABC SWITCH ON TO FAULT TRIP
V Fail P T FUSE FAIL ALARM
PSB POWER SWING OPERATED

RELAY INDICATIONS FORDISTANCE PROTECTION SCHEME (ABB)

A): RAZFE

FLAG DESCRIPTION
RN R Ph to GROUND FAULT
SN Y Ph to GROUND FAULT
TN B Ph to GROUND FAULT
2Ph. Phase to Phase FAULT
3Ph. 3 Ph FAULT
Z 1 ZONE 1 START
Z 2 ZONE 2 START
TK 2 ZONE 2 TIMER OPTD
TK 3 ZONE 3 TIMER OPTD
P POWER SWING BLOCKING
DC DC FAIL
U DEFINITE TRIP

B): REL 100

TEXT DESCRIPTION
PSR R Ph FAULT
PSS Y Ph FAULT
PST R Ph FAULT
PSN GROUND FAULT
ZM1 OP. OF ZONE 1 ELEMENT
ZM2 OP. OF ZONE 2 ELEMENT
ZM3 OP. OF ZONE 3 ELEMENT
ZM3 R OP. OF REV. ZONE 3 ELEMENT
TRZ 1 TRIP CAUSED BY IMP MEAS. ZONE 1
TRZ 2 TRIP CAUSED BY IMP MEAS. ZONE 2
TRZ 3 TRIP CAUSED BY IMP MEAS. ZONE 3
CSZ CARRIER SEND SIGNAL
CRZ CARRIER RECEIVED SIGNAL
PSB OP.OF POWER SWING
TRSOTF SWITCH ON TO FAULT TRIP
TRVTF TRIP CAUSED BY FUSE FAILURE
TS OP. OF FUSE FAILURE SUPERVISION

RELAY INDICATIONSFORDISTANCEPROTECTION SCHEME (ER)

A): THR

LED DESCRIPTION
r R Ph FAULT
y Y Ph FAULT
b B Ph FAULT
ry R Ph to Y Ph FAULT
yb Y Ph to B Ph FAULT
br B Ph to R Ph FAULT
1 ZONE 1 OPTD
2 ZONE 2 OPTD
3 ZONE 3 OPTD
lc LINE CHECK
pt PERMISSIVE TRIP

List of relay indications in case of Numerical Type.

However it may please be noted that all respective features are supposed to be enabled during commissioning /testing stage.

Distance Protection Relay (For Line)

Sr	Function	LED	Remarks
1	R Phase Trip	Yes	Latch
2	Y Phase Trip	Yes	Latch
3	B Phase Trip	Yes	Latch
4	Neutral	Yes	latch
5	Distance Z1 Operated	Yes	Latch
6	Distance Z2 Operated	Yes	Latch
7	Distance Z3 Operated	Yes	Latch
8	Distance Z4 Operated	Yes	Latch(Reverse Zone)
9	Carrier aided trip	Yes	Latch
10	Power Swing block	Yes	Un-latch
11	Power swing trip	Yes	Latch
12	V.T. Fuse fail	Yes	Unlatch
13	V.T. MCB Trip	Yes	Unlatch
14	Aided Dir-Earth fault trip	Yes	Latch
15	Back up dir-earth fault trip	Yes	latch
16	Carrier Channel 1 fail	Yes	Un latch
17	Carrier Channel 2 fail	Yes	Un latch
18	Broken conductor trip	Yes	Latch
19	A/R In service	Yes	Latch(If internal A/R Sch. used)
20	Over voltage Alarm/trip	yes	latch

Differential Protection Relay (For Transformer)

Sr.	Function	LED	Remarks
1	R-Phase Trip	Yes	Latch
2	Y-Phase Trip	Yes	Latch
3	B-Phase Trip	Yes	Latch
4	Neutral	Yes	latch
5	Idiff> trip(diff-trip)	yes	Latch
6	Idiff>> (diff un-restrain Trip)	Yes	Latch
7	2ed Harmonic Block	Yes	Latch
8	5Th Harmonic Block	Yes	Latch
9	Main Tank B/Z Trip	Yes	Latch (assign for D.R.)
10	Main Tank PRV Trip	Yes	Latch (assign for D.R.)
11	O.L.T.C. B/Z Trip	Yes	Latch (assign for D.R.)
12	O.L.T.C. PRV Trip	Yes	Latch (assign for D.R.)
13	Winding Tempt .high Trip	Yes	Latch (assign for D.R.)
14	OilTempt. high Trip	Yes	Latch (assign for D.R.)
16	H.V.R.E.F.Trip	Yes	Latch
17	L.V.R.E.F.Trip	Yes	Latch
18	Dir. Phase O/C Trip	Yes	Latch
19	Dir. Earth O/C Trip	Yes	Latch

5. DAILY CHECKS

SR No	OBSERVATIONS
1	Cleaning of relay & control panels
2	Observation of load pattern
3	Observation of voltage profile
4	Trip circuit healthiness
5	Indicating lamps/Semaphores
6	Resetting of relays
7	Healthiness of DC source
8	DC earth leakage
9	Healthiness of emergency light
10	Healthiness of PLCC/P&T/Mobile phones
11	Healthiness of VHF sets
12	Healthiness of walky talky
13	Healthiness tele printer
14	Healthiness of Event logger
15	Healthiness of Disturbance recorder
16	Battery pilot cells reading
17	Healthiness of stand by auxiliary AC supply source
18	Purging of air drier plant`
19	Checking the operation period of compressor.
20	General observation in LT room, AC plant , AHU room, Cooling towers, Fire room & Battery room
21	Humming of Transformer/Reactor
22	Oil level in Main & OLTC conservator tank(observation in indicating glass)
23	Observation of MOG for oil level in conservator
24	Oil leakage from transformer/Reactor
25	Oil level in Transformer Bushing / CT / CVT / PT
26	Condition of silica jel & oil level in breathers
27	Breathing of Transformer/Reactor
28	Working of fan & oil pump if temp exceeds the set value
29	Counter reading & leakage current reading in LA
30	Draining condensate from air reservoir of breaker
31	Operation of air compressor
32	Checking of air leakage if any
33	Checking oil leakage from grading capacitor
34	Oil leakage from CT,CVT & PT
35	Air leakage from air pipe line in switchyard.
36	Water leakage from fire extinguishing system
37	Night observation in yard for hot spots & corona
38	Checking of control room & switchyard lighting
39	Checking of aviation lamps
40	Observation of any other abnormality in the yard

POWER TRANSMISSION CORPORTATION OF UTTARAKHAND LTD.

SECTION – II

MAINTENANCE PROCEDURES

Regulatory and Statutory guidelines for carrying out Operation & Maintenance of transmission system

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

Target Availability for Recovery of full Transmission charges

- AC System – 98%

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.

Incentive

The transmission licensee shall be entitled to have incentive on achieving annual availability beyond the target availability as per regulation in accordance with the following formula:-

Incentive = Annual Transmission charges x (Annual Availability-achieved target Availability)/ Target Availability

Provided no additional incentive shall be payable above the availability of 99.75% for AC system.
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.

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

(a) Outage of elements due to acts of God and force majeure events beyond the control of transmission licensee. However on satisfying of the SLDC that elements 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 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.

If the outage of any elements 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 day (s) on which such loss of generation has taken place.

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:-

In Appendix-2 of the Principal Regulations:

At the (b) clause above the following shall be added, namely:-
"If the outage of any element causes power cut in the area of supply of the distribution licensee, then the outage period for the element shall be deemed to be twice outage period for that day (s) on which such power cut has taken place.

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

The operation and maintenance practices are also to be followed keeping in mind the provisions of Sate Grid Code notified by Uttarakhand Electricity Regulatory Commission. Some of the important relevant clauses of State Grid Code are as given under:-

Safety Standard

The applicable safety requirements of 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.

Fault Clearance Time

The fault clearing 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 400KV

(ii) 160 milliseconds for 220KV & 132KV

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.

Operating Policy

Overall operation of the State Grid Shall be supervised from the State Load Dispatch Centre (SLDC). The roles the SLDC shall be in accordance with the provisions of the Act.

The control rooms of the State Load Dispatch Centre including Area Load Dispatch Centers, Power Plants, substations of 132 KV and any other control centers of Transmission Licensees and Users shall be manned round-the-clock by qualified and adequately trained personnel.

System Security Aspects

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 costly equipments is imminent and such isolation would prevent it.

(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.

Users and Transmission Licensees shall provide automatic under frequency and df/dt relay-based load shedding/ isolating 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.

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.

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

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

Demarcation of responsibilities

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 reading and conveying them to the SLDC.

Reactive Power and Voltage Control

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.

PREVENTIVE MAINTENANCE PROCEDURES

INTRODUCTION

The well maintained electrical system not only improves the reliability but also generates more 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 ‘Periodical Maintenance’ is essential to keep the equipment continuously in service with desired output. This also forms the base for ‘Condition Based Maintenance’ which helps in providing advance information about health of the equipment and thereby planning for major maintenance/overhauls.

Preventive maintenance procedures dealt in this chapter will help for timely corrective action and to maintain substation equipment/line minimizing unplanned outage and increasing the availability of power supply.

GENERAL INSTRUCTIONS FOR MAINTENANCE OF SWITCH YARD EQUIPMENT

(a) External Cleaning

String and Post Insulators and insulators of the transformer bushings/ Circuit Breaker / Isolator/CT/VT/other equipment of S/S shall be cleaned from salt and dirt/dust deposition. The time interval for this cleaning shall be based on the pollution level of atmosphere. For installations with higher atmospheric/saline pollution, cleaning frequency may be increased and thus equipments may be protected against mal-effect of 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 may occur after some years, especially when the breaker / isolator is standing in highly corrosive surroundings. The rust stains shall be removed with suitable sand paper and coated /sprayed with rust protection paint. As a rust protection, grease C or Tectyl 506 is recommended.

(c) Lubrication

Lubrication shall be carried out at regular interval or as per recommendations of O&M Manual of respective equipment. The lubricant recommended by manufacturers shall primarily be used. This is especially important in cold climates with temperature 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 may not need lubrication before the major overhaul. Plain bearings in mechanism and accessories 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 mal-operation and/or failure.

(d) Treatment of Contact Surfaces

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

- Silvered contact surfaces shall be cleaned, if necessary, with a soft cloth and solvent (trichloro ethane). Brushing with steel wire or grinding is not allowed.
- Copper surfaces should be clean and oxide free. If necessary, they shall be cleaned with cloth and solvent (Trichloro ethane) or steel brushing - After steel brushing, the surface shall always be cleaned of loose particles and dust.
- Aluminium contact surfaces shall be cleaned with steel brush or emery cloth. The surface is thoroughly cleaned of particles and dust with a dry cloth. After cleaning, a thin layer of Vaseline (Petroleum Jelly) is applied within 5 minutes and the joints shall be re-assembled within 15 minutes.

(e) Moving Contact Surfaces

- *Silvered: I*f necessary, it shall be cleaned with soft cloth and solvent (trichloro ethane). No steel brushing shall be applied.
- *Non-silver coated:* May be *c*leaned as silvered surfaces, but can be brushed with steel wire/sand paper. After 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.

(1) SPECIFIC EQUIPMENTS- 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, service conditions, loading pattern etc. All the maintenance 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.

- **General Supervision**

(a) Dirt and Dust

The external surfaces of transformer shall be inspected regularly; and when whenever required cleaned of dust, insects and other dirt. Transformers/ reactors installed near polluting industry/cement plants, etc., need special care and more frequent cleaning of the bushings and other components. Doors of Marshalling Boxes and OLTC cubicle are to be kept properly closed so that there will be no entry of dust to wirings and accessories inside, which otherwise would be difficult to clean. Also it shall be ensured to wormin proofing.

(b) Rust and Treatment

A regular inspection is to be carried out of the transformer tank and radiators. Possible rust damaged spots are removed and the surface treatment restored to original state by means of the primer and finish-paints of original shade to minimize the risk of corrosion. 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 may be applied and compete re-painting is recommended after five years of service. However transformers in coastal areas and more corrosive atmosphere may require frequent painting/treatment.

(c) Check for any Signs of Mechanical Damage

Transformer/Reactor must be checked for any mechanical damage to the fabrications of main body and accessories. Particular attention should be given to vulnerable areas such as radiators. If damage is found on the equipment, as per the seriousness, corrective actions such as the replacement/repairing of an item are to be taken within reasonable time.

(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 of the exact location of the leakage, if in any. If a leak is suspected on a gasket, the joint must be tightened time being until replacement of gasket. If a leak is apparent at a welded joint ,clean the area and apply liquid chalk and allow to dry. This will highlight the exact point of leakage. It must be attended with proper welding procedures at the earliest conviniency..Before that, the spot must be highlighted with a marker, or something similar, so it is not lost when it is attended.

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, those should be checked regularly.

(e) *Check for Oil Level*

It is good practice to check all oil levels associated with the equipment. This will include the expansion vessel and all oil filled bushings. Also the oil in the oil seal should be maintained. Position of bushings in transformers may be above or below the conservator oil level. Accordingly it should be treated with study. 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 of conservator tank. This is to be observed and accordingly actions shall be taken immediately as failure of bushing may lead to failure of transformer.

Conservator tank of OLTC 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 transformer, 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 with correct torque as per manufacturer's recommendations.

(f) *Check on the* **Surrounding** *Areas*

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

- ## 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. Color of Silica Gel indicates the absorption of moisture by it. The silica gel inside the breather should become pink from bottom to top gradually over a period of time. Any de-colorization at top or sides with normal blue color at bottom indicates the 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 pink in color. 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. It can also be dried in bright sun light to reactivate. 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 while reactivating otherwise the colour impregnation will be destroyed and the silica gel will turn black and useless.

Immediately after re-activation the loose silica gel it must be placed in a sealed container to prevent moisture ingress during storing. It should stored in sealed condition until reuse.

According to one theory, Self indicating (blue) silica gel contains the dye cobalt chloride which has been classified carcinogenic by a European Commission directive and in a banned substance because of its potential health hazards. In Europe the silica gel breathers are to be disposed in 'Class I' 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 may be considered as 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 counter reading each time a check is made and compare it with previous one. Progress of the reading depends upon the atmospheric condition and accordingly dealt with.
- 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.

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 required oil. The correct oil-filling level is specified on the transformer rating plate.

- 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 *Test for 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 maintenance/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 accumulation of air in the Buchholz Relay at some later stage causing mal-operation of Alarm/Trip
- 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,the air cell may be considered healthy (not having any leakage).

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.

Check for Cubicle and Marshalling Kiosk (MK) and Valves

The following points need to be checked and ensured while inspecting the MK Box

- Condition of paint
- Operation of door handles, Hinges
- Condition of door seal.
- Door switches
- Working of Lights and heaters
- Operation of Thermostats
- Operation of heating and lighting switches
- Secure mounting of equipment

- Checking of tightness of cable terminations
- Checking of operation of contactors
- HRC fuses condition and its rating
- Operation of local alarm annunciation by pushing push buttons provided for lamp test, acknowledge, reset, system test, mute etc. to cover all system functioning.
- Checking the healthiness of all auxiliary power source by putting off power sources alternatively.
- Check for plugs for dummy holes, glass windows and replacement, if found missing/ broken.

The following points shall be checked for vales

- Check the physical condition of valve, rusting etc. Attend the same as per general guidelines given.
- Check that operation arrow is visible. It should be marked with red color.
- Check the operation of valve as per valve schedule given in manufacturer's O&M Manual of transformer.
- Check the leakage of oil from any part of valve and attend it if found.

- **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 dirt. The cleaning is suitably carried out by means of water flushing at high pressure. Precaution should be taken to cover the fan-motor to prevent the moisture entry in motor ckt. 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. Check the operation of all the fans and its sound level. If the sound level of any fan found more than normal let it be first tighten for all mounting supports and if still sound persists , 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 affect the cooling of transformer oil and may result into high temperature.

(c) Calibration of OTI / WTI

Temperature indicators in transformers are not only used for indication purpose but they are also used as protective device. The accuracy of these devises is to be ensured for correct operation of alarm and tripping and also to prevent any 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 temperature rise value (say 55°C). Check that the fans of those coolers set to first stage are operating. Continue rotating the pointer to the second stage value (say 65°C). Check that the fans of those coolers set are operating. Continue rotating the pointer to the alarm value (say 85°C). Check with the control room to ensure that the alarm signal has been received. Continue rotating the pointer to the trip value (say 95°C). Check with the control room to ensure that the trip signal has been received.

- If the substation is situated at the location where wide range of variation in ambient temperature is observed, the Alarm and Trip temperature settings shall be finalized for two different seasons in two different set in consultation with manufacturer or with careful study.

(e) Gas Pressure Relay

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 (or Gas Surge 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. There are two types of gas pressure relays. The most common type is mounted at the transformer top body. 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 after 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.
To check the relay for oil surge, manufacturers recommendations for particular relays to be followed

(f) Buchholz Relays

The use of Buchholz (gas-operated) relay as protection for oil-immersed transformers is based on the fact that faults such as flashover, short-circuit and local overheating normally result in gas-generation. The gas-bubbles gathering in the gas-operated relay causes a change in status of float-controlled contact that gives an alarm signal on smaller extent of collection of gas and trip if collection of gas is more in the relay's chamber
For testing of the contact functions, buchholz relay is 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 subsequently the tripping device.
- After testing is over, screw on the protective cap back as normal.

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 in next stage trip contact should operate which confirms the healthiness of relay.

(g) Bushings

Bushing is the most failure prone component in transformer/ reactor. Failure of bushing may lead to the fire in transformer and thereby total failure. For uniform voltage distribution across capacitor grading of bushing, its porcelains shall be cleaned properly from dust and dirt during maintenance. In heavily polluted areas where the air contains impurities like salt, cement dust, smoke or chemical substances, shorter interval of maintenance is required.

• Operational Checks and Inspection / Maintenance of Tap Changer

EHV Transformers are provided with On Load Tap Changer (OLTC) to control voltage during service. Tapings may be located either on the high voltage winding or the low voltage winding, depending on the requirement of the user, the cost effectiveness of the application and tap changer availability etc. 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 to be taken

The inspection/testing shall be carried out during shutdown and under total de-energisation condition. To ensure the same, isolation of transformer from high voltage and low voltage side with physical inspection of open condition of the concerned isolators/ disconnectors shall be done. In case presence of tertiary winding the same is also ensured with the isolation prior to commencement of testing

(b) Tap Changer Hand Operation

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

(b) Tap Changer Electrical Operation

Electrical power and control circuit shall be checked for its healthiness.

- Switch on the motor power supply and control supply.
- Check the function of Local /Remote (L/R) switch. With (L/R) switch on Local mode, operations shall be checked at Drive Mechanism Box.
- Check the Raise and Lower operation by “Raise” button from Tap no 1 to max tap, back to tap no 1 by gradually operating it with the help of “Lower” button
- After the max tap is reached, keep the motor supply Off and control supply ON, Push the ‘Raise’ button , the “Raise” contactor should not operate. Check the same for operation beyond tap no 1 on Lower side. This will ensure the operation of limit switch to lock the operation beyond the range. For example particular Tap change has position no 1 to 17 , the ‘Lower’ operation after tap postion no 1 and ‘Raise’ operation after tap no 17 should not be permitted by limit switch.
- With L/R switch on Remote mode , all the operations of Lower and Raise shall be checked from RTCC(Remote Tap Changing Control cubicle)

(c) Maintaining Control Circuit during transition.

Check that the control circuit of drive mechanism should be maintained during transition period of OLTC.With power and control supply in switched off condition, it may be checked by correct sequence hand operation of tap keeping it on half way of unit of particular tap and then remove the handle. Energize the drive motor circuit and ensure that the motor continues to drive the tap changer in the same direction.

(e) Drive Motor

Following steps shall be taken to decide correct overload protection for Drive Motor

- With the tap changer in mid position check the direction of rotation and measure the starting 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.

(f) Out of Step Relay

Checking of Out of Step Relay healthiness

- Move one tap changer out of three-phase bank so that it become out of step with other two. Check the tap changer faulty alarm is activated. Repeat for other two phases.
- Hold the raise push button to ensure it only moves one tap at a time hence checking the step relay. Similarly check the operation for Lower push button.

(g) Tap Change Incomplete Alarm

Check the operation of the tap changer incomplete alarm, including the flag relay,

- moving the unit by hand half way through a tap change and monitoring their correct operation and time to operate.

(h) Remote Indication

Check the remote indication and control facility is proved to the outgoing terminals of the marshalling kiosk.As per the drawing of RTCC, all functions shall be checked.

(i) 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 to bring back to normal position.

(i) *Inspection and Maintenance of OLTC*

Normally the temperature of the OLTC compartment remains lower than that of main tank. If temperature approaching or above that of the main tank , it should be investigated as it indicates an internal problem.

- Prior to opening the OLTC compartment, it should be inspected for external symptoms of potential problems. Such as integrity of paint, weld leaks, oil seal integrity, pressure relief device and liquid level gauge etc
- 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 carbon deposition should be removed.
- Min value of oil BDV should be 50 kV for transformer in operation and 60kV for new transformer and moisture content should be less than 20 PPM for transformer in operation and 10 PPM for new transformer.

- **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 due to incipient fault 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)
- ❖ Oxygen (02)

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 dissolved in the oil. For Dissolved Gas Analysis to be useful and reliable, it is essential that sample taken for it should be representative of lot, no dissolved gas be lost during transportation and laboratory analysis be precise and accurate. Effective fault gas interpretation should tell us whether there is any incipient fault in the transformer and if yes what kind of fault it might be. It also detects about the seriousness of the fault and weight-age to be given for attendance.

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 type and urgency of corrective actions 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 µ1/1)						
	H2	CH4	C2H6	C2H4	C2H2	CO	CO2
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, PPM	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.

MAINTENANCE SCHEDULE FOR POWER TRANSFORMER

ATTENDING FREQUENCY	ITEM TO CHECKED	ACTIVITIES /NOTES	ACTIONS REQUIRED IN CASE OF ABNORMALITY
DAILY	Ambient Temperature	Verify	
	Oil Temperature	Check whether it is within safe limits?	Shutdown the Xmer and investigate
	Winding Temperature	Check whether it is within safe limits?	
	HV side voltage	Check with the rated values	Inform the upper level switchyard personnel for controlling.
	HV side current	Check with the rated values	Check the loading conditions and control it
	LV side voltage	Check with the rated values	Regulate it with OLTC
	LV side current	Check with the rated values	Check the loading conditions and control it
WEEKLY	Oil Level in conservator tank	Check the mark	Check for any leakage, top up with fresh oil through filter.
	Oil Level in Bushing	Check the mark	Check for any leakage, top up with fresh oil
FORT NIGHTLY	Breather	Check the air passage and color of silica jel.	Clean the passage/ Change/reactivate the Silicajel.
MONTHLY	MK BOX, OLTC DB BOX	Check for cleanliness, vermin proofing,operation of fan/pump , contactors etc component	Clean the compartment, Seal it if required. Rectify the circuit/ component fault etc.
QUARTERLY	Drive mechanism	Check for smooth operation	Lubricate it.
	Cooling fans/pumps	Check for smooth operation, , control operations	Cleaning,lubricating repairing if not working, calibration with requirements of temperature variation.

HALF YEARLY	Transformer oil	Check the dielectric strength and water content (ppm)	Corrective actions to recover the properties
	Bushings	Check for any crack/leakage	Rectify the defects
	Buchholtz Relay	Check the Alarm Trip operation,Check control ckt,	Rectify the defects
	WTI,OTI	Check the Alarm Trip Operations, check the control contactors/component	Rectify the defects
YEARLY	Bushing test	Tan delta measurment	Take prior action if needed
	Transformer routine tests	Carry out all the routine tests on transformer to confirm the healthiness	Take prior action if needed
	Gaskets	Check the condition/leakage,	Tighten the bolt nuts, replace the gasket.
	Cable box	Check the sealing ,compound position/crack etc	Rectify/ Replace
	Relay Alarm control ckt	Check all the relay operations, healthiness of control ckt,annunciation, etc	Rectify wherever required.
	Earthing	Check the condition of earthing conductors hardwares, Measure the earth resistiance value for electrodes	Rectify wherever required.
	Equipment bus Conductor, clamp connectors	Check the tightness, condition of conductor	Rectify wherever required.

2. CIRCUIT BREAKERS

Circuit breaker consists of two main parts, the interrupting chamber(s) and the operating mechanism. The interrupting chamber normally does not require routine preventive maintenance except cleaning of housing insulator. Operating mechanism requires proper upkeep.

(a) Interrupting Chamber

Circuit breaker interrupting chamber is an enclosed unit filled with oil or SF6 gas. LV or MV class 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 as per advice of the manufacturers or expert study advice/recommendations given based on condition monitoring tests.

(b) Operating Mechanisms

Circuit breakers have mainly three types of operating mechanism-pneumatic, hydraulic and spring type depending upon the requirements of operating force for opening and closing operation. Since operating mechanism has number of moving parts, it 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 manufacturer.

(c) SF6 Gas

Mostly the HV class CBs are having SF6 gas 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 2.5 times that of air. As SF6 is Green House gas, it needs to be handled carefully to take care to prevent leakage to the atmosphere.

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

The breaker is evacuated by means of the Gas Handling kit that purifies and also compresses the gas for storage, so that it can be refilled. 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/sieve unit provided in the gas handling plant. When SF6 is suctioned from a gas compartment, the gas is passed automatically through filters, which dry and purify the gas.

(e) Evacuation and gas refilling in SF6 Circuit Breakers

After maintenance/overhaul of the circuit breaker, it should be evacuated by vacuum pump before filling in the SF6 gas to prevent it to mix with ambient air and also humidity and dust particles are removed. With vacuum pump, a final vacuum must be reached less than 5 mbar. Soecial Gas Handling Kit of repute make is used for this process.

CHECK LIST FOR MAINTENANCE OF CIRCUIT BREAKER.

Sr No.	Point of observation	Interval of maint.
1	Cleaning of porcelain parts of Insulators & visual Inspection.	Half Year (HY)
2	Checking of SF6 Gas pressure ,Low gas pressure alarm & lockout circuit and its operation.	Yearly (Y)
3	Check the oil leakage from Grading capacitors	HY
4	SF6 Gas Leakage test	Y or as required.
5	Measurement of Dew point of SF6 Gas	2Y
6	Check the leakage of air	As & when required.
7	Check the pressure setting of Low Air Pressure, Breaker closing &Tripping Lockout& Auto Reclose	Y
8	Measurement of capacitance and Tan delta for grading capacitor	2Y
9	Measurement of IR values and comparing with past records	Y
10	Measurement of Resistance of PIR	2Y
11	Checking the operation control switching Device(CSD)	Y
12	Measurement of operation timings	Y
13	Measurement of Contact Travel	2Y
14	Measurement of Dynamic Contact Resistance (DCR) Contact speed, wipe, arching length etc.	2Y
15	Measurement of Static Contact Resistance (CR)	Y
16	Check the operations Local/Remote/Relay and Indications/facia , trip/close and other control ckt.	HY
17	Check operation of Pole Discrepancy relay	HY
18	Check the AC auxiliary control circuit	HY
19	Checking of Conductors, clamp connectors hardwares	HY
20	Check for rusting of metallic part, crack of metallic, rubber materials	Y
21	Checking of tightness of cable terminations in MK and aux box , vermin proofing , gaskets	HY
22	Auto start Stop operation of compressor	Qtrly
23	Check the Operations as per Duty Cycle.	Y
24	Check the Air pressure drop during operations as per duty cycle.	Y
25	Check the healthiness of operation counter	Y
26	Check the tightness of foundation and support structure bolts and nuts.	Y
27	Checking of concrete condition /crack etc. in foundations	HY
28	Air compressor maintenance (oil level, oil quality, air filters V belt tightness etc.)	HY
29	Check and lubricate the operating mechanism.	HY
30	Check the condition of all earthing risers. Tightness of bolt nut.	HY

3. PREVENTIVE MAINTENANCE OF INSTRUMENT 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 leakage is 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 bellow is provided in CT, 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 CT and immediate actions 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 Junction Box cable terminals. This gives better grip even if more than one wire is connected to one terminal. 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. All terminals of unused/spare CT secondary terminals are to be properly shorted to avoid development of abnormal voltage and subsequent failure of CT. 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.

Similar aspect will be applicable for other instrument transformer i.e. Potential Transformer (PT)

CHECK LIST FOR MAINTENANCE OF CURRENT TRANSFORMER.

Sr.No.	PARTICULARS	FREQ.OF MAINT.
1	Cleaning of Porcelain and visual inspection	HY
2	Checking of Oil level/leakage	HY
3	Checking of tightness of clamps connectors, hardware, conductor condition	HY
4	Checking of oil leakage in sec term box	HY
5	Checking of tightness of sec connections , measuring CT sec resistance , lead resistance, Star point & its earthing	Y or as required in case of any mal operation
6	Measurement of Insulation Resistance and comparing with past records	HY
7	Measurement of Tan delta value	2Y or as required in case of failure of adjacent CT
8	Checking of tightness of earthing of Tan delta terminal in sec box	Y
9	DGA and BDV of oil if Tan delta is poor and/or IR value is low	As and when required.
10	Check the working of oil level indicator glass	HY
11	Checking of N2 pressure	2Y
12	Checking of JB (MK) and sec term box for tightness of gasket, vermin proofing, cleaning	HY
13	Checking of working of space heater in MK box	HY
14	Checking of earthing of all structures, MK box, sec conn box	HY
15	Checking of rust or damage in any metallic part of main body, sec connection box , structures	Y
16	Checking of any breakage/crack in cementing part	HY
17	Measurement of CT Ratio ,burden ,Knee point voltage and	Y or as required in case of any failure /incidence

CHECK LIST FOR MAINTENANCE OF POTENTIAL TRANSFORMER.

Sr.No.	PARTICULARS	FREQ.OF MAINT.
1	Cleaning of Porcelain and visual inspection	HY
2	Checking of Oil level/leakage	HY
3	Checking of tightness of clamps connectors, hardware, conductor condition	HY
4	Checking of oil leakage in sec term box	HY
5	Checking of tightness of sec connections , , lead resistance,Star point & its earthing	Y or as required in case of any mal operation
6	Measurement of Insulation Resistance and comparing with past records	HY
7	Measurement of Tan delta value	2Y or as required in case of failure of adjacent PT
8	Checking of tightness of earthing of Tan delta terminal in sec box	Y
9	DGA and BDV of oil if Tan delta is poor and/or IR value is low	As and when required.
10	Check the working of oil level indicator glass	HY
11	Checking of N2 pressure	2Y
12	Checking of JB (MK) and sec term box for tightness of gasket, vermin proofing, cleaning	HY
13	Checking of working of space heater in MK box	HY
14	Checking of earthing of all structures, MK box, sec conn box	HY
15	Checking of rust or damage in any metallic part of main body, sec connection box , structures	Y
16	Checking of any breakage/crack in cementing part	HY
17	Measurement of PT Ratio ,burden ,Knee point voltage and	Y or as required in case of any failure /incidence
18	Measurement of resistance of Earthing electrode .	Y

4. CAPACITOR VOLTAGE TRANSFORMERS/ COUPLING CAPACITOR

(a) Visual Inspection

The bel1ow provided in most of the CVTs is not visible from outside. Hence needs to be checked periodically while maintenance. CVT and CC are also oil fil1ed equipments and oil leak is to be observed. If found in anyone stack, the entire CVT should be replaced. CVTs are tuned units and replacement of any one 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 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 Marshaling Box/Junction Box (JB) 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 JB 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.

CHECK LIST FOR MAINTENANCE OF CAPACITOR VOLATGE TRANSFORMER /COUPLING CAPACITOR

Sr.No.	PARTICULARS	FREQ.OF MAINT.
1	Cleaning of Porcelain and visual inspection	HY
2	Checking of Oil level/leakage	HY
3	Checking of tightness of clamps connectors, hardware, conductor condition	HY
4	Checking of oil leakage in sec term box	HY
5	Checking of tightness of sec connections , , lead resistance, Star point & its earthing	Y or as required in case of any mal operation
6	Measurement of Insulation Resistance and comparing with past records	HY
7	Measurement of Capacitance and Tan delta value	2Y
8	Checking of tightness of earthing of Tan delta terminal in sec box	Y
9	Visual checking of earthing of HF point (in case CVT is not used for communication purpose)	HY.
10	Check the EMU tank oil for BDV	Y or as per requirment
11	Checking of JB (MK) and sec term box for tightness of gasket, vermin proofing, cleaning	HY
12	Checking of working of space heater in MK box	HY
13	Checking of earthing of all structures, MK box, sec conn box	HY
14	Checking of rust or damage in any metallic part of main body, sec connection box , structures	Y
15	Checking of any breakage/crack in cementing part	HY
16	Measurement of VT Ratio ,burden ,Knee point voltage and	Y or as required in case of any failure /incidence
17	Measurement of resistance of Earthing electrode.	Y

5. DISCONNECTORS/ISOLATORS

Disconnector has two main components: current carrying arms and operating mechanism for connection and' disconnection. Isolator is off-line device hence it is air break type. Types of isolators used in switchyard are

- Horizontal Double Break (HDB)
- Horizontal Center Break (HCB) ,
- Pantograph, (Vertical break Disconnectors) are in use for EHV isolations.

The alignment of Disconnector 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.

6. 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.

CHECK LIST FOR MAINTENANCE OF ISOLATOR /EARTH SWITCHES

Sr. No.	PARTICULARS	PERIODICITY
1	Cleaning of support insulator & checking of cracks in Insulator	HY
2	Cleaning & lubrication of operating mechanism hinges, lock joints, pins, gears,bearing etc.	HY
3	Checking of alignment	HY
4	Check the condition of male –female contacts	HY
5	Checking & alignment of earthing blades	Y or as required in case of any mal operation
6	Cleaning of contact of isolator /earth blade	HY
7	Operation of isolator /earthing switches &its interlocks	HY
8	Contact resistance measurement for isolator /earth switches contacts	2Y
9	Apply petroleum jelly on male- female contact	HY.
10	Check the tightness of mounting bolts	HY
11	Checking & tightening of stopper bolts.	HY
12	Checking of earth connection of earth blade as well as structure earthing	HY
13	Checking of remote / local operation, with indication & semaphore position.	HY
14	Cleaning & checking of auxiliary switch contacts	HY
15	Checking tightness of clamp connector	HY
16	Checking the operation of AC &DC switches in MOM box	HY
17	Check the operation of contactors	HY
18	Check the contact of pantograph with hanger of bus	HY
19	Checking of aluminium / copper flexible connectors.	HY
20	Vermin proofing	HY
21	Checking of space heater in MK Box	HY
22	Checking of gaskets in MK box	HY
23	Checking structure earthing	HY
24	Checking for rusting & paint if required	Y

7. LIGHTING ARRESTER/SURGE ARRESTER

Surge arresters are to be maintained to give protection to other connected switchyard equipments against the surges. 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. To monitoring the deterioration of blocks in SA, leakage current measurement is good tool. This is one king of condition monitoring system in substation.

CHECK LIST FOR MAINTENANCE LIGHTING ARRESTER

Sr.No.	PARTICULARS	PERIODICITY
1	Cleaning of porcelain of insulator	HY
2	Measurement of capacitance Tan-delta.	2Y
3	Checking of leakage current	2Y
4	Checking of healthiness of counters	HY
5	Checking of earth connection between surge arrestor, surge monitor & earth	HY
6	Measurement of earth pit resistance & its connection	HY
7	Checking tightness of terminal connector	HY
8	Checking structure earthing	HY
9	Checking for rusting & painting	HY.

8. BATTERY

Generally Lead Acid batteries to supply DC auxiliary power are used in Substation. There are many brands of maintenance free batteries are now available in the market. As DC system has to play vital role in protection and control system battery may be considerded as heart of the substation. Hence upkeepment 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 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.

CHECK LIST FOR MAINTENANCE OF BATTERY SET.

Sr.No.	PARTICULARS	FREQ OF MAINT.
1	Pilot cell readings- select 5 to 6 cells every day with changing the cell next day , measure sp gravity and end cell voltage. (normal sp gravity 1.20 and normal votage is 2.1V)	DAILY
2	Clenaing and tightness of terminals	WEEKLY
3	Apply anti-oxidation greese /jelly	WEEKLY
4	Checking of electrolyte level and topping up with DM water.	WEEKLY
5	Measurement of sp.gravity, end cell voltage total set voltage	WEEKLY
6	Checking the working of exhaust fan	WEEKLY
7	Measurement of battery cell impedance measurement.	Y
8	Run down test- Discharge cycle test to confirm AH capacity	Y
9	Checking of earth leakage	Qtrly
10	Checking of cable connection at battery end and charger end.	Qtrly
11	Voltage measurement at each point, battery terminal, charger ,DCDB, upto last CR panel	HY
12	Check and apply acid resistant paint to floor and walls of battery room	Y
13	Check and apply dark black paint to windows of battery room	Y

9 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.

BATTERY CAPACITY TESTING

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

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 IO% 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.

CHECK LIST FOR MAINTENANCE OF BATTERY CHARGER

Sr.No.	PARTICULARS	FREQ OF MAINT.
1	Cleaning and tightness of connections	HY
2	Checking of vemin proofing.	Qtrly
3	Checking of working of space heater.	WEEKLY
4	Checking of operation of Float and Boost sections, auto /manual mode	WEEKLY
5	Checking the working of cooling fan if any	WEEKLY
6	Checking of earthing of panel.	HY
7	Checking of earth leakage	Qtrly
8	Checking of working OV,UV, constant current , constant voltage mode etc. all operations, indication ckt. as per schematic	HY
9	Checking of cable connection	Qtrly
10	Voltage measurement at each point, battery terminal, charger ,DCDB, upto last CR panel	HY
11	Checking of rusting in panel or other subcomponent	Y
12	In case of 3 Phase AC operated charger, check the Single phasing preventer relay.	Qtrly

TROUBLE SHOOTING FOR BATTERY & BATTERY CHARGER

BATTERY TROUBLES	SYMPTOMS / CAUSES	REMEDIES
Over Charging	1) Excessive gassing 2) Failing of active materials 3) Buckling of plates 4) Increased temperature 5) Bulging of container	1) Reduce the charging rate till the sp. gravity attains value 1.2 2) Add distilled water
Under Charging	1) Low specific gravity 2) Lighter colour of plates 3) Reversal of cell voltage 4) Buckling of plates 5) Oxidation of battery links	1) Increase the charging rate till the sp. gravity attains value 1.2 2) Remove & clean in warm water
Loss of Capacity	Abnormal drop of voltage during a normal discharge without corresponding rise in temperature due to: 1) Clogging of the pores of the lead sponge impurities 2) Contraction of the pores of the mass 3) Loss of active material from grid 4) Formation of Sulphate 5) Loss of electrolyte	Contact manufacturer (Needs special treatment)
Corrosion of Plates	Impure Electrolyte	1) Remove Electrolyte 2) Flush with distilled water 3) Refill with pure electrolyte
Fracture & Bucking of plates	1) Excess or unequal expansion 2) Discharge carried too far 3) Discharge at too rapid rate 4)Unequal distribution of current over plates 5) Defective plates 6) Plates exposed to direct Sun 7) Direct discharge	1) Reduce the charge rate 2) Replace the defective plates
Sheding of active Material	1) Overcharging of plates 2) Charging done at high rate 3) Defective material 4) Material improperly applied on plates	Charging & discharging limits should be maintained to 2.4 & 1.8 volts respectively and 1.220 to 1.300 sp. gravity limits

Excessive	Light colour of plates all over or in spots due to 1) Under charging 2)Too stronger, too weak acid 3) Over charging 4) Local action 5) Short circuits 6) Too rapid discharge 8) Plates exposed to 9) Air on account of evaporation of electrolyte	**1)** Sulphation at initial stage can be cured by low rate repeated charging & discharging **2)** Sulphation at advanced stage contact
Reversal of Negative Plates	When an undercharged or weak cell is in series with good ones, its discharge is ended before the others, which over powers the defective cell & reverse it	Charge the weak cell externally by Booster
Internal Discharg e local action	1) Perceptible gassing even when battery is idle 2) Abnormal gassing during charge 3) Reduction of capacity, due to decomposition of electrolyte, due to metallic impurity or the grid being in contact with the active material & forming a local voltaic couple	Use pure electrolyte & keep plates well covered
Hardening of Negatives in air	Oxidation & heating in air or exposed plates	1) Cover the plates properly with distilled water 2) Continue overcharge at low rate
Loss of Voltage	Excess sulphation	Sulphation at initial stage can be cured by low rate repeated charging & discharging. Sulphation at advanced stage: contact manufacturer for special treatment
Short Circuit	1) Low specific Gravity 2) Rapid loss of capacity after charge 3) Low open circuit voltage due to Buckling, lodging of some conducting material between plates & around	Remove shorts & use new separators

10. MAINTENANCE OF BUS OF ALL VOLTAGE LEVEL (OUTDOOR)

All voltage level of bus shall also need attention periodically in order to maintain the reliability of power supply fed to surrounding region.

CHECK LIST FOR MAINTENANCE OF BUS

Sr.No.	PARTICULARS	PERIODICITY
1	Cleaning of porcelain of insulators and checking of hardwares, conductor strands	HY
2	Checking and tightening of all the clamp connectors for all the bays	HY
3	Checking the operation of ES provided to the bus	HY
4	Lubricating the ES mechanism	HY
5	Checking of earthing connections, conductor, tightness etc for towers for bus support	HY
6	Checking and tightening of hangers/scissor connected to bus	HY
7	Checking of clearances (phase to ground)	2Y
9	Checking for rusting & painting	2Y.

10.2 CHECK LIST FOR MAINTENANCE OF 11kV/66kV CAPACITOR BANK

Sr.No.	PARTICULARS	PERIOD OF MAINT.
1	For maintenance of other bay equipments like LA, Isolator ES , Reactor, CT ,CB etc. follow the check list of maintenance for the respective item given elsewhere in this manual.	HY
2	Cleaning of capacitor cells , bushings	Q
3	Checking of leakage oil/fluid from terminal, /welded parts	M
4	Checking of tightness of clamps connector	Q
5	Check for the crack or bulging	HY
6	Measurement of IR value of capacitor unit (generally more than 50 M ohm)	HY
7	Measurement of capacitance value of each unit	HY
8	Checking of cracks etc in cable joining kit	HY
9	Measurement of IR Value of HT cable	HY
10	Checking the condition of fuse material of capacitor cell (in case of external fuse type arrangement), replace if necessary	HY
11	check the RVT for cleanliness, tightness of connections, fuse etc Checking of function of NDR (Neutral Displacement Relay) or Unbalance E/F relay,	Y
12	Checking of all protection and control ckt and relays	Y
13	Checking the tightness of foundation bolts if any	HY
14	Checking of earthing of all structure part and equipments	HY
15	Checking of tightness of bolt nuts for frame structure of capacitor and other structures	HY
16	Checking the rusting of metal, pipe and painting	3Y

11. MAINTENANCE OF OTHER AUXILIARY EQUIPMENTS

11.1 DISTRIBUTION TRANSFORMER
CHECK LIST FOR MAINTENANCE OF DIST.TRANSFORMER

Sr.No.	PARTICULARS	PERIODICITY
1	Cleaning of all bushings, tank, radiators	HY
2	Checking and tightening of all the clamp connectors , conductors, cable connections	HY
3	Checking and cleaning of breather, replacement/reactivation of silica gel	HY
4	Checking of earthing connections, conductor, tightness etc for neutral and body	HY
5	Checking for rusting & painting	2Y.
6	Checking of oil level/leakage	HY
7	Measurement of IR value	Y
9	Testing of Oil for BDV and ppm	Y

11.2 LT AC DISTRIBUITON BOARD (ACDB)

CHECK LIST FOR MAINTENANCE OF ACDB

Sr.No.	PARTICULARS	FREQ OF MAINT.
1	Checking of tightness of connections	HY
2	Checking of vemin proofing.	Qtrly
3	Checking of working of space heater.	WEEKLY
4	Checking of earthing of panel.	HY
5	Cleaning of panels, bus bars insulators etc.	HY
6	Checking of rusting in panel or other subcomponent	Y
7	Measurement of IR value of bus and cables	Y
8	Checking the operation of CBs	HY
9	Checking the working of switches, changeover switches	HY
10	Checking of indication lamps and meters, annunciation etc	HY
11	Testing of CTs, energy meter and relays	Y
12	.Checking of correct rating of fuses w.r.t. load	Y

11.3 AIR CONDITIONING PLANT

CHECK LIST FOR MAINTENANCE OF AIR CONDITIONING (AC) PLANT

Sr.No.	PARTICULARS	FREQ OF MAINT.
1	Checking of leakage of refrigerant and oil	M
2	Checking of oil level and top up if required	M
3	Checking of tightness of flywheel, bolts ,nuts	Q
4	Checking of pressure switches of LP/HP,, cutout switches solenoid	Y
5	Checking the operation of thermostat	HY
6	Chekcing of water pressure for inlet/outlet , cleaning of side plates	HY
7	Checking of any water leakage	M
8	Checking the operation of Inlet/outlet valve	M
9	Checking of water Quality	HY
10	Cleaning of cooling water circuit	Y
11	Checking of operation of level switch.	HY
12	Cleaning of soft water tank	Y
13	Check the regeneration of chemicals	M
14	Cleaning of nozzles for clogging of cooling tower	HY
15	Cleaning of sediments	HY
16	Checking of terminal connections of motor and panel	HY
17	Cleaning of bus bars ,insulators etc. in panel	HY
18	Cleaning of suction Air Filter	Qtrly
19	Checking of AHU bearing condition	HY
20	Checking of earthing of panel and equipments	HY

11.4 CHECK LIST FOR MAINTENANCE OF AIR COMPRESSOR (PLANT)

Sr. No.	PARTICULARS	PERIODICITY
1	Servicing of first, second & third stage head valve for the operation of safety	HY OR AS & WHEN REQD
2	Checking of compressor oil and top up / replace the oil	M
3	Cleaning of inter cooler pipe	HY
4	Checking & replacement of core valve	HY OR AS & WHEN REQD
5	Checking of unloader	M
6	Replacement of safety valve	HY OR AS & WHEN REQD
7	Replacement of piston rings	HY OR AS & WHEN REQD
8	Replacement of piston & its cylinder	HY OR AS & WHEN REQD
9	Replacement of piston crank	HY OR AS & WHEN REQD
10	Checking of air leakage from pressure gauge	M
11	Checking of shaft & its bearing	HY
12	Checking of shaft & its bush	HY
13	Replacement of bundy pipes for air leakages	HY OR AS & WHEN REQD
14	Replacement of “C” pipes for air leakages	HY OR AS & WHEN REQD
15	Replacement of “S” pipes for air leakages	HY OR AS & WHEN REQD
16	Servicing of Non return valve	HY
17	Checking of air drain valve	HY
18	Replacement of oil seal provided on flywheel	HY OR AS & WHEN REQD
19	Checking the condition of gasket of first, second & third stage head.	M
20	Checking the condition of gasket of first, second & third stage cylinder	M
21	Replacement of “O” gasket of intercooler	HY
22	Check & replace air filter	HY
23	Operation check of low oil level switch	QY

11.5 CHECK LIST FOR GENERAL MAINTENANCE OF SWITCHYARD.

SR NO	PARTICULARS	PERIODICITY
1	Watering of Earth pit watering	M
2	Measurement of resistance of all the pits and reactivation if required.	HY
3	Measurement of resistance of earthing grid and take corrective actions if required	Y
4	Carrying out Riser integrity Test, Grid conductor Integrity Test, Measurement of Touch and step potential- Earthing system Adequacy Tests Similarly Lightning Protection adequacy is also to be ensured.	5Y
5	Measurement of soil resistivity and overall grid resistance in case of extension of switchyard	5Y OR AS & WHEN REQD.
6	Checking the layer of metal gravel spread over the live switchyard and around fencing ,it should be maintained as per designed thickness of layer (100 mm or 150 mm)	HY
7	Thermograph of all clamps/connectors and attending hot point if any as per respective bay/bus maintenance.	HY
8	Grass cutting in yard	AS & WHEN REQD.
9	Inspection of switchyard and surrounding area for any abnormality like Earth settlement, structure deformity,	2Y OR AS & WHEN REQD.
10	Cleaning of cable trench	HY
11	Draining of water from cable trench.	PRE& POST MONSOON WEEK
12	Check condition of signboard/name plate boards	HY
13	Check Switchyard lighting and aviation lamps	Q
11	Check Condition of approach roads.	HY
12	Removal of all scraps lying in the switchyard.	AS & WHEN REQD
13	Check galvanizing of structure members	HY
14	Check for rusting of metallic parts & paint it if required	Y
15	Check the position fencing, compound wall, gate	Y
16	Observe the corona effect on all insulators (strings and BPI , bushings) take corrective actions in respective shutdown.	W
17	Check Condition of jumper and clamps & connectors	W

11.6 MAINTENANCE OF FIRE FIGHTING SYSTEMS.

(A) CHECK LIST FOR MAINTENANCE OF FIRE EXTINGUISHER

Sr.No.	PARTICULARS	PERIOD OF MAINT.
1	Check pressure/weight	M
2	Check the operation	Q
3	Check the healthiness of nozzles	Q
4	Check the expiry period of extinguisher material.	AS AND WHEN REQD
5	Refilling of fire extinguisher	AS AND WHEN REQD

(B) CHECK LIST FOR MAINTENACE OF HYDRANT SYSTEM

Sr.No.	PARTICULARS	PERIOD OF MAINT.
1	Check the pressure of hydrant system at last terminal	Y
2	Check the auto starting of pump & diesel engine.	Y
3	Checking the alignment of pump set	Y
4	Check the diesel level in tank	M
5	Check the water level in sump	M
6	Cleaning of fire post box	Q
7	Checking of fire hose & nozzle	Q
8	Checking & operation of valves	Q
9	Checking the tightness of foundation bolts	Y
10	Check the healthiness of battery	M
11	Recoupment of diesel in diesel tank	AS & WHEN REQD.
12	Check quantity& quality of oil in diesel Engine	Q
13	Checking /replacement of fuel oil/lubricating oil/air filter	Y
14	Replenishment of grease in pump/engine	AS & WHEN REQD.
15	Checking of terminal connection of motor	HY
16	Adjustment of glands for leakages & tightening of nuts & bolts	HY
17	Overhauling of Pump, Engine	3Y or As & when reqd.

(C) CHECK LIST FOR MAINTENANCE OF MULSIFIRE SYSTEM

Sr.No.	PARTICULARS	PERIOD OF MAINT.
1	Checking of water leakage, oil leakage, provide	Q
2	Check the auto starting of pump & diesel Engine and provide lubricating if reqd.	M
3	Checking the alignment of pump set	Y
4	Check the diesel level in tank	M
5	Check the water level in sump	M
6	Adjustment of glands for leakages & tightening of nuts &bolts	HY
7	Replenishment of grease in pump/engine	AS & WHEN REQD.
8	Recoupment of diesel in diesel tank	AS & WHEN REQD.
9	Check quantity& quality of oil in diesel Engine	Q
10	Checking the tightness of foundation bolts	Y
11	Check the healthiness of battery	M
12	Checking /replacement of fuel oil/lubricating oil/air filter	Y
13	Check the pressure at various points	Q
14	Check the operation of pressure switches	HY
15	Checking of terminal connection of motor	HY
16	Check the operation of deluge valve	HY
17	Cleaning and tightness of terminals in panel	HY
18	Checking of operation of Alarm system	HY
19	Checking the operation of entire system	Y
20	Checking of earthing connections	HY
21	Checking the rusting of metal, pipe and painting	3Y
22	Overhauling of Pump , Engine	3Y or As & when reqd.

11.7 MAINTENANCE OF DIESEL GENERATOR SET

CHECK LIST FOR MAINTENANCE OF D.G.SET

Sr.No.	PARTICULARS	PERIOD OF MAINT.
1	Checking of leakage lub oil ,air leakage,	M
2	Cleaning of Air Filters	HY
3	Replacement of Air cleaning element	Y
4	Replacement of oil filter after recommended working hours	Y OR AS & WHEN REQD.
5	Checking of radiator air blocking ,	M
6	Checking of coolant level	M
7	Checking of fan hub , drive pulley,and water pump	Y
8	Checking of governor linkage, fuel transfer pump and fuel line connections	Y
9	Check the diesel level in tank, recoupment of diesel if required.	M
10	Check the Exhaust restriction , air leak etc.	Y
11	Tight exhaust manifold and turbo charger cap screw.	Y
12	Draing sediments from fuel tank, change fuel filter and clean fuel tank breather.	Y
13	Check the starting of diesel Engine and provide lubricating if reqd.	M
14	Checking of electrical connections for tightness.	HY
15	Testing of protection system, controls and alarm etc ckt operations	Y
16	Checking and cleaning of slip rings, brushes	HY
17	Replenishment of grease in pump/engine	AS & WHEN REQD.
18	Checking the tightness of foundation bolts if any	Y
19	Check the healthiness of battery for control system (voltage and sp gravity measurement)	W
20	Take TRIAL RUN on no load for 15 min	W
21	Take TRIAL RUN on load for 30 min	HY
22	Checking /replacement of fuel oil/lubricating oil/air filter	Y
23	Checking the earthing connections	HY
24	Check the efficiency.	Y
25	Checking the rusting of metal, pipe and painting	3Y
26	Overhauling of Engine	3Y or As & when reqd.

11.8 GENERAL TROUBLE SHOOTING CHART

Sr.No.	Description of Trouble	Probable reason (Actions to be taken)
1	Non-working of Alarm bell	Loose connection, Disturbing of bell adjustment Burning of bell coil, Alarm DC fuse blown, Relay self-scaling not proper (aux relay faulty), check related control ckt.
2	Failure of Trip Healthy Indication	Fusing of lamp, loose connection in Trip ckt., Resistance in Trip Ckt. may be opened, Alignment of Aux contacts of CB got disturbed, Trip coil open.
3.	Non-wrorking of OLTC control	Position of Local Remote switch not proper ,Failure of AC supply, Failure of aux. transformer 220/110V AC, Contacts in Lower/Raise button not proper,MCB for motor ckt. tripped, improper phase sequence. Single phasing preventer relay optd.,motor stuck up relay optd, problem with control ckt
4	Compressor not starting automatically	Pressure switch faulty, Loose connection, check the control ckt.
5	CB of any feeder not tripping during fault	Check the points shown at sr. no 2,trouble in operating mechanism, relay faulty (check voltage across terminals of O/C E/F relay) , SF6 gas pressure on lockout position,
6	Noise in CT	Opening of CT sec ckt, Loose connections in CT secondary ckt., star point opened from circuit
7	Spring Charging motor of CB or switchgear not starting automatically.	Failure of AC supply, Failure/loose or open connection of limit switch, defective motor, check entire control ckt.
8	Non closing of CB	DC fuse blown/MCB tripped, Local Remote switch position is improper, SF6 gas pressure on lockout(or insufficient air pressure), spring not charged, Loose connection, defect in push button, closing coil opened, closing coil defective, trouble in mechanism, misalignment of aux contacts, check entire ckt,

9	Flashover in panel wiring /apparatus	Short ckt due to inspects like lizard/rat etc. failure of insulation,
10	CB tripping without fault	DC earth leakage, relay mal operated, check the entire ckt
11	Alarm bell is not resetting	“Accept” switch faulty, Aux relay faulty, DC leakage, check entire ckt.
12	Battery charger Float mode not working	AC supply main fuse blown/MCB tripped, Switch defective, float transformer faulty, failure of Diode,
13	Battery charger Boostt mode not working	AC supply main fuse blown/MCB tripped, Switch defective, Boost transformer faulty, failure of Diode, Capacitor faulty,
14	Indication lamp not working	Fusing of lamp, defect in aux. switch, loose connection, check control/indication ckt.
15	Semaphore not working	Semaphore coil burnt, defect in aux. switch, loose connection, check control/indication ckt.
16	For HV/MV switchgear, feeder VCB tripped but fault cleared by upstream CB tripped as per set delay time.	Check the mechanism ,push rod connection of particular feeder VCB if it tripped late, if tripped on set time, vacuum might be lost or leaked
17	CB of HV feeder tripped without any relay indication on test trial line stood OK	Tripping relay faulty, Under freq relay faulty or flag non-working
18	Particular CB trips and simultaneously DC fuse blows.	Tripping coil is defective , it draws excessive current
19	At the time tripping of particular CB , noise is heard in battery room	Tripping coil draws over current and some of the battery cell got defective

11.9 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) MAINTENANCE OF NUMERICAL RELAYS (IED)

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 tripping or no tripping	Call T&C engineer for checking the settings & time grading 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.

11.10. 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

11.11. TELEPHONE EXCHANGE

1	Maintenance of EPAX as per recommendations of the manufacturers	SOS

GENERAL TECHNICAL REQUIREMENTS FOR MAIN AND AUXILIARY SUBSTATION EQUIPMENT

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	Vacuum and Sulphur hexa fluoride (SF6)
72.5 kV	Vacuum, Air blast and Sulphur hexa fluoride (SF6)
145 kV and 245 kV	Air blast and Sulphur hexa fluoride (SF6)
420 kV	Air blast and 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

(b) Total Breaking 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

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

(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 with-standing 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

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	400 kV	220 kV	132 kV	66 kV	33 kV
2.	Highest system voltage	420 kV	245 kV	145 kV	72.5 kV	36 kV
3.	Frequency	50 Hz	50 Hz	50 Hz	50 Hz	50 Hz
4.	Basic insulation level (kV peak)	1425	1050	650	325	170
5.	Power frequency withstand strength	630	460	275	140	70
6.	Rated primary current	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
8.	Rated short time current for 1 sec.	40 kA	40 kA	31.5 kA	25/31.5 kA	25 kA
9.	Secondary current amps.	1	1	1	1	1
10.	No. of cores	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
14.	Class of accuracy (a) Metering Core (b) Protection Core	0.2S 3P	0.2S 3P	0.2S 3P	0.2S 0.2S 3P 3P	0.2S 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

Note: Rated burden may be reduced considering the low burden requirement in case of numerical relays and microprocessor based meters.

(c) Capacitor Voltage Transformer

Voltage	400 kV	220 kV	132 kV
Transformation ratio	400/√3 kV 110/√3V	220/√3 kV 110/√3V	132/√3 kV 110/√3V
No. of secondary winding	3	3	3
Voltage factor	1.2 Continuous & 1.5 for 30 seconds		
Rated capacitance	4400 PF/8800 pF	4400 pF	4400 pF
Rated burden	100 VA/50 VA	IOOVA/50 VA	100 VA/50 VA
Insulation Level (a) Rated one minute power frequency with stand voltage kV (rms)	630	460	275
(b) Impulse withstand voltage (1.2/50) micro second wowe shaped kV (Peak)	1425 1350	1050 -	650 -
(e) Switching Impulse withstand voltage (250/2500 Micro micro secs	1050	-	-
Class of accuracy (a) Core I (Metering) (b) Core 11(Protection) (e) Core III (open Delta)	0.2S 3P 3P	0.2S 3P 3P	0.2S 3P 3P

TRANSFORMERS

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

33 KV Power Transformers

Three Phase Rating MVA	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 MVA	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

Vector 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
100	220/33 kV	15.0	ONAN/OFAF or ONAN/ODAF

(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%	12.5	45	30	ONAN/ONAF Or

		16 steps of 1.25%				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

6. PROTECTION AGAINST LIGHTNING

A substation has to be shielded against direct lightning strokes either by provision of overhead shield wire/earth wire or Lightning Masts.

Every switchyard is designed with adequate Direct Stroke of Lightning Protection.

For the protection against the surges SA are used.

Typical technical parameters adopted for surge arrestors are as follows:

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

7. INSULATORS

The creepage distances for the different pollution levels are provided as per the following table:

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

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 at least one of them being carrier aided non-switched four 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 differential line protection relay with inbuilt distance protection.Distance protection only active when communication fails. Further, if Main-I and Main II Dist Proteciton schemes are used , then preferably each one them should be of different make but compulsorily with different platform. 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) Dirctional Over current E/F relay with higher time delay.

(iv) Carrier aided directional earth fault Relay.

(v) Broken Conductor

(vi) P.T. fuse failure

(ii) 220 k V Lines

There should be at least one carrier aided non-switched four zone (three forward and one reverse direction) 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, Direction E/F feature shall be enabled in numerical distance relay.

(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.

Numerical bus bar protection scheme is more preferred; as it is having in built breaker failure relay and identical C.T. for all the bays are not required. In case of High Impedance BusBar Protection scheme, identical CTs. For all the bays are required.

(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) Over-fluxing 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 for main tank and OLTC and Pressure Relief Device for main tank and OLTC.
(vii) Protection for tertiary winding
(viii) Overload alarm
(ix) Negative Seq 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 and remote end CB are required to be tripped with minimum possible delay through LBB protection.
There is a re-trip scheme in numerical relay, LBB relay issue a re-trip command after 100 ms to both trip coils to prevent the mal operation of 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 $		Safety 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**	6500

* 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 and equipments. 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 attainable step and touch potentials should be lesser than the allowable Step and Tough Potential.

To meet these requirements, an earthing system comprising an earthing mat buried at a minimum 0.5 m below ground, Verticle Ground rods at suitable points are provided in the substation. The non-current-carrying parts of all the equipment are connected to main earhing mat with two connection called risers. 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 and rods as below:

(a) Each neutral of transformer should be connected with two no of vertical electrodes and those electrodes are, in turn connected to main earhing mesh(Mat).

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

(c) All extraneous metal frame work not associated with equipment.

(d) Each Surge arrester is to be connected with vertical electrode Length of Riser from counter to electrode should be as minimum as possible.The electrode inturn will be connected to main mesh.

(e) Each ground part of primary winding of Potential Transformer/CVT shall be connected to vertical electrode which in turn shall be connected to main mesh.

(f) Switchyard fence, rail , other metallic body like pipe lines , poles etc. shall be connected to main mesh.

Switchyard areas are usually covered with about 100 mm (or more if required by design) of gravel or crushed rock which increases the allowable touch and step potential thereby safety of personnel against shocks,

The other benefit of metal spreading: it 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 firefighting 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 and 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 firefighting equipment and system should be properly maintained. Regular mock drills should be conducted and substation staff made aware of importance of fire protection and imparted training in proper use of the firefighting 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. Firefighting 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 firefighting 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.

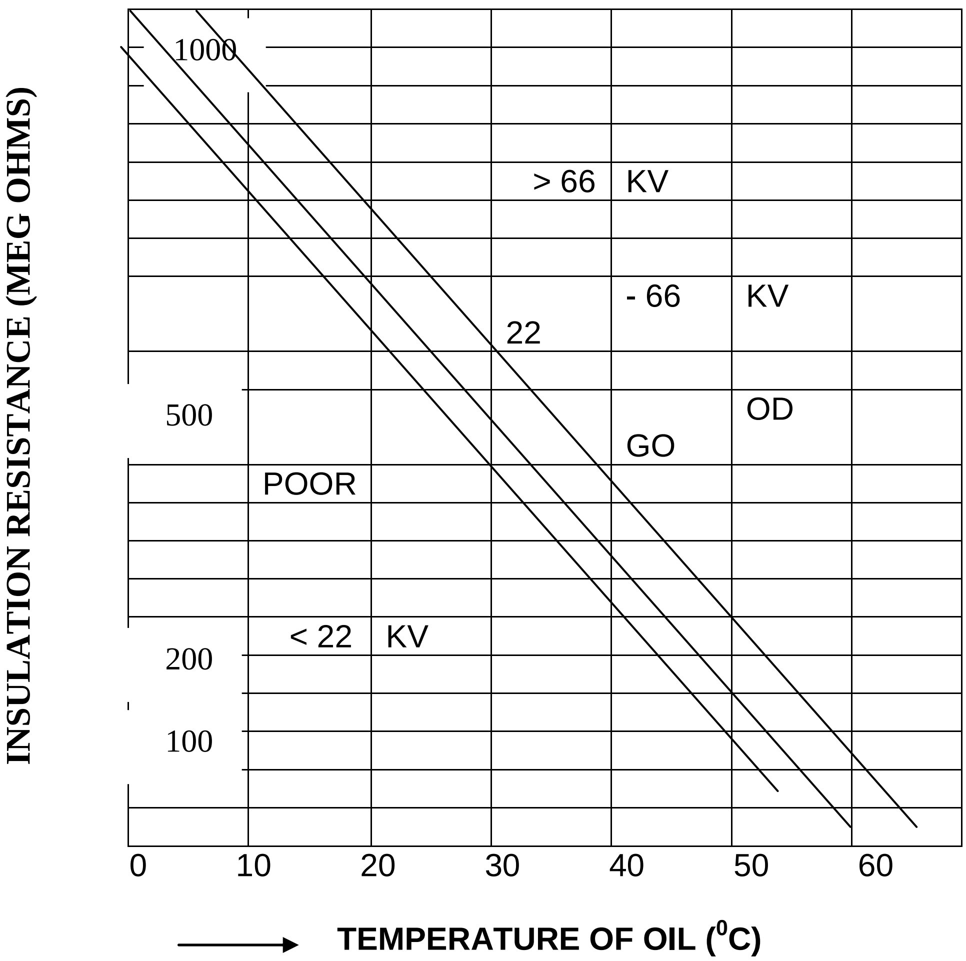
Filtration/Hot Oil Circulation

- 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 increase 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 2000V 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 145/220/400KV class respectively). Break down voltage (more than 60 KV at 2.5 mm gap). Resistivity (> 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.



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 required.

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.

SPECIAL CONSIDREATIONS IN CASE OF SUBSTATION GIS SUBSTATION AUTOMATION SYSTEM /SCADA

(A) GAS INSULATED SWITCHGEAR (GIS)-SUBSTATION

1. INTRODUCTION

The main advantage of Gas Insulated Substation 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 Switchgear 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

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.

I. Conditions Monitoring of GIS

Generally GIS requires no or very little maintenance and monitoring the SF6 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.

SF6 Gas

As SF6 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 Sf6 gas should also be monitored as the property of SF6 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 and 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

INTRODUCTION

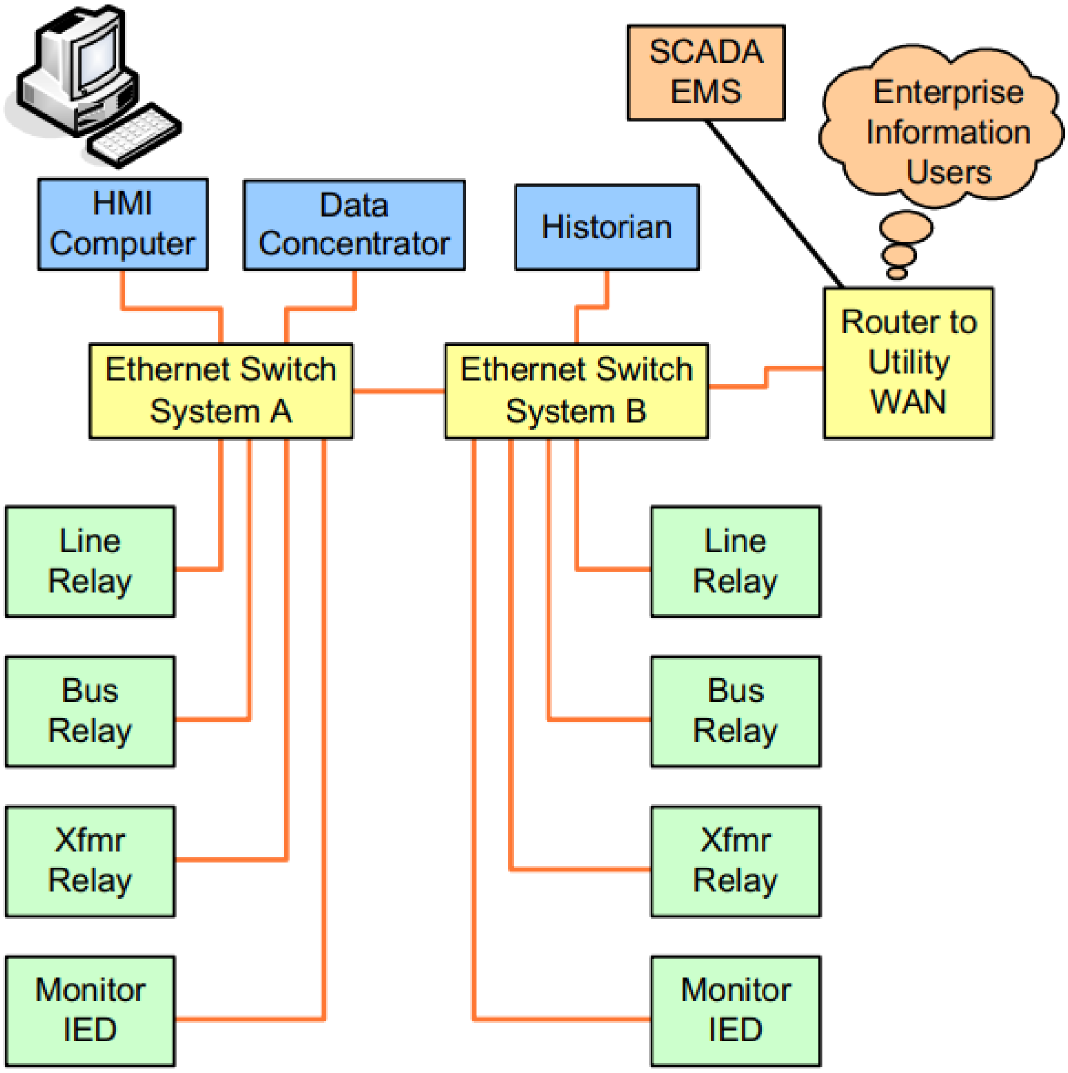
Automation system in any field is nothing but to minimize/eliminate the intervention of human being in the system. As far as the substation is concerned, traditionally we are collecting the energy export and import reading of all the feeders in sub-station and make the record in log book. Similarly any disturbance in the sub-station, like tripping or alarm of protective relay of any feeder, transformer tempt. alarm, air pressure, gas pressure alarm of breaker are being noted with time by operating staff. According to the severity of the alarm, actions are taken by the operating person and it is conveyed to the respective officers through communication media.
All most all control operations, except A/R scheme and air compressor operations are done by operating person. it means most of all activities either data collection or any operation are being carried out by human.
SCADA (SUPERVISORY CONTROL AND DATA ACQUISITION) is the system developed to perform data collection and report to the remote control station automatically. Similarly operations can also perform from the remote control station. Each station is having one of more R.T.U. and it communicates with master control station.

SCADA is useful in mass collection of data like voltage,current, energy export/import, frequency, active and reactive power, status of bay equipments like isolators, CB, transformer tap position, in short all most all data those are essential for records and also needed for decision. These DATA are collected by R.T.U. and sent to the remote control center with time stamp.
The accurate and timely collected DATA helps to optimization of plant operation. Further it is more efficient, reliable and most importantly it offers safe operation. It lower the operation cost.
There are five level of SCADA system,

- Field level, i.e. protective relays, indicating meters, energy meters, breaker, transformer tap changer etc.
- R.T.U.
- Communication system
- Remote master control station
- data processing .

SCADA Software

SCADA software is divided in to two types, proprietary or open. Company develop their own software that communicate only with their hardware. The main problem of this system is, one has to depends only on the manufacture life long for any problems, addition, alteration.
Open system has gain popularity because of interoperability means different manufacturer relay can be communicate on the system.



Inter connection of two or more devices with digital communication is the first step towards establishing a network. in addition to the hardware requirements, the software problems of the communication must be solved. Where all the devices on the network are of same make, hardware and software problems are easily solve because the system is design with in same guide lines and specifications.

Open systems are those that confirm to the specifications and guidelines, which are open to all. This allows the equipments from any manufacture who complies with the standards, to be used on the network.

Migration of the numerical technology in the protection, protective relay have so many function like D.R, S.E.R. and can directly communicate with R.T.U. and also inter relay communication. Now it is call I.E.D.(intelligent electronic device), it may be a protective relays, bay control relay, energy meter or smart transformer parameter monitor.

Due to development of the communication and numerical technology an open source protocol IEC 61850 is develop, especially for sub-station automation. But now it is migrate in other field also like wind turbine control, water supply etc. This is open source protocol is ever expand, as the communication technology develop.

IEC 61850 is not only for communication but it also for the DATA organization with in IED.

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.

MAINTENANCE PROCEDURES
OF
EHV
TRANSMISSION LINES

MAINTENANCE PROCEDURES OF EHV TRANSMISSION LINES

A. INTRODUCTION

1. Today, PTCUL is operating and maintaining transmission lines of Voltage class upto EHV 400KV AC. These lines cross the entire length and breadth of Uttarakhand State and power is transmitted on these lines to the remotest corner. 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 to be 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. The Assistant Engineer along with his team 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 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 mm^2 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 line men who work on the transmission towers, conductors or fittings, shall wear and make use of all safety belts/ harnesses 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, lineman 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, conductor, filling and men shall be removed from the work site. The last line man 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 be 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 outside 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 Tone).	2 Nos.
3.	Two meter fibre round sling (5 Tone).	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 / Al) - 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 fiber round slings.
- If required, attach fiber 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 15mm diameter endless polypropylene rope	1 No.
2.	Tension Insulator changing rig	1 No.
3.	12meter long 16mm diameter wire bond with soft eyes both ends	1 No.
4.	5.25 meter long 14mm 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

Sl. 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

Sl. 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 helmet	5 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 pulley 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 pulley 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 pulley 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 pulley block with rope should be used so that the 4 sheave pulley 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 pulley 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 overlap 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 centering 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.	5 Nos.
3.	Piece of Earth wire of same size	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.

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

1. INTRODUCTION :- As per policy of the different Power Transmission Corporation, O&M procedures are prepared and reviewed after 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 hereunder.

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 Chief Engineer (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).

ACTIVITES FOR MAINTAINING TRANSMISSION LINES

Sl. No	Normal Routine Works to be done by Regular Staff	Maintenance & Breakdown Works to be done by Outside Agency
1.	***Checking*** of Patrolling reports, ***Visiting*** the Site/Locations of defect detected by Outside Agencies, Analyzing shut down etc. Keeping watch on works of agencies on line. Preparing Estimates.	**(A)** ***Regular Patrolling*** of complete line Tower to tower bi-monthly & submitting the Patrolling Report giving the details of defects. For example hot points, dislocation of dampers, weak joints & condition of the conductor Earth Wire & Clamps etc.
		(B) ***Checking & Tightening*** the Nuts & Bolts & washers of the Tower, Jumpers & Jumper Clamps.
		(C) ***Repairing*** of broken conductor & Earth Wire by providing mid span Compressive joints including loading the Conductor jointing & Sagging.
		(D) ***Fabrication & Fixing*** of missing Tower part and providing missing Nuts & bolts.
		(E) ***Replacing*** of broken disk insulators 70/120 KN
		(F) ***Fixing*** of missing vibration dampers of conductor & earth wire.
		(G) ***Repairing*** of damage conductor by providing repair sleeves.
		(H) ***Cutting*** of tree & tree branches & wide bushes & making 27 mtr. wide gallery, clean quarterly (every three month)
		(I) Constructing revetment on the locations where erosion of soil, cutting of mud taken place.
		(J) Repairing of rusted and broken legs of towers in water logged area

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)
400	400
220	335, 350, 375
132	315, 325, 335
110	315, 325, 335
66	240, 250, 275

(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.

400 KV Lines

Terrain/tower type		Permissible Weight Span (m)			
		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 ' Twin 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 Conduct or (mm)	Approx current carrying capacity		Approx cost of conductor kg/km			Approx. Ultimate Tensile strength (kg)
		Al	Steel		At 40^0 ambient temp(A)	At 45^0 ambient tem (A)	Total	Al	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 load ability 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)	125	187	250	375
(iii)	132 KV (with Panther)	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 load ability 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
Minimum ground clearance(mm)	5500	6100	7000	8840

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

8. Clearance between Conductor and Ground wire "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
Minimum mid span clearance (mm)	3000	6100	8500	9000

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**
Highest voltage Rating of crossing line (KV)	Minimum electrical clearance (mm)			
72.5	2440	3050	4580	5490
145	3050	3050	4580	5490
245	4580	4580	4580	5490
420	5490	5490	5490	5490

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
Min. clearance between power conductor crossing telecommunication line (mm)	2440	2750	3050	4480

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

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**	**132KV**	**220KV**	**400 KV**
Clearance	(Minimum Value in m)			
(i) Clearance to Ground				
Across Street	6.1	6.1	7.0	8.80
Along Street	6.1	6.1	7.0	8.80
Other areas	5.5	6.1	7.0	8.80
(ii) Clearance to Buildings				
Vertical (*) –from highest object	4.0	4.6	5.5$	7.30
Horizontal (+) –from nearest point	2.3	2.9	3.80$	5.6

$: 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.
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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

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

14. Important Mechanical Data of various Conductors

Sl. No.	Code	Strands		Ultimate strength (kg)	Overall dia (cm)	Total sectional area sq. cm	Unit Wt. Kg/m
		Al 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 earth wires and OPGW (Optical Ground Wire) is given in Table.

Sl.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 Alloy 19/2.48 Steel	1.005	18.12	194.6
	c) O.P.G.W.			
10.	13/2.34mm AS+12/9.3I1m /3 Al extruded tubes	0.468	12.5	83
11.	7/3.80mm AS +12/811m11 (tube)	0.5238	12.58	92.58
12.	1/5+8/3.2 Optical Fibre Glass	0.458	11.40	71.41

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

17. PROBABLE CAUSES OF FAILURE OF THE TRANSMISSION LINE COMPONENTS

17.1 Introduction

In the power system, Transmission lines have to play a very vital role by transmitting of power with safety and reliability. For that, it is desirable to have minimum power breakdowns/ outages on the transmission lines. To minimize break-down on the lines planned preventive maintenance is considered to be absolutely necessary. This aspect also helps avoiding lot of inconvenience to the consumers etc. and bring economy to the concerned utility/undertaking.

While considerable emphasis has already been laid for carrying out proper maintenance of the transmission lines, it still becomes very important to know the causes leading to failure of the transmission line components.

EHV transmission lines has a number of components which are affected by environmental problems like corrosion, pollution, lightening, normal wear and tear etc. Instances of damage carried out during strikes and civil disobedience, damage of insulators during shooting practices, theft of tower members etc. could also affect the line performance. In this chapter, probable causes of failure/damage of transmission line components mentioned as under have been brought out :-

A. Insulators and Hardware fittings.

B. Conductor and Conductor Accessories

C. Earth wire and Earth wire Accessories

D. Tower, Nuts and Bolts

E. Tower foundation

F. Tower Earthing

It is observed that the break-down(s) occur due to various reasons such flash over on disc insulators, snapping of conductor from the mid span joints, dead end compression type clamps, breakage of conductor under suspension points. Some-times , jumpers also break due to loose nuts and bolts on dead end compression type clamps etc.

17.2 Probable Causes of Damage of Insulators and Hardware Fittings

The insulator strings comprising of insulator discs and hardware fittings are provided for supporting and anchoring the conductors to the towers and insulating the live conductors from the ground. Hardware fittings comprise of suspension clamps, dead-end compression type clamps, corona control rings, arcing horns etc. With the passage of time, there can be any type of deterioration in hardware fittings due to poor quality of material, sparking and rusting of clamps etc. split pins of hardwares/ security clips of disc. insulators may also break or found missing on these fittings.

A. Disc Insulators

1) Poor quality of disc insulators & hardware fittings (Cap., pin, security clip, etc.) used on the transmission lines.

2) Insulators exposed to industrial pollution (brick kilns, chemical industries, Cement, Factories, Fertilizer plants, etc.) and coastal pollution (salt sea fog) are likely to get contaminated because of smoke/ chemical / salt deposit etc. from time to time. Such locations/towers are vulnerable for flashing over of disc insulators particularly during foggy weather.
3) If earthing of tower is not proper, back flashover due to lighting stokes, direct lighting strokes or switching over voltages will not get discharged effectively and disc insulators are likely to get flashed over leading to fault online. Accordingly, the Earth Resistance of towers must be ensured within permissible limits. (in most cases it should be >= 10 ohms)
4) Excessive vibrations on conductor
5) Dropping of birds/ refuse/ defection by birds on insulators where bird's guards are not provided.
6) Throwing of stones, missiles, shooting pracitceds etc. by miscreants or children on insulators.
7) Poor I.R. values of disc insulators due to ageing.
8) Failure of security clips of disc insulators.
9) Looseness of arcing horn rods of the insulators string and missing/dropping of arcing horns and grading rings from the insulator string.
10) Damage due to blasting in nearby quarries, road formation cutting in hills or practice firing in nearby firing range.
11) Falling of trees etc. on disc insulator string.
12) Dropping of long wires/big bones of dead animals etc. by vultures/birds on the disc insulators.
13) Improper handling of insulator disc/ insulator strings during transportation and erection of the insulator string causing damages in the cemented portion of the cap and pin.
14) Improper quality of cement and cementing process during fixing of cap and pin on the shell.

B) Hardware Fittings

1) Poor quality of hardware fittings used on the lines e.g. forging, casting, galvanizing, mechanical strength etc.
2) Deterioration/failure of corona control rings, split pins, other accessories with the passage of time.
3) Excessive vibration on line.
4) Loose fittings.

17.3 Probable Causes of Failure of Conductor and Conductor Accessories

Conductor and conductor accessories are vital components in a transmission line. The conductor is the main current carrying component of a transmission line installation. In EHV transmission lines, ACSR and Aluminum Alloy conductors are generally used. In transmission lines. Conventional lines with ACSR conductors are operated up to a maximum temperature of 75C and Aluminum Alloy conductor up to a maximum temperature of 85C.

Conductor accessories comprise of mid span joint, repair sleeve, vibration dampers, spacers, spacer dampers, armour rods, etc.

These components may fail due to

- premature ageing,

- incorrect design (vibration system design, clamping arrangement and bolt tightening torque, mechanical strength etc.),
- poor quality of material,
- sparking and rusting of components,
- loosening/breaking of split pins, bolts and nuts, etc.

A. Conductor

1) Loose fittings on conductor i.e. vibration dampers, spacers/spacer dampers, straight through joints, dead end clamps, repair sleeves etc.
2) Failure of hanger cleats, looseness/failure of nut-bolts attached to hardware fittings and due to cracks in hardware fittings etc.
3) Snapping/dropping of conductor due to lightening stroke causing failure/decaping of disc. Insulators due to high earth resistance etc.
4) Excessive vibration causing wear and tear/damage of conductor.
5) Looseness between aluminium and steel portions of compressed joints (straight and dead end joints) causing air gap and thus breakage of conductor.
6) Falling of big trees on the conductor/disc insulator strings.
7) Throwing of chain/wire etc. on the conductor by the miscreants and hitting by crane booms/hoist and other such machinery etc.
8) Failure of disc insulators due to poor quality/ageing and due to failure of split pins etc.
9) Loosening of performed armor rods due to poor quality of material, vibrations and improper installation etc.
10) Hitting by flying objects Aeroplane / Helicoptors GI sheets etc. during storms, blasting etc.
11) Sparking/arcing corona at the conductor surface due to scratches, wear and tear caused during stringing of conductor, sticking of foreign material on the conductor, incorrect intra conductor bundle spacing, distorted bundle configuration etc.
12) Overheating resulting loss of strength of conductor due to over loading.
13) Bird caging of conductor causing opening of conductor at clamping points resulting in overstressing/damage of conductor.
14) Improper design of conductor i.e. incorrect lay ratio, chemical composition, incorrect procedure of wire drawing, low mechanical strength, high electrical resistance, etc.

B. Conductor Accessories

1) Incorrect design and poor quality of material of conductor accessories causing fatigue failure, cracking, fretting, hot spot, etc.
2) Loosening of nuts &bolts of damper due to vibration etc.
3) Poor workmanship (spring washers etc. not used with nuts & bolts); improper bolt tightening/torque.
4) Improper design of vibration system vis-à-vis environments.
5) Improper placing of vibration dampers, spacers and spacer dampers.
6) Improper compression of mid span joints, repair sleeve etc.
7) Improper application of tightening torque for clamping bolts of suspension clamps, vibration dampers, spacers/spacer dampers etc.

17.4 Adverse affects of vibration

In case vibration dampers/spacers are not provided or partly provided and not maintained properly, it adversely affects all the components of transmission line up to foundation as under:

i. Conductor & Earth Wire :

Life of earth wire and conductor is reduced and chances of their breakage are increased. The earth wire and conductor generally gets damaged in suspension clamps. Some-times, at hooking points conductor strands are broken.

ii. Armor Rod :

The armor rod looses its grip on conductor due to which there is sparking at armor rod ends.

iii. Effect on clamps and its Nuts & Bolts:

Due to vibration, the damper nuts and bolts get loosened and some-times its cotter split pins get broken causing slipping of conductor from the hooking point resulting into the break-down. Some-times hardware plate gets cracked due to vibrations.

v. Effect on Tower Members and Nuts & Bolts

Tower as a whole with its members and bolts & nuts when exposed to severe vibrations leads to loosening of bolts and nuts thereby disturbing the load sharing which may result in overstressing of some members and cause failure. The vibrations transmitted to the foundations may cause loosening of chimney/muffing and the stub, cause rusting of stub due to seepage of water in the stub and chimney/muffing joint and cause foundation failure due to loss of bond length and effective area of reinforcement. Audible noise from the tower also increases.

v. Effect on Insulators

Due to vibrations, chances of breakage of disc insulators increase.

vi. Effect on Arcing Horns.

Arcing horns get loosened and the gap is changed defeating its very purpose. The conductor side arcing horn causes sparking on the conductor due to looseness.

vii. Effect on Jumpers

Jumper start vibrating e.g. during lightening discharges and flow of fault current. Sparking develops and jumpers break. In case of crimp jumpers all nuts and bolts in the system of jumper get loosened and cause sparking further leading to jumpers failure.

viii. Effect on Earth Wire Flexible Bonds

Due to vibration the nuts and bolts in the earth bond fixing get loosened which causes sparking resulting in damage of earth wire copper bond

17.5 Probable Causes for Damage of Earth wire and its Accessories

a. Earth Wire

Earth wire and earth wire accessories play an equally important role as conductor and conductor accessories in a transmission line. They protect conductor and insulator strings from damage due to lightning strokes. The material used for manufacture of earth wire is generally galvanized stranded steel wire. However in coastal areas, aluminum alloy conductors are used as earth wire in place of galvanized stranded steel earth wire to prevent damage due to galvanic action from salt. Further, ACSR conductors and aluminum alloy conductors are also used as earth wire in place of galvanized stranded steel earth wire to reduce voltage induction on open overhead telephone circuits due to earth fault in the transmission lines. The earth wire is designed to operate at 53C (45C as the maximum ambient temperature +8C temperature rise due to solar radiation). In EHV transmission lines up to 220kV, single earth wire is generally used except for horizontal configuration lines where two earth wires are used. In case 400kV and above voltage lines, two earth wires are used.

Earth wire accessories comprise of mid span joint, repair sleeve (for 220kV and below voltage lines), vibration dampers, suspension clamps, tension clamps, etc. These components can fail due to premature ageing, incorrect design (vibration system design clamping arrangement and bolt tightening torque, mechanical strength etc.), poor quality of material, rusting of components, loosening/breaking of split pins, boltsand nuts, etc.

Damage to earth wire of overhead lines occurs due to the following probable reasons:

1) Improper design of earth wire i.e. incorrect lay ration, chemical composition and incorrect procedure of wire drawl, low mechanical strength, high electrical resistance, incorrect method of galvanization etc.
2) Frequent lightning discharges and earth faults between conductor and earth wire resulting in high temperature stresses, burning and loss of mechanical strength.
3) Falling of trees on the earth wire, hitting of flying objects to the earth wire, etc.
4) Damage of earth wire near joints because of improper crimping and bad quality of material.
5) Breakage of split pins provided in suspension clams. This may cause dislodging of suspension clamp holder and the earth wire may fall.
6) Accumulation of moisture and water in suspension clamp portion holding earth wire which may cause rusting and hence damage of earthwire. The design of earthwire/suspension clamp with reference to environmental effects has to be taken care of properly.
7) Breakage of strands of earth wire, suspension clamp, dead end points etc. due to vibrations.
8) Inadequate earthing and also due to lightening discharges and ageing.
9) Loose flexible earth bond with the earth wire. In this case during lightening stroke(s) the earth wire may get damaged/broken.
10) Use of improper/ineffective earth wire vibration dampers etc.

b. Earth Wire Accessories

1) Poor quality of earth wire accessories i.e. earth wire, suspension clamps, dampers, earthing bond etc.
2) Improper design of clamps.(Not taking into account the environmental effect).
3) Incorrect application of tightening torque for clamping bolt of suspension clamps, tension clamps of bolted type and vibration dampers".
4) Incorrect design of vibration system leading to failure of vibration dampers wherever used.

17.6 Probable Causes for Failure of Towers

The tower and hardware (and bolts and nuts) are the backbone of a transmission line. The towers support conductors, insulator strings and earth wire. The towers mainly comprise of main legs and bracings of different configuration. The towers are fabricated out of mild and high tensile steel, hot dip galvanized bolts, nuts and spring washers.

The failure/collapse of a tower can cause interruption of power supply for prolonged periods. The erection of a new tower in place of the defective tower is quite a difficult job which may even take several days for restoration of power supply. It is, therefore, very essential to give proper weight-age to the aspect.

The tower hardware comprises of number plate, circuit plates, danger plate, a set of phase plates, anti-climbing device, earthing device, tower earthing bonds, bird guards, etc.

Installation of these hardware on towers in addition to meeting statutory requirement also improves the operational performance of lines in terms of tripping of the lines due to lightning discharges, earth faults, pollution flashovers, etc.

a. Towers may collapse due to following reasons:-

1. Faulty detailed survey, check survey, setting of line, incorrect type of towers, etc.
2. Poor quality of tower material bolts nuts and spring washers etc.
3. Tower super structure of improper design and not meeting reliability, security and safety loads and narrow front wind loads
4. Soil erosion
5. Foundation not matching with the soil data (i.e. incorrect soil data)
6. Poor workmanship and negligent foundation casting i.e. improper setting of stub, in correct laying of reinforcement, improper fixing of foundation form work while concreting, not following the drawings properly, etc.) besides poor quality of foundation material.
7. Not maintaining proper sum of adjacent spans, maximum and minimum span etc.
8. Missing of tower members due to theft/pilferage etc.
9. Hitting by vehicles and flying objects such as Aeroplane/helicopters
10. Damage by miscreants
11. Uplift of tower not properly compensated
12. Backfill not properly compacted
13. Eccentricity in the tower/out of verticality
14. Improper detailing of joints.

b Bolts and Nuts

1. Due to conductor vibrations, the tower vibrates and causes loosening of nuts and bolts.
2. While fixing nuts and bolts, some-times, washer is not provided. The nuts and bolts are not fully tightened even not punched. Such nuts and bolts get loosened due to vibrations and fall on ground.

3. The nuts and bolts break sometimes due to sparking/flashover due to improper earthing

4. Nuts and bolts may break due to over tightening

5. Some-times, if the breaking of the tower is fitted forcibly, nuts and bolts are subjected to bending and due to addition of vibrations these break and fall down.

6. Due to non-provision of washers, the nuts are subjected to uneven pressure and these break

7. If the threads of bolts go inside the hole due to reduction in diameter, the bolts can not take the force and fail.

8. Improper tack welding of bolts and nuts resulting in burning of bolt material.

c. Probable Causes for Rusting

1. Due to deposit of dust on the roadside, cement pollution near cement factories etc. tower super structure/anti climbing devices may get rusted.

2. Due to poor quality of material used in super structure and anti-climbing devices

3. Due to poor galvanizing of material

4. Due to the effect of chemical industries near the vicinity of towers

5. Heavy growth of grass & bushes, collection of chemical active soil, collection of water, etc. around the legs/stubs and honeycombing during concerting of stub causing exposure to chemicals present in sub soil water.

6. Collection of rain water due to non-provision of drainage holes in the pockets formed in assembled structure

d. Probable Causes of Failure of Tower Foundation

Foundation is the vital component of a transmission line. It serves as a base for erection of tower. The foundations for normal types of towers are of mass concrete or reinforced concrete type. Special types of foundations (well type, pile type, etc.) are used with special type of towers, river crossings, etc. The materials used for casting of foundations are cement, coarse and fine aggregates and reinforced rods. Classification of a foundation depends on type of soil and sub soil water level. The grade of concrete (M15,M20 etc.) depends upon the loads to which the foundation is to cater.

The probable causes of failure of towers foundation are given as under :-

1. Land slide

2. Sinking of hill

3. Soil erosion

4. Faulty casting of foundation (poor concrete mix, incorrect size and laying of reinforcement bars, improper compaction and curing, etc.

5. Unequal movement of various legs of foundation due to earth quake.

e. Causes of Erosion at the Base of Foundation/Tower Legs

1. Due to diverted flow of rain water/flash floods.

2. Due to river/canal/nallah adjacent to the tower and possible breach etc.

3. Excavation works carried out by farmers near the tower. Also excavation done by other agencies for mining, quarrying and earthwork material for constructing roads etc.

4. Natural erosion of soil due to rain water (surfacial and sub surfacial flow).

5. Other causes including opening of gates of the spillways on upstream side of the tower etc.

17.7 Probable Causes of Damage of Earthing Electrode and Earthing strip

The earthing system of the transmission towers play a major role during normal working as well as during abnormal conditions Earthing system of transmission line comprises of towers, earth wire including jumpers, earthing bonds, individual earthing electrodes of the tower and connections thereof or a set of counter poise earthing. Every tower is provided with individual earth by providing earth electrodes and connection with MS flat on one leg. The values of tower footing resistance of towers are required to be kept as low as possible but not beyond limits (Max. 10 ohms).

The probable causes for damage of earthing rods/strips are given as under:-

1. Nuts and bolts, earthing strip and earthing electrodes provided for earthing of towers get rusted/deteriorated with the passage of time and get damaged.

2. Vibrations lead to loosening of nuts and bolts used for fixing MS Flat to tower.

3. Lightening strokes and discharges can cause damage to earthing electrodes/earthing strips due to loose nuts and bolts

4. Theft of earthing material (M.S. flat used for connection, galvanized stranded steel wire used as counter poise).

ESSENTIAL REGISTERS
TO BE
MAINTAINED
AT
EACH SUBSTATION

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.	Sealing Register	18
19.	Monthly Energy Account Register	19
20.	Carrier Fault Register	20
21.	Compressor Reading Register	21
22.	LA’s Surge Counter Reading Register	22
23.	Daily Log Sheet	23

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/ Biometric Machine

Attendance register/Biometric Machine 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	
1	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.	
1	2	3	4	5	6	7	8	9	10	11	12

18. SEALING REGISTER:

POWER TANSMISSION CORPORATION OF UTTARAKHAND LIMITED

Sealing Register ………………………………… **Name of Feeder-**

Date	Type of seal	P.T. Terminal plate			P.T. Junction Box	CT Terminal Plate			C.T. Junction Box	Energy Meter					Control Panel back door where energy meter installed	Reason for Change the Sealing	Remark	EE/ AE T&C	EE/ AE O&M
		R-Phase	Y-Phase	B-Phase		R-Phase	Y-Phase	B-Phase		Meter Body or cover	Meter Terminal cover	Meter test terminal Block	MRI Port	Meter cabinet					
	Paper Seal																		
	Poly corbonate																		
	Lock																		
	Paper Seal																		
	Poly corbonate																		
	Lock																		
	Paper Seal																		
	Poly corbonate																		
	Lock																		

19. MONTHLY ENERGY ACCOUNT REGISTER:

Sl. No.	Voltage	Name of Feeder/transformers	IMPORT					EXPORT					Calculation of Losses
			00:00 hrs reading of First Day of the Month	24:00 hrs reading of Last Day of the Month	Diff.	MF	Nett. Energy in MWH	00:00 hrs reading of First Day of the Month	24:00 hrs reading of Last Day of the Month	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)

20. 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

21. 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

22. 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

23. DAILY LOG SHEET – As per Substation requirement

FORMAT OF RECORD TO BE MAINTANED AT EHV SUBSTATION

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 COMPLE TED (IN%)	SIGNAT URE (MAINTE NGR)	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…………………

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									
	B ø									
	52 KV BUSHING									Rate of rise of Capacitance value per year =+/- 1%Max.
	R ø									
	Y ø									
	B ø									
	LINE REACTORS Bushings									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.
	R ø									
	Y ø									
	B ø									
	145 KV Neutral Bushing									
	NGR 145 KV Maiins-Comm.									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.

* 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

Please refer respective Check list mentioned in this manual for detaling at col PARTICULARS/ACTIVITY

ACTIVITY	OBSERVTION & REMARKS
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			

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…………….

Please refer respective Check list mentioned in this manual for detaling at col PARTICULARS/DESCRIPTION

(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

(a) Checking of space heater & illumination

(b) Checking of healthiness of Rubber Gaskets

(c) Visual Check of auxiliary contacts

(d) 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
Please refer respective Check list mentioned in this manual for detaling at col PARTICULARS/ACTIVITY

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:**

Please refer respective Check list mentioned in this manual for detaling at col PARTICULARS/DESCRIPTION

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

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

Signature : Signature :

Name : Name :

MONTHLY MAINTENANCE FORMAT FOR SUB-STATION FIRE FIGHTING SYSTEM

SUB-STATION : **DATE OF MAINTENANCE :**
PTW NO : **DATE :**
Please refer respective Check list mentioned in this manual for detaling at col PARTICULARS/DESCRIPTION

S.NO.	PARTICULARS	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 :**

Please refer respective Check list mentioned in this manual for detaling at col PARTICULARS/DESCRIPTION

S.NO.	PARTICULARS	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………………

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

MAINTANANCE ACTIVITIES AT SUBSTATION TO BE DONE DEPARTMENTALLY / OUTSIDE AGENCY

Sl. No	Name of Equipments	Normal Routine Works to be done by Regular Staff	Maintenance & Breakdown Works to be done by Outside Agency
1.	**400/220/132 KV *C.B.* SF_6/MOCB**	***Tightening*** of ***Nuts & Bolts***, ***Observing & Maintaining*** the SF_6 Gas pressure, maintaining ***Compressor air pressure, Filling*** SF_6 Gas, ***Changing*** Mobile oil, ***Compressor belts***, ***Topping up oil***.	**(A)** ***Dismantling*** of old ***C.B.*** Completely.
			(B) Erection of new ***C.B.*** Completely.
			(C) Cabling & ***Termination*** at Control room & up to the breaker Operating works.
			(D) ***Replacing*** Old Jumpers by new.
			(E) Replacing Jumpering Clamps.
			(F) Stopping oil leakage by changing the gaskets o-rings etc. by lifting the pole assembly.
			(G) Removing the Mechanical faults of the breakers opening & Closing Operations.
			(H) Removing the Electrical faults of the breakers opening & Closing Operations, including repairing of charging motors, its contactor etc.
2.	**33KV C.B. SF_6/VCB**	***Tightening*** of Nuts & Bolts, ***Observing & Maintaining*** the SF_6/Gas pressure, maintaining Compressor air pressure, filling SF_6 Gas, ***Changing*** Mobile oil, ***Compressor belts, Topping up oil***.	**(A)*****Dismantling*** of old ***C.B.*** Completely.
			(B) ***Erection*** of new ***C.B.*** Completely.
			(C) Cabling & Termination at Control room & up to the breaker operating works.
			(D) ***Replacing*** Old Jumpers by new.
			(E) ***Replacing*** Jumpering Clamps.
			(F) Removing the mechanical faults of the breakers opening & Closing Operations.

			(G) ***Removing*** the Electrical faults of the breakers opening & Closing Operations, including repairing of charging motors, its contractor etc.
3.	**400/220/132/33 KV *C.T.***	***Tightening*** of Nuts & Bolts, ***Topping up oil***, ***Tightening*** of Jumpers ***C.T.*** Connectors etc.	(A)*Dismantling* of old *C.T.* Completely. **(B)** *Erection* of new *C.T.* Completely. ***(C)*** *Replacing* Old Jumpers by new. ***(D)*** Stopping oil leakage by changing the gaskets/Packings at the Connector of the *C.T.* **(E)** *Replacing* of old damage *C.T.* Connectors with new.
4.	**400/220/132/33 KV Isolators**	Routine ***Tightening*** of Nuts & Bolts adjusting Jaw & Blade contacts for smooth operations, regularly inspecting the jaw & Blade contacts and remove any loosening there in.	**(A)** ***Replacing*** old & damage isolators with structure completely. **(B)** ***Erection*** of new isolator with insulator structure completely. **(C)** ***Replacing*** old & new Jumpering & damage Clamps by new. **(D)** ***Replacing*** burnt & worn out jaw & Blade of the Isolator. **(E)** ***Overhauling the Isolator*** operating mechanism oiling & greasing making proper adjustment for proper fitting of jaw & Blade with minimum contact resistance.
5.	**400/220/132/33 KV *C.V.T./P.T***	***Tightening*** of Nuts & Bolts, Topping up oil, ***Tightening*** of Jumpers ***C.V.T.*** Connectors etc.	**(A)** ***Dismantling*** of old ***C.V.T*** Completely. **(B)** ***Erection*** of new ***C.V.T*** Completely. **(C)** ***Replacing*** Old Jumpers by new. **(D)** ***Stopping oil leakage*** by changing the gaskets/Packings at the Connector of the

			C.VT. **(E)** ***Replacing*** of old damage ***C.V.T.*** Connectors with new.
6.	**48/110/220 Volt Battery & Battery Charger**	***Maintaining*** Battery register daily & Fortnight, Topping up the distilled water regularly, ***Measuring*** Voltage, gravity of each cells regularly, observing & ***Recording*** chargers float current and Voltage its operation	**(A)** ***Dismantling*** of old Battery set Completely **(B)** ***Erection*** commissioning of new battery Completely. **(C)** ***Detecting & Removing*** the fault of battery chargers. **(D)** ***Replacing*** defective cards in the battery chargers.
7	**11KV Switch Gears**	***Regular observing & maintaining*** 11KV Switch Gears, ***Tightening*** of loose points in cable, **C.T.** spouts, Bus bar, having close watch on hot points in the Switch Gear regularly	**(A)** Trip base, replacing oil overhauling of 11KV **MOCB**. **(B)** ***Replacing*** of old damage spouts Rose Contacts & U Clamps. **(C)** ***Replacing*** of damaged Cable Termination kits by providing a new kit or straight through joints in cable. **(D)** ***Maintenance & Overhauling*** of 11KV **P.T.**
8	***Cleaning*** **Grass cutting of Sub Station**	***Cleaning*** of Control room & annxee Panels & Switch gears on daily & regular basis including Battery room & career room.	(**A**) Grass Cutting In the whole Switch yard six times in a year **(B)** Cleaning of Switch Yard & Store yard completely at least once in a month. **(C)** Cleaning of various Equipments erected in Switchyard such as for Breakers, Isolators, CTs, C.V.Ts, Polygon Insulators & Transformers fortnightly etc.
9	**Painting Various Equipments**		***Painting*** of Sub Station equipments Transformers, ***C.T.***, ***C.V.T***, Breakers,

			Isolators, Structures columns & Gantry etc.
10.	**Transformers 315/160/80/40 MVA**	***Checking of oil level*** of conservators, operation of cooling fans, ***Replacing*** Silica Gel periodically, Topping of oil, ***Replacing*** oil of ***OLTC.***	**(A)** ***Repairing the oil leakage*** C***hecking*** by ***Replacing*** of the gaskets. **(B)** ***Repairing*** of the burnt & defective cooling Fans. **(C)** ***Replacing*** defective **OTI/WTI** instruments. **(D)** ***Replacing***/***Repairing*** of old & damaged Buhholz **(E)** ***Repairing*** /***Replacing*** of defective Contractors of cooling Fans. (**F**) Testing of Oil samples of transformer yearly (DGA Test, Tan Delta Test)
11.	**Capacitor Bank**	***Cleaning*** the Capacitor bank Yard	**(A)** ***Replacing*** the defective units of the Capacitor bank by new unit
12.	**Lighting of Sub Station**	***Maintaining*** the light arrangements of Control Room &Annxee by ***Replacing*** Tube lights, Bulbs fittings etc. ***Maintenance & Operation*** of **LT** Supply Switch Yard & Colony	**(A)** ***Replacing*** defective lighting points like **HVSV** bulbs, Chokes. **(B)** ***Replacing*** the defective lighting points of Store yard & Colony by providing florescent Lamps, **HVSV** Lamps & maintaining the as illumination point basis.
13.	**Security**		**(A)** ***Providing*** Arm Security guard for two nos. : ***1.*** ***Sub Station*** (24 hours**)** **2.** ***Store yard & Colony*** (24 hours**)**
14.	**Fire Fighting**	Checking of Fire Fighting Equipments proper working. Checking the CO^2 Gas	**(A)** Refilling of CO^2 Gas Cylinders **(B)** Refilling of Foam

		Cylinders, Foam Type extinguished Cylinders. Operating of the Fire Fighting Equipments whenever Fire hazards takes place.	Type Cylinders regular & periodically. **(C)** Refilling of dry Chemical Cylinders. **(D)** Repairing/ Replacing old damaged Cylinders, Pipes etc.
15.	**Transportation /Carriage & Cartage**	If vehicle is available	**(A)** Hiring of Diesel running vehicles on contract basis as per applicable norms to officers/officials **(B)** Cartage & Carriage of substation equipments, T&P and spares etc as and when required

FORMAT OF RECORD TO BE MAINTANED AT EHV LINES

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

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.

Monthly Patrolling Programme

OFFICE Subdivision

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 Chief Engineer (O&M) Office with monthly report

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

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			

LOG BOOK OF LINE DEFECT

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

Description of defects													
SL .N O.	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

SUMMARY OF LINE DEFECTS FOR THE MONTHS OF ……………

(To be submitted to Chief Engineer (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			

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			

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			

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			

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			

STANDARD ACCEPTABLE TECHNICAL VALUES AND REFERENCES

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 DBPC – Phenolic type inhibitor	IS 335 – 1993
	(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 29.5^0C (Max)	0.89 g/cm3	Not Essential	IS 1866 - 2000
	(k) Kinematic Viscosity at 27^0C (Max)	27 cSt	Not Essential	IS 1866 - 2000
	(l) Pour point (Max)	-6^0C	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 20^0C	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 20^0C	0.007	IEEC/C57.12.90.1999
	Ten Delta for Windings at 20^0C (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 current test)	If the excitation current is less than 50 milli amperes (mA), the difference between the two higher currents 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.	Transformer Diagnostic USBR, June 2003
	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	

<table>
<tr><td rowspan="20"></td><td></td><td colspan="2">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.</td><td></td></tr>
<tr><td rowspan="4">IR Value of Winding (Min)</td><td>Rated Voltage Class of winding</td><td>Min desired IR value at 1 minute at 30^{0}C (Mega ohm)</td><td rowspan="4"></td></tr>
<tr><td>11 kV</td><td>300</td></tr>
<tr><td>33 kV</td><td>400</td></tr>
<tr><td>66 kV & above</td><td>500</td></tr>
<tr><td rowspan="7">Polarization index (Ratio of IR values at 10 min to 1 min)</td><td>Polarization index</td><td>Insulation Condition</td><td rowspan="7"></td></tr>
<tr><td>Less that 1</td><td>Dangerous</td></tr>
<tr><td>1.0-1.1</td><td>Poor</td></tr>
<tr><td>1.1-1.25</td><td>Questionable</td></tr>
<tr><td>1.25- 2.0</td><td>Fair</td></tr>
<tr><td>2.0-4.0</td><td>Good</td></tr>
<tr><td>Above 4.0</td><td>Good</td></tr>
<tr><td>CORE INSULATION TEST Min (Between CL and CC +G with tank grounded)</td><td colspan="2">1000K Ohms at 2.5/3.5 kV DC for 1 min</td><td></td></tr>
<tr><td>Transformer Neutral Resistance Value</td><td colspan="2">Below 1 ohm</td><td></td></tr>
<tr><td>Turret/ Neutral Resistance Value</td><td colspan="2">±3%</td><td>IS – 2705</td></tr>
<tr><td>Vibration level for Reactors</td><td colspan="2">200 Microns (Peak to Peak)
60 Microns (Average)</td><td></td></tr>
<tr><td>Sweep Frequency Response Analysis Test (20 Hz to 2 MHz)</td><td colspan="2">In general, changes of +/- 3 dB (or more) in following frequency range may indicate following faults:
Frequency Range
Probable Fault
5Hz to 2 KHz
Shorted turns, open circuit, residual magnetism or core movement
50 Hz to 20 KHz</td><td>Euro – Double Client Committee Transformer Diagnostic
USBR, June 2003</td></tr>
</table>

		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.			
	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
	(G) Rate of rise in Tan dalta	0.001 per year (max)			

			factors for different types/ makes are different. Hence no standard temperature error factors can be applied
	(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 - Operating air pressure switches - Operating oil pressure switches	Within ±0.1 Bar of set value. 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	 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)		IS- 1866

	IFT at 27^{0}C Tan delta at 90^{0}C Flash Point	1.0 Max 125^{0}C (Min)	
	(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 (B) Thermovision Scanning - Temp upto 15^{0}C (above ambient) - Temp above 15-50^{0}C (above	1.0 Ohm (Max) - Normal - Alert	IEEE/C37.010.1979

	ambient) - Temp above 50^0C (above ambient	- 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 (B) Specific Gravity	10 Micro-Ohm ±20% 1200 ± 5GM/L at 27^0C	ANSI/IEEE/450-1987
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	-15^0C	-36^0C	At the time of commissioning
		-7^0C		During O&M
		-5^0C		Critical
2	M&G		-39^0C	At the time of commissioning
			-32^0C	During O&M
3	CGL	-15^0C	-35^0C	At the time of commissioning
		-10^0C	-31^0C	During O&M
4	ABB	-15^0C	-35^0C	At the time of commissioning

		-5^0C	-26^0C	During O&M
5	NGEF	-15^0C	-36^0C	At the time of commissioning
		-7^0C	-29^0C	During O&M
		-5^0C	-27^0C	Critical
6	For all make	-15^0C	-35^0C	To be followed for substations having ambient temperature less than 0^0C

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

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