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MESSAGE FROM THE DESK OF CMD

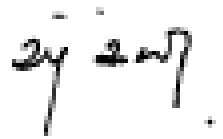
RVPN has been dedicated to provide the pathway for power in Rajasthan. It owns, builds, maintains and operates the high-voltage electric transmission system that helps to keep the lights on, businesses running and communities strong, RVPN is operating and maintaining about 34688 ckm of transmission lines all over Rajasthan with a total installed transformation capacity of about 69456 MVA distributed in about 523 sub-stations.

As operating and maintaining such a vast EHV Transmission network is a complex process, it is of utmost importance that a documented Operations and Maintenance Manual is prepared and published to ensure standardization of processes, safety of equipment and manpower.

There have been significant changes in the methods used for project management, quality audit, operation, maintenance and construction activities over the years and a genuine requirement of revised Operation and Maintenance Manual, tailored to today's needs was felt essential, which I am sure, is getting fulfilled by this edition .

I would like to commend the whole team for the painstaking efforts put in to bring out this detailed Operations and Maintenance Manual for Sub- Station and Transmission Lines. It incorporates the lessons learnt over years of experience and the best practices prevalent in leading STUs of the nation. Implementation of this Manual will benefit RVPN in terms of improved system availability and reliability, enhanced grid discipline, regulatory and commercial orientation. I hope that the Manual will be of immense use to various wings of RVPN.

I earnestly request your co-operation in following the Manual in letter and spirit and play a meaningful role in realizing our company's vision of providing reliable power transmission service to all stakeholders.



(Sanjay Malhotra)

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CHAPTER-1

1.1 GENERAL

Preamble

This manual has been prepared to help the GSS / Shift Incharge to perform their duties which primarily involve operation and maintenance of Grid Sub-Stations and the EHV Transmission lines associated with the GSS. The GSS / Shift incharge are expected to go through the manual and follow it. Based on their experience they can always send suggestions which can be incorporated in the manual from time to time.

The main duties and responsibilities of a shift engineer/ In-charge are explained below:

- 1.1.1 Whenever an engineer is posted for the first time in an EHV GSS duty, he should be given some time to go through the operation and maintenance instructions of the GSS specially safety instructions and knowledge of the safety equipments and other equipments like circuit breaker, transformer, DC system etc.

1.1.2 SHIFT INCHARGE:

The Shift In-charge should be trained by the In-charge of sub-station, so that they learn thoroughly about the above item and are in a position to prevent, as far as possible, any outages of supply, break down of plants and equipments, and to restore service quickly and correctly in the event of occurrence of such outages or break downs. The Shift Engineer should be trained in such a way that his conceptions are quite clear and that he may carryout operations calmly and quickly in sudden emergencies without loosing patience, i.e. he should be quite confident of the operation which he is going to initiate. The Executive Engineers, during their periodical inspections, should examine the shift in-charge to ensure that they are well trained and fit to take independent charge of the station. The Superintending Engineers and Executive Engineers should periodically conduct mock drills for firefighting and break down and also hold safety classes. All the workers and operators should also be conversant with the safety regulations to be followed in the handling and operation of plants and equipments in their charge.

- A) General important instructions for GSS / shift In-charge.
- i. First of all the in-charge has to get him well acquainted with the technical details of each and every equipment which he is supposed to operate and maintain.
 - a) The detailed electrical lay out and wiring of the Station, equipment and the operating facilities of the system to which the station can be connected.
 - b) The operation & working of the machinery and equipment in the station.
 - c) The limitation with regard to load, voltage etc., and the equipments under his charge.
 - d) Approved instructions for routine and emergency operations.
 - ii) The In-charge should thoroughly go through the safety instructions published by RVPN.

- iii) The In-charge should see that all the safety equipments/ items/ devices are available and are in proper working condition.
- iv) GSS In-charge should ensure that the relevant drawings and technical literature of all the equipments installed are readily available in the control room and are kept in a safe custody of maintenance Incharge. Proper record of these items should be kept.
- v) No book/ literature/drawing should be allowed to be taken away by any non concerned person outside the GSS. AT the same time a literature and drawing should be made available to the shift staff and maintenance staff so that they can study and update their knowledge.
- vi) The In-charge should see that following items are maintained in perfect working conditions:
 - a) Security system.
 - b) Fire fighting system
 - c) Communication system
 - d) Station auxiliary supply and its alternate / standby source which is a life line for the sub station.
 - e) DC system
 - f) Emergency light
- B) Items also to be attended:**
 - a) Regular cleaning of switchyard including grass and weeds etc.
 - b) Cleaning of trenches
 - c) To see that no water logging is there in the trenches and switchyard
 - d) To keep relay panels/ control panels and trenches inside the control room neat and clean from insects and reptiles which may damage the wiring.
 - e) Trench covers and walk ways in the switchyard should be in proper condition to avoid any accident due to open / broken trench covers and walk ways especially during emergency.
 - f) The entry point of control cables from switchyard to the control room should normally be kept sealed so that animals, reptiles etc. may not enter inside the control room through the cable trenches.
 - g) Switchyard lighting should be well maintained

- h) The Marshalling Kiosks, CT &PT junction boxes, Buchholz relay & OSR Relay should be covered with polythene sheet during rainy season.
- C) The GSS In-charge must see that the following items of basic human needs are made available and are maintained properly in the GSS for the shift staff. For this, concept of house keeping has to be honestly adopted in which facilities for drinking water, for preparing tea, coffee etc.,Ladies Wash room and proper sanitation should be available so that the shift staff can do their duties with sincerity.

Grass lawn, flower plants and flower pots should be maintained In front of the control room building.

1.1.3 DUTIES AND RESPONSIBILITIES OF SHIFT ENGINEERS DURING O&M PERIOD:

The shift Engineer in a sub station is responsible for:

- A) Operation of sub station equipment under their charge efficiently and economically in accordance with the power demand, statutory instructions regulation of voltage and frequency. They will be responsible for:
 - i) Maintenance of continuity of supply under both normal and abnormal conditions of operation.
 - ii) Correct logging of:
 - a) Loads, Voltage, Currents, Temperature, etc. of equipments.
 - b) Interruptions, breakdowns and other occurrences.
 - c) Operation carried out under normal and abnormal conditions.
 - iii) Reporting of break downs of equipments, failure of supply, accident and other serious occurrences immediately to the concerned Superior Officer who will report to his higher authorities with the position after leaving a guide line to the Shift Engineer in connection with the action to be taken at his level or after obtaining the instructions from his Supervisors. This all will base on the seriousness of the position.
 - iv) Issue of permits to work (PTW) on station equipments and lines emanating from the sub-station, after completely isolating, discharging and grounding the concerned equipments and line effectively.
 - v) Checking up of equipments &lines after return of permits and satisfying that the equipments &line are clear of men, materials and ground before energizing them or ready for charging.
 - vi) Testing of Battery circuits.
 - vii) Checking up the fuses of trip and alarm circuits.
 - viii) Safe custody of keys for the various switches, isolators, cubicles etc.

- ix) Maintaining the rubber gloves, operating rods, and discharge & grounding rods, etc. in good condition.
- x) Cleaning of the switch boards, telephones and panels.
- xi) Preparation of daily reports for submission to the Superior Officers.
- xii) Receipt and transmission of telephone messages correctly and without delay.

B) REPORTING OF BREAKDOWNS ETC.

- i. Breakdown of Extra High Voltage equipments (Rated 66 KV and above) should be reported as per grid code, to the LD Control Room, CE / Add. CE / Dy. CE, concerned M&P AEN / XEN over Phone / Mobile / e-mail depending upon the seriousness of the case (As decided by the SE) irrespective of its effect on supply. This report should be followed by detailed report.
- ii. Breakdown on H.V. equipment of voltage up to 33 kV and interruptions exceeding 15 minute should be reported immediately to the Superintending Engineer , Executive Engineer and those exceeding one hour to the Chief Engineer concerned, followed by a detailed report.
- iii. The detailed report should indicate the following:
 - a. The details of occurrences and operations in brief.
 - b. Action taken to restore supply and rectify defects or damages.
 - c. Duration of interruption and if duration is excessive, the reasons thereof.
 - d. The cause for the trouble and remedial measures, if any, proposed to be taken.
 - e. The areas affected indicating the name of feeders consisting of Relay flags/indications/fault record
- iv. Copies of the detailed reports should be sent to the Superintending Engineer concerned for study and suggestion of any remedial measures or for taking up the case with the supplier, if deemed proper.

1.2 INSTRUCTIONS FOR THE SAFE WORKING ON ELECTRICAL EQUIPMENTS AND PREVENTION OF ELECTRICAL HAZARDS:

- 1.2.1 The instructions for safe working on equipments detailed in the “Safety code” should be strictly followed by the staff engaged on the job of operation and maintenance to avoid any sort of mishap.

Hazard in respect of electrical equipments may be due to:

- a) Insulation failures.
- b) Fires.

Hazards in operation arise mainly due to:

- a) Non observance of the instructions regarding safety precautions to be taken while working on/ or near electrical installations and equipments and,
- b) Over confidence and carelessness on the part of the operating staff.

1.2.2 Some of the more important measures to be adopted to guard against hazards to equipment and in operation are detailed as under:

- a) **SAFETY PRECAUTIONS TO BE ENFORCED TO AVOID ACCIDENTS:**
 - i) Complete isolation, discharging and effective grounding of the concerned circuit/equipments before starting work.
 - ii) Use of rubber gloves/gantlets, while operating switches/links and during discharging and grounding.
 - iii) Obtaining proper permit to work before commencing work on any line/equipment. If the operator has to work himself, he should avail selfline clear recording all operations and then only work. Self line clears should be limited to emergencies only.
 - iv) Return of the “Permit to work” (by the same person who takes it) after ensuring that all equipments are free from men, material and ground.
 - v) Authorization of persons by name to work on particular clause of line/equipment. An approved list.
 - vi) Efficient Supervision by a qualified and responsible person while carrying out works to adjacent energized circuits.
 - vii) Use of “Safe for Work” boards on equipment declared safe for work.
 - viii) Locking and hanging “men–on-line” Boards on Switches controlling Circuits declared safe for work.
 - ix) During shut-down the working area should be marked with Red Ribbon / Rope. While working on elevated positions, safety belts and ropes should be used. If a ladder is being used, ensure that it does not fall or reach outside the working area marked with Red Ribbon / Rope.

Note: Every Communication line on the support carrying a length of high voltage line shall, for the purpose of working there, be deemed to be high voltage line.

- b) Hazards to operation staff: Non observance of the instructions regarding safety precautions by the operating staff may lead to:
 - i) Coming into contact with live parts of equipments not declared “safe for work”
 - ii) Fall from elevated position, resulting in injuries due to fall.

1.2.3 Since, a little (even a very little) carelessness/negligence on the part of the worker working on an electrical network may have to pay a very heavy cost resulting in a fatal accident; the instructions for safe working on electrical equipments/lines/systems and prevention of hazards should be strictly adhered to as the human life is quite precious and the Organization cannot afford losing its valuable employees. It is a must for the field Supervisors/Engineers to put their maximum possible efforts to over come such casualties. The fruitful results would be achieved, in case the staff sent on a particular job to perform is fully trained and meets with the satisfaction of the field Supervisor/Engineer to the effect that the work entrusted to a worker is within his ability/capability.

1.2.4 MITIGATION OF DAMAGES WHEN ELECTRICAL ACCIDENTS ACTUALLY OCCUR.

The following steps should be taken to mitigate damages to equipment or other works when electrical accident occurs.

- i All O&M Staff should know about First Aid.
- ii. Supply of cards containing instructions for artificial respiration in English and Hindi to all sub stations and insistence on their being hung at a conspicuous place as per the requirements of Indian Electricity Rules, 1956.

NOTE:

- i. P.T.W. on equipments should be issued or taken only by the persons who are directly in-charge of the lines or equipments concerned.
- ii. Helpers should work under the guidance of higher category officials only, except in isolated stations, where selected men may be authorized by name, when necessary, and considered quite justified by the Executive Engineer on recommendation of the Assistant Engineer.

1.3 SHUT DOWN PROCEDURE FOR WORKING ON LINE & EQUIPMENTS:

Before signing the PTW, the Shift-in-charge should himself see that the breaker is “off” position, all the three phases of isolators have been disconnected and the earth blade had been switched “on”, wherever necessary. Then only, the PTW should be signed.

Similarly, after clearance of PTW and before switching on the feeder, the Shift-in-charge should ensure that all earthing and earth blades have been removed and isolators have been put “on” and all the three phases of the isolators are making contacts fully.

1.3.1 Line Clear: Line clears are the permits issued to work on lines or equipment which are in service but disconnected from mains or supply and are considered as taken or the safe working provided if, all necessary safety precautions before carrying out the work are observed.

1.3.2 PERMIT TO WORK IS NECESSARY:

No employee shall climb up the supports of line or work on apparatus in service or in proximity or live conductors unless the in-charge of the work has obtained necessary permit to work in the specified form and specifically instructs him to proceed with the work.

1.3.3 ISSUING/TAKING OF PERMIT TO WORK:

Permit to work shall be taken only by the authorized persons and shall be issue by shifts engineers or other authorized persons in charge of the operations after obtaining the written requisition in proper form, specifically indicating the line/equipment etc, to be isolated on which the work is propose to be carried out. The permit taken should be returned by the same person and this procedure should be followed

1.3.4 When it is not possible to issue the written Permits, Permission of taking and return of PTW over phone should be limited to RVPN shift / maintenance in-charge of the directly connected GSS only. Code word should be used for issue and return of PTW. Duplicate copies of the permit should be sent as soon as possible for record at either end after duly cancelling the same.

1.3.5 Permit Books:

Permit books should be treated as very important. The sheets and books should serially numbered. These should kept by the Assistant Engineer concerned under his custody. Proper record of its issue & receipt must be maintained. It should not be detached or used for any other purposes.

1.3.6 No person shall work on any line and equipment unless it is made dead by cutting off the supply at the concerned switch or switches near the line or apparatus on main fuse if any, shall be removed and kept in custody and the switch locked or made imperative in the “Off” position.

1.3.7 Identification of circuits on which permits to work

Portions of the circuits on which “line clear” is issued should be clearly tagged and caution boards with the “Men on Line” displayed. Boards with the words “Men working Do not switch on” should be hung on switches (CBS, switches and control points etc.) controlling the position of the circuit on “line clear”.

1.3.8 Repairing of line equipment :

No repairs of any kind shall be carried out on line equipment except by the authorized persons complying with the precautions laid down for the work.

1.3.9 Whenever, works are to be carried out with “line clear” on certain equipment alive, one inch manila rope may be tied round the danger zone at a height of say about 3 feet from the ground and wooden boards painted with a white background with word “DANGER” written in post office red colour should be hung by means of ropes around the area of danger zone at convenient distance. This means that the area inside the rope is a danger zone, while area outside this enclosure is safe for working. This will prevent the men working in the safe zone for walking into the danger zone.

In addition to the above precautionary measures, before commencing work on a transformer or an outdoor C.B.s., a ladder should be put on the equipment with the top of the ladder firmly tied on the equipment. The men to work on the equipment should be instructed to reach to the equipment only along the ladder. This practice, if observed, would prevent men

climbing by mistake to the live equipment (not on “line clear”)as the men will naturally look forward for the ladder before reaching up to the equipment.

1.3.10 Carrying maintenance works :

While doing the periodical operation and maintenance works, all the safely and special precautions stipulated by manufacturer(s) for each of the electrical equipment and apparatus should be strictly adhered to.

1.3.11 Check for back feed: It should be ensured that there is no possibility of back feed of power supply to the zone under maintenance. Three earth rods shall be used on both sides of zone under maintenance.

1.3.12 The In-charge, on completion of the work and after assuring that the team working under his direction and control is in safe position, shall remove the protective grounds/earthings and report to the person who had issued the permit and thereafter return the permit duly cancelled.

1.3.13 Restoring service after completions of work :

Lines and equipment's, for which permits are issued, should not be charged unless the permits/line clears are returned duly cancelled. Special care should be taken to ensure that there are no men, tools &plants, earth on the circuits and conditions have been restored to normal. A written undertaking to this effect should be obtained along with the return of permit/line clear.

1.3.14 Procedure for working on lines/equipments :

A) OVERHEAD LINES: Before approaching/touching the conductors, every element of these shall be discharged by means of discharging rod and properly earthed. This shall be done at two points, on each side of the place where work is to be carried out. In addition, the conductors should be earthed on the poles (towers) on which the work is actually carried out.

In case, more lines are meeting or crossing at a pole/tower, which forms the site of work, all the lines crossing or ending at that pole/tower shall be effectively earthed, as stated above.

B) OUT-DOOR CIRCUIT BREAKERS: These shall be fully discharged at all their six main terminals and connected to earth.

The isolators on either side of the breaker shall be locked in “Off”/ “open” position and danger boards fixed to their handles.

C) OUT DOOR BUS-BAR ISOLATORS ETC.: It is important that the whole section of the switch gear of bus-bars, on which permit to work is required, is carefully isolated from all sources and grounded.

The limits of the “ dead section” must be specially pointed out to the receiver of P.T.W. and recorded in the permit. Generally, one side of the isolating switches, at the extreme limit, is likely to be alive. Such position should be specifically pointed out to the receiver of P.T.W. and never be forgotten to be recorded in the P.T.W.

Maintenance works which involve ascending above ground level may, in some cases, bring workmen within reduced clearance of conductors which are alive. This should

be clearly pointed out, so that the receiver of P.T.W. may put up temporary barrier(s) on the physical position of site of work.

D) A system of code-words may be adopted for permits issued and returned over phone.

1.4 PRECAUTIONS TO BE TAKEN BY THE ISSUER OF PERMIT:

It shall be the duty of the Shift Engineer to cut-off supply to the apparatus or line effectively (for which permit to work is to be issued), discharge the static charge and ground the equipment or line to earth before handing it over for carrying out the work.

First operation is to isolate the source of supply to the equipment or line (as per the standing operating instructions issued on the subject), thereafter, the general look-out and grounding instructions (detailed as under), are required to be followed for various equipments.

1.4.1 POWER TRANSFORMERS IN STEP DOWN AND STEP UP STATIONS:

The isolators provided on primary & secondary sides controlling the transformers shall be locked out in open ("Off") position and danger notices by providing wooden boards, written with "DO NOT CLOSE-MEN WORKING" should be hung securely at the isolators.

Where Isolators are controlled remotely, additional danger boards should be hung at essential switch handles. Control circuit fuses of control panel shall also be taken out and kept under the custody of issuer of permit.

The transformer shall be effectively discharged, both on the Primary & Secondary side terminals, by means of discharge grounding rods which shall be left in position till the permit is return.

1.4.2 LOGGING OF PERMIT ISSUES & RETURN:

The issuer of the permit shall carefully log the various operations performed by him in connection with the issue and return of the permit in the daily main station log-book, in the sequence in which the operations have been carried out.

The final issue (or return) of permit shall be logged in the log book, in "Red Ink".

When change of shift occurs during the pendency of a permit, the Shift In Charge going to be relieved shall specifically confirm to the reliever Shift In Charge coming on duty, as well, by logging the position in respect of the existence of the line clear/permit in handing over register. The Shift Engineer coming on duty shall also sign the logging in token of support that he has noticed the pendency of permit(s), thereby taking over further responsibility.

All the Stations and Shift Engineers with the issue/receipt of P.T.W. (s) shall adopt the similar logging procedure.

The person who took the permit should return, not necessarily to the same issuer, but to the Shift Engineer on-duty at the station from which the permit was obtained.

1.4.3 E.H.T. Over head line:

The circuits and conductors to be worked upon shall be made electrically “dead” by opening the controlling circuit breaker (or breakers) and opening the “live” links. In case of double circuit feeders, the switches on both ends of the line should be opened. Then the earth switch(es) at both ends, if provided, shall be closed, the line be earthed and thereafter the permit to work shall be issued.

In case the feeders are controlled by drawn out metal switchgears, the gears should be kept in racked out position.

In case where earthing switch is not provided for the circuits, the line conductor shall be discharged and effectively earthed by means of earthing rods.

Earth switch on 132 kV / 220 kV isolator should not be closed unless the line is isolated from all the supply ends. After the main isolator is opened at one end the interlock which stops the earth switch from closing is no longer there. Now the earth switch will get closed even if the line is still charged from the other end. This may cause serious accidents.

After an isolator is opened, ensure visually that all the three poles are in full open position. Its open position should be locked to avoid any accidental closing.

1.4.4 EHT Underground Cable Feeders:

In addition to the application of general procedure adoption for over head lines, the conductors should be discharged and earthed at a suitable point at cable boxes, before the cable is handed over for carrying-out the work.

1.5 Operation of Transformer

1.5.1 General:-

Transformer is a static device and does not consist of any moving parts except OLTC. Therefore, the possibility of any sort of damage by way of wear does not arise. Copper and Iron Core can last indefinitely. It is, however, subjected to many strains and stresses under operation such as occurrences like lightning surges, short circuits and over voltages; each of which leaves its effect on the winding structure. Yet being a sturdy equipment, a transformer does survive all these and gives a long life, if it is installed, operated and maintained intelligently.

The normal life of a transformer manufactured by a concern of repute can be taken to be about 30 years, provided it is well looked after. It can last much longer, say for about 50 years, if operated with care. Gross negligence in its proper operation and maintenance may cause damage prematurely and its life span reduced to even 10 years. There should be a vigilant check on temperature rise and humidity as the excessiveness of these is quite harmful and should never be allowed beyond permissible limits. At 75°C, the insulation lasts indefinitely. As per past experience, it has been estimated that every 8°C rise in temperature above the permissible limit halves the life of the insulation. Abnormal over loading can certainly char the insulation and damage the transformer badly in an hour or so. The overloading beyond the capacity can be a very costly affair and it should not be allowed in any case.

The life expectancy of transformers depends upon the rate of deterioration of the insulation. Generally the rate of deterioration of insulation at various operating temperatures doubles with each 8°C temperature rise above 100°C. The deterioration is also proportional to the time for any given temperature above 100°C.

Since the actual temperature is the sum of the ambient temperature and temperature rise, it is apparent that the ambient temperature very largely determines the load at which the transformer can be operated in service.

Therefore,

- i. The Shift-in-charge / engineer should ensure that the transformer shall not run at a load more than the rated load, except for an unavoidable shorter period.
- ii. The Shift-in-charge shall observe/notice the sound of the transformer. Any abnormality observed is to be reported to the Incharge (GSS)
- iii. The Shift-in-charge shall check that the fans are running, if the winding temperature of transformer is 60° C or above. In case the fans are not running then they shall be switched on manually and non-operation of auto system shall be reported to the Incharge (GSS) If the winding temperature is below 60° C , he shall check the operation of fans by switching them on manually and after checking, the Auto / Manual switch be returned to Auto position. Intimation of defective fans, if any, be reported to Incharge (GSS) for rectification.
- iv. The winding / oil temperature of the transformer shall not be allowed to be abnormal looking to the load and ambient temperature. Difference in the oil and winding temperature meters of the transformer shall not be more than 15° C. If it is more, it shall be reported to the Incharge (GSS).This may be either due to the defective temperature meters or due to some abnormality in the transformer.
- v. The oil level of the transformer, as shown by the magnetic oil gauge, should be corresponding to the oil temperature of the transformer. This can be checked from the temperature mark given on the Magnetic Oil Gauge. If this is not so, the matter be reported to Incharge (GSS) for immediate action.
- vi. The oil level in sight glass should be full in air cell type conservator. If not full, the matter should be reported to Incharge (GSS)
- vii. The Shift-in-charge, on assuming the charge of shift, shall check the breather for the following:-
 - a. The colour of silica gel should be blue. If not, it should be reported to the Incharge (GSS).
 - b. The oil level in the breather oil cup (at bottom) shall be up to required level. If not, he should arrange to get transformer oil filled up to the marked level.
- viii. The Shift-in-charge, on assuming charge of shift, shall check the relief vent pipe for the following:-

- a. No oil is visible in the sight glass, where provided on the relief vent pipe. If visible, the matter be reported to the Incharge (GSS) for immediate action.
- b. The diaphragm provided on the top of relief vent pipe is intact. If not, matter be reported to the Incharge (GSS) for immediate action.
- ix. In case the high oil temperature or high winding temperature alarm is received, it indicates that the oil temperature or winding temperature is approaching the set limits. Normally a difference of 5°C/ 10°C is kept between the setting for alarm and the setting for tripping. If either or both of these alarms are received, then the following shall be checked:-
 - a. That all the fans and oil pumps are running. Any fan and pumps which is not running should be switched on. If any fan & pump is defective, the load should be restricted to avoid unnecessary tripping of the transformer. Information of defective fan be intimated to the Incharge (GSS)
 - b. If the load on the transformer is more than the rated load, the load should immediately be restricted to rated load.
 - c. That the temperature should not be allowed to be high corresponding to the load on the transformer and the ambient temperature.

If it is high, then the load is to be restricted and intimation given to the Incharge (GSS) to analyze the cause of abnormal temperature rise. If the temperature rise is corresponding to the load and the ambient temperature, then the trend of the rise is to be observed. If the rate of rise is abnormal, then the load should be reduced to prevent tripping of transformer and Incharge (GSS) be informed.

If the rate of rise is not abnormal, the transformer can be run upto rated load and vigilant watch be kept on the temperature of the transformer.

- x. In case the over-flux alarm is received, the tap position of the transformer should immediately be lowered to a tap corresponding to the voltage of High Voltage side. If the voltage is above the rated voltage of tap No.2, then message should be given to the feeding 400 kV/220 kV/132 kV GSS and Load Dispatch Center to reduce the system / supply voltage. If the voltage is more than 6% higher than the rated voltage at tap No. 2, the transformer should be switched off and Load Dispatch Center intimated.
- xi. Transformer tripping on operation of buchholz relay or OLTC Surge Relay (OSR).
 - a. In the event of the operation of buchholz alarm, buchholz trip, OLTC buchholz surge trip etc., the transformer is to be isolated from the system immediately. Where the buchholz alarm is not connected to trip the HV/LV breaker, both the HV/LV breakers shall be tripped manually. Transformer shall be isolated from system by opening the required HV/LV isolators and intimation be given to the Incharge (GSS)
 - b. After isolating the transformer, the Shift-in-charge shall carry out the physical inspection of main buchholz relay and OLTC surge relay to observe the collection of gas in the relays or for indication of their operation and shall record his findings. In

case of NGEF make transformer, the operation of micro switch as provided on the OLTC top cover is to be confirmed as in such transformers, instead of gas operated relay, micro switch is provided for OLTC protection. Gas collected in relay is not to be released till the same is tested.

- c. The transformer is not to be energized till it is thoroughly tested and the possibility of internal damage to the transformer is ruled out.
- xii. In the event of operation of differential protection of the transformer, the transformer is to be isolated from the system immediately. The Shift-in-charge shall carry out the physical inspection of all the equipments (such as LAs of 400 kV/ 220 kV/ 132 kV/ 33 kV/ 11 kV, Cable Boxes and transformer) installed between 400 kV, 220 kV, 132 kV and 33 kV or 11 kV transformer CTs and also 400kV,220kV,132 kV, 33 kV or 11 kV CTs themselves. The buchholz relay of the transformer shall be checked for any collection of gas. The relief vent diaphragm is to be checked. The Incharge (GSS) is to be informed immediately. The transformer is not to be energized till reason of operation is diagnosed.
- xiii. In the event of the transformer tripping on HV side O/C and E/F only, the following is to be checked:-
 - a. If tripping is due to over current as a result of over loading, the transformer can be charged after shedding the excess load.
 - b. If it is due to non-tripping of the outgoing / incoming breaker due to mechanical defect, the transformer can be taken back into service either after taking the defective breaker out of service or rectifying the defective breaker. The report of the defective breaker is to be made to the Incharge (GSS)
 - c. It may also be due to the improper coordination of the protection. The matter, in this case, is to be reported to the Incharge (GSS) and by him to the Executive Engineer (Prot.) but the transformer can be charged if no abnormality is observed.
 - d. Before energization of the transformer, all the feeders / incoming breakers are to be tripped manually. In the event of the transformer tripping again on charging, it is to be isolated from the system and intimation given to the Incharge (GSS) The transformer is not to be re-energized till the same is thoroughly tested and the possibility of internal damage to transformer is ruled out.
- xiv. In the event of the transformer tripping on the oil / winding temperature trip, the following is to be investigated:-
 - a. If it is due to the over loading during the high ambient temperature, the transformer can be taken back into service after load shedding and cooling.
 - b. If it is due to defective fans, the transformer can be charged after cooling, and arrangements are made for repair of defective fans. Till fans are repaired, load is to be restricted so as not to cause the tripping of transformer on high winding temperature. Details of defective fans are to be reported to the Incharge (GSS) for immediate repairs / rectification.

- c. If it is due to defective winding temperature indicator, replacement should be arranged immediately. Till the replacement is received, the transformer is to be run on reduced load. The defective winding temperature meter is to be immediately reported to the Incharge (GSS) for replacement / rectification.
- d. If it is due to the closing of the radiator valves, then the transformer can be charged after opening the valves and cooling the transformer.
- e. However, if all other conditions are normal, then the temperature rise may be due to some abnormality in the transformer. In that case, the matter is to be reported to the Incharge (GSS) and the transformer is not to be energized till the same is thoroughly tested and the possibility of internal damage to the transformer is ruled out.
- xv. In the event of transformer tripping on over-flux protection, the system voltage should be observed. The tap position of the transformer should be brought down to tap No.2. The transformer is to be charged only if the voltage is not more than 6% above the rated voltage of tap No.2.

1.5.2 OVER LOADING OF TRANSFORMERS:

Transformers may be overloaded when any other unit fails, when a spare unit is not available and when load shading is not possible. The cooling system in such cases should be made effective by:

- i. Increasing the circulating oil supply, if the transformer is of the oil cooled type or,
- ii. Increasing the cooling air supply by blowers.

It is, however, important that overloads should not be allowed on transformers without an investigation of the various limitations involved. Among these limitations, which should be checked in the field, are (i) Oil expansion, (ii) Heating of bushing lead, (iii) Soldered connections, (iv) Tap changers, (v) Heating of the associated equipments such as cables, reactors, circuit breakers, disconnecting switches, current transformers, etc. Any one of these may constitute the practical limit in load carrying ability. Rapid and wide changes in operating temperature should be avoided, as much as possible since, these aggravate the changing effects carried by temperature expansion and contraction of the copper on the winding insulation.

- iii. When system voltage is low taps should be increased considering both HV and LV side currents of the transformer. In such conditions the HV side of the transformer may become overloaded even if the LV side load is within limits.

1.5.3 Parallel operation of transformers in sub station:

If transformers are to operate in parallel in a sub station, they must have:

- a. The same voltage ratio,
- b. The same polarity,
- c. The same percentage impedance (or impedance voltage) to its own base MVA rating,
- d. The same phase rotation i.e. vector diagram,

- e. The difference in KVA capacity should not exceed the ratio of 3:1.

1.6 Operation of D.C. System:

- 1.6.1 D.C. auxiliary Power supply: Being most reliable, the D.C. auxiliary power supply is provided for supplying power to protection relays, circuit breakers, indicating circuits, communication system, etc.

D.C. Auxiliary power supply is provided from storage batteries maintained continuously charged by some source of D.C. supply set or a charger.

The voltage of the D.C. auxiliary supply is maintained at 110/220 volt for all the time for effective protection & control of sub station equipment.

- 1.6.2 DC float voltage is to be maintained between 118 to 121 volts for 110 volt system while it is to be 236 to 242 volt for 220 volt system.

- 1.6.3 For conventional type of battery sets:

The Shift- In-charge shall, on assuming the charge, measure the gravity of three battery cells at random which shall be in the range of 1210 ± 5 (corrected to 27°C) for Standard make battery cells and 1200 ± 5 for EXIDE /EMCO make battery cells. If the measured gravity is outside this range, matter is to be reported to for the in -charge (GSS) for remedial action.

NOTE:-

Temperature correction is to be applied to the readings of the specific gravity for converting it to the reference temperature of 27°C .

For cell electrolyte temperature 1° Cabove 27°C , 0.7 is to be added to the reading of the hydrometer for correcting it to 27°C and for below 27°C , 0.7 is to be subtracted from the reading of the hydrometer for correcting it to 27°C . $[SG_{27} = SG_t + 0.7 (t-27)]$.

Examples:-

- a. Suppose the temperature of battery cell is 32°C and the hydrometer shows the reading of specific gravity as 1205, then the corrected specific gravity at 27°C will be $1205 + 0.7 \times (32-27) = 1208.5$.
- b. Suppose the temperature of battery cell is 22°C and the reading of hydrometer is 1205, then the corrected specific gravity at 27°C shall be $1205 + 0.7 \times (22-27) = 1201.5$.

- 1.6.4 For Maintenance Free VRLA Battery sets:

The Shift In-charge shall, on assuming the charge, measure the voltage of three cells at random. The voltage should be in the range of 2.16 to 2.20 volts corrected to 27°C . If not, matter is to be reported to In-charge of Sub-station for remedial action.

Note:-

The temperature correction factor for cell voltage is (-) 0.003V for 1° C rise of ambient temperature from 27° C, and (+) 0.003V for 1° C for temperature below 27° C.

Examples:-

- a. If the ambient temperature is 32° C and the cell voltage is 2.18 V, then the voltage at corrected temperature of 27° C will be $2.18 - 0.003 \times (32 - 27) = 2.165$ V.
- b. If the ambient temperature is 22° C and the cell voltage is 2.18V, then the voltage at corrected temperature of 27° C will be $2.18 + 0.003 (27 - 22) = 2.195$ V.
- c. During the boost charging of the battery set, the float circuit of the battery should also be 'ON' so that full battery voltage is available to the loads; otherwise the load will get voltage as appearing at the tapping point which is lower than the full voltage.
- d. Healthy trip circuit is to be checked for all panels after assuming the charge of the shift and after every closing of the breaker by pressing the designated push button. If the trip circuit is not healthy, the concerned breaker is to be disconnected from the system and intimation be given to the Incharge of Sub-station for attending defect immediately.
- e. In case of 400 kV/220 kV/132 kV/33 kV panels having trip circuit supervision relays, if the annunciation shows TC-1 and/or TC-II faulty or the flag of relays 195 CA, 195 CB, 195 CC, 295 CA, 295 CB, 295 CC are operated, the breaker is to be disconnected from the system as these indicate that the trip circuit is faulty and intimation be given to Incharge (GSS) for attending the defect immediately.
- f. The Shift-in-charge, on assuming the charge of the shift shall check the annunciation panel/facia by pressing the lamp test push button. If any of the windows do not light up, the matter is to be reported to the Incharge (GSS) immediately for rectification.
- g. If for any reason, there is total failure or non-availability of D.C. supply to the GSS, the breakers of all the transformers should be immediately tripped manually and intimation given to Load Dispatch Center as well as Controlling officers. The reasons of failure are to be investigated and D.C. supply restored. The transformer should be switched only after D.C. supply is restored and established.

1.7. Operation of Circuit Breakers:

1.7.1 The Shift-in-charge shall check the following in case of MOCB / ABCB /SF-6 breakers:-

- i. The oil level and oil leakage shall be checked in case of MOCB. If the level is less or leakage is there, it shall be reported to the Incharge (GSS).
- ii. The closing spring of 132 kV BHEL make HLD type breaker should be kept in charged condition when the breaker is in service so as to keep second trip coil also in operation.
- iii. The pressure of nitrogen in case of 132 kV HLR breaker of M/s BHEL, shall not be below 5.4 kg/ cm^2 as indicated by the pressure gauge on the top dome of each pole. If found low, Incharge (GSS) be informed.

iv. Air pressure in case of ABCB and SF-6 breakers shall be checked and if low, it shall be maintained at correct level. The normal operating pressure for some of the breakers is given below:-

a.	220 kV SF-6 ABB make	20.5 kg/cm ²
b.	220 kV SF-6 NGEF make	32 kg/cm ²
c.	220 KV ABCV DLF ABV make	31 kg/cm ²
d.	132 kV SF-6 HBB/ABB make	i) 20.5 kg/cm ² ii) 16.0 kg/cm ²
e.	132 kV DCF/DCvF ABCB, HBB make	16.0 kg/cm ²
f.	132 kV ABCB DLF HBB make	30.0 kg/cm ²
g.	132 kV ABCB Voltas make	17.0 kg/cm ²

Note:- The Shift-in-charge shall verify the correct operating pressure of the breaker installed at his grid sub station.

v. Air pressure in the central compressed air plant shall be checked. If low, it shall be maintained at the correct level. Some typical values are given below:-

132 kV HBB DCF/ DCvF ABCB 40	- 30/16 kg/cm ²
220 kV/132 kV HBB DCF/DLF ABCB 50	- 60/30 kg/cm ²
132 kV TMG ABCB 40	- 35/17 kg/cm ²

vi. Hydraulic oil pressure in case of hydraulic oil operated breakers, shall be checked and, if low, shall be maintained at the correct level. The normal operating pressures for some of the breakers are given below:-

400 kV BHEL make breaker	- 305 – 320 kg/cm ²
132 kV Jyoti make breaker	- 305 -- 336 kg/cm ²

vii. The Shift-in-charge, on assuming the charge of shift, shall get the moisture drained from the air bottles of the SF-6 breakers and compressed air plant installed in compressor room.

viii. If any leakage is observed in hydraulic / pneumatic system, it shall be reported to the Incharge (GSS) for immediate action.

ix. If the SF-6 low alarm is observed in Annunciator panel, it shall be immediately reported to the Incharge (GSS).

1.8 Capacitor operation.

1.8.1 The capacitor bank is to be kept in service only if the power factor is below 0.98 lagging and the voltage is also below the normal. If, with the capacitor bank ON, power factor is below 0.98 lagging and the voltage has a tendency to increase above the normal value with the transformer operating on higher taps, then the tap position should be reduced, so as to keep the voltage upto the normal value. This will enable the optimum use of the capacitors to improve power factor. If the power factor goes above 0.98 lagging or the voltage exceeds the

normal voltage even after reducing the tap position of the transformer, the capacitors bank is to be switched OFF.

- 1.8.2 As guidelines (for keeping capacitor bank in circuit and where power factor meters are not provided or are defective), the minimum values of load current are given below for keeping capacitor banks in the circuit:-

Voltage class	Min. load current	MVAR to be switched on
33 kV	60 Amps.	2.5/3.3/3.6 MVAR
33 kV	120 Amps.	5.0/6.6/7.2 MVAR
11 kV	150 Amps.	2/2.3 MVAR
11 kV	300 Amps.	4/4.6 MVAR

Whenever any capacitors are put into circuit, the load current on the transformer incoming panel should be observed. If the load current remains the same or is increased by switching on the capacitors, the capacitor should be immediately switched OFF. If the load current is reduced, then only the capacitor shall be kept in the circuit.

- 1.8.3 Wherever there are two or more separate capacitor banks of the same voltage rating on the same bus but controlled by separate breakers, then two or more of them cannot be switched on unless they are provided with series reactors. At sub stations, where two or more capacitor banks are installed and one of them is not provided with series reactor, then the capacitor bank without series reactor is to be switched ON first and the capacitor bank (s) with series reactor is (are) to be switched ON there after. To explain, the first capacitor bank to be switched ON can be without series reactor, but any second or later capacitor bank switched on should have series reactor.
- 1.8.4 The capacitors should not be switched on within 5 minutes of switching OFF so that by that time the capacitors are discharged to a safe value.

1.9 PRECAUTIONS TO BE TAKEN IN CONNECTION WITH THE POWER LINE CARRIER COMMUNICATION:

- a. Carrier line traps (wave traps) shall not be worked on while the conductor is energized or unearthed.
- b. Coupling capacitor stacks shall not be worked on while the conductor is energized or unearthed. After the capacitor has been disconnected from the line conductor, the top connection shall be discharged by momentary earthing with an earthing stick.
- c. No contact shall be made with the carrier lead-in-conduct except when using rubber gloves or with lead-in conductor earthed through the earthing switch.
- d. Carrier lead-in-conductor shall not be disconnected from the line tuning unit unless the lead-in-conductor is definitely earthed at the coupling capacitor with the earthing switch which is provided. Operating rod shall be used for operating the earth switch.

Whenever, it is necessary for an employee to work along on the carrier transmitter receives sets, arrangements shall be made in such a way that the operator may check

with each other every fifteen minutes by means of telephonic contact, when visual contact may not be possible.

1.10 Operational Instructions:

1.10.1 The Shift-in-charge, on assuming the charge of the shift, shall take a round of the yard and carry out visual inspection of the clamps and connectors for any hot spot / sparking. If any hot spot / sparking is observed, it shall be reported to the Incharge (GSS) for immediate rectification.

1.10.2 Supply failure (radial supply):

- i In the event of failure of supply at sub station having single source of supply, the breaker controlling the transformers shall be tripped. All LV side breakers shall also be tripped. The Tap position of the transformer shall be brought to Tap No.2 manually.
- ii After restoration of supply, the transformer is to be charged only if the voltage does not exceed 6% of the rated voltage of Tap No.2. If the voltages are within the permissible limits, the transformer can be charged and load can be taken gradually by switching ON the feeders, one by one. The Tap position can then be changed corresponding to the required LV side voltages.

1.10.3 Supply failure (multiple supply):

- i In case of supply failure at sub stations having alternate source of supply, the breaker and isolator of the source which had failed shall be opened and HV transformer breaker shall be tripped and alternate source taken on bus. The tap position of the transformer shall be brought corresponding to the voltage of the alternate source of supply and then the transformer can be charged after taking permission from Load Dispatch.
- ii while restoring the system to the normal / original position, the above procedure is to be followed principally.

1.10.4 Voltage control:

- i Keep a check on the incoming voltage and keep the transformer tap corresponding to the tap on rating plate. To avoid frequent tap change of the transformer, the voltage on LV side is to be maintained between prescribed limits.
- ii In the event of high voltages, which are likely to be experienced in off load season (particularly during the night hours), 33 kV and 11 kV voltages may be allowed upto 35 kV and 11.5 kV respectively after bringing the transformer to the tap No. 1. If the voltages exceed the above values, then the transformer is to be disconnected from the system.
- iii In operating the Tap Changer, extreme Tap Positions are to be avoided, However, if required, the transformer can be brought to Tap No.1 or the highest tap i.e. 15/17, as

the case may be, but the operation of the Tap Changer to the lowest and the highest Tap shall be done manually even if the Tap Changer is operating electrically, to avoid the possibility of the damage due to failure of inter-locking system. Similarly, the tap position from 1 to 2 and from 15/17 to 14/16 shall be also changed manually.

- iv In the event of experience of fault on any feeder, if the concerned breaker fails to trip and, instead, the incoming breaker or 132 KV breakers clear the fault then, that particular feeder breaker is not to be charged till the defect is rectified and clearance given by the In-charge (GSS).
- v The Shift-in-charge should also keep a watch on the voltage and the load during the shift and take remedial measures in the event of any abnormal increase/decrease in the voltage and any abnormal increase/ decrease in the load.
- vi The Shift-in-charge shall check that all the energy meters are in running condition and the PT supply in all the three phases is available by operating the selector switch.
- vii For the panel having VT selection relays, the shift engineer shall check that required selection relays are energized.
- viii In the event of tripping of 220 kV/132 kV/33/11 kV breaker provided on the feeder on distance/back up protection, the feeder can be switched ON after 3 minutes. However, if on energisation, the breaker again trips on distance/back up protection, the feeder may be declared faulty and shall be re-energized after taking clearance from concerned In-charge of the line.
- ix whenever any annunciation is received, it shall be accepted but before resetting it, the necessary recording shall be done in the log sheet.
- x Isolator of any circuit should not be operated if the circuit breaker of that circuit is closed.
- xi Outage of transformer.
 - a. Whenever any transformer is taken out of service for investigations/checking due to operation of protection, information shall be given to the Load Dispatch (Heerapura), concerned Executive Engineer/ Superintending Engineer (TCC) and concerned O&M Officer.
 - b. In the event of outage of a transformer, the 33/11 KV back feed supply shall be taken on the sub station bus for station auxiliary and also distributed further in consultation with O&M officers, if required.

1.11 Essential Testing Instrument Plants, Tools and Fire Fighting Equipment required for Sub Station Operation and Maintenance

Section – A General Purpose Testing Instrument

S. No.	Name of Instruments & Specifications	Functions	400 kV GSS	220 kV GSS	132 kV GSS
1	<u>MEGGER</u>	Insulation testing at	1 No.	1 No.	1 No

	kV (1.0, 2.0, 3.0, 4.0, 5.0 kV) Hand cranked generator and with Main Power Supply 1 \square 50 Hz AC.	voltage between 1 kV and 5 kV			
2	<u>MEGGER</u> 2.5 kV – 5 kV Hand cranked generator	Insulation testing at voltage between 2.5/5 kV	1No	1 No	1 No.
3	<u>CLAMP ON TESTERS</u> current range 0.100- mA to -300 mA-300 A Power Supply. Dry cells	AC current measurement	1 No.	1 No.	1 No.
4	<u>DIGITAL MICRO OHM METER</u>	For measuring CB/ isolator contact resistance	1 No.	1 No. per circle	
5	<u>EARTH TESTER</u> Earth resistance ranges Ω - 1999 Ω Accuracy : \pm 2% Power supply – dry cells	For earth resistance and earth resistivity measurement	1 No.	1 No.	1 No. per const. division
6	<u>DIGITAL MULTIMETER</u> (Hand held) DC voltage – 0 to 200 mV / 2V / 20 V/ 200V / 1000 V AC voltage – 0 to 200 mV / 2V/ 20V/ 200V/ 250 V/500 V AC/DC currents 0 to 2 mA/ 20mA/ 200mA/2A/10A Resistance – 0 to 2 M Ω (Multiple range) Power source- battery	For measurement of AC/DC parameters , resistance etc.	2 No.	2 No.	2 No.
7	<u>ANALOG MULTIMETERS</u> Voltage DC 100mV to 1000 V- Current DC 50 μ A to 10A Voltage AC 1V to 1000 V Current AC 10 mA- 10A Resistance ranges 0 Ω to 20 M Ω - multiple ranges	For measurement of AC/DC parameters , resistance etc.	1 No.	1 No.	1 No
8	<u>TRANSFORMER WINDING RESISTANCE METER</u>	Measurement of trf / reactor winding resistance	1 No.		
9	<u>SF-6 GAS DETECTOR</u> Suitable to detect SF-6 gas leakage from breakers Battery operated.	To detect leakage of SF-6 gas Where SF-6 breaker installed	1 No.	1 No.	1 No. for each const. division

Section B - Special Testing Instruments for sub stations

S.No.	Name of Instruments & Specifications	Functions	400 kV GSS	220 kV GSS	132 kV GSS
1	<u>BDV TEST KIT</u> Power supply- 1 \square , 50 Hz AC output voltage – 0 to 60 kW Electrode Gauge – 2.5 mm and 4.0	Testing of dielectric strength of oil	-	1 No. where MOCB's are installed	

	mm			
2	<u>DEW POINT METER</u>	To measure Dew point of SF-6 gas	1 No.	1 No. for each circle
3	<u>LEAKAGE CURRENT MONITOR</u> Suitable for monitoring LA	For testing LA's	1 No.	1 No.
4	<u>C AND TAN DELTA MEASURINGKIT</u> (automatic) input – 230 V AC at 50 Hz.	Testing of loss angle and capacitance of bushing and winding.	1 No.	1 No.
5	<u>CIRCUIT BREAKER OPERATIONANALYZER WITH DYNAMICCONTACT RESITANCEMEASUREMENT</u> 10 Khz.	To measure CB timings and DCRM	1 No.	1 No.
6	<u>THERMOVISION CAMERA</u>	To scan hot spots in switchyard/lines.	1 No.	1 No.

Section C Plants and tools for substations.

S.No.	Name of Instruments & Specifications	Functions	400 kV	220 kV	132 kV
1	<u>OIL SAMPLING BOTTLES</u> 1 litre Capacity 300 ml. capacity	For testing oil samples from transformer CTs/CVTs	Nos. 2 Nos. per transformer	Nos. 2 Nos. per transformer	Nos. 2 Nos.
2	<u>SF-6 GAS EVACUATION PLANT WITH STORAGE CAPACITY</u>	For evacuation of SF-6 from circuit breakers	1 No.	1 No. For each Zone	
3	<u>OIL FILTER MACHINE</u> (High vacuum) Capacity 6000 ltr./ hour With transformer evacuation system.	To filter transformer oil and put transformer under vacuum	1 No.	1 No. For each circle	
4	<u>FILTER MACHINE</u> 1000 ltr. / hour capacity high vacuum	To filter the oil of OCB , MOCB and OLTC	1 No.	1 No. where MOCB's are installed and one for each circle	
5	<u>WALKIE TALKIE SETS</u>	For communication during maintenance	1 set	1 set for big size of GSS	
6	<u>TWO WAY PULLEY / THREWAY</u> pulley (brass) 3 ton capacity with ½", ¾", 1", rope	For maintenance of equipment	1 No.	1 No.	-
7.	<u>EARTHING RODS OF FIBRE GLASS WITH AUTOMATIC CLAMPS</u>	For earthing of voltage	6 No.	6 No.	6 No.
8	<u>HAND GLOVES</u>	Operation of earthing switch and	6 No.	6 No.	3 No.

		isolators			
9	<u>SAFETY BELT</u>	To work on height	6 No.	4 No.	4 No.
10	<u>FIRST AID BOX WITH MEDICINE</u>		2 No.	1 No.	1 No.
11	<u>WOODEN LADDER</u>	To work on height	2 No.	2 No.	2 No.
12	<u>ARTIFICIAL RESPIRATION SYSTEM WITH CHART</u>		1 No.	1 No.	1 No.
13	<u>FIRE FIGHTING INSTRUCTION CHART</u>		1 No.	1 No.	1 No.

Remarks:

- a) The above quantities are required to be maintained at the prescribed levels.
- b) T&P / equipment which become defective are to be got repaired and replaced, if not repairable.
- c) T&P/ equipment which got worn out due to long use are to be replenished from time to time so that prescribed quantity is available.

CHAPTER-2

2.1 GENERAL:

A rigid system of inspection & maintenance will ensure long life, trouble-free service and low maintenance cost. It is a well known fact that the slackness in maintenance of equipment may not only result in the reduced life-span, it may rather, some-times, become a cause of complete failure. The maintenance of equipment is of great importance and has a valued role in satisfactory performance and long survival of the equipment. Maintenance should consist of regular inspection, testing and reconditioning, wherever necessary.

2.1.1 TRANSFORMER MAINTENANCE:

The principal object of maintenance is to maintain the insulation in good condition. Moisture, dirt and excessive heat in contact with oxygen, are the main causes of insulation-deterioration and avoidance of these will, in general, keep the insulation in good condition. The limiting factor is the aging of the insulation and decline in the quality of the insulation during the aging process due to Chemical and Physical effects. The decay of the insulation follows the chemical reaction rate and in case of oil immersed transformers, if the sustained operating temperature exceeds the normal operating temperature of 75°C by about 8°C to 10°C, there will be a shortening of the life of the transformer.

2.1.2 FACTORS AFFECTING THE LIFE OF TRANSFORMER:

The following are the factors, which affect the life of transformer:-

- i. Moisture
- ii. Oxygen
- iii. Solid impurities
- iv. Varnishes
- v. Slackness of windings.

i. Effect of Moisture: Transformer oil readily absorbs moisture from air. The effect of water in the oil is to decrease the dielectric strength of the oil as well as of the insulating paper which absorbs and stores the moisture due to higher affinity of water to paper. All possible preventive steps should, therefore, be taken to guard against moisture-penetration to the inside of the transformers. This will include blocking of all openings for free access of air in storage and frequent reactivation of breathers in service.

ii. Effect of Oxygen: Oxygen may be present in the transformer due to air remaining in oil, air pockets trapped in the winding etc. Oxygen reacts on the cellulose of the insulation and the decomposed products of the cellulose lead to the formation of organic acids soluble in oil & sludge which blocks the free circulation of oil. The adverse effect of oxygen, which may be aggravated by catalytic action between hot oil and bare copper, increases the operating temperature rapidly. To take out the oxygen from the transformer, the oil should be filled under vacuum.

- iii. **Effect of solid impurities:** The dielectric strength of the oil diminishes appreciably by minute quantities of solid impurities present in the oil. New transformers may contain particles of insulating materials and other solid impurities. It is, therefore, a good practice to filter the oil after it has been in service for a short time, especially for the units of higher voltage class.
- iv. **Effect of varnishes:** Some varnishes, particularly of the oxidizing type, enter readily and in reaction with transformer oil precipitate sludge on the windings. Synthetic varnishes, having acid inhibiting properties, generally delay the natural formation of acid and sludge in the oil. This fact should be borne in mind by the Maintenance Engineer when rewinding and replacing the coils during repairs of transformers.
- v. **Effect of slackness of windings:** Although modern transformers have pre-shrunk coils, natural setting of coils may take place during the first few months' operation. Slackness of windings may cause a failure due to repeated movements of coils which may wear the conductor insulation at some places and lead to an inter-turn failure. The coils condition or momentary short circuit may cause electric and magnetic unbalance and produce even greater displacement. It is, therefore, good practice to lift the core and windings of a transformer and fill up any slackness which may have developed by tightening tie rods, pressure screws (where provided for this purpose) at the first inspection. In all cases, the instructions given by the manufacturer should be followed closely.

2.1.3 INSPECTION:

For the purpose of maintenance of transformer, it is necessary to carry-out inspection of transformer. The inspection can be divided into the following manner:-

- i. External Inspection
- ii. Internal Inspection

i. External Inspection: An external inspection of a transformer is an inspection of all parts on/ or related to a transformer that can be examined with the transformer taken out of service but without opening the tank or lowering the oil. For example, the oil can be sampled and tested. Megger tests, ratio tests, can be carried out. Bushings, breather gaskets, oil level, diaphragm, tank foundation, conservator, radiators, buchholz relay and all visible/accessible auxiliaries can be thoroughly examined.

ii. Internal Inspection: An internal inspection constitutes a careful examination of all parts inside the transformer tank, with the oil level lowered sufficiently to expose the top of the transformer. In such an inspection, radiators can be examined for sludge. The conditions of coils and insulation, the lower ends of bushings and bushing current transformers, and the position of thermometer can also be examined. A thorough inspection will also reveal any missing parts, such as nuts and bolts, small particles of copper or burnt and broken tape. Oil tests, megger and ratio tests should also be carried out as an external inspection.

2.2 EXTERNAL INSPECTION OF TRANSFORMER:

GENERAL MAINTENANCE

2.2.1 Dirt & Dust:

The external transformer surfaces shall be inspected regularly and, if required, shall be cleaned from dust, insects, leaves and other airborne dirt.

2.2.2 Rust damages, Touch up painting:

A regular inspection of the surface treatment of the transformer should be carried out. Possible rust damages are removed and the surface treatment restored to original state by means of the primer and finish paint of the transformer to minimize the risk of corrosion and its subsequent spreading. These checks also include looking for signs of oil on gasket areas and welded areas containing oil. The touch-up paint, as and when required, as per site condition and re-painting is recommended once in a five years as per one of the manufacturers of the transformer.

2.2.3 Checks to be carried out

- Check of signs of corrosion.
- Check for any signs of mechanical damage.
- Check all joints for sign of leakage.
- Check oil levels.
- Check that surrounding areas are clean and tidy.

2.2.4 Check Procedures

i. Check for Signs of corrosion

Carry out a visual inspection on all external surfaces of the transformer and its associated equipment. If damaged areas are seen, these must be treated immediately to prevent the spread of corrosion. The repair procedure is detailed below:

Using a wire brush, remove all loose flakes of paint, ensuring that the surrounding areas are given attention. Using the abrasive paper, rub the damaged areas so that all contours to the edges are smooth and that no steps in the paint work are obvious. Prominent dent marks and pits on external surfaces are to be filled up with knifing putty. When putty is dry, smoothen it with emery paper and clean with clean rag. Clean the local area with a suitable solvent like methyl alcohol that contains no salts.

Depending upon the extent of the damage, i.e. depth, apply the necessary number of coats of paint to build up the overall thickness (min. 80 microns). The minimum number being two: one undercoat and one top coat after two coats of primer. Please note that paints should be applied so that the layers feather-in with each other and there should not be any steps in layers. Spray painting (50-60 PSI) for radiators should only be applied.

Allow each coat of paint to dry before over coating with the next coat. This procedure must only be carried out either in warm, dry weather or while under cover with clean plastic sheeting.

Two coats of finishing paint should be applied as per specification which is generally Light Grey.

ii. Check for any signs of mechanical damage

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

iii. Check all joints for signs of leakage

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

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

iv. Check oil levels

It is good practice to check all separate oil levels associated with the equipment. This will incorporate the expansion vessel and all oil filled bushings. This check must be carried out with the equipment at ambient temperature. Also the oil in the oil seal should be maintained.

v. Check that surrounding areas are clean and tidy

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

vi. Oil Leakage and moisture absorption:

Possible leakage: 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 as indicated below:

- Tank, Cover, Conservator: about a month after taking into service, when required.
- Bushings, Turret: about a month after taking into service, when required.

The torque on the bolt should be as per manufacturer's recommendations. If no clear cut guidelines are recommended, the following may be used which is valid for joints between details of steel, as per IS: 1367:-

The maximum recommended torque has been calculated on the basis of the material properties and 70% of the proof stress has been considered as limit value for tightening torque.

The breather contains an oil-cup that prevents spontaneous air circulation/filtration of debris. This cup should remain filled with oil to the specified.

vii.. Marshalling Cubicle and Kiosk Check

The transformer and associated equipment need not be put out of service, isolated or earthed while carrying out these checks. All results must be recorded in formats for comparison during future checks.

Checks to be carried out

- Condition of paint work.
- Operation of door handles.
- Operation of doors and hinges.
- Condition of door seal.
- Door switches working.
- Lights working.
- Heater working.
- Thermostats working.
- Operation of heating and lighting switches.
- Mounting of equipment secure.
- Manual operation of switches satisfactory.
- Checking of tightness of cable terminations.
- Checking of operation of contactors (isolating the trip signals, if any).
- HRC fuses and their rating.
- Operation of Local alarm Annunciator by pushing push buttons provided for lamp test, acknowledge, reset system test, mute etc. to cover all system function.
- Source change over test check by putting off power sources alternatively.
- Check for plugs for dummy holes and replacement, if found missing.

2.3 TRANSFORMER AUXILIARIES

2.3.1 COOLING SYSTEM

The transformer and associated equipment must be put out of service, isolated, earthed and obtain a 'Permit to Work' from the Shift Engineer while checking the operation of the fans, pumps, radiators and coolers. The cooling surfaces shall be inspected regularly and cleaned from dust, insects, leaves or other airborne dirt, if required. This is especially important in case of fan cooling. The cleaning is suitably carried out by means of water flushing at high pressure. Precautions should be taken to cover the fan motor so that water may not go inside. Alternatively, cleaning can be done with cleaning solution and cloth. Normally, no measures are necessary for keeping the internal cooling surfaces clean as long as the oil is in good condition. If, however, sludge formation has set, then the sludge may get deposited on horizontal surfaces in radiators and coolers. In such a case, the radiators and coolers should

be flushed internally with clean oil in connection with oil exchange. If the sludge does not loosen, we can firstly flush with petrol etc. and then with oil. This activity is to be carried out in consultation with the manufacturer. The cooler bank should be inspected regularly. All coolers can be cleaned by pulling out the tube packets and thus making them accessible for cleaning. The fan-motors are provided with permanent – lubricated bearings and double sealing rings. The motor bearings are axially clamped with spring washers. If the sound level of the fan increases, re-tighten all mounting supports.

2.3.2 Cooling System-Fans-Controls

- i. **Fan Controls** are designed to operate both manually and automatically. The automatic function is basically related to load and energisation or both.
- ii. **Manual Control:** The fan control should be turned “ON” for a brief period to ensure that each stage has sufficient voltage to operate. Fan operation should be observed. Oil pumps should be checked by observing their flow gauges. In case of any malfunctions, manufacturer’s recommendations should be referred to.
- iii. **Temperature Control:** The temperature bulb should be removed from its pocket/well on the side/top of transformer. The MASTER CONTROL should be set to the automatic position. Using a temperature controlled calibration instrument, the temperature of the bulb should be slowly raised and observed for proper calibration/operation.
- iv. **Load Control:** The secondary current of the controlling CT should be checked to ensure that it is operating properly. After shorting out the secondary of CT (if transformer is energized), the secondary lead should be removed from the control circuit, current should then be injected in to the control circuit and the level of this current is varied in order to observe proper operation.

2.3.3 Cooling System-Fans-Visual Inspection: Visual inspection should be done without taking shut down of transformer to ensure that fans are operating at their design speed, airways are not blocked and guards & blades are not damaged.

- Visual check for contamination of motor and fan blades.
- Check for build up of moisture in the motor.
- Check bearing lubrication.
- Check for correct rotation.
- Check for unusual noise.
- Check for corroding parts.

2.3.4 Cooling Fans- Rotation: The rotation of the fan blades should be observed to ensure that the air flow is in the correct direction for the type of device involved. The observations may be facilitated, if it is performed at a lower than normal speed e.g. during either start up or immediately after switching off. Corrections to rotation should be made as indicated by inspection.

2.3.5 Improper Air Flow: Improper air flow can reduce cooling system efficiency, cause overheating and result in damage to electrical equipment. All fans, which are not running at

design speed, should be replaced after stopping the fans. Any obstructions to air flow should be removed and any damaged fan guards or blades should be replaced or repaired.

2.3.6 Check for build-up of Moisture: Drain holes in the motor are provided at the lowest part of the motor and are fitted with plugs on the totally enclosed motors (wherever applicable). These plugs should be removed to allow any moisture to drain away and then put back in place.

2.3.7 Check bearing lubrication: Regular greasing of the bearings should be carried out and, as a general guide, one or two shots from a grease gun should be sufficient at intervals of 1,000 running hours. It will only be necessary to maintain the grease in the bearings.

Note: An increase in running temperature, after greasing, is to be expected. However, this will return to normal after a short period. If too much grease is applied and the bearing is overfilled, the temperature of the bearing will rise considerably due to 'churning'. This may lead to complete bearing failure.

It is, therefore, recommended that, at least, every two years the bearings and housings be flushed out in white spirit and inspected for wear. Worn parts should be replaced, where necessary, and repacked with grease.

When a motor remains idle for long period, the grease should be inspected regularly. Checking be done for hardening or separation and, if possible, by rotating the shaft through 90 degree at intervals.

2.3.8 Precautions: Different grades (or makes) of grease MUST not be mixed. The bearings, housings and grease pipes must be thoroughly cleaned of the old grease and correctly packed with new, if a change of grease is required.

2.3.9 Replacement of bearings (to be carried out if unusual noise can be heard): Cleanliness is of vital importance when handling ball bearings and their lubrication. Special precautions are necessary for the removal of bearings especially when they have been shrunk on to the shaft. Refer manufacturer's instructions for replacement of bearings.

2.3.10 Visual Inspection: Carry out a visual inspection on the motor casing and fan guards for early signs of corrosion. Any sign must be treated straight away to prevent further rusting.

2.3.11 Cooling system – Pumps – Visual Checks

- The transformer and associated equipment need not be put out of service or isolated while carrying out visual checks on the pumps.
- Obtain a 'Permit to Work' from the Shift Engineer.
- Obtain keys to the transformer compound and marshalling kiosk.
- All results must be recorded in a log for comparison during future tests in service.

2.3.12 Checks to be carried out:

- Check for correct rotation.
- Check for unusual noises/abnormal vibration- replacement of rotor & bearings.
- Check for corroded parts.
- Check for electrical problems.

2.4 CHECK PROCEDURE

2.4.1 Check for correct rotation: Provide a supply to the pump and check it for correct rotation. The pump has a direction and flow indicator which is fitted on the top of the pump.

2.4.2 Check for unusual noises – replacement of rotor bearings:

- While the pump is running, check the motor and bearings for unusual noises.
- All unusual noises must be investigated further by removing the pump for visual inspection.
- After removing pump from the system, the end play of shaft should be measured. The manufacturer's guide should be consulted to determine if excessive bearing wear exists as indicated by amount of shaft end play observed. Any indicative of wear on the impeller and impeller housing is indicative to excessive thrust bearing wear.
- **Precautions:** Care must be taken to ensure that damage is not caused either to the windings or the impeller during removal and assembly. Removal of a cooling pump requires a very precise knowledge of the arrangements of the cooling system. Equipment and cooling pump should be de-energised first. Cooling system surrounding pump should be effectively isolated from the remainder of the equipment's cooling system. Isolating valves should be closed and the system drained before the pump is removed. It is recommended that blanking plates be installed after pump is removed. Pump should never be run without complete immersion in insulating oil.

2.4.3 Check for corroded parts: Carry out a visual inspection on the motor casing for any signs of corrosion. This should not occur as the casing is cast iron construction which is painted. However, any sign of corrosion must be treated urgently to prevent further spread.

2.4.4 Check for Electrical Problems: The current flowing in each electrical terminal of each pump motor should be accurately measured in running condition of the pump. Any significant imbalance of current between the terminals greater than 15-20% is indicative of the problem with the pump motor. Differences between current ranges for like pumps on the same electrical equipment should be compared. Any significant difference may be indicative of a restriction in the area of the cooling system, where the pump with the higher current drain is located, or a problem with in the pump itself.

2.4.5 Check for Cooling Pump – Oil Flow Gauge: Oil flow gauge shows only whether there is oil flowing through the pump or not and it is not indicative of velocity of the oil or condition of the pump.

After making sure that oil cooling pumps are "ON", flow gauges should be observed for indication of flow of oil. If pump is "ON" and no flow is indicated, sending unit may be defective. If pump is turned "OFF" and flow gauge continues to indicate flow, then gauge is probably stuck in flow position and sending unit or the entire gauge needs to be replaced. It is normal for gauge to continue to indicate flow for a brief period before indicating off (no flow), following the turning off of a pump. This is due to conservation of momentum in respect of oil.

Precaution: Lack of flow from oil cooling pumps during operation may be indicative of imminent failure. Necessary corrective action should be taken immediately.

2.5 On Load Tap Changers (OLTC): OLTC are designed to be operated while the transformer is energised. OLTC may be located in either the high voltage winding or the low voltage winding, depending on the requirement of the user, and the cost of effectiveness of the application and tap changer availability. OLTC, being a current interrupting device, requires periodic inspection and maintenance. The frequency of inspections is based on the time in service, range of use and number of operations.

2.5.1 DEFINITIONS:

- i. ON LOAD TAP CHANGER (OLTC)**
A device for changing the tapping connections of a winding, suitable for operation, while the transformer is energised or on load. Generally, it consists of a diverter switch (with transition impedance) and a tap selector (which can be with or without a change-over selector).The whole being operated by the transition impedance. In some forms of tap-changers, the functions of the diverter switch and the tap changer are combined in a selector switch.
- ii. DIVERTER SWITCH:** A switching device used in conjunction with a tap selector to carry, make and break currents in circuits which have already been selected. A diverter switch of spring operated type includes an independent means of storing energy for their operation.
- iii. TAP SELECTOR:** A device designed to carry, but not to make or break, current used in conjunction with a diverter switch to select tapping connections.
- iv. SELECTOR SWITCH:** A switching device capable of making, carrying and breaking current, combining the duties of a tap selector and a diverter switch.
- v. CHANGE-OVER SELECTOR:** A device designed to carry, but not to make or break, current used in conjunction with a tap selector or selector switch to enable its contacts and the connected tappings to be used more than once when moving from one extreme position to the other.
- vi. TRANSITION RESISTANCE:** A resistor consisting of one or more units bridging the tapping next to be used for the purpose of transferring load from one tapping to the other without interruptions or appreciable change in the load current and at the same time limiting the circulating current for the period that both tappings are used.
- vii. DRIVING MECHANISM:** The means by which the drive to the tap changer is actuated.
- viii. MOTOR-DRIVE MECHANISM:** A driving mechanism as defined above which incorporates an electric motor and control circuit.
- ix. STEP-BY-STEP CONTROL:** Electrical and mechanical devices stopping the motor drive mechanism after completion of a tap change, independently of the operating sequence of the control switch.
- x. TAP POSITION INDICATOR:** An electrical and / or mechanical device for indicating the tap position of the tap changer.

- xi. TAP CHANGE IN PROGRESS INDICATION:** A device indicating that the motor drive mechanism is running.
- xii. LIMIT SWITCHES:** Electro-mechanical devices preventing operation of the tap changer beyond either end position, but allowing operation towards the opposite direction.
- xiii. OPERATION COUNTER:** A device indicating the number of tap changes accomplished.
- xiv. MANUAL OPERATION OF MOTOR DRIVE MECHANISM:** Operation of the tap changer manually by a mechanical device, blocking at the same time operation by the electric motor.

2.5.2 TEST SCHEDULE AND FREQUENCY:

Operation checks: Every year.

Inspection & Maintenance: Once in 3 years or 50,000 operations, whichever is earlier, as per Preventive Maintenance Schedule.

- 2.5.3 ISOLATION REQUIRED:** The maintenance is carried out on full shut down of the transformer where both the (HV and LV) side breakers are OPEN, isolators are OPEN and necessary earthing has been done. All protections for the transformer are kept OUT by switching off the DC supply. The transformer bushings are connected to earth as an additional precaution. The testing shall be carried out during shut down period and all testing shall be done under proper/prior sanction from LD.

PRECAUTIONS: Testing shall be carried out during shut down period. Ensure the isolation of transformer for High Voltage and Low Voltage side with physical inspection of OPEN condition of the concerned isolators / dis-connections. In case tertiary is also connected, ensure the isolation of the same, prior to commencement of testing.

2.6 PROCEDURES:

2.6.1 OPERATIONAL CHECKS ON OLTC

- i. TAP CHANGER HAND OPERATION:** Check hand operation of the tap changer UP and DOWN in the full range before electrical operation is attempted and that the handle interlock switch will not allow electrical operation while the handle is inserted. Continuity check should be done for any discontinuity, during tap changing operation, by connecting an analogue multi-meter across HV & IV bushing and change the tap positions from maximum to minimum.
- ii. MAINTENANCE CIRCUIT:** Check the maintaining circuit for correct sequence by hand winding unit half way through a tap and then remove the handle. Energise the drive motor and ensure that the motor continues to drive the tap changer in the same direction.

- iii. **LIMIT SWITCHES:** Check the operation of the limit switches at both ends of the range.
- iv. **DRIVE MOTOR:** With the tap changer in mid position, check the direction of rotation and measure the start and running currents in both the raise and lower mode of operation and record their values. Set the motor overload to 10% above running current.
- v. **RAISE & LOWER CONTROL**

Step by Step relay operation: Check that the tap changer moves one tap at a time by pressing R or L push button.

Out of Step Relay: Move one tap changer in the three phase bank to be one position out of step with other two. Check that the tap changer faulty alarm is activated. Repeat for other two phases. Firstly, check the satisfactory operation of the local/remote switch. By local control, raise and lower the tap changer over its full operational range. Repeat the above, using the remote raise and lower facility over the full range. Check that either the local and remote switches can not operate the tap changer when it is in the other mode and vice versa. Hold the raise and lower push buttons in following a tap change to ensure it only moves one tap at a time, hence checking the step by step relay.

Tap Change Position Indicator: Check accurate indication of mechanical position indicator in all positions. Also check that the remote instrument operates in the same sequence with the same accuracy. Without remote instrument connected, operate the tap changer and measure the output from each binary coded matrix.

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

Operation Counter: Check that the tap changer counter operates and records readings correctly.

Remote Indication: Check that the remote indication and control facility is provided to the outgoing terminals of the marshalling kiosk.

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.

2.6.2 INSPECTION AND MAINTENANCE OF OLTC

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

Following de-energisation, close all valves between oil conservator transformer tanks and tap changer head. Then lower the oil level in the diverter switch oil compartment by draining of the 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.

The following check points / guidelines for inspection and maintenance should be addressed and the manufacturer's service engineer should be consulted for details of maintenance / overhauling activity to ensure the absence of problems and proper operation in future.

- a. Function of control switches.
- b. OLTC stopping on position.
- c. Fastener tightness.
- d. Signs of moisture such as rusting, oxidation or free standing water.
- e. Mechanical clearances as specified by manufacturer's instruction booklet.
- f. Operation and condition of tap selector, changeover selector and arcing transfer switches.
- g. Drive Mechanism operation.
- h. Counter operation.
- i. Position indicator operation and its co-ordination with mechanism and tap selector positions.
- j. Limit switch operation.
- k. Mechanical block integrity.
- l. Proper operation of hand crank and its interlock switch.
- m. Physical condition of tap selector.
- n. Freedom of movement of external shaft assembly.
- o. Extent of arc erosion on stationary and movable arcing contacts.
- p. Inspect barrier board for tracking and cracking.
- q. After filling with oil, manually crank throughout entire range.
- r. Oil BDV and Moisture Content (PPM) to be measured and recorded.

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

Quarterly- Oil in Tap changer selector compartment (if provided separately)- check for dielectric strength. Minimum values prescribed as per IS: 1866-2000 are as below for various equipment voltages:

- a. 145 KV and above: 50 KV
 - b. 72.5 KV & less than 145 KV: 40 KV
- Below 72.5 KV: 30 KV

Take suitable action to restore quality of oil. Procedure for testing of dielectric strength of oil is given in Appendix-A.

Quarterly or after 5000 operations whichever is earlier- Oil in OLTC Diverter Switch compartment- Check for dielectric strength. Minimum BDV value should be 30 KV- Take suitable actions for restoring BDV of Oil to 50 KV.

Half Yearly- Oil in tap changer selector compartment (if provided separately) - Check for the following:

- a. Dielectric strength:
Minimum values given at Item No.10
- b. Water Content: Maximum values for various voltage class of transformers are given below:
 - i. 25 PPM for 145 KV & above.
 - ii. 35 PPM for below 145 KV
 - iii) 1.0 (100%) for below 145 Kv.
- c. Resistivity: Minimum value= 0.1×10^{12} Ohm cm. At 90C
- d. Tan Delta : Maximum value=0.2 (20%)for 145 KV class & above
- e. Acidity: Maximum value =0.5 mg.KOH/per gram.
- f. Sludge content: No sediment or precipitable sludge should be detectable
- g. Flash Point : Decrease of 15C (Max.) from the initial value, minimum value 125C)
- h. Inter facial Tension: Minimum Value=0.018 N/m
Dissolved Gas Analysis

Procedure for sampling of oil for these tests is given in Appendix-B.

- a. Take suitable action to restore quality
- b. Recondition, if the value of Ten Delta permits, or otherwise reclaim or replace
- c. Recondition, if the value of specific resistivity permits, or otherwise reclaim or replace oil
- d. Reclaim or replace oil
- e. Recondition oil, if sediment is detected
- f. Replace oil, if more economical for other tests

2.7 Protective Devices And Measuring Instruments:

1. Relays should be regularly inspected and tested. To provide the expected protection, the relays must function properly when called upon to do so and this can only be assured by regular inspection and testing.
2. Obtain a sample of any gas which may be present in the gas chamber of the Gas Detector and test it for inflammable gasses. The presence of an inflammable gas definitely establishes the fact that trouble has occurred or is developing inside the transformer.

2.8 Oil Level Gauges:

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 MOG is marked at the 35°C (of normal) point, High & Low. These letter indications are relative and have no specific relationship to any real value. The oil level, indicated by MOG on the side of conservator, should be recorded along with top oil temperature. The top

oil temperature reading should be used to correct the oil level gauge reading. The corrected oil level should be in the normal (35°C) range.

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

In case of stuck MOG or broken lever of MOG and where there is no oil level gauge, the prediction of oil level is difficult. In such cases, the actual oil level is to be ascertained by attaching a PVC pipe to the drain valve of conservator tank and holding the pipe vertically.

In addition, level gauge (wherever fixed) may be observed and compared with oil level reading of MOG. The cause of any incorrect level should be determined/rechecked and corrective steps taken prior to taking any other action e.g. check for oil leakage.

2.9 Breathers:

Silica gel dehydrating breathers are filled with a sight glass so that the color of the crystals may be seen. The color changes from blue to pink as the crystals absorb moisture. When the crystals get saturated with moisture, they become predominantly pink and should, therefore, be reactivated. The body of the breather should be removed by loosening/ undoing the nuts. If the crystals have been kept in an inner container, the container should be removed, but if they are not, the crystals should be removed into a shallow tray. The crystals should be heated at temperatures of about 200°C until the whole mass is at this temperature and the blue colour has been restored. Clean the breather and replace the dry crystals and renew the oil in the cup at the bottom. Also ensure that air passage is free. Clean air passage, if blocked.

2.10 Bushings:

- a. Bushings generally require little or no maintenance other than periodic checking of the oil level as indicated by the gauge and cleaning of the porcelain. Bushing exposed to salt spray, cement dust or other heavy deposits are subjected to a greater hazard and must be cleaned regularly to prevent flash over.
- b.
 1. Examine bushings thoroughly for broken porcelain, fine hair line cracks, or any signs of flashover or heating.
 2. Inspect all connections and leads. All connection should be tight and examined for broken strands.
 3. Oil in oil-filled & non-hermetically sealed bushing-Check for dielectric strength (minimum BDV should be 40 kV). If low, filter or replace oil.
 4. Inspect oil level filled bushings and examine these thoroughly for loss of oil. If oil level is low, fill the oil of 60kV BDV
 5. Inspect cement which secures porcelain and collar for scaling or other damages.

6. Examine bushing for evidence of undue transverse stresses, which may be caused by external connections.
7. It is desirable that periodic Tan Delta and Capacitance measurements be made on the bushings and the values compared with those stamped on the name plate .The tan delta bridge used should be preferably operate at 5 K.V. or higher for useful results, but low voltage bridges are still capable of indicating the entrance of moisture into the bushing.

Capacitance and Tan Delta of condenser type bushings - Measure capacitance & tan delta. If capacitance has increased by 10% or more as compared with the original values, replace bushings.

i. If the tan delta values exceed the limits given below for different types of bushing, replace bushing.

a. BHEL OIP Bushing-0,007(0.7%)

b. BHEL SRBP Bushing-0.015(1.5%)

All other makes-0.01(1.0%)

2.11 CONSERVATOR TANK

Working of Air Cell type conservator.

Air cell performs two main functions. First, it separates the transformer insulating oil from the atmosphere (thus preventing gas or moisture contamination of the oil). Second, it maintains a constant atmospheric pressure on the transformer oil. The flexible air cell is connected to top of conservator tank through a gasket joint. The airline from this connection is connected to dehydrating breather which ensures dry atmosphere inside the air cell. Under normal operation, the air cell is completely surrounded by oil and floats, as high as it can, in the conservator. As the transformer oil volume changes, the air cell inflates or deflates by equivalent volume. The float of magnetic oil level gauge makes contacts with the underside of air cell and follows the motion up and down thereby giving an indication of the oil level inside the conservator.

In the event when the air cell becomes damaged and gets filled with oil, it will sink and activate the low level alarm on the oil level gauge. The system will then function as the normal conservator and it will not affect the normal operation of the transformer.

Air in atmoseal conservators with glass- Oil level in oil sight glass should be full. If oil level in oil sight glass is not full, it means there is air in contact with oil in the conservator. Ascertain reasons. Then release air from conservator as per procedure given below.

FOR RELEASING AIR FROM CONSERVATOR FITTED WITH PRONAL: Pressurise the Pronal up to a maximum of 0.1 kg. /cm² and open the air vent valves until oil start coming out. Then close the valves. Release pressure from the pronal.

Oil level in transformer- Check oil level in conservator as shown by MOG with reference to oil temperature and then check oil level in OLTC Conservator also. Top up with fresh filtered oil, if low. For conservators fitted with pronal, the oil is to be filled from the bottom drain

valve of conservator through filter machine and air is to be released from the conservator as per procedure given above. For conservator fitted with diaphragm, oil is to be filled from the bottom drain valve of conservator keeping the air release valve open till oil starts coming out of the air release valve. Stop oil filling and close the air release valve. Then lower the oil up to the MOG mark corresponding to the oil temperature.

2.12 Pressure Relief Devices (Explosion Vent):

Pressure relief devices play a vital role in the protection of power transformer systems. Power transformers are filled with insulating cooling oil. Should a fault or short circuit occur, shall instantaneously vaporize the oil causing extremely rapid build up of gaseous pressure. If this pressure is not relieved adequately within several thousands of a second, the transformer tank will rupture spraying flaming oil over a wide area. The damage and fine hazard possibilities of this consequence are obvious, and it is imperative that measures be taken to prevent them.

Examine diaphragm for punctures. Check oil in the sight glass provided in double diaphragm type relief vent. If oil is visible, it indicates that diaphragm is broken. In case the diaphragm is broken, replace it. Inspect the edges of outer diaphragm gaskets for signs of decomposition of fatigue. These edges should be painted to prevent weathering.

2.13 PRESSURE RELIEF DEVICE (PRD)/ SUDDEN PRESSURE RELAY (SPR)

PURPOSE: Pressure Relief Device / Sudden Pressure Relay plays a vital role in the protection of power transformers from excessive pressure inside which may occur due to internal fault or any other reason.

If a short circuit occurs inside a transformer, the arc vapourises the transformer oil and a heavy pressure is built up. If the pressure is not released immediately in a few milli second, the transformer tank will get bulged and will rupture with oil spreading everywhere creating a fire hazard.

When pressure inside the transformer tank rises above pre determined safe limit, a spring mounted diaphragm lifts from its seat for releasing the oil, vapour or gases to reduce the pressure inside the transformer tank. The diaphragm regains its position as soon as the pressure in the tank drops below set limit.

The lifting of the diaphragm also operates a flag indicator and a micro switch which is connected for annunciation/tripping. The flag and the micro switch remain operated until they are manually resetted.

ISOLATION REQUIRED: The testing is carried out on complete shut down of the transformer / reactor and the DC supply to the relay is extended while carrying out the operational checks. Though DC supply is extended, the tripping is isolated so that the trip command is not extended to the breaker.

PRECAUTIONS:

- i. The operating and resetting pressures are not site settable; no effect is made to set the pressure setting at site.

- ii. The flag unit is very delicate and care must be taken while handling the same.
- iii. Gasket to be changed when cable terminal box is fitted back after the test is over.
- iv. Read the manufacturer's instructions before any operation.

PROCEDURE:

Only the operation of the micro switch and the associated cabling and correct operation of the relays are tested during routine maintenance.

The functioning of the switch operation is tested by actuating the flag by lifting the operating rod manually or as advised by the manufacturer and the annunciation in the control panel as well as the extension of the trip command to be monitored.

It is also necessary to check the condition of the gasket at the cable termination box. The gaskets are to be changed every time the terminal box is opened.

2.14 Foundations:

1. Examine foundation for cracks in the surface, which would permit water to penetrate.
2. Inspect foundation for uneven settling.
3. Examine anchor bolts for signs of corrosion and loosening. In many cases anchor bolts, which have worked free, may provide a path for water to penetrate into the body of the concrete. This should be repaired.
4. Check steps for transformer track to see that transformer will not roll off.

2.15 Gaskets:

- A) The material used for gaskets is often cork-bonded with an oil proof agent, such as Neoprene, and it is recommended to stock a set of spare gaskets.
- B)
 1. Examine all gaskets for leaks. These may be due to improper fitting or unequal tightening of bolts or studs. Improperly installed studs may frequently be the cause of trouble.
 2. Inspect all exposed edges for decomposition and fatigue. The exposed portion should be given a protective coating.
 3. Inspect studs and nuts. All nuts should be tight and studs should be threaded sufficient to permit full travel of nut.

2.16 External Connections:

Earthing Connections:

- a. All connections should be tight. If they appear blackened or corroded, undo the connection and clean down to bright metal with emery paper. Remake the connections and give it a heavy coating of grease. It is particularly important that heavy current carrying connections should be properly maintained. If the metal has the characteristic blush tinge (which indicates that it has been hot) then, in most cases, the connection shall not be considered satisfactorily. Either it has become loose or dirty, or the conductor is not suitable for carrying over the current.
- b. The earth connections shall be properly maintained. A small cooper loop to bridge the top cover of the transformer and the tank may also be provided to avoid earth fault-current, passing through the fastening bolts, when there is a lightening of high voltage surge or failure of bushings.

- c. The importance of proper grounding has also its own place. Improperly grounded apparatus constitutes hazard not only to the electrical equipment but to every person who may come in contact with it.
- d. All ground wires should be thoroughly examined and tested as follows:
 - i. Inspect ground wire to see that it is of proper size.
 - ii. Examine connections at both ends. These should be solid and making good contact. A ground wire from the transformer tank should be solidly connected to station ground. All connections should be welded properly.

2.17 WINDING TEMPERATURE INDICATOR TESTS:

The transformer and associated equipment must be taken out of service, isolated and earthed while checking the operation of the winding temperature indicators.

All results must be recorded in the log for comparison during future checks in service.

If the winding temperature in a transformer shows a tendency of rising without a corresponding increase of the load, which may be due to reduction in the cooling ability of the cooling equipment (dirt, dust), the thermometer should be checked first.

Temperature Indication Calibration of the Winding Temperature Indicator

Remove the winding temperature indicator bulb from the transformer pocket positioned in the tank cover.

Insert the bulb into the calibrated temperature controlled bath.

Raise the temperature of the bath in 5°C steps and check the response of the winding temperature indicator after ten minutes. This procedure should be continued up to a maximum temperature of 130°C. The tolerance for the temperature indication is $\pm 3^\circ\text{C}$.

Lower the temperature of the bath in 5°C steps and check the response of the winding temperature indicator after ten minutes. At the same time, check the transducer output. The tolerance for temperature indication is $\pm 3^\circ\text{C}$.

Check the alarm and trip switch settings by rotating the pointer slowly to the set temperatures. These settings will be indicated using a multi-meter. Record the values at which the switches operated.

Once these checks are completed, return the bulb to the pocket in the transformer cover. Do not forget to bring the maximum level pointer to match the temperature indicator.

2.18 Oil Temperature Indicator Tests:

Remove the OTI bulb from the pocket on the transformer lid and insert it into the calibrated temperature controlled oil bath.

Increase the temperature of the oil bath in 20°C steps from 0°C up to a maximum temperature of 120°C. Check and record OTI readings against bath temperatures up the range (tolerance $\pm 3^\circ\text{C}$).

Access the oil temperature indicator and rotate the pointer slowly to the alarm value (95°C) and the trip value (110°C) and check their operation by using a resistance meter across the switches.

2.19 Oil (Transformer Oil)

2.19.1 Oil Deterioration:

The oil deterioration of insulating oils is generally due to oxidation, especially under conditions of prolonged high temperature operation. The acid and sludge formation proceeds slowly with operating temperatures but the rate is considerably increased if the temperature is allowed to rise above 75 ° C. Experience has shown that the rate of chemical reactions is almost doubled for every 8° to 10° rise in oil temperature above 75 ° C. The presence of metals, such as copper and iron, accelerates oxidation. Contamination with water and other foreign matter including varnishes, besides reducing dielectric strength of oil, promotes its oxidation. The rate of deterioration is, therefore, affected by design of equipment by the manufacturer and the operating conditions, particularly the load cycle, ambient temperature and other atmospheric conditions.

2.19.2 Oxidation:

This is probably the worst type of deterioration due to the formation of acids, sludge and water, which accompanies the chemical change. Oxygen makes contact with the oil or oil vapor in the space between the oil level and tank cover. Due to the need for breathing, a certain amount of interchange of air with conservator takes place which lowers the area of oil surface in contact with the air and also lowers the temperature of the oil at the point of contact. Other suggested methods of reducing or entirely preventing oxidation are the use of air below type conservator in which no air is in contact with oil. Other factors affecting the oxidation are the catalytic effects of metal surfaces, such as iron and copper. The presence of electric stress, mixture of oil vapor and oxygen is also thought to have a detrimental effect as pointed out by some investigators.

2.19.3 Sludge Formation:

- a. Sludge formation is a serious form of deterioration because it is very difficult to clean a transformer with sludge deposits without dismantling it. However, severe sludge formation is not frequently experienced in transformer oil. Sometimes rust, scale or dust having similar appearance may be taken for sludge.
- b. If the solid material is identified as sludge (although the acidity is comparatively low), its presence may be accounted for incomplete cleaning of the transformer following the use of an oil which has deteriorated to the point of sludge deposition.
- c. The absence of visible solid deposit does not eliminate the possibility of the existence of sludge.
- d. The appearance of precipitated sludge in a transformer needs immediate action. In bad cases, the oil should be changed and the transformer should be cleaned immediately after the oil has been removed to prevent hardening of sludge.

2.19.4 Dielectric strength:

The dielectric strength does not give a true indication of the worthiness of oil. Oil, which is highly deteriorated, will give high dielectric strength when dry. The dielectric strength is also affected by the presence of foreign particles, such as cellulose fibers, which absorb moisture and orient themselves across point of trees and cause arcing. The presence of oil deterioration particles, water, and foreign contaminants results in a general overall reduction in the efficiency of the apparatus. Normal method of oil purification only maintains the dielectric strength but do not improve the deteriorated condition of the oil. It is, therefore, not advisable to rely solely on the dielectric strength of the oil by periodic test without verifying its chemical composition

2.19.5 Acidity:

High acidity may not affect the dielectric strength of oil materially and there may be little or no sludge formation, but the complex petroleum acids developed in service may attack the insulations and copper of the windings. Before corrosion in a transformer is likely to take place, the presence of moisture is almost inevitable in preliminary condition, irrespective of the acidity of the oil. It is, therefore, important that both (soluble and insoluble) water should be removed which can be accomplished by vacuum dehydration.

Water soluble acids are some of the worst by products of hot oil oxidation. They result in metals, such as the transformer tank and lid, being attacked while insulation is also weakened. In the case of large transformers, periodical test of acidity should be carried out. The analysis of record so maintained would indicate any dangerous increase in their values.

Acids value of 0.2 to 0.3 milligrams of KOH per gram of oil should not give trouble (unless reached in a very short time) and will not indicate rapid deterioration of the oil. Acid value as high as 1.0 milligram of KOH per gram of oil, however, shows that the life of the oil may be limited and careful watch for change in acidity should be kept. It is unwise to allow high acid values to develop as the transformer core and windings then become contaminated to such a degree that even the most careful cleaning and washing out with new oil will not remove all traces of acidity. A new filling of oil would then tend to deteriorate at an increased rate with new, correspondingly, shortened life. Some transformers may, sometime, get badly affected that rewinding and rebuilding of the cores become necessary.

2.19.6 Arcing under Oil:

Any burning or arcing under oil will produce carbon particles. which may settle on the winding surfaces may produce of low resistance path. Burning will also give rise to cracking of the oil, which produces little more volatile members of the same group of compounds. The presence of free acetylene, as might collect in the chamber of a Buchholz Relay would indicate cracking of the oil

In view of the above, the testing of oil for a acidity, sludge and dielectric strength so as to find out, if it has deteriorated so that corrective action can be taken, which is utmost important.

2.19.7 SAMPLING OIL FOR TESTING:

The dielectric strength (break down voltage) of oil is greatly affected by the minute traces of certain impurities, particularly moisture. It is, therefore, very important, that the samples be handled with utmost care to avoid contamination.

- a. Samples should be normally taken on dry and clean day so as to avoid contamination of the oil with moisture.
- b. Samples shall be taken from a tank only after it has been allowed to settle for a minimum of sixteen hours. If the tank is in the open samples may be taken in dry weather only.
- c. It is desired to obtain a sample of that part of the oil in a tank which is in the worst condition, since water is heavier than oil, the sample must be taken from the bottom of the tank.
- d. Draw off enough oil through a sampling valve to ensure that the sample will be composed of oil from the tank and not from the area immediately adjacent to the sampling valve. This oil must not be drawn off into sample container.
- e. Draw off small quantity of oil into the sample container. After using this to rinse the container, discard it. Then draw up the required quantity of oil for sampling purposes being careful to have the oil flow into the bottle without it touching the fingers. till bottle is full and seal in a suitable manner. Do not open the bottle again except in a warm room after allowing it to reach room temperature.
- f. Tag the sample jar, giving particulars of the apparatus from which the sample is taken, serial no, etc and whether from bottom middle or top of the tank, also date and name of the person taking the sample.
- g. Sample taken from barrels should be taken by means of glass or brass tube which should be cleaned and dried before use. This tube should be lowered into the barrel with the thumb over the top and until it is about $\frac{1}{2}$ from the bottom the barrel. The thumb is removed, allowing the tube to fill and then replaced in order to lift out the sample. Do not touch the bottom of the tube. The first sample should be allowed to waste, in order to rinse out the tube

2.19.8 INSPECTION OF SAMPLES:

Colour & Odour give useful information, such as

- a. Cloudiness in oil may be due to suspended moisture or suspended solid matter, such as iron oxide or sludge. Oil of a muddy colour usually contain moisture. The moisture may be detected by crackle test.
- b. Dark brown colored oil may indicate the presence of dissolved asphaltenes.
- c. A green colour indicates the presence of dissolved copper compound and rapid deterioration of the oil may be expected.

- d. The information thus obtained shall be noted for record purposes.

2.19.9 TEST ON OIL SAMPLES:

a. DIELECTRIC STRENGTH TEST:

The test shall be performed in accordance with the method described in Appendix ‘E’ of IS:335.1953 specification for insulating oil for transformers and switchgear(low Viscosity type) oil shall withstand a test voltage of at least 30 kV for one minute without breakdown. If the sample fails, a test shall be performed on another sample. If that also fails, the oil shall be suitably treated.

Frequently transient sparking suggests the presence of foreign matter, for example, moisture, material, carbon particles etc.

A higher minimum proof voltage may be desirable of certain apparatus, particularly apparatus of very high voltage type of apparatus of which a higher voltage is recommended by the manufacturer.

b. CRACKLE FREE TEST FOR WATER:

The test shall be performed in accordance with the method described in Appendix ‘F’ of I.S:335-1953 . Specification on Insulating oil for transformers and switchgear(low viscosity type) . If the first sample fails to pass the test, two more samples shall be tested. Both shall pass the crackle test for the oil to be considered satisfactory. In case of failure, the oil shall be treated suitably./ This test is only qualitative and is not a substitute for the laboratory test for dielectric strength.

c. ACIDITY:

1. The acidity of oil shall be determined by any of the methods 1 and 2 given in Appendix D of IS 0 1866-1961.

Where circumstances do not justify precise determination of acidity, a simple form of test by the method 3 given in Appendix B may be carried out on the site to find out whether the acidity has exceeded a predetermined value.

2. The recommended limits for acidity are as follows:

a	Acidity below 0.5 mg. KOH/G	No. action need be taken, provided oil is satisfactory in all other respects.
b	Acidity between 0.5 and 1.0 Mg. KOH/g.	Oil be kept under observation
c	Acidity exceeds 1.0 KOH/G	Oil should be treated or discarded. Consultation with oil supplier may be desirable.

3. Acidity greater than 1.0 mg KOH/g gives rise to risk of sludge precipitation and corrosion of metal surfaces above oil level by condensed acidic vapors. If there is evidence of dissolved sludge, oil having acidity exceeding 1.0mg KOH/g should not be kept in service.

d. SLUDGE TEST:

The traces of solid matter in oil samples may be examined according to Appendix B of IS – 1866-1961 to determine whether they consist of oxidation sludge or any other foreign matter.

2.20 INSULATION RESISTANCE MEASUREMENTS:

With electrical equipment the Chief factor in reducing insulation resistance is moisture with older plant many other factors enter such as embitterment and oxidation with accompanying cracking, while displacement due to expansion and contraction may affect insulation and bonding materials. Surface contamination as opposed to sectional properties of insulation may also be important.

Insulation resistance is best reassured by a meager. The meager reading gives a good picture of the amount of moisture absorbed by windings. If the readings are recorded at regular intervals, they would be very useful for finding out when drying out should be taken up. Remember that temperature has a direct bearing on the insulation resistance obtained and that it comes down with a rise of temperature. For Class 'A' insulation, the insulation resistance in megohms gets halved for every 10 °C to 15 °C rise. Therefore, the temperature should be noted every time the insulation resistance is taken. The polarization index shall also be recorded.

2.21 RELATION BETWEEN MEGGER OUTPUT AND TRUE INSULATION RESISTANCE:

The reading on the scale of a meager is determined by the ratio of the voltage applied to the windings under test and the current output from the instrument. This current is made up of three components and does not immediately assume its final value. There is firstly, the true capacitance charge which depending on the size of the equipments, may be large but will only take a few seconds to supply, secondly, there is the charge which must be supplied due to the insulation being placed under strain and which is known as dielectric absorption. Lastly there is the constant leakage through and over the insulation which is a measure of the insulation resistance. It is clear therefore that until the first two charging currents have died away a true value of the insulation resistance cannot be obtained.

In practice, if the insulation is damp or dirty, leakage current will be large in relation to the charging currents and will result in the pointer of the meager coming up to a 'final' value very quickly so that continued turning of the instrument will make very little if any noticeable differences. When therefore a meager indicates in this manner and particularly if the equipment under test is large the presence of dampness. If on the other hand the insulation is in good condition, the leakage current will be small and the dielectric absorption current will have a pronounced effect while it is flowing. In fact if the insulation is dry, dielectric absorption may continue for several hours. The absorption current is heavy at first and gradually dies away as the insulation reaches its final state. Hence with large equipments it is essential to apply the meger test as long as possible. If a motor driven meger is available, reading should be taken after 10 or 15 minutes. If a hand driven meger is used then only 1 to 2 minutes test will be practical.

It is important to decide on a definite time interval and to stick this throughout any series of tests. The effect of dielectric absorption is very noticeable and will result in a gradual rising of the pointer of the instrument. When the windings are damp, the 1 minute and 10 minutes or 10 seconds and 60 seconds test insulation resistance values do not greatly differ. After the windings have dried out, however, dielectric absorptions has an increasing effect, the higher values for the prolonged test becoming more evident.

When dielectric absorption is an important influence, insulation resistance should not be taken at close intervals as the effects of voltage application will influence successive readings. Readings at hourly interval swill be satisfactory and the windings would be earthed when not under test.

The object of test is to obtain an indication of the true insulation resistance of the windings so that their condition may be gauged. But in this respect the 1 minute reading is a useful compromise as it eliminates normal charging currents and only leaves surface leakage and the remnant of dielectric absorption to effect the result.

2.21.1 EFFECT OF TEMPERATURE:

Temperature reduces the value of the insulation resistance considerably. Readings at low temperature may be deceptive and not gives an accurate guide to the condition of the insulation. If possible, therefore, check test should be taken at temperature not less than 60 o C where records of insulation resistance test are kept for reference, a note should be made of the durations of the test, the temperature of the windings, cleanliness of bushings and temperature and humidity of the surrounding air. When this is done, subsequent tests will have much low value as indication of insulation deterioration.

A further useful point to record along with the temperature of the winding, is whether this is taken immediately after taking out of operation or after the equipment has been off sufficiently long for the temperature gradient to be eliminated. The presence of a temperature gradient corresponds more closely to the practical operating condition.

When readings of temperature and insulation resistance are plotted on ordinary equally ;divided coordinates, a curved characteristics is obtained. On the other hand if graph paper is used on which the insulation resistance scale is laid out in logarithmic divisions the graph becomes straight line for any definite condition of the insulation. This method of plotting is sometimes useful as it enables the graph to be established form two readings only thus allow the prediction of the insulation resistance at higher temperatures. Also any subsequent change in the slope of the characteristic which new readings might disclose will indicate a change in the insulation conditions

2.21.2 EFFECT OF VOLTAGE:

Megger sets are made for a verity of voltages from 500 to 5000 volts. It sometimes an advantage to take insulation readings at different voltages for purpose of comparison. The insulation resistance value, will be in the general for clean and dry insulation slightly less for the higher test voltage due to the dielectric absorption effects but where a large decrease in insulation resistance with the higher, test voltage is obtained, this is usually an indication that the insulations in a less satisfactory condition perhaps due to dirt or moisture. Voltages stress thought to cause a reorientation of the water molecules thereby causing apparent resistance

decrease, where large equipments have been tested with high voltages meggers, care should be taken to discharge the windings before touching any connections, as the stored energy can be dangerous. insulation resistance of; windings:

After commissioning a large an important unit therefore, it is worthwhile to obtain, as apparently arises,

A set of readings of insulation resistance at various operating temperatures, which will enable a curve to be drawn, any large or progressive variations from the curve would indicate deterioration of the insulation, which taken in conjunction with consideration of oil value would allow appropriate action to be taken before a breakdown occurred.

2.21.3 VALUE OF INSULATION RESISTANCE:

A question is sometimes, raised regarding the minimum insulation at which a transformer can be charged.

There are two ways of getting a good idea of the state of the insulation of the transformers.

- i) **IR Values** : There is no hard and fast rule, since the IR value varies with the size of transformer and the voltage rating. A safe general rule is to aim for about two megohms for each 1000 volts of operating voltage. The following values may be considered as satisfactory when the transformer is warm (45°C).

TABLE

Voltage windings	Minimum insulation resistance in megohms	Voltage of Megger
400 volts	2	500 volts
2.2 KV	10	500 volts
11 KV	50	1000 volts
33 KV	150	2000 volts
132 KV	500	2500 volts
220 KV	1000	5000 volts
400 KV	2000	5000 volts

When using a hand operated megger, keep turning the handle at full speed and ensure that the voltage generator is steady. There will be appreciable capacitance in the windings. The insulation value will be low initially, but rise up quickly as the windings get full charged, when it will show the correct readings. If the cranking speed at any time is reduced slightly, there will be a reverse flow of current from the accumulated charge, and the needle will shoot up to infinity, giving an incorrect reading.

The above difficulty will overcome if motor driven megger is used, which will be a distinct advantage when testing large high voltage transformers. Make sure that test leads themselves are in first class condition, and show high insulation resistance.

2.21.4 POLARISATION INDEX :

In this an ordinary 2500 or 5000 V motor driven megger is used to measure the insulation resistance. Two readings are taken, one at 15 seconds and the other at 60 seconds, the pressure being maintained all the while. The value obtained for 60 seconds should be higher than for 15 seconds, if the material is sound. The ratio R60/R15 called the polarization index gives a positive assurance of the good condition of the insulation, if it corresponds with the manufacturer's test figures. Table gives an idea of the type of figure recorded for a large transformer

TABLE
Insulation resistance in megohms

Test points			30oC			57oC		
R15	R60	R60/R15	R15	R60	R60/R15			
HV & earth			700	960	1.37	240	280	1.17
LV & earth			900	2400	2.67	480	790	1.65
HV & LV			1000	2600	2.6	610	950	1.56

2.22 INTERNAL INSPECTION OF TRANSFORMER

- a. Before lowering the oil in a transformer for and internal inspection, it is advisable to take oil samples from top and bottom for testing.

Clamps of the core, In the case of a core type transformer, the oil should be lowered sufficiently to expose the top coils of the windings.

Always open the hand cover of the conservator tank or provide other means for adequate entry of air while the oil is being lowered. An example would be the petcock to the explosion vent.

- b. The following safety measures are recommended before entering a transformer for an internal inspection.
1. Men working in or on open transformer must remove all objects from their pockets. All tools must be attached to suitable hand lines so that the tools may be withdrawn if accidentally dropped inside the transformer.
 2. Boxes or approved containers of a convenient size to hold loose nut bolts and other small objects must be provided and used when working on the top of a transformer which is open.
 3. Care should be taken to keep all openings suitably covered.

2.22.1 BUSHING :

The items to be examined are

1. Examine bushings thoroughly for broken porcelain cracks, or any signs of flashover.
2. Inspect all connections and leads. All connections should be tight. Flexible through the leads should be disconnected tested and examined for broken strands.

3. In condenser bushings, where bindings wire is used at the central section, this wire should be inspected and tested for effective ground connections.
4. Clean indicator glass and renew gaskets, if necessary.
5. Inspect cement which secures porcelain and collar for a scaling or, their damage.
6. Examine bushing for evidence of undue transverse stress which may be caused due to external connections.

2.22.2 BRACKETS :

All brackets supporting under cover, current transformers, cooling coil, low voltage leads or jumpers high voltage leads, mechanical operating parts of ratio adjusters etc. must be carefully inspected for :

1. Damage to the bracket itself
2. loose or missing bolts, nuts, cotter pins etc.
3. Examine insulation for excessive heating
4. Short circuit due to bushing type CT brackets

2.22.3 BRACING

1. Inspect all bracing and blocking parts for mechanical damage loose or missing nuts, bolts washers etc.
2. locate or account for any missing parts

2.22.4 HV & LV WINDINGS :

1. Examine high and low voltage coils for damaged insulation or sign of bucking.
2. Examine spacer insulation for tightness, loose or missing spacers usually result in damage to the coils, through bucking.
3. Inspect ventilating ducts. These should be free of sludge or varnish.

Small particles of copper or nuggets may sometimes be found. It indicates that the transformer has been on trouble and that it should be overhauled unless decisive evidence is found that the particles have come from some place above the core.

2.22.5 CONNECTIONS

1. Carefully examine all connections to bushings, tap changers and terminal boards for loose nuts. Both sides of the terminal board must be examined.
2. Inspect all soldered lugs, where soldered lugs are used, the lug be full of solder and secure.
3. Inspect normal board supports. All bolts and nuts must be in place and secure.
4. Carefully inspect neutral ground connections if fitted and test for continuity.

2.22.6 CORE GROUNDS

1. Examine core grounds for signs of fusing or loosening of connections. If fusing or the burnings of the core ground is found, there are possibly additional grounds on the transformer, forming a circuit. This is especially true in the case of core type transformers. Megger any bolts which can be reached.

2.22.7 INSULATION

1. Carefully examine the insulation. If the insulation is still in good condition. The inspector may assume that the transformer has not been overloaded for any length of time and has been treated normally. However, if the insulation is dark and brittle or a heavy carbon like deposit is formed, the transformer has been heavily overloaded for a considerable length of time.
2. Any rancid odours inside a transformer should be investigated. This odours are usually caused by decomposition of the insulation due to overheating.
3. Any evidence of loose or broken taps must also be investigated as it indicates electrical or mechanical damage.

2.22.8 TAP CHANGER

1. Examine mechanical working of tap changer on all tap position.
2. Examine supporting blocks, bearings and braces for loose bolts, nuts, cotter pins, meshing of gears, etc.
3. Test ratio on all tap position.
4. Check spring pressure of tap changer contacts.
5. Check for proper functioning of indicator.

2.22.9 TANK

1. Examine under cover for condition of point of signs of rust.

2.22.10 TERMINAL BOARD

1. Examine all mounting bolts and studs for tightness
2. Examine bushings and boards for cracks which might contain moisture
3. Examine bushing and boards for possible creepage path or indications of previous flashover between live part.

2.22.11 THERMOMETER

1. Examine location of thermometer. Thermometer should be properly positioned and the capillary tube properly rechecked for proper clearance to live parts.
2. Check the thermometer against a standard thermometer
3. Inspect gaskets and packing glands for poor fittings decompositions or fatigue

2.22.12 HOT SPOT EQUIPMENT

1. Examine switches, meters and connections
2. Check current transformer resistances.

2.23 MAGNETIC BALANCE TEST

This test is conducted only in three phase transformers to check the imbalance in the magnetic circuit.

Isolation required: Disconnect transformer neutral from ground.

Take all safety.

Precautions: No winding terminal should be grounded; otherwise results would be erratic and confusing.

Testing Procedure:

- Keep the tap in nominal tap position.
- Disconnect transformer neutral from ground.
- Apply single phase 230V across one phase of Intermediate Voltage (IV) winding terminal and neutral (call it v_1) then measure voltage in other two IV terminals across neutral (call them v_2 and v_3 respectively). Repeat the test for each of the three phases.
- Repeat the above test for HV winding also.

Evaluation of Test Results:

- From the measurement carried out as per 8.3 ensure that $v_1+v_2+v_3$ respectively.
- Zero voltage or very negligible voltage induced in other two windings should be investigated.
- Also the applied voltage may be expressed as 100% and the induced voltages as percentage of applied voltage. This will help in comparison of two results when applied voltages are different.

2.24 MAGNETIZING CURRENT TEST

Purpose : Excitation / Magnetising current test is performed to locate defect in magnetic core structure. Shifting of windings, failures in turn insulation or problems in tap changers.

Definition : Exciting / Magnetising current is the current required to force a given flux through the core.

Isolation required : Ensure the isolation of Transformer from High Voltage & Low Voltage side with physical inspection of open condition of the concerned isolators/disconnectors. In case tertiary is also connected, ensure the isolation of the same prior to commencement of testing.

Precautions :

- This test should be done before DC measurement of winding resistance to reduce the effect of residual magnetism.
- Magnetising current readings may be effected by residual magnetism in the core. Therefore, transformer under test may be de-magnetised before commencement of magnetising current test.

Testing Procedure :

- i. Keep the tap position in the lowest position and HV & LV terminals open.
- ii. Apply 1 phase 230V supply on HV terminals one by one.
- iii. Measure the voltages applied on each phase (Phase-neutral) on HV terminals and current in each phase of HV terminal.
- iv. After completion of the above steps keep the tap position in Normal Position and repeat the steps (ii) & (iii).
- v. After completion of the above steps keep the tap position in Highest Position and repeat the steps (ii) & (iii).
- vi. Keep the tap position in normal position and keep HV & LV terminals open.
- vii. Apply 1 phase 230V supply on LV terminals one by one.
- viii. Measure phase to Neutral voltage between the LV terminals and current on each of the LV terminals.

2.25 EARTH RESISTANCE MEASUREMENT AND VOLTAGE RATIO TEST

Measure earth resistance of each Neutral of Transformer to ensure connectivity.

Purpose: To determine the turns ratio of transformers.

Definitions: Turn Ratio – The turn ratio of a transformer is the ratio of the number of turns in a higher voltage winding to that in a lower voltage winding.

Isolation required: Ensure the isolation of Transformer from High Voltage & Low Voltage side with physical inspection of open condition of the concerned isolators / dis-connectors. In case tertiary is also connected, ensure the isolation of the same prior to commencement of testing.

Precautions: The voltage should be applied only in the High Voltage winding in order to avoid unsafe voltage.

Testing Procedures :

- i. Keep the tap position in the lowest position and HV and LV terminals open.
- ii. Apply 1 phase 230V supply on HV terminals.
- iii. Measure the voltages applied on each phase (Phase-Phase) on HV & LV terminals simultaneously.
- iv. Repeat steps (ii) & (iii) (above) for each of the tap position separately.
- v. Repeat the steps (i) to (iv) above) after interchanging the voltmeters of HV & LV windings and then average the readings for final calculation of ratio.
- vi. The above tests can also be performed by Transformer turns ratio (TTR) meter available in convenient portable form. They have a hand crank power supply, with the voltages commonly used being very low such as 8-10V and 50-60 Hz, so that the test may be performed on a transformer even the oil is removed. Two windings on one phase of a transformer are connected to the instrument, and the internal bridge elements are varied to produce a null indication on the detector, with exciting current also being measured in most cases.

Operating Procedure (Test Equipment): Please refer manufacturer's operating instructions for the instrument available at site.

Evaluation of Test Results:

- The turns ratio tolerance should be within 0.5% of the name-plate specifications. For three phase Y connected winding this tolerance applies to phase to neutral voltage. If the phase to phase voltage is not explicitly indicated in the name-plate, then the rated phase-to-neutral voltage should be calculated by dividing the phase-to-phase voltage by $\sqrt{3}$.
- If there are shorted winding turns, the measured ratio will be effected. Out of tolerance ratio measurements may be symptomatic of shorted turns, especially if there is an associated high excitation current. Out of tolerance readings should be compared with prior tests because in some instances, the design turns ratio may vary from the name-plate voltage ratio on some taps because of the need to utilise an incremental number of winding turns to make up the taps while name-plate voltage increments may not exactly

correspond. This error may combine with measurement error to give a misleading out-of-tolerance reading.

- Ratio measurements must be made on all taps to confirm the proper alignment and operation of the tap changers. It should be noted that on transformers with OLTC that operate on positions bridging two tap contacts (check the name-plate chart for tap connections), there will be a circulating current in the tap section being bridged. This circulating current is limited in some manner, usually by a reactor or resistance device. The losses due to this circulating current will cause an increase in exciting current and some voltage regulation. It is therefore important to have prior data with the measurement system employed to properly analyse these transformers.
- Open turns in the excited winding will be indicated very low exciting current and no output voltage. Open turns in the output winding will be indicated by normal levels of exciting current but no very low levels of unstable output voltage.
- The turns ratio test also detects high resistance connections in the lead circuitry or high contact resistance in tap changers by higher excitation current and a difficulty in balancing the bridge.

2.26 CHECK LIST FOR RE-ENERGIZATION OF TRANSFORMER AFTER MAJOR REPAIRS OR OVERHAUL.

2.26.1 PRELIMINARY CHECKS

1. Release air at the high points, like oil communicating bushings, buchholz petcock, tank cover and the cooling devices including headers, radiators, pumps, expansion joints etc. of the transformer.
2. Check the whole assembly for tightness and rectify where necessary.
3. Check the general appearance and retouch the paint work if need be.
4. Check that the valves are in the correct position :
 - Tank : Valves closed and blanked.
 - Cooling circuit : Valves open.
 - Bye-Pass: Valves open or closed as the case may be.
 - On Load Tap Changer : Valves open.
5. Check that the silica gel in the breather is blue and that there is oil in the breather cup (oil seal).
6. Check the oil level in the main conservator and the conservator of on-load tap changer, bushing caps, flanges, turrets, expansion bellows as per manufacturer's recommendation. Level should correspond to 35oC mark on oil level gauges for BHEL transformers.

7. Check the Bushings :
 - Oil level (bushings fitted with sight-glasses).
 - Adjustment of spark-gaps/arcing horn-gaps, if provided.
 - Conformity of connection to the lines (no tensile stress on the terminal heads).
 - Bushing CT secondary terminals must be shorted and earthed, if not in use.
 - Neutral bushing effectively earthed.
8. Check the On-Load Tap changer :
 - Conformity of the positions between the tap changer control cubicle and the tap changer head.
 - Adjustment of the tap-changer control cubicle coupling.
 - Electric and mechanical limit switches and protective relays.
 - Step by step operation – local and remote electrical operation as well as manual operation and parallel operation, if any.
 - Signaling of positions.
9. Extraneous materials like tools, earthing rods, pieces of clothes, waste etc. should be removed before energization.

2.26.2 CHECKING OF CORE COIL ASSEMBLY

1. Measurement of all transformation ratio using a ratio measuring bridge.
2. Measurement of winding resistance at all taps before connecting the lines to the bushings.
3. Verification of the vector group / polarity.
4. Measurement of the insulation resistance of the windings in relation to each other and in relation to the ground (tank).
5. Measurement of the consumption in mA of each HV phase, the phases being supplied by 220V or 415V three phase current, with the tapping winding at the middle position.
6. Check the operation of the taps as follows :
 - Feed the HV with single phase 220 or 415V supply between phase and neutral (neutral brought out) or between phases.
 - Check the progression of the secondary voltages and of the primary current as well as the anomalies i.e. out of step, short circuit etc.

This test should be carried out on each phase.

7. Check the quality of the oil :
 - Draw off a sample from the bottom of the tank.

- Carry out DGA and oil parameters test (i.e. BDV, Moisture Content and DDF) before energization.
8. Measurement of tan delta and capacitance of all bushings.

2.26.3 CHECKING OF AUXILIARY AND PROTECTIVE CIRCUITS

1. Check temperature indicator readings and their calibrations.
2. Check the setting and working of the mercury switches of winding and oil temperature indicators and presence of oil in the thermometer pockets.
3. Check the operation of the buchholz relay and the surge protective relay of the tap-changer.
 - Alarm and tripping.
 - Protections and signals interlocked with these relays.
4. Check the insulation of the auxiliary circuits in relation to the ground by 2 kV Megger for 1 Minute.
5. Check the earthing of the tank and auxiliaries like cooler banks at two places.
6. Measure the supply voltages of the auxiliary circuits.
7. Check the cooling system :
 - Check the direction of rotation of the pumps and fans.
 - Check the working of the oil flow indicators.
 - Check the setting of the thermo overload relays.
 - Go through the starting up sequence, control and adjust, if necessary, the relay time delays.
8. Check that there is efficient protection on the electric circuit supplying the accessories and tightness of all electrical connections.
9. Check the heating and lighting in all cubicles.
10. Check the differential protection, over-current protection, restricted earth fault protection, over-fluxing protection etc are in service.
11. Measure the Earth Resistance of Transformer Neutrals

After the inspection / tests are completed, the transformer may be energized from the incoming side on NO LOAD. The initial magnetizing current at the time of switching will be very high, depending upon the particular moment in the cycle. The transformer should always be soaked for few hours under constant care i.e. keep it energized for one or two hours. It is preferable to keep the settings of all protective relays to the minimum during this period. Excessive vibrations of radiator parts etc. should be located and corrected. The

transformer hum should be observed for any abnormality. After that it may be checked for gas collection. Should the gas prove to be inflammable, try to detect the cause which may probably be an internal fault. If the breaker trips on differential, buchholz or any other device, the cause must be investigated thoroughly before re-energizing the transformer / reactor. After successful charging, performance of transformer / reactor should be checked under loading, OTI/WTI readings should be monitored for 24 hours and ensured that they are as per loading.

2.27 AN ABSTRACT ON SOME OF THE GENERAL PROBLEMS IN POWER TRANSFORMERS AND THEIR POSSIBLE CAUSES

S.No.	Nature of Problem	Possible causes
I.	Low IR Value	<ul style="list-style-type: none"> • Ageing. • Ingress of Moisture through the breather. • Sludge formation within the transformer. • Error in measurement, such as measuring leads falling on the transformer itself.
II.	Oil leak in the bushing	<ul style="list-style-type: none"> • Crack in the porcelain. • Worn out gasket. • Ageing/Damaged oil seal. • Heating due to improper fastening of bushing clamp. • Failure of gasket of air release plug.
III.	Heating in Bushing Clamp	<ul style="list-style-type: none"> • Improper fastening. • Inadequate clamp size. • Bimetallic action.
IV	Low oil level indication in the conservator.	<ul style="list-style-type: none"> • Leak through worn out gasket. • Loss of transparency in the oil level view glass. • Defective MOG.
V.	Over-flow of OLTC oil.	<ul style="list-style-type: none"> • Development of contact resistance in the OLTC and consequent heating. • Failure of epoxy board barrier between the main tank and OLTC. • Loose in “Kerosene-plug” of OLTC chamber.
VI	Absence of breathing action in the breather.	<ul style="list-style-type: none"> • Blockage in the breather pipeline. • Leak in breather pipeline. • Failure of diaphragm in the explosion vent.
VII	Failure of Diaphragm in the explosion vent.	<ul style="list-style-type: none"> • Blockage in the breather/breather pipe line. • Inadvertent closing of valve between the Explosion Vent and the main conservator. • Inadvertent closing of the valve in the Buchholz pipeline. • Mechanical failure. • Ageing.
VIII.	MOG Alarm	<ul style="list-style-type: none"> • Leak in the transformer. • Loss of oil in the conservator due to repeated sampling followed by sudden fall in load and / or ambient temperature. • Detachment of float assembly/entry of oil into the float of the MOG, inside the conservator.

		<ul style="list-style-type: none"> • Freakish operation due to entry of rain water / rodents into the terminal casing of MOG.
IX	Temperature Alarm/Trip	<ul style="list-style-type: none"> • Continuous overload. • Failure/inadequate fans/pumps. • Mechanical damage to the capillary tube of the I.T. • Defect in the temperature indicator. • Freakish operation due to entry of water/rodents into the Marshalling Box. • Loosening of core assembly in transport. • Failure of insulation of the core laminations / core assembly. • Inadvertent closing of radiator valves.
X.	Buchholz Alarm	<ul style="list-style-type: none"> • Incipient fault inside the transformer. • Accumulation of air in the Buchholz chamber, which would have got trapped inside the transformer due to improper filling of oil. • Leak in the radiator/pipelines of the cooling pump (only in transformers with forced oil cooling). • Freakish operation due to entry of rain water / rodents into the terminal casing of the B.Ralay. • Loss of oil due to leakage.
XI	Buchholz Trip	<ul style="list-style-type: none"> • Major electrical fault inside the transformer. • Major jolting of the winding assembly for a fault in the feeder or in the LV close Bus. • Incorrect inclination/cross section of the pipeline between the tank and conservator. • Freakish operation due to entry of rain water / rodents into the terminal casing of the B.Relay.
XII	OLTC Surge Relay Trip	<ul style="list-style-type: none"> • Loss of oil due to leak in the OLTC/OLTC conservator/pipe line of the Surge Relay. • Development of Contact resistance in the OLTC and consequent heating. • Freakish operation due to entry of rain water / rodents into the terminal casing of the Surge Relay.
XIII	Pressure Relief Device – Trip	<ul style="list-style-type: none"> • Electrical fault inside the transformer. • Inadvertent closing of the valve in the Buchholz pipe line. • Freakish actuation due to entry of rain water / rodents into the terminal casing of the PRD.

2.28 ACTION WARRANTED IN CASE OF BUCHHOLZ ALARM/TRIP, SURGE RELAY-TRIP, PRESSURE RELIEF DEVICE TRIP.

1.	Buchholz Alarm/Trip	<ul style="list-style-type: none"> • Transformer shall be isolated from service. It should be put into service only after ensuring the healthiness of the transformer by MRT. • Collection of gas/air shall be checked through the view glass. • If no collection of gas/air, then the alarm may be freakish or the diaphragm of the Explosion Vent would have got punctured or the PRD would have acted.
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		<ul style="list-style-type: none"> • Combustibility of gas/air collection shall be checked. • Gas/air shall be subjected to Precipitation Test with AgNO₃ and AgNO₃ + Ammonia solution. • If the collection is proved to be air, check for leak in the radiator/pipelines of the cooling pumps and suction of air. • If the collection is proved to be gas, healthiness of the transformer shall be tested by MRT.
2.	Surge Relay-Trip/Pressure Relief Device-Trip	<ul style="list-style-type: none"> • Transformer shall be isolated from service. • The transformer shall be tested by MRT for the healthiness of the contacts in the OLTC gear.

2.29.1 APPLICATION AND INTERPRETATION OF TESTS ON OIL IN TRANSFORMERS AND REACTORS (INCLUDING SELECTOR TANKS OF ON-LOAD TAP CHANGERS)

Sl. No.	CHARACTERISTICS	EQUIPMENT VOLTAGE	SUGGESTED INITIAL PERIODICITY OF TESTS	PERMISSIBLE LIMIT SATISFACTORY FOR USE	ACTION IF OUTSIDE PERMISSIBLE LIMIT
(1)	(2)	(3)	(4)	(5)	(6)
i)	Electric Strength (Breakdown voltage – kV)	145 kV & above 72.5 kV & less than 145 kV Below 72.5 kV	After filling or re-filling prior to energizing, then after 3 months and after one year.	50 kV (Min) 40 kV (Min) 30 kV (Min)	Recondition oil, or alternatively if more economic or other tests dictate, replace oil.
ii)	Water content (PPM)	145 kV & above Below 145 kV	After filling or re-filling prior to energizing, then after 3 months and after one year.	25 PPM 35 PPM (Max)	Recondition oil, or alternatively if more economic or other tests dictate, replace oil.
iii)	Specific resistance (resistivity, ohm-cm) at 90°C	All voltages.	After filling or re-filling prior to energizing, then after 3 months and after two year.	$\times 10^{12}$ ohm-cm (Min) at 90°C	Recondition, if the value of the DDF permits, reclaim or replace if not.
iv)	Dielectric dissipation factor (tan delta) at 90°C	145 kV & above. Below 145 kV	After filling or re-filling prior to energizing, then after two year.	(Max) 1.0 (Max)	Reclaim or replace oil (limit to be adopted depends on the type of equipment and instructions from the manufacturer).

v)	Neutralization value (total acidity)	All voltages.	After filling or re-filling prior to energizing, then after two year.	0.5 mg KOH/h (Max)	Reclaim or replace oil.
vi)	Sediment and/or perceptible sludge	All voltages.	After filling or re-filling prior to energizing, then after two year.	No sediment or precipitable sludge should be detectable.	Recondition oil if sediment is detected. Alternatively if more economic, or other tests dictate replace oil. Reclaim or replace oil if precipitable sludge is detected.
vii)	Flash Point	All voltages	After filling or re-filling prior to energizing, then after two year.	Decrease in the flash point 15°C (Max) of the initial value, minimum value 125°C.	Reclaim or replace oil after checking causes.
viii)	Interfacial Tension at 27°C	All voltages	After filling or re-filling prior to energizing, then after two year.	0.018 N/m (Min)	Reclaim or replace oil.

2.29.2 PERMISSIBLE CONCENTRATION OF DISSOLVED GASES IN THE OIL OF A HEALTHY TRANSFORMER

GAS (in PPM)	LESS THAN 4 YEARS IN SERVICE	4-10 YEARS IN SERVICE	MORE THAN 10 YEARS IN SERVICE
H ₂ (Hydrogen)	100/150	200/300	300/400
CH ₄ (Methane)	50/70	100/150	200/300
C ₂ H ₂ (Acetylene)	20/30	30/50	50/100
C ₂ H ₄ (Ethylene)	100/150	150/200	200/300
C ₂ H ₆ (Ethane)	30/50	100/150	150/200
CO (Carbon Monoxide)	200/300	300/400	500/600
CO ₂ (Carbon Dioxide)	2500/3000	3000/4000	7000/10000

If C₂H₂ is detected even within the permissible limits, greater attention to that transformer is advisable.

2.29.3 FAULTS AND THE GASES THEY PRODUCE

TYPE OF FAULT

MAIN GASES PRODUCED

HOT SPOT IN OIL	H ₂ , <u>CH₄</u> , <u>C₂H₄</u> , C ₂ H ₆ , <u>C₃H₆</u> , C ₃ H ₈
OVERHEATING IN SOLID INSULATION	<u>CO</u> , <u>CO₂</u> , H ₂ , <u>CH₄</u> , <u>C₂H₄</u> , C ₂ H ₆ , <u>C₃H₆</u> , C ₃ H ₈ .
ARCING IN OIL	H₂, CH₄, C₂H₂, C₂H₄, C₃H₆
ARCING IN SOLID INSULATION	<u>CO</u> , <u>CO₂</u> , <u>H₂</u> , <u>CH₄</u> , <u>C₂H₂</u> , <u>C₂H₄</u> , <u>C₃H₆</u> .

GASES UNDERLINED ARE THE MOST CHARACTERISTIC ONES.

2.30 SAFETY ASPECTS ON OPERATION AND MAINTENANCE

2.30.1 INTRODUCTION

The rapid growth of electrical power systems and their inter-connected operation calls for reliable, economic and safe operation of the system. With this growth, the complexities of various system elements have also increased. During system disturbance or fault on the equipment, fault data for prompt analysis and decision making through DAS or sequence of Event Recorders have become essential. Operating instructions for Normal, Emergency and Special condition are used for restoring normalcy choosing the best and safest procedure subsequent to outage or disturbance.

As a source of energy, electricity should be handled with utmost caution and care. Failure to take suitable precaution in its use, creates conditions which would result in fatal accident and damage to the equipment. Accidents cause human sufferings and loss of production to the organization. These are caused either singly or in combination with the human factor, the machine factor and the environment factor. Anxiety, fear, worry and other distractions may cause accidents. Troubles at home, rift with colleagues and superiors prevent concentration and alertness required for the job.

It is said that more than 90% of the accidents are avoidable. Out of avoidable accidents, 20% are the result of faulty conditions. 20% due to faulty behaviour and 60% due to combination of both.

In view of the above facts, it is essential to promote safety measures to prevent electrical accidents. At all costs, safety of personnel against electrical accidents must be ensured by all concerned and this can be achieved by well organized preventive steps in understanding the cause of electrical accidents. Success of safety measures depends on safety mindedness of the management, supervisors and workers. Safety consciousness can not be maintained in employees if interest is not taken by supervisors and management. Some of the methods to improve safety consciousness are given below :

1. Efforts of supervisors to enlist understanding and co-operation of all employees in their day to day work.
2. Training in safety,
3. Prompt investigation into accidents pinpointing cause of accident and taking remedial steps.
4. Maintaining accident statistics.

5. Formation of safety cells.
6. Ensuring the use of personal protective equipment such as helmet, goggles, gloves, ear muffler etc.
7. Arousing safety consciousness through the use of posters, films, house journals, safety talks, safety competitions etc.

2.30.2 GENERAL SAFETY PRECAUTIONS

1. All voltage levels, even low voltage shall be considered dangerous even though the voltage may not be high enough to produce serious shock.
2. All electrical circuits are to be treated “live” and no work should be carried out on any part of electrical equipment unless it is (I) De-energised (II) Isolated from all the sources and (III) Effectively connected to ground. Maintenance, repairs and construction work on electrical equipment shall not be carried out until working conditions are safe and proper authorisation is obtained.

2.30.3 FUNDAMENTALS OF SAFETY

1. Prevention of accidents requires whole-hearted co-operation of all members of the organization. A capable mentally alert employee will avoid accidents. However, an unsafe person is a liability. He is danger to himself, his fellow workers and to the equipments and organization.
2. Unsafe acts which may cause accidents :
 - a. Operation on equipment without authority or warning.
 - b. Operations or working without proper instructions.
 - c. Making defective equipment or its improper use.
 - d. Using defective equipment or its improper use.
 - e. Working nearby dangerous or live electrical equipment which could otherwise be conveniently de-energised.
3. Unsafe conditions which may cause accidents are
 - a. Ungrounded equipment.
 - b. Defective material or equipment.
 - c. Improper illumination.
 - d. Non-standard design or construction.

Accidents are the result of unsafe conditions or unsafe acts or combinations of both.

2.30.4 SAFETY PRECAUTIONS AND PRACTICES IN OPERATION AND MAINTENANCE

1. No unsafe operation will ever be permitted. Feedback regarding unsafe operation / condition should be taken into consideration with proper spirit and review should be made to avoid accident.

2. Interlocks should not be bye-passed unless it is very essential. Written permission should be obtained from the departmental head-in-charge of the station. Extra precaution should be taken by all the parties during each cases.
3. Equipments are designed for certain operation conditions. It should be operated within prescribed operation limits. Over-stressing of the equipments should be for minimum possible time within permissible overloading limit. They will avoid damage to the equipment.
4. Operation & maintenance staff should be familiar with the station layout and operating limits of different equipment such as breakers, transformers, Isolators, CTs, PTs, etc. A person should be allowed to operate or take over the equipment only after he has acquired adequate knowledge of the equipment.
5. Operations should be carried out as per operating instructions. This will help in carrying out operations safely and maintaining uniformity. In case of any modifications / changes in the layout, operating instructions should be reviewed and all personnel are appraised of the modifications / new instructions.
6. Operations and maintenance manuals/manufacturers instructions for different equipment should be available and should be referred to before taking out equipment for maintenance.
7. It is the responsibility of the supervisor to interpret correctly and explain safety rules and regulations to all the persons concerned and ensure that they thoroughly understand the same.
8. Breach of safety rules should be suitably dealt with.
9. Only authorised persons shall be allowed to carry out operation & maintenance.
10. Supervisor shall guard against the use of defective safety appliances, tools and materials.
11. In case of any emergency, in which quick action is necessary in order to safeguard life or property, persons are authorised to take necessary action, which is thoroughly understood by them. Under no circumstances attempt shall be made to carry out operations which are not safe.
12. Updated drawing of station layout giving details of equipment should be displayed.
13. All persons must use the standard protective equipment intended for the job.
14. All protective equipment should be periodically tested.
15. Metal ladders should not be used in switchyard.
16. Adequate number of first aid and fire fighting equipment shall be maintained.

17. Every person should be familiar with fire fighting and should know how to operate fire fighting equipment, so that fire can be extinguished promptly minimizing damage.
18. In the event of fire on electrical installation, the affected part shall be immediately switched-off and isolated from all the sources.
19. First aid and artificial respiration chart should be exhibited.
20. Use only HRC fuses of proper capacity.
21. While opening the isolator, confirm that it is not carrying load current. Do not break load current on isolator. Similarly, isolator should not be closed on load. However certain isolators are designed to change / discharge transformer (without load) and small length of overhead lines or cables.
22. Under-rated circuit breakers should not be used to clear the fault. However it can be used as a non-automatic breaker.
23. No breaker should be operated beyond stipulated operation duty.
24. While working on the breaker, its operating mechanism should be de-energised such as discharging spring, release air pressure etc..
25. Transformer should be discharged and grounded from all sides (windings). Neutral grounding of the transformer should not be treated as grounding.
26. Current transformer secondaries should never be left open circuited.
27. After cutting out capacitor bank, it should be allowed to discharge through discharge PT for about 5 minutes. The bank should be grounded with hot stick before commencing the work.
28. ASKAREL compound used in capacitor bank as a dielectric is very toxic and harmful. Hence, should be handled with great care.
29. Apparatus, frame work and other non-current carrying metal parts associated with power system are to be effectively grounded.
30. Lightning Arrestors shall be grounded independently.
31. Isolators provided for generators and synchronous condensers and other rotating machines should never be opened when connected to any voltage source even when the machine is carrying out no load.
32. The area should be cordoned off indicating location of work on the particular equipment.

2.31 Fire Protection of Power Transformers

2.31.1 General

i Introduction

The hazard of fire originating in or spreading to Power Transformers has always been recognized in the Power Industry. With the increasing size of Generating units and associated Transmission and Distribution networks the number of transformers of large capacities has increased phenomenally thus necessitating more stringent protection measures to prevent fire risk to transformers and damage to equipment. This section of the transformer specifications discusses the various aspects of transformer fire protection.

ii. Strategy

The strategy for safeguarding against fire is to emphasize fire prevention rather than fire fighting. Nevertheless, it is equally important to provide adequate fire fighting arrangements. This applies also to associated equipment like bushings, circuit breakers, instrument transformers, cables, etc. since a fire originating in these can easily spread to the power transformer. In effect, all the transformer installations should be provided with fire prevention as well as fire detection and fighting system.

iii. Other Factors

Factors like proximity of the transformer to buildings and other equipment such as switchgear play an important role in design of the fire prevention scheme. It is desirable that these equipments be segregated from the transformer installation or be provided with fire prevention measures to avoid spread of fire to the transformer installations.

2.31.2 Design Considerations

A majority of fires originating in transformers are due to inadequate design and installation, apart from faulty operation and maintenance practices. Proper installation, house keeping and maintenance can reduce fire hazards to a great extent. Hence, fire hazards must be given utmost attention while designing, selecting and installing power transformers and correct operation and maintenance procedures must be adhered to strictly.

i. Bushings

Bushings are often the source of transformer failures and consequent fires. This is due to the fact that dielectric stresses in bushings are very high and sometimes oil tightness may not be ensured. Only bushings of proven design, which have been fully type tested and have passed all acceptance tests shall be used, Bushings shall be provided with test taps and regular (annual) checks of bushing tan delta shall be carried out. Also, the oil level in oil filled bushings, shall be checked daily.

ii Tap Changer

Tap changers, particularly on-load type are a potential fire risk. The selection of tap changer design and proper maintenance of its mechanism are important. In no case should an off-load tap changer be operated when the transformer is energized from any of its windings.

iii Cable Sealing Ends.

The level of compound in the sealing ends should be checked periodically.

2.31.3 Installation Requirements: General

The general recommendations for safeguarding power transformers are given below and specific recommendations are given in item 4. The requirement relevant to transformers, in increasing order of importance in installation is:

- a. Soak pits
- b. Drain pits
- c. Barrier walls
- d. Fire detection systems
- e. Fire hydrant
- f. Deluge, spray or Mulsifyre system

In case of remote controlled or unattended sub station automatic fire detection and fighting system must be provided.

1. Outdoor Transformers

a. Soak Pit and Drain Pit

The transformers foundation shall be surrounded by a suitable soak pit enclosed by a 150mm high non-combustible curb. This soak pit shall be filled with coarse crushed stones about 25mm in diameter to a minimum depth of 300mm. The volume of the soak pit minus the volume of the stones should be sufficient to contain the entire oil content of the transformer if the oil content is less than or equal to 5kl. In case the oil content is more than 5kl. The volume of soak pit minus the volume of stones should be sufficient to contain atleast one third of the total oil content. The excess should be led through two or more hume/concrete pipes(min. 150mm dia) from bottom of pit to a central remote burnt oil tank.

b. Barriers between transformers

Barrier walls of brick or reinforced cement concrete shall be provided for separation of transformers wherever adequate space is not available (Refer Chapter-4). The Barriers shall extend at least 300mm above the highest transformer bushing and pressure relief vent and lengthwise 600mm beyond the transformers including any radiators and tap changer enclosures.

c. Fire Detection, Hydrant and Deluge System

Selection of these systems should be based on the importance of an installation. The fire detection system only detects a fire and sends an alarm, whereas the other systems are active fire fighting systems. Selection guidelines are given in Chapter 4.

ii. General

The requirements laid down in item 5 of Tariff Advisory Committee's "Regulations for the Electrical Equipment of Buildings" and Section 7.9 of IS: 10028(Part-II) shall be followed

for all transformer installations. In addition, the following measures are recommended for cables.

- a. The power cables entering the transformer shall be coated with fire resistant material in the immediate vicinity of the transformer cable box entry so as to prevent spreading of fire from or to the transformer cable.
- b. Cable trenches shall be filled with sand to prevent spread of fire.

It is recommended that trenches of more than 1000cm² cross-sectional area be divided by incombustible barriers at intervals not exceeding 45 metres. The barriers shall be atleast 50mm in thickness and of the same height as of the cable trench. The cables shall be carried through holes in the barriers which shall be made good thereafter to prevent passage of fire beyond the barriers.

2.31.4 Installation Requirements: Specific.

A summary of various recommendations for fire protection and fighting systems for indoor and outdoor transformers is given below:

- i. Fire Protection for Outdoor Power Transformers

Size (each)	Number	Transformer Protection
(a) Under 10MVA	One or more	Hydrant protection
(b) 10 to 100MVA	One only	Hydrant protection with water spray equipment.
(See Note 2)		Provide a 7.5m clearance between units a spary nozzles;

Notes :

1. The enclosure should consist of a masonry barrier with wing walls of the same height extending 0.6 to 1 m beyond the transformer, including any radiators and tap changer enclosures. The enclosure should also be provided with a roof of equal fire resistance to the walls.
2. Where there are important or high value bus structures exposed to a transformer oil fire and / or electric service or production could be interrupted for an extended period resulting in large loss, a fixed automatic water spray system should be provided to minimize the physical damage from fire and reduce the down time for repairs.
3. Multiple transformer of 100 MVA and above may be protected as single units if separated by a minimum of 35 m. For those separated by a distance between the minimum clearance shown and 35 m transformer protection may be either barrier or fixed water spray. L
4. Cables, isolated bus duct, or cable tray penetrating an exposed wall should be sealed with a fire barrier or stop. Ventilation louvers should be relocated to an unexposed area.
5. Wherever water spray nozzles are provided, the nozzle should be separated from the transformer by over 4 m for voltages below 250 kV . For voltages beyond this an for solid hose streams , this distance varies with factors such as water pressure wind velocity and direction, size of nozzles etc.

2.31.5 Recommended maintenance and testing practices

It is essential to monitor ascertain parameters to check the healthiness of the transformer and to minimize fire risks. The parameters to be checked and their frequencies shall be as brought out elsewhere in the transformer manual. Some of the parameter more relevant to transformer fires is discussed below.

i. Oil leakage

Oil leakage from transformer tank, bushings or radiator may become sources of major fires. It is recommended that all transformer installations be inspected daily for leakage of oil. Any leakage detected should be immediately attended to. In case of excessive leakage the transformer should be de-energized and repair work carried out.

ii. Hot oil circulation

During hot oil circulation in the transformer, it must be ascertained that all combustible materials are kept at a safe distance from the transformer. The transformer shall be covered with non-combustible materials. Under such condition, it is essential that the transformer is kept under close watch.

iii. Terminal equipment

Sparks from improper terminal connectors and neighboring etc. falling on the transformer can cause great fires. To prevent such occurrences it is recommended that the terminal connectors be regularly inspected for overheating / sparking. Infrared temperature scanners can be use for this purpose. It is also recommended that fuses be installed at a distance from the transformer such that sparks generated during their operation will not reach the transformer.

iv. Transformer oil

The condition monitoring of transformer oil can give valuable insights into the healthiness of transformers. It rs recommended that dielectric strength, acidity and oil tan delta (90C) be monitored continuously and detailed investigation be carried out whenever any of them characteristics indicate signs of deterioration of oil quality.

v. Housekeeping

The importance of good housekeeping and cleanliness in reducing fire hazard cannot be over-emphasized. Many fires have been caused by oil drips and collection of rags in dirty cluttered surroundings. It is very important to remove possibilities of such fires, by ensuring that the installations are spacious and the vacant spaces are periodically cleaned to remove obstructions to ventilation and movement personnel.

2.31.6 Fire Fighting Equipment

In addition to the fire protection system prescribed above. It is essential to provide primary fire lighting equipment for every transformer installation. The equipment required for indoor and outdoor installation should be as per following guidelines:

Typical size of transformer	For the first two units			For every additional two units or part thereof		
	45 ltrs. Form type Etinguishers	2 ltrs. Form type Etinguishers	Sand & water buckets	45 ltrs. Form type Etinguishers	2 ltrs. Form type Etinguishers	Sand & water buckets
Upto 20 MVA	2	4	each (Indoor) 4 each (outdoor)	1	2	each (Indoor) 4 each (outdoor)
Upto 50 MVA	3	6	each (Indoor) 4 each (outdoor)	2	2	each (Indoor) 4 each (outdoor)
Above 50 MVA	4	8	6 each	2	2	6 each

2.31.7 Mulsifyre System

i Automatic Mulsifyre System

The system is widely used for fire fighting of outdoor transformer. Fire detectors located at various strategic points are used to sense high temperature heat the transformer. If the temperature exceeds the set value the automatic mulsifyre system sprays water at a high pressure on the surface of the transformer to control fire on any burning oil spilled over. Various sub systems are used to make a complete mulsifyer system.

a. Main Hydrant

This is used to carry the water to various parts of the switch yard or transformer sub station and forms the backbone of the system. Sturdy corrosion free pipes and valves should be used for this purpose. The materials should be able to withstand fire for a reasonable duration.

b. Fire detectors

Fire detectors can either be thermocouples or specially designed bulbs which burst when a high temperature is applied and release any valves or checking devise to start the water spray.

c. Ring mains and nozzles

Ring mains which surrounded the transformer are provided to feed the water to the nozzles at various levels. Since the water pressure is high the ring mains should be designed to withstand these pressures. Nozzles should be located such that the water sprays, in the event of a fire, envelopes the entire surface of the transformer. The whole system should be periodically checked to detect any leakages.

Pumps

Pumps are provided to fill the hydrants initially and to maintain its pressure. Pumps driven by electrical motors are a standard provision: However the standby comes should preferably be diesel engine driven. It is recommended that the main and standby pumps in a pump house be segregated.

ii Sprinkler and Hydrant System

This system is similar to the multi-fire system but water in this case is sprayed on the transformer body at lower pressure. Hence the name sprinkler. This system is normally not capable of extinguishing large fires. For this reason, it is desirable to connect an alarm to the sprinkler system. Whenever the sprinkler operates an alarm is given to signal requirement of additional fire fighting arrangement. The auto starting from valves and alarm must be periodically checked.

iii Foam System

This system is used to cut off the oxygen supply to the burning parts and thereby extinguish the fire. For this it is essential that the entire surface of the burning part of oil be covered with foam.

The system includes a foam compound chamber, which contains the compound. In the event of a fire, this compound comes in contact with water and air to form foam. This foam is then sprayed onto the burning parts. The compound chamber should be corrosion proof and the valves should be periodically tested to ensure their healthiness.

iv Other system and selection

Various other systems are available for the fighting of transformer fires, notable among them being:

- a. Carbon-dioxide and Halon Systems for indoor or enclosed installations, and
- b. 'Drain and Stir' method for outdoor installations in which on detecting fire, oil is partially drained from the transformer and Nitrogen gas is bubbled into the transformer tank to quench the fire.

2.31.8 Fire Protection System

Carry out mock drill of operation of fire protection system once in a year and procedure is to be followed as described by the equipment supplier.

CHAPTER-3

3.1 GENERAL

3.1.1 GENERAL INSPECTION:

Periodic inspection of switchgear, when it is in service, provides a check on its condition and reveals faults and defects which may develop during operation (failure in insulation, over – heated connection etc.) and makes it possible to take timely remedial measures.

Attended type of sub stations should be attended externally once a day. In addition, night inspection with lights off should be conducted once a week to reveal points of voltage or corona discharge and hot spots.

All troubles and defects discovered during an inspection should be entered in an inspection book and remedial action taken as soon as possible.

3.1.2 REGULAR INSPECTION:

On regular inspection, the GSS in charge should:

- i. Examine the insulators, bus bar contacts and current carrying parts of apparatus for over all condition.
- ii. Inspect the circuit breakers for over all conditions.
- iii. For indoor circuit breakers, examine the switchgear premises, the doors, windows and locks. Make sure that the roofing does not leak; the heating system and ventilating facilities are in order.
- iv. Test the alarm circuit for continuity and proper operation and safety aids for healthy condition.

3.1.3 INSULATION:

Insulation resistance test (where practicable) and visual inspection indicate possible incipient failure for oil immersed insulation. Consistency of the insulation resistance measurement for a given piece of equipment is more important than the actual value, and for this reason, it is necessary to ensure that tests are made in a consistent manner, noting those factors such as temperature and whether which can cause a variation in the results. The more elaborate forms of testing, such as capacitance, power factor or dissipation measurement require specialized knowledge to obtain reliable and consistent results and are necessary only at rare intervals or when trouble is suspected.

Capacitance testing has, however, recently been developed into a relatively simple technique for the purpose of checking the condenser bushing. This method uses a portable a. c. bridge with electronic detection failure of a layer or layers of a condenser bushing which can be replaced before further deterioration takes place.

Porcelain insulator requires no maintenance, other than periodic cleaning, and judgment of the time when cleaning is necessary is very much a matter of visual observation of the amount of deposits which may be washed by a water jet when they are alive, subject to strict control of the method used. Live washing lessens the deposits but does not remove the need for periodical hand cleaning during planned shutdown.

3.1.4 SECONDARY EQUIPMENT:

Secondary equipment should not be overlooked in maintenance, since small wiring defects are a common cause of unwanted tripping or a failure to trip. The continuity of all important connections and the freedom of terminal boxes from moisture or tracking over moulded insulation are important.

3.1.5 PREVENTIVE MAINTENANCE:

Preventive maintenance of electrical equipment primarily amounts to testing the insulation and contact resistance of the various pieces of equipment.

3.1.6 INSULATION

i. RESISTANCE TESTING:

Insulation resistance test reveal defects and faults which cannot be detected by external inspection. Though not upsetting normal operation of the equipment at the time of testing, these defects may later lead to a breakdown.

Insulation defects may be due to variety of causes, such as overheating due to overloads, excess moisture, mechanical injury, ageing etc.

For preventive purpose, it is normal practice to test the insulation of support insulators and circuit breaker.

Insulation resistance may be tested with a megger only on de - energized circuits or equipments.

For its ability to detect weak spots in insulation, measurement of insulation resistance depends on the fact that any deterioration in the insulation is accompanied by a sharp drop in the insulation resistance of one phase relative to another or to earth. In the absence of any evidence of insulation breakdown, megger measurement mainly indicates the degree to which moisture has been absorbed by the insulation or deposits that have accumulated on it.

Moisture absorption is usually evaluated from the ratio of two values of insulation resistance measured with a megger after 60 seconds and 15 seconds respectively. This ratio is called the coefficient of moisture absorption and is calculated by the

$$\text{Equation} \quad 'K' = (R-60) / (R-15)$$

Where, 'K' is Co-efficient of moisture absorption.

R-60 insulation resistance as measured by megger after 60 seconds.

R-15 insulation resistance as measured by megger after 15 seconds.

Damp insulation will have co-efficient value closed to 1. As the insulation dries out, the co-efficient rises and when it becomes 1.3 or above, the insulation is considered to be dry.

ii. INSULATION GRADIENT TESTING:

Faulty suspension and support insulators are detected while they are in service by measuring the voltage gradient across the individual units of a string or support insulator. This method uses special high potential tester. The measured voltage distribution is then compared with characteristic curves plotted for good insulators of the same type. The gradient will be lower across faulty units and higher across good ones.

An insulators unit requires replacement when the voltage across it drops by a third to half of its normal share.

The condition of oil filled, compound filled, bakelite paper insulators and terminal bushing can be assessed on the basis of dielectric losses. However, instead of dielectric loss, which varies with the size of an insulator, it is more convenient to use what is known as the tangent of the loss angle (δ) or power factor which is practically equal to the ratio of the leakage current (I_l) to the capacitive current (I_c) or $\text{Tan } \delta = (I_l) / (I_c)$

The power factor is usually measured by suitable measurement bridges.

iii. INSULATION(POWER FACTOR):

The power factor provides a check on the ageing of laminated insulating materials. With time, these begin to separate and form voids where air as well as moisture may ingress. These changes impair the quality of laminated insulation and their dielectric losses increase. The dielectric power factor test is obligatory for all oil filled, compound filled, bakelite paper terminal bushing and for other types of equipment. Bushing with an increased dielectric power factor should be replaced.

3.1.7 STOCK OF SPARES:

The emergency replacement stock of equipment spare parts and components should be examined, tested, cleaned and lubricated every two years.

3.1.8 CONTACT RESISTANCE:

Bush connections in outdoor switchgear are tested by contact resistance measurement. The contact resistance of bush joint should not be greater than 1.2 times of the resistance of the same length of the bush.

3.1.9 GENERAL TESTING:

In addition to inspection of insulation tests, switchgear equipment should also be tested for proper functioning and specified performance. Among other things, the apparatus should be

tested for positive closing and opening under service conditions of control voltage and air pressure variations (where air blast circuit breakers are installed) for functional alignment of the associated assemblies in an apparatus, for the power or air requirement etc. Tests and inspections when thoroughly conducted will go a long way towards reliable and trouble free operation of switchgear equipment.

3.1.10 GENERAL PREVENTIVE MAINTENANCE:

The preventive maintenance of switchgear equipment includes the following:

- i. A thorough visual inspection of the entire installation, cleaning of the equipment and also cleaning of the premises.
- ii. Checking of the fastening and bus bar clamps and joints for tightness, replacement of damaged insulators.
- iii. Checking of draw out chambers in metal clad switchgear units,
- iv. Checking of earthing system and connections.
- v. Sampling and replenishing of all oil filled apparatus.
- vi. Checking operating mechanism (closing and tripping) to see if it is working smoothly and whether there are any worn parts.
- vii. The gear should be inspected for dust or oil, particularly on the insulation.
- viii. All springs should be examined to see that they are in good condition.
- ix. The moving contact should be checked/adjusted so as to check that arcing contacts are making in advance of secondary contacts and that secondary contact are making in advance of main contacts.
- x. All pivots and rollers should be checked to see if they are reasonably well lubricated, but care should be taken not to apply too much grease.

3.2 OIL CIRCUIT BREAKERS

3.2.1 GENERAL ASPECTS REGARDING MAINTENANCE OF OIL CIRCUIT BREAKERS.

The static nature of these circuit breakers makes them liable to be neglected in the matter of periodic examination and testing of oil depending on the amount of load switching which is carried out. Circuit breakers should be examined once a month at least. Where a circuit breaker is known to have cleared a short circuit, it should be inspected at the very first opportunity, irrespective of the normal periodic maintenance inspection. The oil should be tested by taking a sample from as near the tank bottom as possible. If it is badly blackened by carbonization, or not withstand a test voltage of at least 40 kV, it should be replaced. Of even, more importance is the deposits of carbon and moisture on insulator surfaces, which may lead to flashover, even when the oil test is satisfactory.

Circuit breakers, not periodically operated, may fail to trip on fault due to stiffness developing in the mechanism or to defects in the trip circuit. It is, therefore, recommended that automatic circuit breaker should be tripped and re - closed at least once every month, if it has not tripped during that month, to guard against such eventualities.

Circuit breakers with battery operated trip coils should be tripped by operation of the relay and those, with series trip coils should be tripped by a manual operation of the plungers, where this is possible.

3.2.2 ROUTINE INSPECTION AND MAINTENANCE:

A general inspection of the sub-station or switch room should be made at regular intervals. Attention being given to general cleanliness, heating and ventilation, evidence of overheating and audible discharge. Leakage of oil or compound, any unusual smell which may denote over heated or acid oil, an electrical discharge or noise indicating surface leakage or looseness of a component, should be investigated.

Regular checks should be made to ensure that ancillary equipment such as special tools, isolating equipment, earthing equipment, etc., are available and are in good condition.

All switchgear, whatever it's class of duty, should be given close examination at intervals not exceeding one year in order to determine the extent of maintenance required. In power stations and important switching stations, the intervals may be shorter, e.g., six months.

In special case, a shorter interval may be desirable such as when switchgear controls highly inductive circuits, transformer not on load or capacitive circuits such as power factor correction capacitors. Particular attention may also be required where switchgear is subjected to frequent operation or is installed in adverse conditions or by reason of its age.

All replacement parts should be obtained from the manufacturers to ensure interchangeability. In this connection the manufacturer's spare parts list is useful.

The following program is recommended to be followed for routine maintenance (the recommendation is supplementary to and should be read in conjunction with the manufacturer's operation and Maintenance Instructions):-

3.2.3 CLEANING:

All loose external dirt should first be removed. When cleaning switchgear, it is most important not to use what is generally known as cotton waste. Cloth used for this purpose should be cleaned and free from loose fibers, common metallic thread or similar particles. Brushes and blower nozzles should contain no metallic material.

Care should be taken to prevent loose parts, tools, metal fillings or dirt falling into the apparatus.

3.2.4 INSULATION:

Clean and inspect, renew where necessary. Porcelain insulation should be examined for cracks or other defects. Bonded and laminated fiber insulations should be examined. Insulation resistance tests are strongly recommended for detection of signs of cracking, blistering or delaminating.

3.2.5 MAINTENANCE AND TESTING OF INSULATION:

General:

Close visual inspection and regular testing of insulation are most essential, since security of supply shall always depend on the quality of insulation of the switchgear. Visual examination, usually, suffices for porcelain insulation but other insulation, such as synthetic resin bonded paper or fabric and impregnated or laminated wood, is particularly susceptible to the ingress of moisture, overheating or tracking, and visual inspection should be supplemented by regular testing. Insulation resistance measurements can be easily made and are the most suitable for routine test, but for their proper interpretation systematic testing and recording methods are essential. Resistance tests are strictly comparative only, in that for each item tested, a rejection value can only be fixed on the basis of experience, by comparison with earlier results. Test values obtained should be logged, together with the humidity and temperature at the time of the test, and in general, a steady fall of resistance over a period of time is a more reliable indication of deterioration than is a relatively low value which remains sensibly constant.

On long pieces of insulation such as lift rods on large circuit breakers, deterioration may not occur uniformly and resistance measurement taken over the entire length may not reveal localized deterioration. It is, therefore, recommended that, where possible, an electrode be placed mid-way along the insulation and the resistance to each end measured separately. If there is a marked difference between readings, the insulation should be rejected.

Particular attention should be paid to the lift rods of circuit breakers, where these are made of hickory or other natural wood. These should be examined for the wood shearing along the grain, and for pulling out of the riveted end where this method of fixing is employed.

Where possible, the insulation, to be tested, should be allowed to reach ambient temperature before resistance tests are made.

3.2.6 CONDENSER BUSHINGS:

Resistance measurement would indicate serious ingress of moisture, though it may not reveal partial tracking or internal deterioration. Any oil filling should be periodically checked for presence of moisture, and if this is suspected, the outer porcelain should be removed and the bushings examined for tracking. The joints should be examined to determine where the moisture, if any, has entered.

With compound filled bushing, a resistance measurement will not necessarily indicate the presence of moisture, and once every five years, where practicable, the space above compound should be examined for moisture ingress. If the presence of moisture is suspected, the bushings should be returned to the manufacture to be decompounded and subjected to power factor test. Care must be taken on reassembly to ensure that all joints are properly re-

made where covers have been removed. It is advised to check that the earth connection is sound during inspection

Power factor measurements are difficult to be done at site, and they should be confined to the testing of bushings at long intervals, or when suspected.

3.2.7 PROCELAIN INSULATION:

Porcelain insulation does not deteriorate in the manner of synthetic resin bonded insulation but it may give low resistance readings under humid conditions. Careful interpretation for test results is necessary and a thorough visual examination for cracks or other mechanical damage is as important as electrical tests.

3.2.8 CONTACTS:

Examine for burning and other damages and recondition or replace as required. Check that any backing springs are exerting proper pressure and that the contacts are in correct alignment.

Slight burning or tarnishing of copper or copper alloy contact faces may be removed by using a fine glass paper (Emery or carborundum papers should not be used). Silver contacts seldom require cleaning despite a black appearance. Plate polish may be used, if it is desired to clean them.

The amount of material removed from contact should be kept to a minimum and it is imperative that the spring pressure between the contact surfaces should not be materially reduced.

Modern high pressure point or line contacts will normally carry their rated current satisfactorily, even if there is some pitting of the surface. Large beads or ridges on the contacting members, that would seriously impede closing, should be removed.

Contact pressure alignment and wipe should be checked, when contacts are replaced or renewed.

3.2.9 ARC CONTROL DEVICES:

These should be examined and cleaned or if badly burnt, renewed. Care should be taken that vent holes and orifices are clean and the devices should be flushed out with clean oil before being replaced.

Resistance, if pitted, should be checked for continuity or its resistive value.

3.2.10 VENTING:

Examine the venting system to ensure that the free passage for oil gauge exists. Where there is a joint between movable portions of the gear, ensure that it is in sound condition.

3.2.11 MECHANISM:

During inspection or maintenance of mechanism, care should be taken to avoid the fingers being trapped in any part of the mechanism and to avoid the possibility of any one being struck by moving parts of the mechanism, or of the moving parts.

Clean, examine and renew worn parts. It is particularly important to ensure that the rolling or sliding surfaces in the trip mechanism are free from dried up lubricate. The mechanical details of the closing mechanism should be checked. Lubricate in accordance with the manufacturers instructions.

Extreme care should be taken to verify that adjustments and confirm with the manufacturers instruction. Check for overall current operation.

3.2.12 AUXILIARY SWITCHES, INDICATING DEVICES AND INTERLOCK

Auxiliary switches should be kept clean and in sound condition because, upon them, depends the correct functioning of other items of equipment, including protective gear.

Examine the contacts, clean or renew, if necessary. Check for good contact pressure, freedom of the operating links and for correct timings of the contacts in relation to the main contacts. Indicating devices such as mechanism and/or indicator etc. should be examined to ensure that they are in good working order.

Interlock and locking devices should receive particular attention, especially those associated with earthing and testing facilities. A strained or looking device may result in dangerous reduction of clearances.

Particular attention should be paid to the timing of the auxiliary contact controlling the trip circuit to see that these may not operate before the main contacts.

3.2.13 CIRCUIT BREAKER OIL:

Deterioration of oil in circuit breaker depends mainly on the duty of the circuit breaker and the efficiency of its own control device. In general, the design permits certain degree of contamination. The frequency of testing the oil should be decided by experience and in consultation with the circuit breaker manufacturer. The following recommendations may, however, serve as useful guide:-

The condition of oil should be checked after any severe operation on fault and, with older and less efficient types of circuit breakers, after any operation on fault. The oil in circuit breakers, operated frequently on normal currents, should be checked after 500 operations or if operated regularly to switch out unleaded transformers and long cables, after 200 operations. Circuit breakers operating frequently in service conditions, such as furnace control, require special consideration.

Circuit breakers, which are frequently operated and which are not operated on external faults, should have oil checked half yearly/yearly. This period may be extended, if the results of tests are normally satisfactory. Outdoor circuit breakers, in which water contamination due to internal condensation occurs, however, require more frequent checking.

Moderate carbonization of dry oil is not normally deleterious. Carbonization in moist oil rapidly produces tracking of any backalized paper insulation, and even in clean oil, moisture will, in the time, give rise to the same trouble.

a. DISCOLOURATION:

Oil which is not clear and light in colour or which has an acrid smell should be purified or renewed, even though it might have passed the tests described below:-

The oil should be checked for dielectric strength, crackle of acidity. Flash point test is not necessary till the oil has an unusual odor, remembering that the oil in circuit breakers, which have operated on fault, may be expected to have an odor of acetylene.

b. OIL TESTS:

i. DIELECTRIC STRENGTH

The dielectric strength measured in the standard test cell should not be less than 40 kV for one minute.

ii. CRACKLE

Generally, oil which shows signs of moisture on crackle test will not withstand the dielectric strength test, but no oil showing signs of moisture on crackle test should be accepted for the service even though, samples may have passed test for dielectric strength.

iii. ACIDITY

As the normal working temperatures of switch gear are generally low, the oil is not likely to develop acidity, but if it has an unusual odor or if there is evidence of corrosion of metal parts within the tank, it should be changed.

iv. OIL FILLING

Before filling the oil tanks, they should be carefully cleaned and inspected. If rags are used for wiping out, care must be taken that fibrous particles are not left behind.

All oil circuit breaker tanks or compartments will be provided with an indication for correct oil level, either the dipstick method or by an oil level indicator. It is important that the correct level should be maintained, as the depth of oil determines the volume of the air cushion above, and in turn affects the stresses set up in the breaker when opening on a short circuit and in part also governs the oil pressure available for arc extinction.

Where portable oil handling equipment is used, flexible pipe work and hand pumps should be carefully inspected to ensure that they are free from dirt and water and should be flushed with oil before use. Oil from barrels or drums shall only be used, if it has been recently tested. The filling of barrels or drums should be clean and dry. Minimum oil is experienced when there is no splashing during filling. It is, therefore, recommended that when filling a circuit breaker,

the nozzle of the delivery pipe should be held between the surfaces of the oil. If excessive accretion is noted under this condition, attention should be given to pipe work joint and pump glands etc., which may cause accretion. Hot oil should not be used for filling switchgear tanks. If the oil handling pipe work is of the fixed and permanently connected type, it is strongly recommended that the tanks should be filled from the bottom so that splashing of the oil is reduced to a minimum. Houses used for clean or dirty oil should be clearly marked and provided with plugs. Oil should be clearly marked and provided with plugs for sealing the ends when not in use. Even if the oil in the storage tank has been filled satisfactorily, a sample should be taken, wherever practicable, from the switchgear tanks after filling. Such samples should, preferably, be tested for bioelectricity strength and crackle test in accordance with the tests already set out.

To ensure satisfactory de-accretion of the oil in the switchgear tanks, it should be allowed to stand for a period after filling. When the recommendations for filling given above have been followed, the period will be a minimum and on switchgear operating at voltage above 11 kV not less than one hour should be allowed before commissioning the equipment.

3.2.14 MAIN CONNECTION

Ensure that all fastenings are tight and good contact is maintained.

3.2.15 SECONDARY WIRING

Ensure that connections are tight so that good contact is maintained and that terminal boxes are free from dirt and moisture. Check insulation resistance and continuity of wiring to the time limit fuses, instrument transformers, relays, instruments, meters and other associated items.

Auxiliary plug and socket contacts should be cleaned and re-lubricated, where necessary. Fuses should be tested for continuity. Fixed contacts, carrying the fuses, should be cleaned and tested for satisfactory contact.

3.2.16 FINAL CHECKING:

An insulation resistance test for the primary connections should be made and it should be checked for correct operation, before the circuit breaker and its ancillary apparatus are returned to service.

Correct operations of safety shutters should be checked as the switchgear is restored to the service position.

Where practicable, the closing and tripping of the circuit breaker, after it has been restored to the service position, should be checked.

3.2.17 MAINTENANCE AFTER OPERATION UNDER FAULT CONDITION:

It is desirable that a complete inspection and overhaul be made as soon as possible in order to re-sort the making capacity, breaking capacity, normal current carrying capacities and insulation level to the original rated values, after fault operation. This is particularly important in the case of old switchgear.

Isolation of withdrawable metal clad circuit breakers should be delayed for not less than 10 minutes after operation on fault to allow for the dispersal of any ignitable gases in the live spouts.

The maintenance required after operation under fault conditions should generally follow the recommendations given below:-

a. CURRENT CARRYING PARTS:

All contacts, including isolating contacts, should be examined. The arcing contacts and arc control devices should be reconditioned or renewed, as required.

Lack of attention to arcing contacts may result in burning of the main current carrying surfaces at some future operations.

b. INSULATION:-

The insulation should be examined to see whether it suffered damage and should be cleaned and examined for burns and renewed, if necessary.

c. INSULATING OIL:-

If the oil is badly discolored or shows evidence of carbon particles in suspension, it should be reconditioned or changed in accordance with the procedure detailed.

d. JOINTS AND SEALS:-

All joints and seals should be examined for tightness and particular attention should be paid to tank gaskets where these are fitted.

e. GENERAL MECHANICAL INSPECTION:-

A general inspection for mechanical damage or distortion of the general structure and mechanism, both internal and external to the tank, should be made. The switchgear should be closed and tripped by each of the methods provided.

3.3 ABSTRACT OF MAINTENANCE OF MINIMUM OIL CIRCUIT BREAKERS

1	Checking of oil level in each interrupter	If the oil level is low, top up the oil
2	Checking of visible oil leaks	If any oil leakage is observed attend to the same.
3	Checking of heater function	Replace the damaged/defective heater
4	Visual inspection of breaker and operating mechanism	Replace the damaged/broken parts. Fix the loose parts properly. Exposed metal parts should be protected by a thin coating of rust preventing oil/grease after de rusting. If dust collection is excessive, cleaning with non-fluty cloth at the earliest opportunity is essential. For removing oil/grease and carbon deposit, use Acetone.
5	Checking of breaker operation and removal of coating developed on current carrying parts	Breaker should be operated electrically from local and remote controls a few times on no-load with isolators on both sides "open". Tripping of breaker with mechanical push button should be checked. In this process any coating developed between the sliding surfaces will get removed.
6	Cleaning of porcelain bushings	Clean the bushings; period may be reduced in case of highly polluted atmospheric conditions.
7	Checking of oil leakage from oil dash pot in operating mechanism	Replace the damaged/defective o-rings in the event of any oil leakage.
8	Checking of dielectric strength of oil	Filtering/replacement of oil is essential if withstand value is less then 40 kV.
9	Checking of contact burning	If burning is slight, removing the burn beads and polishing the surface are sufficient. Replace the tips and arcing ring when burning is heavy. Make sure that the contact surface at the joint is clean and loosening & tightening of tips is done a few times before final tightening.
10	Checking of extinguishing chamber	Extinguishing chamber should be removed from the breaking unit and rinsed with transformer oil, keeping the chamber upside down. If the condition of any part indicates severe burning, dismantle the chamber; replace the burnt or the damaged parts.
11	Cleaning and lubricating	Clean the mechanism, base frames and link boxes (inside and outside) with non-fluffy cloth.

		<p>Rust should be removed from the metal surfaces and unpainted steel surfaces should be smeared with grease of the grade recommended by the breaker manufacturer. The interrupter heads and insulators should be cleaned with non-fluffy cloth, oil, grease and carbon deposits be removed with Acetone. Lubricate all the points provided with grease nipples in the mechanism and breaker with grease of the grade recommended by the breaker manufacturer. Gear wheels should also be lubricated with the same grease, avoiding excessive lubrications. Care should be exercised to keep the friction clutch free from lubricants. Sliding parts, catches, rollers and operating magnets should be lubricated with the recommended lubricating oil.</p>
12	<p>Checking of locking elements of the rod system, outer mechanism (on interrupter) and in the operating mechanism.</p>	<p>Replace the damaged locking elements with new ones. During assembly after overhaul all the locking elements coming in the moving parts should be replaced even though they are not damaged.</p>
13	<p>Checking / tightening of foundation bolts and all hardware in breaker and mechanism.</p>	<p>Satisfactory movement of links and arms should be checked after tightening the fixing bolts by slow operation. Remove earth connection before taking the breaker into service.</p>
14	<p>Checking of control dimensions in a closed breaker.</p>	<p>If the control dimensions are deviating from the given values, corrective action should be taken by adjusting the gap with the help of the pull rods.</p>
15	<p>Checking/tightening of all electrical terminals and earth connections.</p>	<p>Tighten all the terminals and earth connections properly after removing oxide coating, if any.</p>
16	<p>Checking of auxiliary switch</p>	<p>Clean the auxiliary switch contacts and replace the broken parts, if any, making sure that the adjustment of auxiliary switch is unaltered.</p>
17	<p>Checking of arching horns</p>	<p>Check and adjust the distance of arcing horns.</p>
18	<p>Checking of limit switches and friction clutch.</p>	<p>If the sequence of operation of limit switches is not proper, check for the disturbed settings on limit switch operating screws and main operating stud. Care should be taken while re – adjusting the main operating stud, so that the locking of interlocking plates with pin is</p>

		possible and there is possibility of moving the stud further about 1-2 mm upward. To eliminate the slipping of clutch, dismantle and clean with acetone, replace the worn out friction studs and adjust the clutch for correct torque.
19	Checking of closing/tripping coils.	Check the pick up values of the coils and replace, if necessary.
20	Checking of spring charging mechanism.	Clean the commutator with carbon tetrachloride and replace the worn out brushes.
21	Resistance measurement of main current path.	If variation is more than $\pm 10\%$, checking of fixing bolts of extinguishing chamber, fixed contacts; proper tightening of moving contact tip and proper cleaning of the surfaces in the current transferring joints in the main current path should be carried out.
22	Overhauling.	Slow operation after overhaul should be carried out as described and recommended by manufacturer before attempting fast operations.
23	Speed measurement.	Variation of about $\pm 0.2\text{m/sec}$ in the specified range need not to be viewed seriously. Variation of $\pm 0.5\text{m/sec}$. indicates abnormalities in the breaker operation hence checking for misalignment during reassembly, excessive friction in the couplings of rod system, the missing disc spring washer/distributed setting of tripping unit (if dismantled for overhaul) and variation in closing spring bridge movement due to disturbed stopper bolts should be done.
24	Measurement of operating timings of the breaker.	If the variation of operating timings is more then $\pm 5\%$ inspection for disturbed operating voltage, variation in closing position indicating gap and control dimension should be carried out.

3.4 MAINTENANCE OF SF6 & AIR CIRCUIT BREAKERS

3.4.1 General Instructions for Maintenance of SF6 & Air circuit Breakers.

The equipments shall be inspected at regular intervals in line with general maintenance schedule. Manufacturer's recommendations shall also be followed.

3.4.2 General checks /maintenance instructions :

i. External cleaning :

The insulators of the Breaker should be cleaned from salt and dirt/dust deposition together with the cleaning of the other insulators in the substation. The time interval for this cleaning shall be based on the polluting atmosphere or the periodicity mentioned in maintenance schedule.

ii. Rust Protection :

Some parts of the mechanism in 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 is standing in strong corrosive surroundings. The rust stains shall be cleaned with emery paper and new rust protection shall be painted or sprayed on. As rust protection, grease G or Tectyl 506 is recommended.

iii. Tightness check :

The breakers are provided with density monitor switches (temperature compensated pressure gauges). Every density monitor switch is provided with an alarm contact which gives an electrical signal if abnormal leakage takes place. With the first inspection, the bolted joints on the breaker and operating mechanism shall be tightened up. All the wiring joints in the terminal blocks of the operating mechanism shall be re-tightened at regular intervals as per maintenance schedule. It is not necessary to repeat this tightening, only after bigger overhauls. SF6 gas leakage is to be detected using suitable gas leak detector.

iv. Lubrication:

The lubricants recommended by manufacturer shall be used for lubrication. The bearings of the breaker and operating mechanism are to be lubricated with grease G and they normally do not need lubrication before the major overhauls/larger revision.

3.4.3 Treatment of gaskets and sealing surfaces :

Whenever any gasket part is opened, it is to be replaced always with new one.

General:

- Sealing surfaces and O-rings shall be sparsely greased to accomplish a better sealing against this surface and at the same time protecting it against corrosion.
- Material for de-greasing and cleaning: *Dichloromethane*.
- Material for greasing of O-ring : *Grease – G*
- Material for greasing of O-ring and nitrate rubber in moving sealing : *Grease – G*
- Material for removal of contact glue : *Acetone*
- Material for rust protection of untreated or phosphatised steel : *Valvoline Tectyl 506*

3.4.4 Treatment of contact surfaces

The contacts of breaker shall be treated according to the following directions.

- Silvered contact surfaces:* Silvered contact surfaces shall be cleaned, if necessary, with a soft cloth and solvent (trichloroethane). **Steel brushing or grinding is not allowed.**
- Copper surfaces:* Copper surfaces shall be cleaned oxide/sulphate free. If necessary, they shall be cleaned with cloth and solvent (Trichloroethane) or steel brushing – After steel brushing, the surface shall always be cleaned from loose particles and dust with dry cloth/solvent.
- Aluminium surfaces:* Aluminium contact surfaces shall be cleaned WITH STEEL BRUSH OR EMERY CLOTH directly. Afterwards the surface is very thoroughly cleaned from particles and dust with a dry cloth. After this, a thin layer of Vaseline is applied. This shall be done within 5 min. after the cleaning. The joints shall be assembled within 15 minutes.

Moving contact surfaces

- Silvered:* Cleaned, if necessary, with soft cloth and solvent (trichloro ethane). **No steel brushing.**
- Non- silvered:* Cleaned as silvered surfaces, can be steel brushed. After steel brushing, they shall be thoroughly cleaned from loose particles and dust.

3.4.5 Lubrication :

Lubricant – Grease K is applied in a very thin layer on the surfaces of the male contact and the puffer cylinder. The superfluous grease is carefully removed.

3.4.6 Emptying and re-filling of gas

The circuit breaker is evacuated using the gas treatment equipment that purifies and compress the-gas for re-use. SF6 gas, contained in electrical equipments, should not be vented into atmosphere for economical and ecological reasons. The quality of the SF6 gas should be checked prior to the gas removal. The gas from the Equipments is temporarily stored in a suitable vessel having following features:

- Material of vessel/container should be such that it resists the potentially corrosive effects of SF6 decomposition products.

- b. Gas tightness of the service devices and connecting components.
- c. Oil free
- d. Gas storage in liquid or gaseous phase
- e. Suctioning up to 50 mbar
- f. Transportable and easy to handle

Operational contamination should be absorbed with suitable filter unit provided in the gas handling plant. Such filter/sieves should already be installed in to the SF6 gas maintenance/handling unit. Filters must meet the following requirements:

- Dust particles must safely be filtered
- Molecular sieves/filters remove humidity and SF6 decomposition products
- Desiccative in easily exchangeable cartridges for safe and trouble free disposal
- Inputs and outputs should be equipped with self-closing couplings in order to avoid a saturation of the desiccative by ambient air.

When SF6 is suctioned from a gas compartment, the gas is passed automatically through filters which will dry and purify the gas.

i. Filling of re-generated SF6 gas in the equipment:

Service devices have to be used to enable the maintenance personnel to fill regenerated SF6 from the storage tanks in SF6-switchgears. The following criterions should be granted by such a device:

- Oil free
- Filling pressure which can be pre-set by pressure reducer
- Easy handling and mobility

ii. Evacuation of SF6 gas Circuit Breakers :

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

3.4.7 DEW POINT MEASUREMENT

- i. EQUIPMENT AND TEST NAME: Dew Point Measurements SF6 gas/operating air for CBs.
- ii. PURPOSE:
To measure Dew point of SF6 gas & air for EHV class CBs.

iii. DEFINITION:

Dew Point:

Dew point is the temperature at which moisture content in SF6 gas/air starts condensing.

Dew Point at rated pressure of CB:

Dew Point, when measured, keeping regulating valve in service at the outlet of dew point kit to allow required flow rate of gas/air, is called dew point at rated pressure of CB. Regulating valve at the inlet is to be kept in fully opened condition.

Dew Point at atmospheric pressure:

Dew point, when measured by regulating the gas flow by inlet valve of the dew point kit and keeping outlet regulating valve (if provided) in fully open condition so that flow rate of gas/air is maintained as required, is called dew point at atmospheric pressure.

iv. TEST EQUIPMENT:

Dew point kit and associated accessories.

v. ISOLATION REQUIRED:

- CB should be in “open” condition.
- Isolators on both the sides should be in in “open” condition.

vi. PRECAUTIONS:

- a. Ensure that PTW is taken as per norms.
- b. Pipe should be of PTEE (Teflon) or having stainless steel tubing (as per IEC- 480).
- c. All the joints/connectors should be dust and moisture free. If required, these should be cleaned by clean cloth. Dry the joints and pipe by dry air.

vii. MAINTENANCE/TESTING PROCEDURE:

- a. Make the connections to the kit from CB pole ensuring that regulating valve is fully closed at the time of connections of the Dew Point Kit.
- `b. By regulating the valve provided at outlet of the dew point kit then dew point values for rated pressures are to be monitored.

viii. EVALUATION OF TEST RESULTS

- a. Dew Point Measurement of SF6 Gas in CBs:

Measurement of Dew Point of SF6 gas is an adequate parameter for condition monitoring of SF6 gas in a CB which indicates the change in the value of dielectric properties of SF6 gas. The dielectric properties of SF6 gas do get changed with time due to mixing of impurities like moisture; decomposition of products of SF6 gas i.e. Hydrogen, Fluorides, lower valence Sulphur Fluorides, etc.

There are two sources of moisture ingress in SF₆ gas after filling in CB and during O&M:

- Exudation of moisture contained during manufacturing from insulation materials used in Circuit Breakers.
- Permeation of moisture through sealed sections i.e. gaskets, 'O'-Rings etc.

If SF₆ gas contains moisture, it is easily hydrated to produce highly reactive H₂SO₃ and HF (Hydrogen fluorides). As these chemicals cause degradation of insulation and corrosion in the interrupting chamber, monitoring of moisture content in SF₆ gas is very important.

Sulphur Oxy fluorides, Hydrogen fluoride and H₂SO₃ formed in these reactions vigorously attack all materials containing Silicon di – oxide (SiO₂) e.g. glass/porcelain etc. Primary and secondary decomposition products in presence of moisture form corrosive electrolytes which may cause damage and operational failures.

b. Frequency of Dew Point Measurement:

Moisture from the organic insulating material is discharged at faster rate initially and the rate of release is almost negligible after 4-5 years of commissioning and moisture entry in CB pole is only through permeation. In the first year, about 50% of moisture is released; whereas in about 4 years, 90% of moisture is released. Hence frequency/periodicity of dew point measurement is kept as given below:

- First time at the time of Commissioning,
- After Six months,
- After one year thereafter
- Once every two years

c. Monitoring of Dew Point values :

Dew Point of SF₆ gas varies with pressure at which measurement is being carried out. This is due to the fact that Saturation Vapor Pressure decreases with Pressure of the SF₆ gas. Hence, dew point of SF₆ gas at higher pressure is lower than dew point at atmospheric pressure. Therefore, it is to be ensured that, if measurement has been done at a pressure other than the atmospheric pressure, same is to be converted to the atmospheric pressure as given in the table below for various CB manufactures:

(Method for converting dew point at different gas pressures is given/ described in IEC-480).

SL.No.	Make of CB	Dew point at rated pressure (Min)	Dew point at Atmospheric Pressure (Limit) (Min)	Remarks.
1.	BHEL	-15° C	-36° C	At the time of commissioning.
		-7° C	-29° C	During O&M
		-5° C	- 27° C	Critical
2	ABB	- 15° C	- 35° C	At the time of commissioning.

		- 5° C	- 26° C	During O&M
3	NGEF	- 15° C	- 36° C	A the time of Commissioning.
		- 7° C	- 29° C	During O&M
		- 5° C	- 27° C	Critical

d. Dew Point Measurement of air in ABCBs :

Measurement of Dew Point of air in ABCBs indicates the moisture content in the air, being used as insulating and arc quenching medium in these breakers. The arc quenching/dielectric properties of dry air do get changed with aging of CB and quality of air deteriorates as moist air travels to the interrupting chamber of circuit breaker. This will result in deterioration of internal insulation which could possibly lead to unsuccessful arc quenching due to poor dielectric strength of interrupting medium. It is, therefore, necessary to carry out measurement of Dew Point of air in ABCBs.

Permissible limit of dew point of air in ABCBs is - 30° C

3.5 OPERATING TIMINGS MEASUREMENT OF CB

3.5.1 EQUIPMENT AND TEST NAME: Measurement of 440/220/132 kV Circuit Breaker operating Timings including Pre Insertion Resistor Timings.

3.5.2 PURPOSE :

To measure operating timings of 400/220/132 kV Circuit Breakers

3.5.3 ABBREVIATIONS :

C: CLOSING OF CIRCUIT BREAKER

O: OPENING OF CIRCUIT BREAKER

C-O: CLOSE – OPEN OPERATION OF CIRCUIT BREAKER

O-C: OPEN – CLOSE OPERATION OF CIRCUIT BREAKER

O-C-O: OPEN–CLOSE-OPEN OPERATION OF CIRCUIT BREAKER

3.5.4 TESTING SCHEDULE AND FREQUENCY_:

As per Maintenance Schedule of breaker.

3.5.5 TEST EQUIPMENT_:

Circuit Breaker Operational Analyzer and associated accessories.

3.5.6 ISOLATION REQUIRED :

- Isolators on both sides of CB should be in open position.
- Earth switch should be in closed position.

3.5.7 PECAUTIONS :

- i. Ensure that PTW is taken as per norms.
- ii. There should not be any joints in testing cables.
- iii. Test leads should not touch any live part.
- iv. Never connect the test set to energized equipment.
- v. The ground cable must be connected first and removed at the last.
- vi. High voltage plugs should be free from moisture during installation and operation.
- vii. Circuit Breaker Analyzer body should be earthed (if separate earth is provided)
- viii. It should be ensured that whole testing equipment along with testing procedures is available at testing site. Testing must be carried out in presence of duly trained testing personnel(s) only.
- ix. Surface/terminals should be cleaned where the connections for testing are to be made.
- x. Earth point is to be cleaned with sand-paper/wire-brush, where earth terminal is to be provided.
- xi. Ensure that all the poles trip simultaneously through single close/trip command.

3.5.8 MAINTENANCE / TESTING PROCEDURE:

Typical Arrangement for Operating Timings Measurement of CB

- a. Make connections as shown in the analyzer manual. It is to be ensured that R, Y, B phase marking cables are connected with the proper terminals in the CB analyzer and color codes are to be maintained for all the three poles of CB.
- b. Connections is to be made to record the operating timings of auxiliary contacts also.
- c. Extend AC / DC supply to the Circuit Breaker Analyzer.
- d. Give closing command to closing coil of CB and note down the PIR and main contact closing time. Take the print out from the analyzer.
- e. Give tripping command to trip coil-I of CB and note down the main contact tripping time.
- f. After closing the breaker, give tripping command to trip coil-II of CB and note down the main contact tripping time.

- g. Note down the timings for 'C', 'O', 'C-O', and 'O-C-O' by giving respective commands.
- h. If PIR opening time is desired, then it must be isolated (wherever possible) from the main break and treated as a separate contact using different channel of the Analyzer.

3.5.9 EVALUATION OF TEST RESULTS

CB Operating timings are monitored to indicate any problem in operating mechanisms, alignments of main/arc contacts and also difference between two poles and between two breaks of same pole. As pole discrepancy between two poles should not be more than 1/6 of a cycle (3.33 ms) and between two breaks of same pole, it is given as 1/8th of the cycle (2.5 ms). However, the limits for pole discrepancy between pole to pole may be kept as 5 ms for CBs under O&M in view of problems in adjustment of the timings at site. If these timings are not within order, it may lead to over stressing of one particular interrupting chamber. Switching Over Voltage may also be high in case of large discrepancies in closing timings of two poles because of trapped charges already present in the phase in which CB is going to close at the last.

If operating timings of CB poles are not within limits, the same may be corrected by:

1. Equalizing the SF6 gas pressure in different poles.
2. Adjusting plunger movement of trip/close coils
3. Operating Mechanism adjustments
4. Changing trip/close coils (if needed)

It is also important to measure timings of auxiliary contacts from the point of view of variations with respect to the main contacts. If difference in timings of main and auxiliary contacts is maintained within limits, this indicates that there is no problem related with auxiliary contacts assembly or with operating mechanism or with the operating levers of the CB.

3.6 OPERATIONAL LOCKOUT CHECKS FOR CB

3.6.1 EQUIPMENT AND TEST NAME :

Operational Lockout checks for EHV class CBs.

3.6.2 PURPOSE :

To check operational lockouts for 400/220/132 kV CBs.

3.6.3 TESTING SCHEDULE AND FREQUENCY :

As per maintenance schedule.

3.6.4 TEST EQUIPMENT:

Multimeter, testing leads etc.

3.6.5 ISOLATION REQUIRED:

CB should not be in service.

Isolators on both sides of CB should be in "open" position.

DC supply should be switched-off as a precautionary measure.

3.6.6 PRECAUTIONS:

Ensure that PTW is taken as per norms.
There should not be any joints in testing cables.
Test leads should not touch any live part.

3.6.7 MAINTENANCE / TESTING PROCEDURE:

A. SF6 GAS PRESSURE LOCKOUT.

a. Low Pressure Alarm:

Close the isolation valve between CB Pole(s) and density monitor. Start releasing SF6 gas from density monitor till the low pressure gas alarm contacts are actuated which is detected by multimeter. Note down the pressure and temperature at which the contacts get actuated.

b. Operational Lockout Alarm:

Continue releasing SF6 gas from isolated zone till the operational lockout Alarm contacts are actuated which are detected by Multimeter. Note down the pressure and temperature at which the contacts get actuated.

B. PNEUMATIC OPERATING SYSTEM LOCKOUT

a. Compressor START / STOP Switch

Close the isolating valve of CB. Release air in to atmosphere from the compressor. Note down the value of pressure at which the compressor starts building up air pressure and pressure at which compressor stops.

b. CB AUTO-RECLOSE LOCKOUT:

Close isolation valve between pneumatic system and pressure switches. Release air from the isolated zone to atmosphere. Note down pressure at which A/ R lockout (L/O) contacts of pressure switch get actuated which are detected by Multimeter. The leads of the multimeter should be connected to the contactor where the A/ R lockout of CB are made.

c. CB CLOSING LOCKOUT:

Release air from the isolated zone to atmosphere. Note down pressure at which CB Closing lockout (L/O) contacts of pressure switch get actuated which are detected by Multimeter.

d. CB OPERATIONAL LOCKOUT:

Release air from the isolated zone to atmosphere. Note down pressure at which CB closing lockout (L/O) contacts of pressure switch get actuated which are detected by Multimeter.

e. **MECHANICAL CLOSING INTERLOCK: (FOR ABB CBs ONLY)**

CB should be in closed position. Release air from pneumatic system of CB to atmosphere and observe whether CB poles start opening. If so, note down the pressure at which tie rod starts coming down. In such cases the closing interlock is to be opened for inspection. And, if required, replace the closing interlock.

C. HYDRAULIC OPERATING SYSTEM LOCKOUT.

a. **Pump START / STOP:**

By opening pressure release valve, note down the pressure at which pump starts building up oil pressure and pressure at which pump stops.

b. **CB AUTO RECLOSE (A/R) LOCK OUT (L/O) :**

Close isolation valve between hydraulic system and pressure switches. Release oil from the isolated zone to oil tank. Note down pressure at which Auto Re-close (A/R) Lock Out (L/O) contacts of pressure switch get actuated which are detected by Multimeter.

c. **CB CLOSING LOCKOUT**

Release oil from the isolated zone to oil tank. Note down pressure at which CB closing Lock Out (L/O) contacts of pressure switch get actuated which are detected by Multimeter.

d. **CB OPERATIONAL LOCKOUT :**

Release oil from the isolated zone to container. Note down pressure at which CB Operational Lock Out (L/O) contacts of pressure switch get actuated which are detected by Multimeter.

3.6.8 EVALUATION OF TESTS RESULTS

A. SF6 GAS PRESSURE LOCKOUT.

The setting of all the SF6 gas pressure switches should be checked and corrected with ambient temperature. Settings of these switches should be within ± 0.1 bar/Kg/cm² of the set value (after taking in to account the temperature correction factor).

B. AIR PRESSURE LOCKOUT

The setting of all the air pressure switches should be checked and corrected .It should be within 0.1 bar/Kg/cm² of the set value.

C. OIL PRESSURE LOCKOUT

The setting of all the oil pressure switches should be checked and corrected. It should be within 0.1 bar/Kg/cm² of the set value.

3.6.9 STATIC CONTACT RESISTANCE MEASUREMENT

1. EQUIPMENT AND TEST NAME:

Measurement of Contact Resistance of:

- CB main Contacts
- Isolator Contacts
- Connections Etc.

2. PURPOSE:

To Measure Contact Resistance of Main Contacts, Connectors etc., in order to evaluate the condition of the contacts against erosion / mis-alignment of the contacts.

3. TESTING SCHEDULE AND FREQUENCY:

As per Maintenance Schedule of breaker.

4. TEST EQUIPMENT:

Contact Resistance Kit (100 amperes D.C. minimum)

5. ISOLATION REQUIRED:

- a. CB should be in “open” position.
- b. Isolators on either side of CB should be in “open” position.

6. PRECAUTIONS:

- a. Ensure that proper PTW is taken as per norms.
- b. There should not be any joints in testing leads/cables.
- c. Test leads should not touch any LIVE part.
- d. Never connect the test set to energized equipment.
- e. High voltage plugs should be free from moisture during installation and operation.
- f. Before connecting the instrument, clean the surface where the test clips are to be connected and make sure that the current clamps are solidly in contact with the metal surface.
- g. Make sure that one side of Isolator is earthed by grounding switch.
- h. It should be ensured that whole testing equipment along with testing procedures is available at testing site. Testing must be carried out in presence of duly trained testing personnel only.
- i. At the time of connections, both sides of isolator should be earthed by closing earth switches or by temporary earths. After the connections, ear things should be removed.

- j. Before connecting the instrument, clean the surface where the test clips are to be connected and make sure that the current clamps are solidly intact with the metal surface.
- k. Make sure that one side of the Isolator is earthed by groundings switch.

3.6.10 MAINTENANCE / TESTING PROCEDURE

The Ohm Meter operates on the four wire measurement principle. To measure the contact resistance, connect the respective leads and adjust the variac so that app. 100 Amps current flows through the contacts. Value of contact resistance is directly displayed on the digital LED display screen.

Four Terminal method of Contact Resistance Measurement

By using Four Terminal Method we nullify the resistance of test leads, if input impedance of measuring device (IC) is very high.

3.6.11 EVALUATION OF TEST RESULTS:

Contact resistance of the main contacts indicates wear out and misalignment of the main contacts. If the value of contact resistance exceeds the permissible limit, this could result in over heating of the contacts. Therefore, the problem of high contact resistance should be attended immediately by making proper alignment of contacts or by replacing finger contacts.

3.6.12 DYNAMIC CONTACT RESISTANCE MEASUREMENT

1. EQUIPMENT AND TEST NAME:

Measurement of Dynamic Contact Resistance (DCRM) and Contact Travel of EHV CBs.

2. PURPOSE:

To monitor the condition of Main and Arcing contacts of the CB without opening the interrupter. Hence, decision regarding major / final overhauling / inspection of Main / Arcing contacts may be taken.

3. TESTING SCHEDULE AND FREQUENCY:

As per Maintenance Schedule of the breaker.

4. TEST EQUIPMENT:

100 Amp. DCRM kit with CB operational analyzer.

5. ISOLATION REQUIRED:

- a. CB should be in open position.
- b. Isolators of both sides of CB should be in "open" position.
- c. Earth switch of one side of CB should be in "closed" position. .

6. PRECAUTIONS:

- a. Ensure that proper PTW is taken as per norms.
- b. There should be no joints in testing leads/cables.

- c. It should be ensured that whole testing equipment along with testing procedures is available at testing site. Testing must be carried out in presence of duly trained testing personnel only.
- d. Current leads should be connected such that voltage leads are not outside area of current flow.

7. MAINTENANCE / TESTING PROCEDURE:

- a. Follow the standard procedure as given in instruction manual.
- b. The tightness of connections at CB flanges is most important to ensure error free measurement. During C-O operation, the CB generates lots of vibrations and failure of connections during this period can dramatically change the dynamic signatures of the CB resistance.

Typical Arrangement for DCRM of CB

1. Clean the portions of incoming and outgoing flanges of CB with polish paper to remove paint, oxidation etc., at points where current clamps are mounted.
2. Select this point of connection, as close as possible to the end of porcelain insulator, to ensure that minimum resistance is offered by flanges, bolts, terminal connectors etc.

8. EVALUATION OF TEST RESULTS:

Dynamic Contact Resistance Measurement (DCRM) is the technique for measuring Contact Resistance during operation (Close / Trip) of a Circuit Breaker. A D.C. current is injected through the Circuit Breaker. The current and voltage drop are measured and resistance is calculated. The resistance versus time data provides useful information on the condition of the Circuit Breaker contacts and is used as a diagnostic tool.

3.6.13 Dynamic Contact Resistance Measurement for Arcing Contacts Condition:

Condition of arcing contact can be predicted by application of Dynamic Contact Resistance Measurement. If signatures of DCRM match with the Pre-Commissioning value, then Arcing contacts will generally be alright. If DCRM signatures show wide variations and also there is change in Arcing Contact insertion time, then it indicates erosion of the Arcing Contacts. Such a condition may lead to transferring of Current from Arcing contacts to Main contacts and subsequent commutation failure.

Contact Travel Measurement:

Transducers and fixture are attached to the operating rod or interrupting chamber, in order to record the contact travel. When CB closes, contact travel is recorded. Contact bounce or any other abnormality is also clearly indicated by the Contact Travel Measurement. If Contact travel is recorded with Dynamic Contact Resistance, the length of Arcing contact shall also be monitored. It is expected that after some time, due to erosion of the Arcing contact, tip length reduces and such conditions may lead to commutation failures. As already explained,

arc may shift from arcing contacts to main contacts. This condition may lead to faster damage of the main contacts.

If contact speed and contact acceleration signatures are compared with the original signatures (pre-commissioning values), then it may indicate problems related with the operating mechanism, operating levers, main/arcing contacts, alignments etc.

3.6.14 POLE DISCREPANCY RELAY TESTING

1. EQUIPMENT AND TEST NAME:
Checking of Pole Discrepancy relay and timer for 400 & 220 kV Circuit Breakers.
2. PURPOSE:
Pole Discrepancy and timer checking for 400 & 220 kV CBs.
3. DEFINITION:
Pole Discrepancy is defined as the different in closing & opening timings of different poles of the CBs.
4. TESTING SCHEDULE AND FREQUENCY:
As per Maintenance Schedule of the breaker.
5. TEST EQUIPMENT:
Testing leads, Standard timers, etc.
6. ISOLATION REQUIRED:
 - a. Isolators of both sides of CB should be in “open” position.
 - b. Earth switch should be in “closed” position.
7. PRECAUTIONS:
 - a. Ensure that PTW is taken as per norms.
 - b. There should be no joints in testing cables.
 - c. Test leads should not touch any live part.
8. MAINTENANCE / TESTING PROCEDURE:

WHEN CB IN OPEN POSITION

Closing command is extended to CLOSE one pole, say R-pole of CB. After closing R-pole of CB, this Pole should automatically OPEN after 2.5 seconds (as per pole discrepancy timer settings). Repeat the test for remaining two poles of CB.

WHEN CB IN CLOSED POSITION

Tripping command is extended to TRIP one pole, say R-pole of CB. Remaining Y and B- poles of CB should automatically OPEN after 2.5 seconds. Repeat the same test for remaining two poles of CB.

9. EVALUATION OF TEST RESULTS:

Permissible value of pole discrepancy between two poles of CB is 3.33 m sec. from System point of view and it should not be confused with the setting of pole discrepancy relay setting which is generally 2.5 seconds.

3.6.15 LIST OF RECOMMENDED SPARE PARTS, REQUIRED FOR OPERATION AND MAINTENANCE OF VARIOUS TYPE OF 11/33/132/220/400 KV BREAKER

33 kV /11 kV MOCB

S.No.	Name of spare part	Quantity
1	Over hauling kit for complete pole including insulator	1 Nos kit for Ist 3 MOCB, additional 1 kit for every 3 MOCB at 132 kV GSS.
2	Gasket for pole and insulator part of Arch chamber.	Nos. kit for 3 MOCB, additional 2 Nos kit for every 3 MOCB at 132 kV GSS.
3	Insulated operating Rod	One for each type at circle level.

400/220 /132/33/11 kV SF6 Breaker.

1	Overhauling kit for complete pole including insulator.	for 33/11 kV 2 kit per above 132 kV kit / circle.
2	Operating Road	One each type at 400 kV One for each type at circle level
3	SF6 gas	100 kg. at 400 kV GSS. 100 kg. at 220 kV GSS. 50 mg at const. division.

33 kV /11 kV VCB's

1	Over hauling kit for complete pole including insulator.	1 Nos. kit for 20 VCB's per Circle.
2	Vacuum Interrupter	One Nos. for 20 VCB's per Div.

**SPRING TYPE MECHANISM
(132/33/11 kV MOCB's , SF6 VCB's)**

1	Trip coil with variable resistance	2 Nos. of each type at 400 kV GSS. 2 Nos. of each type of 220 kV GSS. 2 Nos. each type per Div.
2	Closing coil with variable resistance	2 Nos. each type per Div.
3	Spring charging Motor	Nos of each type at 400 kV GSS. 1 Nos. of each type at 220 kV GSS.
4	Tripping spring	1 Nos. of each type at 220 kV GSS.
5	Closing spring	1 Nos. of each type at 220 kV GSS.
6	Auxiliary Switch assembly	1 Nos. of each type at 220 kV GSS.

7	Closing and tripping assembly	Nos of each type at 400 kV GSS 1 Nos. of each type at Circle level.
8	Damper dash pot	Nos of each type at 400 kV GSS 1 Nos. of each type at Circle level.
9	Trip catch assembly	Nos of each type at 400 kV GSS 1 Nos. of each type at Circle level.
10	Close catch assembly	Nos of each type at 400 kV GSS 1 Nos. of each type at Circle level.
11	Spring charging Assembly	Nos of each type at 400 kV GSS 1 Nos. of each type at Circle level.
12	Operation counter	Nos of each type at 400 kV GSS 1 Nos. of each type at Circle level.
13	Tripping / closing Roller/Pin / cam etc. as provided in the breaker.	One Nos. set of each type 400 kV GSS.
14	Contractor for spring charging circuit with resistance.	1Nos. at 400 kV 1Nos. per Circle for each type of breaker.
15	Contractor for monitoring circuit	1Nos. at 400 kV 1Nos. per Circle for each type of breaker.

Pneumatic operating mechanism (with compressor) for all type of breaker.

1	Tripping coil with variable resistance	2Nos. of each type of 400 kV GSS 2Nos. of each type of 220 kV GSS 2Nos. of each type at Divisional level.
2	Closing coil with variable resistance	2Nos. of each type of 400 kV GSS 2Nos. of each type of 220 kV GSS 2Nos. of each type at Divisional level.
3	Compressor Motor with compressor	One each type at 400 kV GSS One each type at Circle level.
4	Closing spring if provided	One each type at 400 kV GSS One each type at Circle level.
5	Auxiliary switch assembly	Nos. of each type at 400 kV GSS 1 Nos. of each type at 220 kV GSS.
6	Magnetic ventile	One each type at 400 kV GSS One each type at Circle level.
7	Over hauling kit for magnetic ventile	2 Nos. each type at 400 kV GSS 2 Nos. each type at Circle level.
8	Operation counter	Nos. each type at 400 kV GSS 1 Nos. each type at Circle level.
9	Contractor for monitoring circuit	Nos. each type at 400 kV 1 Nos. each type at Circle level.
10	Over hauling kit for actuator	set for each type at 400 kV GSS. 1 set for each type at Circle level.
11	Closing interlock Assembly	set for each type at 400 kV GSS. 1 set for each type at Circle level.
12	Non return valve	No. for each type at 400 kV.

		1 No. for each type at Circle level.
13	Safety valve	No. for each type at 400 kV GSS. 1 No. for each type at Circle level.

Hydraulic operation Mechanism

1	Tripping coil with resistance.	2Nos. of each type of 400 kV GSS 2Nos. of each type of 220 kV GSS 2Nos. of each type of Divisional level.
2	Closing coil with resistance.	2Nos. of each type of 400 kV GSS 2Nos. of each type of 220 kV GSS 2Nos. of each type of Divisional level.
3	Oil pump motor with oil pump.	2Nos. of each type of 400 kV GSS 1No. of each type at Circle level.
4	Auxiliary switch assembly	No. for each type at 400 kV GSS 1 No. for each type at 220 kV GSS
5	Closing and tripping assembly	No. for each type at 400 kV GSS. 1 No. for each type at Circle level.
6	Accumulator	No. for each type at 400 kV GSS. 1 No. for each type at Circle level.
7	Operation counter	No. for each type at 400 kV GSS. 1 No. for each type at Circle level.
8	Contractor for spring charging circuit with resistance.	No. for each type at 400 kV GSS. 1 No. for each type at Circle level.
9	Non return live	No. for each type at 400 kV GSS. 1 No. for each type at Circle level.
10	Safety valve	No. for each type at 400 kV GSS. 1 No. for each type at Circle level.
11	Hydraulic oil	Quantity equal to one complete refilling of 400 kV breakers at 400 kV GSS. Quantity equal to one complete filling of 220 kV breakers at Circle level.

Remark:

1. Above quantities are required to be maintained at the prescribed level.
2. Spare parts, used for maintenance, are to be replenished from time to time so that prescribed quantity is available.
3. The overhauling spare part required for breaker as per manufacturer recommendations/ maintenance schedule should be purchased at Circle level.

Essential spares required for 33 & 11 kV VCB's

1	Vacuum Interrupter	One No. on 4 -5 No. CB's
2	Upper Insulator	One No. on 5 No. CB's
3	Lower Insulator	One No. on 10 No. CB's
4	Insulating Rod	One No. on 10 No. CB's
5	Tripping & closing coils	One each on 4 -5 CB's

Essential spares required for 33 & 11 kV SF-6 CB's

1	Tripping & closing coils	One each on 4 -5 CB's
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Essential Spares required for 245/145 kV ABB SF-6 Circuit Breaker

1	Tripping & closing coils	One each on 4 breakers
2	Resistance for Tripping & closing coil spares for magnetic ventile	One each on 4 breakers
3	K slot ring	
4	Damping gasket	
5	Piston long	
6	Piston short	
7	K slot ring	
8	Sealing Ring	
8	K slot ring	
9	K slot ring	
10	K slot ring	

According to numbers of SF6 breakers, the overhauling kit as recommended by manufacturer shall be stored at Divisional or Circle level. The spares can be issued for maintenance of breakers at GSS as and when required. Spares issued to GSS for maintenance should be repurchased, so as to consume the same for overhauling the breaker as per recommendation of manufactures within 2-3 years and again the new overhauling kit, should be purchased, i.e. Such spares (generally 'O' ring and gasket) should not be stored for long time because these may get spoiled during long storage being rubber part.

Essential spares required for ABCB's (220/132 kV) tripping & closing coils (one each for four breakers)

There are no parts in ABCBs, which get frequently damaged according to numbers of breakers the overhauling kit as recommended by manufacturer shall be stored at Divisional or circle level. As per requirement the spares can be issued for maintenance of breakers at GSS, as and when required. Spares issued to GSS for maintenance should be repurchased so as to consume the same for overhauling the breaker as per recommendation of manufactures within 2-3 years and again the new overhauling kit, should be purchased. That is such spares (generally 'O' ring and gasket) should not be stored for long time because these may get spoiled during long storage being rubber part.

**ESSENTIAL SPARE PART 'A' REQUIRED FOR
D) 33 kV MEI MOCB TYPE T52/2E**

1. Description
Reptuoing chamber cylinder
2. Complete baffle set with Tumbler sleeve & partition

**ESSENTIAL SPAN PART REQUIRED FOR
11 kV OCB (Kiosk) Make S&S Type R-4/1**

1. R 4/1 main contact poker (male contact)
2. R 4/1 Rose contact assly (female contact)
3. R4/1 Arc control pot
4. Trip latch rod assly
5. Trio coil
6. Charging link with cut
7. Charging link without cut
8. Trip lever
9. Trip seller
10. Closing lever
11. DTMRC Fuse

**ESSENTIAL SPARE PART REQUIRED FOR
kV OCB (Kiosk) make MEI Type ACIR**

1. Female contact (Rose contact assly)
2. Male contact
3. Arc pot assly' Moving contact plug
4. Drum contact assly 2 way
5. Trip catch assly
6. PT MRC fuse
7. Com roller
8. Charging cam

**ESSENTIAL SPARE PART ' REQUIRED FOR
kV VCB Kiosk Type CMX2V ALA/XLV Make CGL**

1. Vacuum Interrupter
2. Tripping coil
3. Drum switch assly
4. Tripping Pridge
5. Tripping roller
6. Trip catch

CHAPTER-4

4.1 PROTECTION

4.1.1 GENERAL

The protection scheme basically consists of protective relays, functions as a sensing device and switching circuit (i.e. circuit breaker), which after getting command from relay disconnects only the faulted element(s) promptly and reliably thereby saving the rest of the system from being affected due to fault.

The protection scheme is, therefore, a very important and vital component of the power system and hence, proper care is necessary for its selection, operation and maintenance.

4.1.2 NEED FOR PROPER COORDINATION OF RELAYS

The protective relays minimize the damage to the system and interruption duration by immediately locating / detecting the fault as well as isolating the faulted circuit / part of the power system. Hence, the reliability, fast action, selectivity and coordinated operation of the protective relays are the desirable features of the protective system, particularly the coordinated operation of the relays is a must in the vast integrated and interconnected modern grids to minimize the duration of the interruption caused to the system and also loss of generation as well as distribution.

4.2 NUMERICAL RELAYS

Latest numerical relays are microprocessor based; a single relay has many features. These compact multi functioned relays cost less and save additionally on space and assembly/wiring cost compared to traditional relaying schemes. These are practically maintenance free.

These relays have memory, communication capability and higher level control system. The protective relay scheme has undergone changes from formerly stand-alone devices to coordinated or integrated components of an overall sub station automation system.

Control panels and panel wiring are getting obsolete which computer terminals and serial communication links are replacing. User friendly and fail-safe sub station operation by fully graphic HMI terminals with comprehensive state indication contribute to a higher level of power system quality.

The high function integration of numerical relays calls for new design and redundancy of concepts. In most cases, only one unit provides all protection functions to one feeder/breaker, of course a second relay package has to be provided for the Main -2 or back up protection functions. The International trend is going for standardization of hardware design and modular software.

In general, these relays contain a user interface with LCD display and keypad, but normally more comfortable setting and read out of data by PC is used.

Load monitoring as well as sequence of events and fault / disturbance recording are now, in general, provided as add-on functions.

The modern numerical relays are widely self-monitored from the measuring inputs to the tripping command outputs.

The maintenance strategy, therefore, is to be changed from regular or routine testing to condition based testing. As self-monitoring cannot cover 100% of the protection system, a combination of self monitoring and on-site testing at longer time intervals guarantees the highest availability.

In this way, self-monitoring leads to economy in test amount and to a considerable reduction in the total life cycle maintenance cost.

4.2.1 Merits and demerits of numerical relays:

Numerical relay technology is from the main stream and is for the designers to provide users with the functions they need at the prices they have come to expect.

Now engineers want to work only with microprocessors, data communications, PC's etc.

4.2.2 Benefits

- Numerical relays have:
- Intelligent functions and features.
- Related functions in one package
- Non – fault monitoring and information.
- Detailed fault recording and information.
- Data by remote communication.
- Supports network- based sub station control (SCADA).
- Self-monitoring, no routine maintenance.
- Less panel space, battery power, CT PT burden.

Merits of computer based relaying.

- These are standard products and are configured via settings as per system requirement.
- No custom system engineering or wiring is required.
- Supply period is very short.
- Fewer inventories are required.
- Very less maintenance spares are required.
- Fast field repair by swap – out.

Demerits of computer based relaying.

- Microprocessor based devices including protective relays have short life cycle.
- While each generation of Microprocessor based devices increases the functionality compared with the previous generation, the pace of change makes the equipment obsolete in shorter times. This makes it difficult for the users to maintain expertise in using the latest designs.
- Another point of this shortcoming is in the form of changes in the software used on the existing hardware platforms.
- Sometimes these changes effectively generate newer relay designs. This requires that a software tracking system be used for each device own by a utility.
- .
- The multifunction Microprocessor based relays have a significant number of settings. The increase in number of settings may pose problems in managing the settings and conducting functional tests.

4.2.3 Multiple functions

Microprocessor relays provide many functions that were not available in electromechanical or solid state relays. These features include multiple setting groups over programmable logic, adaptive logic, self monitoring, self testing, and sequence of events recording, oscillography and ability to communicate with other relays and control computers. While these features make these relays very powerful, they also introduced factors such as complexity that were not associated with earlier relays.

4.2.4 Cost

The cost per function of microprocessor-based relays is lower compared to the cost of their electromechanical and solid-state counter parts. The lower cost of components, cost of protection equipment and protection technology has resulted.

4.2.5 Custom logic schemes

A major feature of micro- processor based relays that was not available in previous technologies is the ability to allow users to develop their own logic schemes, including dynamic changes in the logic. This benefit, however, comes at a cost because of this capability increases the complexity of the system.

4.2.6 Panel space

Micro processor base protection systems require significantly less panel space than the space required by the electromechanical and solid state relays that provide similar functions. The reduction in size is a result of the high level integration of the hardware and the ability of using one physical device for performing multiple protection functions, such as, over current and multiple zone distance relaying for phase and ground fault protection. The shortcoming of the benefit is that it increases the susceptibility to common mode failure of protection schemes.

4.2.7 Burden on Instrument Transformers.

Microprocessor based relays impose significantly less burden on instrument transformers than the burden imposed by the relays of the previous technologies. In addition, micro processor based relays can be programmed to detect saturation of instrument transformers for minimizing incorrect operations they also require few CT and PT connections because some operating quantities, such as zero sequence currents and voltages are derived by numerical technologies.

4.2.8 Sequence of events and oscillography

Reporting features, including sequence of events recording and oscillography are a natural by product of micro processed based protection system. These features make it possible to better analyze the performance of the relays as well as system disturbances at minimal additional cost.

4.2.9 Self monitoring and self testing

Another advantage of microprocessor-based relays is their ability to perform self-monitoring and self-testing functions. These features reduce the need for routine maintenance because of the relays automatically take themselves out of service and alert the operators of the problem when they detect functional abnormalities.

4.3 Important Recommendations of NREB Protection Committee

4.3.1 Recommendations

- i. Some of the system fault occurrences are due to bus fault. To facilitate faster clearance of the bus fault, faster bus bar protection should be provided at all 400 kV and 220 kV sub stations and also at important 132kV sub stations in the region or those directly connected to generating stations or tie-lines with the Regional Grid.
- ii. One of the reasons for bus fault in old stations was due to lower rupturing/withstand capacity of the sub station equipment like breakers, CTs, isolators, etc. The equipments need to be replaced as per increased fault level in a phased manner.

4.3.2 Other Suggestions

- i. For old inter-state 220 kV lines, the existing electro-magnetic distance relays need to be replaced by static (latest numerical) non-switched carrier-aided distance relays.
- ii. The existing over current and earth fault IDMT relays should be retained with revision of plug setting and TMS settings as and where necessary for proper discrimination.
- iii. Proper directional feature should be ensured and correct directional check on load should be carried out on all overcurrent, earth fault and distance relays under suitable load conditions.
- iv. All the 400 kV distance protection relays should be used in permissive under-reach inter-trip mode so long as no series capacitor is installed in the line. Wherever power swing blocking/tripping feature is provided, its setting should be arrived at after carrying out system studies
- v. It is felt that the winding, oil temperature setting for tripping of the transformer should be set as per the manufacturers' recommendations and advice.
- vi. The setting of the over-fluxing relay should be kept as per the over fluxing capability of the transformer protected and as per the manufacturer recommendations and advice. The existing definite-time over-fluxing relay should preferably be replaced by IDMT over-fluxing relays to match with the over-fluxing capability curves of the transformer. It is suggested that over-fluxing relay should be provided on LV side in addition to HV side. Whenever only the over-fluxing relay is used, it is preferable to provide on LV side.

4.3.3 Corrective Measures:

4.3.3.1 Following corrective measures should be taken to control over-voltage problems: -

- i. Some of the occurrences are caused due to improper operation of the cooling system of the transformers. To avoid this, the following measures are suggested:
- ii. Cooling system must be maintained properly in all grid transformers.
- iii. Switching of fans and pumps should be kept on auto-mode.
- iv. The upper limit in respect of the allowable temperature of transformer as advised by the manufacturers should neither be exceeded nor be lowered under any circumstances.
- v. All fans and pumps should be periodically checked/tested for trouble-free problem.

- vi. Monitoring of hot spots and current carrying clamps and connectors should be carried out particularly by either contact or non-contact methods.
- vii. Whenever possible, operation of the winding and oil temperature monitoring should not be A.C. supply dependent.
- viii. In some of the tie lines, over current relay setting has been kept at a level well below the line (thermal) capacity causing tripping of the line whenever flow exceeds the set limit. This is against the norm of integrated operation and may cause grid disturbance. It is recommended that an over-current tripping should be provided at thermal limit of the conductor (or at 120% of line CT ratio whichever is low).

4.3.3.2 It is suggested that LBB protection should be incorporated in all the major sub stations.

- The directional check for earth fault and over current relays should be done for correct directional operation under appropriate power factor and percentage load conditions as recommended by relay manufacturers.
- In some of the transformers, Buchloz relays may operate during switching of pumps. This check should be included in the pre-commissioning check list.
- In order to identify and analyse the correct sequence of operations disturbance recorder/ sequence event recorder should be provided a major stations (latest numerical relays have this as a built in feature).
- The committee suggests that on all important interconnected sections, redundancy should be available to meet the outage of single lines. In cases of over loading, efforts should be made to regulate the flow on the line immediately.

4.3.4 System Security

It is desired that:-

4.3.4.1 when frequency drops slowly, under-frequency relay could shed the load and save the system. However, under disastrous conditions, df/dt relays would be used. A suitable combination of both could save the system.

4.3.4.2 the lines should not trip unless there is a fault and hence, over-current setting should be adopted as per the thermal capacity of the line.

4.3.4.3 bus bar protection along with the LBB should be provided at all main stations. Particularly at those GSS, which are directly connected to generating stations.

4.3.4.4 Emergency supply for station auxiliaries:

- a. Large and important GSS must be provided with DG set of adequate capacity to give emergency supply to the station auxiliaries. Trial run should be taken at least once in a week to keep it in readiness.
- b. Emergency lighting should be provided in control room and switchyard and this should be automatically switched on when there is power failure.

4.3.4.5 Adequate fire protection for all the oil-filled equipment shall be provided.

4.3.4.6 Oil sump shall also be provided for transformers and shunt reactors.

4.3.5 Maintenance & Testing Procedures of protective relays / equipments and Earthing practices

4.3.5.1 Maintenance and testing procedure

- i. Maintenance and testing procedure given by manufacturers of relays and equipments are generally found to be sufficient and adequate and, therefore, are to be strictly followed by the utilities. The periodicity of maintenance and testing as recommended by the manufacturers may, however, be reviewed by utilities depending on the working environment, site conditions, frequency of faults, behavior and operation of relays/equipments and type of relays etc. However, it is suggested that periodic testing of relays should be done once in a year. Sub committee also recommends on-line testing facilities for important protections/equipments.
- ii. Sub committee noted that in some of the cases, water entered the junction boxes for switchyard equipment like isolator, breaker, MK's etc. and these created faults. To avoid this, the committee recommends that:
 - a. Junction box should be water and vermin -proof and should preferably be located well above the ground level.
 - b. Pre-monsoon check on outdoor junction boxes should be carried out.
 - c. In carrier-aided distance protection scheme, end-to-end tests should be done regularly.

4.3.5.2 Earthing Practice For Protection Equipments;

- i. All the protective devices including CT, PT, relay panels etc. should be earthed properly. Earthing of PT primary separately and adequately must be ensured. Earthing of star point of PT secondary/CT secondary must be done effectively. However, earthing of CT PT secondary at only one point should be adopted.
- ii. Multiple earthed CT/PT secondary winding are a source of trouble and responsible for mal-operation of protective relays.
- iii. Where CT paralleling is a compulsion, earthing of only one star point may be adopted. The star point for other CTs may be kept floating.
- iv. Proper earthing of the relay panel should be ensured. This is very important from the point of operation of static relays.
- v. Armouring of all 400 kV control cables shall be earthed at both ends through cable glands.
- vi. For co-axial cable used for PLCC it is preferable to install flash guards at the control room end for discharge of high voltage developed, during switching operation of HV equipment.
- vii. PVC insulated, stranded copper-armoured control cables should be used in conjunction with static (as well numerical) relays and control circuits.
- viii. **Terminal blocks-** Non-disconnecting stud type terminal blocks shall be used for all circuits except CT PT circuits in the panels. For CT & PT circuits in the panel, either test terminal block (having facilities for automatic shorting of CTs) or disconnecting stud-type terminal blocks are to be used.
For all switchyard equipments, terminal blocks are to be of non-disconnecting stud type.

4.3.5.3 PT Supervision Selection Scheme

Whenever, two sets of PTs are used (for bus bars) and change over of PT supply from one PT to another is affected. 3-phase-4-wire selection scheme should be adopted. Sub-committee suggested that making a common neutral and running a single neutral wire of PT supply for both the PTs should be avoided because this may result in mal-operation/operation of distance protection relay provided specially for protection of short lines.

Note: - Secondly improper operation or non operation of isolators auxiliary contact may cause non switching of VT supply to Distance Protection Schemes which may result in mal-operation of the DPR's. It has therefore to be ensured that the isolator auxiliary contacts are always maintained in perfect working condition. Apart from VT selection, they play important role in various controls and interlock circuits.

PRACTICE OF ON LOAD CHANGE OVER OF FEEDER SUPPLY FROM ONE BUS TO OTHER BUS BY CLOSING BOTH ISOLATORS AT A TIME MUST BE AVOIDED BECAUSE THIS MAY RESULT IN PARALLELING OF VT SUPPLIES AND THEREBY CAUSING VT FUSES IN SWITCH YARD TO BLOW AND FINALLY RESULTING IN TRIPPING OF FEEDERS CARRYING LOAD DUE TO OPERATION OF DISTANCE PROTECTION RELAYS.

4.3.5.4 Bus Bar Protection Scheme

Whenever high impedance bus bar protection schemes are in service, stabilizing resistance range should be reviewed. In future, the stabilizing resistance range should be adopted as 0-1000 ohms, however, in the existing bus bar protection scheme, where the stabilizing resistance is within the range of 0-200 ohms, the position should be reviewed and feasibility of providing higher resistance should be explored depending of fault level.

- Transformer should be made to trip from both sides on operation of bus bar protection instead of tripping the breaker connected to faulty bus alone.
- In case of 400 kV lines, bus bar protection should trip remote end line breaker also.
- Wherever CT switching is involved in bus bar protection, it should be through latch type switching relay and not through direct auxiliary contacts. In the present schemes, wherever the CT switching is through direct auxiliary relay contact, it should be reviewed and modified accordingly.
- If isolator contacts are used for energizing the CT switching relay, three pole contacts should be always connected in parallel for the operating coil and in series for resetting coils. The present schemes need to be reviewed and modified accordingly.

4.3.5.5 Disturbance recorder/Event Sequence Recorder

The sub committee recommends that disturbance recorders and event sequence recorder should be provided in all the 400 kV and major 220 kV sub stations.

4.3.6 Long Term Policy

The sub committee recommends regular load flow studies, short circuit studies and system stability studies to be carried out and revision/ modification/improvement in protection system (including periodic review of the protective relay setting) based on these studies.

Sub committee also recommends the following points:

- a. On-line testing facility of the protective relays with self-diagnostic feature.
- b. Microprocessor numerical based relays and control system.
- c. Integration of control with protection and use of SCADA system.
- d. Use of CTs & PTs with guaranteed transient performance.
- e. Completion of database on regional basis and the Performa of protective relays used in the system. For this, grid disturbance reports, test results, analysis, review shall consolidated.
- f. Possibility of using dry cell battery may be explored.

- g. All major sub stations control rooms, relay/PLCC rooms shall be air-conditioned.
- h. Setting up of well-equipped testing laboratory for protective relay.

Sub committee recommends that adequate training facilities need to be created by utilities for protection engineers with the help of installations like power system testing institution Bangalore and other educational Institutions and also with relay manufacturers/consultants.

4.4 CONCEPT OF BACK UP PROTECTION

4.4.1 CONCEPT

The role/function of back up protection in the overall protection system plays a very important part. It has to be adopted and applied very intelligently and carefully in the existing system. Generally the existing relay/schemes can be made to play a proper role of back up protection by way of its proper application in the system by revision of time setting, reach setting and direction setting and by selecting proper carrier signal application.

The back up protection requirement encompasses a number of aspects. Of primary importance for an EHV transmission network is the requirement to ensure correct, or best possible, operation of the over all fault clearance system even in the event of the failure of one of the components within the protection scheme itself or the failure of an external component within the overall fault clearance system.

The method usually adopted to accommodate failure of a primary relay is to back this relay up by inclusion of a second primary relay. **Complete protection equipment back up is achieved by fully duplicating the main protection systems, and not just the primary protection relays.**

What is necessary, therefore, is a philosophy which clearly defines the role of the different elements of back up protection, sub categorized into those which provide **local backup**, and those which provide **remote backup**, and how they coordinate to provide the best overall solution for the transmission system from a microscopic perspective.

4.4.2 PERFORMANCE

i. SYSTEM REQUIREMENTS

It is the requirement of the system to match the performance capability of the protection equipment to what is needed for adequate protect of the power system.

ii) MAINTENANCE REQUIREMENT

It is the prime requirement to carry out routine maintenance on protection equipment without taking the item(s) of the plant out of service. When testing of the relay is necessary, the protection equipment to be tested can be isolated, keeping the alternative main protection system undisturbed and hence, the primary equipment is in service. This also supports the argument of the employing two main protection systems of identical type.

iii) SELF TESTING FEATURES

This feature is available in latest numerical relays. The development of latest relays has evolved self-checking features built into the protection equipment. As confidence in the feature grows, less and less reliance need be placed on having autonomous back

up functions as well as testing frequency. Should one of the primary relays fail due to an internal failure, this would be flagged immediately and the defective relay could be repaired / replaced within a short period of time. Previously, an internal relay fault could go undetected until the relay was called upon to operate for a fault on the power system, if the power system fault occurred before the next scheduled routine testing.

4.5 CODE OF PRACTICE FOR PROTECTION

4.5.1 Circuitry

- The entire wiring of control circuit for indications, alarm, metering and protection should be of permanent nature.
- There is no place for temporary wiring or adhocism in control and protection circuit.
- The leads should be identified by ferrules near terminals.
- Every lead should end at a terminal point and no junction, by twisting, is allowed. If two wires are to be jointed, both ends should be connected at a common terminal or both ends are to be terminated at two different terminals and a loop be provided.
- The wiring should be by copper leads for CT secondary for all cores, i.e. metering as well as protections.
- The wiring should be by copper leads for PT secondary also, wherever they are intended for protection.
- The copper leads should be preferably stranded but not single lead type.
- Where PTs are employed for commercial metering, stranded copper wires should be used.
- The terminals should be lugged by ring shape ‘O’ lugs. ‘U’ shape lugs should be avoided.
- For CT secondary terminals, two (2) nuts with one spring washer and two plate washers are to be compulsorily used.
- The terminal strips should be stud type with nuts and not screw-in type.
- Wherever two station batteries are available, the primary protection and back up protection should be from different batteries.
- Where there is only one battery at a power sub station, the primary and back up protections should be given DC supply through individual/main circuits with independent fuses run from DC bus.
- When CBs have two trip coils: they must be connected for operation by primary and back up protections.
- DC and AC supplies should not be taken through different cores of the same cable.
- Independent DC cables should be run to each equipment in the yard and looping of DC supply, either in the yard or in control room, from one equipment to the other is not permitted.
- The DC yard lighting for emergency lighting should be through independent cables, which must NEVER be mixed up with protection, and other circuit cables.
- For indications, alarms, annunciators, controls (closing coil, trip coil etc. NEGATIVE of DC supply is always given direct and POSITIVE is supplied through commands like close, trip, protection- trip etc.
- Standard color codes for leads in control cables of different sizes should be used.
- CTs with 1 amp. Secondary rating should be used compulsorily where distance of control room is adjustable from switchyard. .
- The CT ratios available and adopted with No. of cores shall be displayed on each panel as follows.
 - 400-200-100/1-1-1
 - The selected ratio should be underline.

- Wherever CT cores are not used ‘SHORTING LOOPS’ should be provided near CT secondary terminals and not in the marshaling boxes or at panels.
- The cable entries near equipment marshaling boxes and panels should be by use of appropriate size glands leaving no scope for entry of lizards/reptiles etc.
- The wiring inside the panels should be neat and clean and well dressed and also fastened avoiding loose wires.
- All spare wires, not in use, should not only be disconnected but also removed from panels.
- Few cells from station battery should not be used for separate low voltage DC circuits e.g. PLCC etc. Instead, DC-to-DC converters only should be employed utilizing full DC voltages of the entire battery as input.

4.5.2 Equipment wise relaying practices and nomenclatures

S.NO	Equipment	Protection	Philosophy	Indication
1	Power Transformer	a) Main protection	Differential, REF, High Impedance Differential	87
		b) Back up	O/C & E/F	50/51: 64,64R/M/ NX
		c) Over fluxing & NDR	V/f Residual Voltage	99
		d) Gas or surge Operated	Buchholz	63
		e) Thermal	i) Winding temp. high/trip	49/T
			ii) Oil temp. high/trip	26/T
			iii) P.R.D.	30P
			iv) OLTC out of step	OST
2	Line	a) Main protection	i) Distance / impedance relay	21
			ii) Distance / impedance relay	21
		b) Back up	Directional O/C, E/F relay	50/67
			i) Carrier send	85x 1
			ii) Carrier received	85 x 2
iii) Carrier lock out trip	85 LO			
3.	Bus Bar	a) Main protection	Differential,	87
		b) Back up breaker stuck	LBB	50-Z (Timer 2/50Z)
4.	Circuit Breaker	a) Trip circuit supervision/ healthy/indication relay		95
		b) Trip circuit-1/Auto re-closure Indication relay)		195/295
		c) Pole Discrepancy timer		62
		d) Pole Discrepancy lock out relay		162/162X
		e) Auto re-closure blocking relay		96
		f) Auto Re-closure timer for single phase re -closing		197

5.	Miscellaneous	a) Supply (DC/AC) supervision relay		80
		b) Under/over frequency relay		81
		c) DC over current relay		76
		d) VT selection relay		75
		e) Tripping relay		86/186/286
		f) Check Synchronizing relay		25
		g) VT selection (use failure relay)		27/97
		h) Alarm relay		74
		i) Auxiliary relay/Indicator Relay		30
		j) Remote Close/Remote Trip	K15R/K5L	
		k) Local close/Local trip	K15R/K5L	

4.5.3 STANDARD LEAD NUMBERS.

Certain lead numbers are standardized, as followed, and should be compulsively adopted with ferrules at terminals of leads.

J1	DC	Positive
J2	DC	Negative
Controls & Alarms		
Remote close:		K15R
Remote trip		K5R
Local close		K15L
Local trip		K5L
O/C		Relay trip K3, Master trip K9
Trip		Relay trip K3, Master trip K9
E/F trip		Relay trip K3, Master trip K9
Diff. Trip		Relay trip K3, Master trip K9
OSR/OLTC trip		163T
Buchholz		63T
O.T. trip		26T
W.T. trip		49 T
Over-fluxing trip		99
PRV trip		
TER-ALA trip		149T
Buchholz Alarm		63A
WT alarm		49A
OT alarm		26A
TER alarm		149A
Bus bar protection trip		96
Pole discrepancy trip		162
Indication +ve – L		
OFF L3		
ON L5		
Semaphore		OFF L7
Semaphore		ON L9
CB trip alarm		L21
Bus AB switch remote		OFF – L11

Bus indication	ON L13
Line/equipment	OFF L15
	ON L17
	ON L 19
	OFF L21

4.5.4 Norms for transformer protection.

- No Buchholz relay for transformers below 500 KVA capacities.
- Transformers up to 1500 KVA shall have only horn gap protection.
- Transformer 1500 KVA and 8000 KVA and above – Differential protection in addition to Buchholz relay.

4.5.5 SYMBOLS AND NUMBERS USED IN METERING, PROTECTION AND CONTROL CIRCUIT WIRING

Symbol	Used for
A	C.T. wires for main protection
B	C.T. wires for Bus bar protection
C	C.T. wires for back up protection (over current / earth fault protection)
D	C.T. wires for metering
E	PT/CVT wires for Protection & metering
G	PT/CVT wires for synchronizing
H	A.C. supply main wires
J	D.C. supply main wires
K	Control supply wires
L	Indication and Annunciation wires
M	A.C. supply wires
N	A.C. Control supply (e.g. Tap changer)
P	D.C Control supply for bus bar protection /Local breaker back up protection.
U	Spare Contract
X	
Odd numbers 1, 3, 5 etc. for D.C positive/A.C. phase.	
Even numbers 2, 4, 5 etc for. D.C Negative/A.C. Neutral	
Numbers	Used For
11 to 30	R phase
31 to 50	Y phase
51 to 70	B phase
71 to 80	Neutral
81 to 91	Open delta / residual voltage
90	Earthing

4.5.6 Abbreviations of Indications /relays/Flags

Indication	Used For
1	Timer
2	2Z or 2/50Z - Timer for local breaker backup Protection
3	Checking or interlocking relay

6	Circuit breaker, connection or switch
12	Over Frequency/Over Speed Relay
14	Under Frequency/Under Speed Relay
21	Impedance relay/ Distance Relay
25	Synchronizing/paralleling relay
27	Under voltage relay
30	Auxiliary relay for Indicator relay
32	DC Reverse Power/Directional Power Relay
37	Under current or under power relay
40	Field failure/Loss of excitation relay
43	Transfer switching relay/changeover relay
46	Negative Sequence Relay/Phase balance Current Relay
47	Phase sequence voltage relay
48	Incomplete sequence relay
49	Machine or transformer thermal relay
50	Instantaneous Over current relay 50 A local breaker back up protection relay
51/51 N	Over current /Earth fault relay- IDMTL
52	AC Circuit Breaker
52a	AC Circuit Breaker auxiliary contact N/O
52b	AC Circuit Breaker auxiliary contact N/C
54	High Speed DC Circuit Breaker
55	Power Factor Relay
56	Field application relay
59	AC Over Voltage Relay
60	Voltage or current balance relay
62	Circuit breaker pole discrepancy timer 162 x pole discrepancy lock out relay alarm
63	Gas operated or surge operated relay 63 T Buchholz trip 63 A Buchholz Alarm 163 TC/OLTC trip circuit
64	Earth fault relay 64 R Restricted earth fault relay 64 N Earth fault relay 64 NX Auxiliary relay for Directional earth fault relay
67/67 N	Directional O/C + E/F relay 67 ABC phase of relay Reverse power relay
68	Blocking Relay
74	Alarm relay
75	VT selection relay 75 A Bus I side 75 B Bus II side
76	DC over current relay
78	Phase angle measuring relay or out of step protection relay
79	AC Re-closing Relay
80	DC Supply supervision relay
81	Frequency relay

83	Automatic selective control or transfer relay
85	Carrier signal aux. relay 85x1 carrier send relay 85 x 2 carrier receive relay
86	Tripping and Lockout relay 86 A, B, C single phase tripping relay phases wise 86 T three phase tripping relay 186 A, B auto reclose block trip relay 186 Lockout relay 286 trip re-closing
87	Differential relay
91	Voltage directional relay
92	Power Directional Relay
95	Trip circuit healthy Supervision relay/ indication relay. 195 Trip circuit-I 295 Trip circuit-II
96	Auto re-closure blocking relay or bus bar protection tripping relay
97	VT fuse failure relay
99	Over- flux relay 99A – Alarm 99 T- tripping
	Note: Suffix- X is used for Auxiliary relay for contact multiplication of main relay Z- local breaker back up protection relay Prefix 2 timer for main relay

4.5.7 Abbreviations for type nomenclature of relays

Symbol	First letter	Second letter	Third letter
A	Phase angle comparison	Attracted Armature	Auxiliary
B	Balanced current	Buchholz	Testing
C	Current (Amperes)	Induction cup	Carrier or counting
D	Differential	Induction disc	Directional
E	Direction	-	Earth (ground)
F	Frequency	-	Flag & Alarm Indicator
G	-	Galvanometer (Moving coil)	General /Generator
H	-	-	Harmonic Restraint
I	Directional current	Transactor	Inter locked or Industrial
J	-	Mixed types	Tripping
JE	-	-	Tripping (Elec. Reset)
JH	-	-	Tripping (Hand - reset)
JS	-	-	Tripping (self- reset)
JC	-	-	Control
K	Rate of rise of current	-	Check alarm
L	-	-	Load limiting

M	Manual	Magnet (Polarized)	Semaphore or motor
N	-	-	Negative sequence
O	Oil pressure	-	Out of step
P	Poly phase VA	Plug	Potential failure
Q	-	-	Alarm
R	Reactive VA	Rectifier	Re-closing
S	Slip frequency	Synchronous motor	Synchronizing
T	Temperature	Transistor	Timer or transformer
U	-	-	Definite time
V	Potential (volts)	-	Voltage restraint
W	Watts (Power)	Weight (Gravity)	Pilot wire
WA	-	-	Inter posing
WJ	-	-	Inter tripping
X	Reactance	-	Supervisory
Y	Admittance	-	Flash back (back fire)
Z	Impedance	-	Special application
ZS	-	-	Zero sequence

First figure - Indicates the number of units in the relay essential to its operation-not including seal-in auxiliary units.

Second figure- Indicates a particular characteristic of one of a group of similar relays e.g. CDG11, CDG12, CDG13 and CDG14 are all inverse time over current relays but with different characteristic curve such as Inverse time (IDMT), Inverse time (long time delay), very inverse, Extremely inverse etc.

4.5.8 RELAY INDICATION CODE

1)	Operating Quantity
A	Phase angle comparison
B	Balance current
C	Current
D	Differential
E	Direction
F	Frequency
G	Gauss
I	Directional current
K	Rate of rise of current
M	Manual
O	Oil pressure
P	Poly phase volt ampere
R	Reactive volt ampere
S	Slip frequency
T	Temperature
V	Voltage
W	Power
X	Reactance

Y	Admittance
Z	Impedance
2	Basic measurement
A	Attracted Armature
B	Buchholz
C	Induction cup
D	Induction disc
G	Galvanometer
I	Transactor
J	Mixed type
M	Sensitive balanced armature
P	Plug
R	Rectifier
S	Synchronous motor
T	Static circuit
W	Weight or gravity
3	Indication of application
A	Auxiliary
B	Testing
C	Carrier or counting
CB	Capacitor bank
D	Directional
E	Earth
EF	Earth fault
F	Flag or indicator
G	General organization
GF	Generator field
H	Harmonic restraint
I	Inter locked or industrial
IG	General or generator (instantaneous)
J	Tripping
JE or JX	Tripping (ELE-reset)
JH or JY	Tripping (hand reset)
JA or JS or JZ	Tripping (Self-reset)
JB	Control (Tripping)
K	Check alarm
L	Load limiting
M	Motor or semaphore
N	Negative phase sequence
O	Out of step
P	Potential or fuse failure
Q	Alarm
R	Re-closing
S	Synchronizing
T	Transformer or timer
U	Definite timer
V	Voltage control

W	Pilot wire
WA	Interposing auxiliary
WJ	Inter-tripping
X	Supervisory
Y	Special application
ZS	Zero phases sequence
4	No. Of Units The first No. Indicates the no. Of relay units excluding sealing reinforcing auxiliary units e.g. CMM 42 relay consists of a thermal o/c unit, an instantaneous O/c unit, an E/F unit and an instantaneous unbalance unit.
5	Characteristics The second No. Indicates the particular characteristic of one of a group of relays e.g. CMM 41, CMM42 relays are of the same type and composition but differs in their time delay characteristics.
6	Case size
A	Size 1 draw out single ended 10 terminal
B	Size 1 draw out double ended 20 terminal
C	Size 2 draw out single ended 10 terminal
D	Size 2 draw out double ended 20 terminal
E	Size 3 draw out single ended 10 terminal
F	Size 3 draw out double ended 20 terminal
L	Size ½ non draw out (Type VAK relay)
M	Size ½ draw out single ended 10 terminal
P	Size 1½ draw out single ended 10 terminal
R	Size 1½ draw out double ended 20 terminal
S	Size 1½ draw out double ended 40 terminal
T	Size 4½ draw out single ended 30 terminal
U	Handle locked plug in
Y	Size ¼ moulded non draw out 10 terminal
Z	Size 1/2 moulded non draw out 12 terminal
7	Case Mounting
F	Flush vertical
D	Flush Horizontal
8	Identification This may be one or more Nos. or letters and enables to identify rating, contact arrangement etc.
9	Suffix Last letter regarded as a part of identification above if last No. is 5 for 50 Hz. 6 for 60 Hz.
10	Distance Protection Scheme An Exemption to the rules are dist. Protection schemes which have a group of prefix letters to identify type, measurement etc.
M	For MHO characteristic
R	For reactance
SS	Switched scheme
Note	Digit denotes No. of time distance steps and final letter V

	or T indicates the scheme is electromagnetic or static.
	MM3V means 3 step electromagnetic disc scheme with 3 MHO measuring unit for Ph-ph and 3 for ph-N.
	ANSI TERMINOLOGY
No.	Function
3TC	Trip coil circuit monitoring
21	Distance Protection
25	Synchronism check
27	Under voltage protection
32	Directional power protection
37	Under current protection
40	Field loss protection
46	Reverse – phase or phase – balance current protection
47	Phase-sequence voltage protection
49	Machine thermal protection
50	Instantaneous phase O/c protection
50bf	Breaker failure protection
50T	Transformer tank protection
50hr	Instantaneous O/c with harmonic restraint
50N	Instantaneous ground O/c protection
50Ns	Instantaneous sustained ground O/c protection
50N/ 50Ns	Instantaneous ground/ sustained ground O/c protection
50Nu/51 Nu	Ground current unbalance protection
500 u/510u	Capacitor bank phase current unbalance
51	Time phase O/c protection
51N	Time ground O/c protection
51N/51Ns	Time sustained g round/ ground O/c protection
51br	Time O/c protection against blocked rotor
59	Over voltage protection
59N	Neutral Over voltage protection
66	Excessive NO. of start – UPS protection
67	Directional phase O/c protection
67N	Directional ground O/c protection
67Nus	Directional neutral protection (ungrounded system)
78	Out of step protection
79	Re-closer
81	Over/under frequency protection
87	Differential protection
95	Special ground O/c protection
95R	Special ground O/c protection

4.5.9 Standards for the different tests on relays

	Insulation test IEC 255-5
	Between circuit and ground 2kV, 50/60 Hz. For 1 min.
	Between independent circuits

	2kV, 50/60 Hz. For 1 min.
	Impulse test IEC 255-5
	5 kV 1, 2 μ s: 0.5 J
	1M Hz. – Disturbance test IEC 255-22-1 class III
	Common mode 2.5 kV
	Differential mode 1.0 kV
	Fast transient test IEC- 255-22-4 class IV
	4 kV \pm 10%
	Radiated electromagnetic field disturbance IEC 1000-4-3
	Amplitude modulated 10V/M
	Pulse modulated 10V/M
	Electrostatic discharge test IEC 255 – 22 – 2 lass III
	8 kV \pm 10%
	Radio frequency emissivity
	EN 55011
	Temperature IEC 255-6
	Operating range – 10 deg. C to + 55 deg. C
	Storage range – 25 deg. C to + 70 deg. C
	Humidity 95% (Non condensing)
	Power supply ripple IEC 255 – 11
	< 20%

4.5.10 Test Plug and Universal Test block

Type MPB/ MPG

Features:

- On load testing of relays and meters without disturbing panel wiring.
- Reduced cost of commissioning and routine measurement.
- Simplified and safer testing

Application

Type MPB test plug is used for testing relays and meters in draw out cases In conjunction with type MPG test block, it can be used for testing relays and meters in non draw out cases of any manufacture.

4.6 MAINTENANCE SCHEDULE FOR DIFFERENT PROTECTION SCHEMES

S.No.	Activity	Condition	Period
I	Line Protection		
A	Distance Protection		
a	Check for all zones (includes Z1, Z2, Z3 and Z3 reverse)	W S/D	5 Y
b	Time measurement	W S/D	5 Y

c	Power Swing blocking (PSB) check	W S/D	5 Y
d	SOTF	W S/D	5 Y
B	YTG		5 Y
a	DC supply monitoring checks	W S/D	5 Y
b	VT fuse failure check	W S/D	5 Y
C	LZ-96		5 Y
a	Op to coupler inputs check (where provided)	W S/D	5 Y
b	Self diagnostic signals check	W S/D	5 Y
D	THR Reyrolle		5 Y
a	Reach check for all 4 zones (includes Z1, Z2, Z3 and Z3 reverse)	W S/D	5 Y
b	Timing check for the same	W S/D	5 Y
c	PSB check	W S/D	5 Y
d	SOTF check	W S/D	5 Y
e	VT fuse failure check	W S/D	5 Y
f	Starters- NPS –impulse (where provided)	W S/D	5 Y
g	Non impulse	W S/D	5 Y
h	PPS -impulse	W S/D	5 Y
I	Phase sequence check	W S/D	5 Y
j	DC supply check	W S/D	5 Y
K	Transmitter checks (carrier send)	W S/D	5 Y
l	Receiver checks (carrier receive)	W S/D	5 Y
m	Modulation threshold	W S/D	5 Y
n	Reflex test	W S/D	5 Y
o	Comprehensive test	W S/D	5 Y
p	End to end test for P-10/ P-40 / THR if exist	W S/D	5 Y
q	Test for ‘a’ x ‘b’ setting for all three modes	W S/D	5 Y

r	Stability check for all three modes	W S/D	5 Y
s	B/U impedance relay reach-forward and reverse	W S/D	5 Y
t	Neutral current relay check	W S/D	5 Y
2	Common test for distance and unit protection		5 Y
a	Trip contacts check	S/D	5 Y
b	Annunciation check	S/D	5 Y
c	Check for carrier send/receive	S/D	5 Y
d	Auxiliary relay healthiness	S/D	5 Y
e	Over voltage relay	S/D	5 Y
f	LBB	S/D	5 Y
g	STUB protection	S/D	5 Y
h	Fault locator initiation check	S/D	5 Y
i	DR, EL initiation check	S/D	5 Y
j	Auto re-close check	S/D	5 Y
k	DC logic	S/D	5 Y
3	Auto transformer protections		5 Y
a	Over fluxing relay	S/D	5 Y
b	Over load	S/D	5 Y
c	Directional over current	S/D	5 Y
d	LBB	S/D	5 Y
e	Auxiliary relays (Buchholz, PRV winding temperature oil level etc.	S/D	5 Y
f	Fuse failure check	S/D	5 Y
g	Transformer differential protection	S/D	5 Y
h	Restricted earth fault	S/D	5 Y
4	PLCC system		5 Y
a	Checking of return loss	S/D	5 Y

b	Power supply measurements	S/D	5 Y
c	Transmitter checks	S/D	5 Y
d	Receiver checks	S/D	5 Y
e	Checks of alarms	S/D	5 Y
r	Reflex test	S/D	5 Y
g	LMU composite/ return loss	W S/D	5 Y
5	Bus bar protection		
a	Primary injection test	S/D	SOS
b	Protection stability and sensitivity checks	S/D	SOS

W S/D Without shutdown
S/D With shutdown
Y Yearly
HY Half Yearly
M Monthly
SOS Emergency / Contingency

4.7 LIST OF SPARE RELAYS/ RELAY SPARES TO BE MAINTAINED AT VARIOUS GSS

S. N O.	NAME OF ITEM	400 KV/220 KV	220 KV/132 KV	132 KV	REMARKS
1	Trip Relay Hand Reset/ Lock out Type	2 for each D.C. rating per GSS		2 relays per GSS	No. of NO/NC contacts and DC rating shall be specified by the indenting officer/ Incharge GSS
2	i) Trip Relay Self Reset/ Non Lock out Type	2 for each D.C. rating per GSS		2 relays per GSS	To be kept at each GSS
	ii) Master Trip Relay	2 for each D.C. rating per GSS		2 relays per GSS	To be kept at each GSS
3	Auxiliary Relay H/R Type for _____	2 for each D.C. rating per GSS		2 relays per GSS	To be kept at each GSS
4	Auxiliary Relay S/R Type for _____	2 for each D.C. rating per GSS		2 relays per GSS	To be kept at each GSS

5	Trip circuit Supervision Relay	One set of relays per five breakers			To be kept at each GSS
6	2 Over Current+1 Earth Fault Relay (set)		1 of each model for 220 kV side 1 of each model for 220 kV side		Equivalent relay shall be numerical having approved make. Preferably, equivalent relay may have universal rating of current & auxiliary supply
	a) Directional	(a) 2 of each model	1 of equivalent type for 132 kV side	1 of equivalent type for 132, 33 & 11 kV	
	a) Non-Directional	(b) 2 of each model	1 of equivalent type for 132 kV side	1 of equivalent type for 132, 33 & 11 kV	
7	Distance Protection Relay (Scheme) including Power Swing Blocking Relay	1 scheme/10 feeders of each type	1 scheme/10 feeders for 220 kV and 1 scheme/20 feeders for 132 kV	1 scheme /20 feeders	One relay of each model/type for each voltage level i.e. 400 / 220/132kV to be maintained at circle level.
8	Differential Relay	One relay each type per GSS	One relay each type per GSS	One relay/ 10 feeders each type	To be kept at 400/220 kV GSS 2(Two) at division level
9	Universal ICT suitable for both 1 A as well 5 A	1 Set (3 Nos.)	1 Set (3 Nos.)	1 Set (3 Nos.)	To be kept at 400/220 kV GSS 2(Two) at division level
10	Over Flux Relay	2	2	2 relay per division	To be kept at 400/220 kV GSS 2(Two) at division level
11	NDR	One relay per GSS	One relay per GSS	One relay per division	To be kept at each GSS
12	Over Voltage Relay	One relay per GSS	One relay per GSS	One relay per division	To be kept at each GSS
13	Under Voltage Relay	One relay per GSS	One relay per GSS	One relay per division	To be kept at each GSS
15	Trip/ Alarm contact assembly units for	One unit per breaker	One unit per breaker	One unit per breaker	To be kept at each GSS

	over current and E/F relays E/M type.				
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4.8 NORMS FOR TESTING EQUIPMENT AND T&P OF PROTECTION DIVISION & SUB DIVISION

S.No	Name of equipment	Sub- Division	Division
1	Primary Injection Test Set	1 No.	-
2	Secondary Injection Test Set	1 No.	.
3	ZFB distance scheme test set	1 No.	1 No.
4	Rheostats	2 Nos.	2 Nos.
5	Phantom Load Test set	1 No.	
6	Electronic Reference Standard Meter (ERSM)	1 No. (0.1class)	
7	Digital /Analog TTR	1 No	
8	AVO meter	2 Nos.	
9	Multi Meter (Digital)	4 Nos.	1 No.
10	Tong Tester		
	a) High range (Digital)	1 No.	
	b) Low range (Digital)	4 No.	1 No.
11	Digital/Analog Insulation tester	2 No. (5 kV)	
12	Earth resistance /resistivity tester (Digital)	1 No.	
13	Clamp on earth tester	--	
14	Digital low ohm meter	1 No.	
15	Universal Computerized relay test set	1 No	
16	Automatic tan delta and capacitance test set	1 No.	
17	Voltage variac	1 No.	
18	Phase sequence meter	1 No.	
19	Hand Drill machine	1 No.	
20	Lap top computer	3 No.	1 No.

21	Tool kit bag consisting of pliers, screw driver & box spanner sets	1 kit per MTR	1 No.
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4.9 Principle of Operation of various Electronics Meters, Installation, Testing and Checking. Presently, static meters have been introduced for metering in HV and EHV system. The electro-mechanical induction type meters are being replaced with static meters by Discoms for consumer metering as well as for HT feeder wise energy accountal. Static meters have also been installed by RVPN in place of induction meters in its EHV system for inter/intra-state metering as well as on LV side of all power transformers. So far the performance of static meters as compared to induction meters is concerned, there is neither any problem in the performance of static meters nor any doubt about the technical superiority of static meters over the electro-mechanical meters.

4.9.1 Principal of operation

Digital Signal Processor is used in static meters for electronic processing of voltage and current signals collected from the CTs and PTs. The electronic meters consist of the following major parts:

- A) Analog section: This consists of highly accurate current transformers and voltage transducers/voltage dividers (Resistor Divider Network) to step down the current and voltage signals. These signals are fed to analog to digital (A to D) converter.
- B) Analog to Digital converter: Current and voltage waveform signals received from analog section are subjected to sampling. A to D converter converts the voltage and current signals into digital forms . High sampling rate gives exceptionally high accuracy in measurement of energy.
- C) Digital Signal Processor
This plays a very important role in the static meter. DSP carries out electronic processing of different type of signals. Digitized current and voltage signals in the forms of serial output data are sent to DSP. DSP stores the acquired current and voltage signals in its internal data memory. The DSP is capable of performing complex digital signal processing functions and tasks on real time basis. The DSP carries out complex digital processing of digitized voltage and current signals in to various parameters by computation like active, reactive and apparent energy etc.
- D) Micro Controller This manages all the peripherals including flash memory (NVM or EEPROM), real time clock (RTC) serial port, LCD display and also boots the DSP. In addition to peripheral management, the micro controller performs the complete data management. The DSP keeps the micro-controller up-dated every moment with its 'bucketful' of processed data.

- E) NVM (Non 'Volatile Memory): NVM of the meter may be in flash memory form or EEPROM form (or NVRAM) which stores the metering data and ensures data safety in case of power failure. All the processed data are stored in non-volatile memory and even if the meter is kept under no power condition or remains un powered for a period of 10 years or so, the data are not lost and are kept secured in NVM.
- F) LCD: Extended temperature type LCD or now backlit type LED's are being used which can be read in poor lighting conditions displaying various parameters measured and processed by the meter. Power consumption of LCD is less than LED, but LED has a bright display and is more convenient to be read in case of poor light available around the meter. Now backlit type LED are being used which can be read in poor lighting conditions.
- G) Power Supply: The power supply of the meter is in form of Switched Mode Power Supply (SMPS), which is used to power up the electronic circuitry. Meter also consists of a nickel cadmium rechargeable battery backup, which is used for operating the meter in absence of power supply.
- H) Real Time Clock: Meter also consists of a real time clock (RTC) to keep record of real time. Even in absence of power supply, various meter data are logged with time tag through the RTC. Permissible drift in the RTC is about minutes per year.
- I) Optical communication port: An optically isolated communication port is provided to read the meter electronically and down load the various data available in the meter through the optical communication port with the help of MRI (Meter Reading Instrument).
Every meter uses a particular communication protocol. There are number of protocols in use like ANSI, PACT, 1107 etc.
- J) Meter Software: Every meter has its own proprietary software designed according to the requirement of the User. Meter output can be configured through the software, which is fully protected against unauthorized accesses Hardware Items:
 - a) PCB: Compactness of the meter is achieved by having Perforated Circuit Board (PCB) using Surface Mounted Technology (SMT). PCB may have two or more layers on the same board. Digital logic circuitry is used to reduce number of discrete ICs, which makes the meter compact and more reliable.
 - b) Terminal block: Different types of terminal blocks are used in whole current, CT operated and CT-Pf operated meters.
 - c) Terminal Covers: Generally, extended type terminal covers are used so that the wiring at the bottom of the meter remains concealed and transparent terminal covers are preferred.

- d) **Sealing Arrangement:** At least two seals are provided to seal the body cover of the meter. Similarly two sealing screws are provided for sealing of the terminal cover. Further, the whole meter (along with test terminal block for CT or CT-PT operated meters) is put inside a meter box having a window for viewing reading of the meter. The box is sealed with one or two seals.

4.9.2 Basic building blocks of an electronic meter:

Basic building blocks of an electronic energy meters can be classified into two major parts namely Mechanical hardware and Electronics hardware.

- A) **Mechanical hardware:** The Mechanical hardware used in the electronic energy meters is identical to those used in conventional electromechanical energy meters. Since the hardware used is not very heavy and bulky, it is more convenient to house the assembly either in polycarbonate-insulated materials or in simple steel metal enclosures. The relevant metering Standards call for certain mechanical tests such as vibration test, shock test and drop test which take care for the mechanical strength of the material used and for the metering assembly processes. With the use of materials, like engineering plastics, it is also possible to do ultra sonic welding of the whole meter enclosure once the meter has been manufactured.

The terminals in which the live wires are terminated are made of good quality brass or copper that will take care of the mechanical strength and the heat dissipation due to current drawn by the loads. The terminals are mounted inside terminal block housing which is generally an integral part of the meter housing. This makes it possible of complete immunity for assessing the terminals once the meters are sealed with the terminal cover.

- B) **Electronics hardware**

The Electronics hardware used in electronic energy meters comprises of the following major components:

- The printed circuit board (PCB) having all the electronic components assembled on it.
- The current transducers and voltage dividers.
- Display devices such as LED, LCDs or mechanical counters.

The PCB used in electronic energy meters are assembled and tested using equipments which are generally used for manufacturing high volumes electronic products including computers to household items. This PCB has all the electronic components required in the electronic circuit for achieving the required metering performances.

The current transducers are generally current transformers used for sensing the load current to be measured. Depending on the applications different type of currents transducers can be used such as current transformers, shunt resistor, Rogowski coils

and Hall effect sensors etc. The current transformers and shunt resistors are the most popular current transducers being used presently. .

The display devices used in electronic energy meters are LEDs, LCDs or mechanical counters. A pulsing LED indicates the , amount of energy being measured by the energy meter. Depending on the meter constant (i.e. pulses/kWh) the LED will give No. of pulse outputs for certain amount of measured electrical energy (say 1 kWh). This LED is also used for meter calibration purpose.

The pulsing of LED replaces the rotation of disk in the conventional energy meter. The LCDs and mechanical counters are used to record the cumulated energy measured by the energy meter.

The unit measured by the energy meters is in kWh. And so, the counts registered are proportional to the kWh of energy consumed by the loads. By using LCD displays it is possible to indicate multiple parameters apart from the kWh being measured. The additional parameters can be such as line voltage, power factor etc. which can be used for monitoring the load conditions.

The 'building blocks in the electronic circuit for an electronic energy meter are:

- Metering IC
- Current sensing
- Voltage sensing
- Power supply
- Display

With the developments of electronics over the years the major circuits involved in energy meter has been integrated into a single chip solution, which is called the metering IC. The Metering IC performs all the required function of an energy meter and also incorporates the flexibility for adopting the IC for different metering applications.

The current sensing is achieved by the current transformer OR a shunt resistor which steps down the current to be measured into the levels which can be further processed by the metering IC.

The voltage sensing performs the same function as current sensing, which steps down the voltage to be measured into levels, which can be further processed by the metering IC. A simple resistor network can achieve this function. Also potential transformer can be used for converting the level if additional isolation is required.

The power supply is integrated into the metering circuit and provides necessary power for driving the metering circuit. Care is taken such that it does not draw more power from the mains where the consumption of the meter itself becomes an unwanted load. The display of the Total Energy consumed is indicated by electro mechanical devices and are driven directly by the metering IC. A simple relay type electro mechanical counter or a most sophisticated stepper motor driven counters are generally used for the application defined in the given circuit diagram. The multi function meter uses display such as LCDs that are driven by micro controllers.

- C) Design of an electronic energy meter: The preliminary data required for designing the electronic energy meter will be the meter rating itself, i.e. The operating voltage, the current range of the meter i.e. basic current and maximum current. and the power factor range (e.g. zero lead to unity to zero lag)
- D) Power Supply: For designing the power supply, the metering standards are used as guidance, which specify that the meter voltage circuit should not draw more than 8 or 10 V A from the mains line. The function of the power supply circuit is to convert the AC mains signal into regulated DC signal to be used by metering circuits. In case of RC supply the AC mains is dropped into low voltage AC by the series resistor and capacitor (R and C). The low level AC is rectified by diodes. High precision voltage regulators and filter capacitors regulate the rectified signal. Other power supply such as, transformer based power supply and SMPS (switched mode power supply) are also available. Each type of power supply has its own merits and demerits in terms of performance and cost.
- E) Metering IC: The metering IC, which is an application specific IC, is the resultant of research and developments taken place in energy meter measurements and electronic technologies resulting in a single chip integrated solutions effectively performing all the metering functions with bare minimum external components. The initial cost for designing and development of the chips is very high but when the same is manufactured and used in high volumes, for the applications such as energy meters, the cost of the end product comes down drastically and helps in fast designs of energy meters. With the help of data sheet and application circuits of the metering IC, it is possible for completing the designing of energy meters with in no time.

Main types of IC's, which are in general use, are SA 9602 by SEMS and AD7751 by Analog Devices.

For high-end metering taken four quadrant tri-vector meters, DSPs are used in place of IC's, which are also application specific type.

- F) Meter Display: In whole current like single phase and three phase kWh meters, energy measured is displayed through mechanical type counters registers. The advantage of LCD type display device is that it can display multiple parameters. The various

parameters measured by 3 Ph 4 W meter are displayed through LED I LCD register. Some of the data displayed are given below:

- 1) LED test
- 2) Real time
- 3) Date
- 4) Rising demand with elapsed time (KV AIKW)
- 5) Meter reading count
- 6) Power on hours
- 7) MD reset counts
- 8) Energy (header)
- 9) Active energy (kWh) Import
- 10) Active energy (kWh) (Export)
- 11) Reactive energy (kV Arh) Lag
- 12) Reactive energy (kV Arh) Lead
- 13) Apparent energy (kV Ah)
- 14) Instantaneous power factor
- 15) Cumulative demand (kV AlkW)
- 16) Instantaneous average current phase wise
- 17) Instantaneous current phase wise .
- 18) Instantaneous load (kWIkVA)
- 19) Temper information (if, occurred)
- 20) Present temper status
- 21) Date and time of latest temper occurrence with temper ID
- 22) Date and time of latest temper restoration with temper ill
- 23) Cumulative temper counts
- 24) TOD maximum demand kV A
- 25) TOD energy resistors
- 26) Maximum demand (0-24) hours kV A
- 27) Bill energy register header
- 28) Bill kWh import register
- 29) Bill kV AH register
- 30) Bill maximum demand register header
- 31) (0-24 hour) bill M.D. register kVA

G) Output Parameters:

Through MRI meter can be read to generate following reports:

- a) Billing report
- b) Instantaneous parameters
- c) Temper and abnormality reports
- d) Historical billing parameters
- e) TOD (time of day) parameters
- f) Load survey for various parameters like active, reactive, apparent, energy frequency, voltage, power factor etc.

- H) **Meter Reading Instrument:** Meter reading instrument is a device, which is made compatible with the meter to read and download various data from meter. Those data are further downloaded from MRI to base computer
- I) **Base Computer Software System (BCS):** The BCS software is designed to handle all available data from meter through MRI and generate output reports as per the requirement of the user. The BCS or base computer software system is installed in the personal computer and data obtained from the meter through MRI are downloaded in the BCS and above referred reports can be generated to analyse the various data conveniently as per the users requirement.

In brief, static meters have taken over the process of measurement of energy from the induction meters. The main features of static meters are:

- a) Capable of measuring bulk energy accurately up to an accuracy class of 0.5 s and 0.2 s.
 - b) Anti temper features
 - c) Same meter can work as a four-quadrant energy meter (Import Export meter) with TOD and load survey feature.
 - d) Consistent accuracy of measurement over a long period of time
 - e) Long memory storage period to store data convenient to read and even can be read from remote place through modem along with some communication system like PSTN, radio frequency or GSM.
- J) **Anti Temper Features:** An electronic meter can sense and detect following types of tampers, which may be attempted on it:
- a) Current reversal. The meter detects and logs the event with date" time and phase on which, CT main load wires are. reversed.
 - b) Current by pass short/open. If current circuit is by passed either from primary side or from secondary side, or current circuit is shorted / opened from secondary side, meter can detect the same with phase identification, date and time.
 - c) PT missing. If voltage display to the voltage circuit of the meter is interrupted, meter can detect the same with phase, ill, date and time.
 - d) Application of external magnetic field (DC/AC). Meter can detect the same with phase identification, date and time.
 - e) Phase sequence reversal. Meter works and records energy accurately even on reverse phase sequence of the primary supply.
 - f) Incorrect phase association. Meter gives voltage current and phase angle parameters and vector diagram through which it is possible to analyse that the meter was subjected to incorrect phase association.
 - g) In single phase and three phases meters, the meter records correct energy, even if, main and load side are reversed or earthed.

- K) Standards: There are different national and international standards for various types of static meters and their components as referred below:
- | | |
|------------------------|---|
| IS 13779: 1999 | for class 1.0 static kWh meters |
| IS 14697 and IEC 62053 | for static energy meters of class 0.2 S & 0.5 S |
- L) Tests: These meters can be tested at site conveniently with the help of reference meters connected in series.
Installation of these meters is very easy and these can be connected to the existing CT and PT circuits.
The electronic meter is a very powerful tool to measure bulk energy accurately with anti temper feature:
- M) Other additional advantages! features of electronic meters are:
- i) Four quadrant metering of active & reactive power, energy demands, PF etc.
 - ii) Additional information like, time of day consumption, temper information, Power ON hours, etc.
 - iii) Sustained accuracy over a long period of time. Therefore, no need for frequent calibration, no hardware calibration. So, no chance of manipulation in meter accuracy at site.
 - iv) No effect of oblique suspension.
 - v) Wide operating range of voltage, current. .
 - vi) Memory storage provides load survey and historical billing data.

4.10 METERING CODE APPROVED BY RERC, (important points) Measurement Equipments

4.10.1 Meters

4.10.1.1 The meter shall be 3-phase 4-wire type, capable to record and display import and export kWh, kV Ah, kV Ah and maximum demand in kW and kV A for 3-phase 4-wire, AC balanced/unbalanced load for a power factor having range of zero lagging to unity to zero leading in all 4 quadrants. In addition, meter shall also be capable of displaying on demand, the present status of supply load, missing potential, CT polarity, current unbalance, anomaly occurrence and logging of occurrences as well as load survey data etc. which shall be downloaded to a user-friendly Basic Computer Software (BCS) through portable data collection devices or CMRI which shall be connected to optical communication port of the meter. Meter shall be equipped with self-diagnostic features also and be capable of recording average values based on their integration on time base for kWh, kV Arh, kY Ah for at least 75 days. Meter shall be capable of measuring the . fundamental as well as total energy, including harmonics separately.

4.10.1.2 Display

Present meter status, real time and date cumulative energy registers, voltages, currents, power factor, present demand, frequency and meter serial number shall be available on demand through push button. .

Any interrogation/read operation shall not delete or alter any stored meter data.

4.10.1.3 Memory

- a) Numerical-values of voltage/current, power factor and cumulative energy registers as well as anomalies/ tempered details along with date and time of logging of and restoration of anomalies (subject to the meter memory space) shall be logged in the meter memory and shall be available for retrieving with the help of the data collection devices (CMRI) through meter optical port and down loading to BCS.
- b) Memory in a static tri-vector meter shall not get erased after reading or retrieving of data through MRI. Data shall be retained for a minimum of 75 days or shall not get erased from meter until replaced by fresh data. However, desired data can be erased from MRI, when memory of an MRI becomes full after downloading of readings of a number of meters, as there is fixed space made available in MRI for.
 - i) Energy registers.
 - ii) Load survey data.
 - iii) Anomaly data etc.

When a fresh data is logged in the memory, the oldest data shall disappear automatically.

4.10.2 Current transformers

Three current transformers shall be used for 3-phase-4-wire measurement system. The secondary current rating of the CTs shall be 1 ampere particularly for 400 kV and 220 kV sub stations but in other cases it may be 5 amperes. Either dedicated current transformers or dedicated core of current transformers shall be provided for metering and that wherever feasible. CTs (or their cores) feeding to main meters and back up/check meters will be separate. The errors of the current transformers shall be checked in the lab or at site. However, if such facilities are not available, or test Certificates issued by Govt. Test house or Govt. recognized test agency should be referred to.

The total burden connected to each current transformer shall not exceed the rated burden of CT.

4.10.3 Voltage Transformers

4.10.3.1 Voltage Transformers are either electromagnetic voltage transformers (VT) or capacitive voltage transformers (eVT) may be used for metering purpose. Hereinafter, the term VT is used to cover both, PT or CVT. The secondary voltage per phase shall be 110/~3 volts per phase. Either dedicated voltage transformers or dedicated core of voltage transformers shall be provided for metering and that wherever feasible, VT (or their cores) feeding to main meters and backup/check meters will be separate. VT fuses of proper rating shall be provided at appropriate locations in the circuit.

4.10.3.2 The errors of the VT shall be checked in the lab or at site. However if such facilities are not available, VT test certificates issued by Govt. Test house or Govt. recognized test agency should be referred to.

The total burden connected to each VT shall not exceed the rated burden of VT.

4.10.3.3 The current transformers and voltage transformers shall meet the requirements as per the relevant standards. Where a combined CTIPT unit is provided, the accuracy shall be as specified under relevant IS.

4.10.4 Testing Arrangements:

4.10.4.1 Two types of test facilities shall be available:

- a) Automatic meter test bench with high accuracy, static source and 0.025 class electronic reference standard meter.
- b) Portable test set with static source and electronic reference meter of 0.1 class shall be used for verification and joint testing of accuracy of static tri-vector meters at site on regular I routine basis.

4.10.5 Metering system:

4.10.5.1 The metering system shall be comprised of main, check, back up and secondary back up meters. In the event of main meter or more than one-meter becoming defective, the order of precedence for . billing shall be (a) main (b) check (c) back up (d) secondary back up.

4.10.5.2 Generating stations: . '

Meters shall be installed on each generator as well as on each auxiliary transformer and outgoing feeders at generating stations to 'work out energy generated and net energy delivered by the power station in the power system.

4.10.5.3 Mini Hydel Stations:

For the energy supplied by Mini Hydel Stations to the RVPN or Discoms, as the, case may be, CTm units of 11/33 kV voltage rating having 2 identical metering cores with main and check meters shall be provided at energy transfer points preferably at the generating stations.

- i) Metering for transfer of power to interstate lines and lines connected to major generations stations.
- ii) Metering equipment shall be provided at receiving end of interstate EHV lines.
- iii) The above meters provided on interstate lines and on the lines connected to major generating stations, within the state, shall have following facilities:
 - a) Metering equipment shall have external/internal modem so as to be capable of remote transmission of all data available in the meter memory through any of the information links viz. radio frequency, public switched telephone network (PSTN), power line carrier communication (PLCC), V -sat network, mobile and other means of telemetry like private network of Transeo or low power radio.
 - b) The meter shall be capable of data transmission to RTD as well intelligent electronic device (IED). The format I protocol of communication fault, data retrieval and data telex should be made known to owner of meter by metering supply.

4.10.5.4 Metering between Transco & Discoms:

- i) For measurement of power delivered by RVPN to Discoms, following type of metering shall be provided on the LV side of EHV transformers (33 kV or 11 kV)
 - a) Main Meters
The main meters shall be provided on LV secondary side of EHV transformers with dedicated CTs, VTs, CT - VT sets of 0.2 class accuracy.
 - b) Back up Meters
The back up meters shall be provided on the existing CTs/NTs having 0.5 class accuracy on the 33/11 kV outgoing feeders.
 - c) Secondary backup meters
Secondary backup meters shall be provided at a later stage on EHV side of the transformers on the existing CTs and VTs.
- ii) Whenever checkback up meters for inter-utility metering are proposed to be provided by a Discom(s), then their accuracy shall be same as that of main meter.
- iii) The meter to be provided shall have the following facilities:
Metering equipment shall have external/internal modem so as to be capable of remote transmission of all data available in the meter memory through any of the information links viz. radio frequency, public switched telephone network (PSTN), power line carrier communication (pLCC), V-sat network, mobile and other means of telemetry like private network of Transco or low power radio.
The meter shall be capable of data transmission to RTUs as well as IED. Meter supplier should make format/protocol of data retrieval and data index known to the owner of meter.

4.10.5.5 Inter Discom Metering

The energy meters shall be provided at such points of the power lines connecting to two Discoms, so that the line in-between is not tapped by the other Discoms.

4.10.5.6 Sub-station Auxiliary Consumption Metering

The sub-station auxiliary consumption shall be recorded on HY IL Y side of station auxiliary transformers through class I ~O static kWh meter.

4.10.5.7 Time Synchronization

The Time Synchronization in all the meters should be from base computer through communication system and modem. The base computer shall be equipped with GPS signal receiver for time synchronization of the meters connected through relevant communication system and modem. As a standby measure, the CMRI will be used for time synchronization of the individual meter. There should also be provision in the base computer to synchronize time at preset time daily with respect to GPS clock of SLDC or central billing station.

4.10.5.8 Remote Transmitting Unit (RTU)

- i) Following data (instantaneous system parameters) shall be made available through transducers and RTUs from selected individual stations through sub load dispatch centre and load dispatch centre continuously:

- a) MW (Import/export)
- b) MY Ar (lag /Lead) -
- c) Voltage
- d) Current
- e) Frequency
- f) The status of various isolators, circuit breakers and transformers tap position.

The requirement of RTUs and transducers shall not be considered where meters, having the capability of transmitting various parameters to SLDC I Sub LDC, exist.

- ii) The accuracy of the transducers shall be 0.2%.
- iii) The -transducers and RTUs shall conform to relevant international / national standards.
- iv) The transducers shall be 3-phase 4-wire type for MW and MVar measurement purposes.
- v) Single transducers giving output of MW, MV Ar, voltage, frequency and Ampere shall be preferred in place of individual transducers for each metering point. The transducers shall be connected to 0.2 Class CTs & VTs and housed inside the meter box of the check meter meant for metering purpose.
- vi) Since the above- metering scheme is for commercial metering purpose, therefore, the complete CT wiring including energy meter, meter test terminal block and transducers shall be housed in the metering cubicle which shall be kept sealed. The output of the transducers shall be connected to RTD through screened signal cable. The RTUs shall be located in the PLCC room. The size of the CT & VT cable(s) to the transducers shall be same as that provided in the metering circuit.
- vii) Transmission of these data to the load dispatch centre can be through any of the information link like radio frequency, PLCC (power line carrier communication), PSTN (public switched telephone network), V -sat, Mobile and other means of telemetry like, private network of Transco or low power radio. The data shall be again processed at load dispatch end in data concentrator unit and converted to analog data and displayed on the monitor screen. The RTU shall be utilized for monitoring and also for remote control of feeders/ breakers located at remote sub station.
- viii) Meter supplier should make format/protocol of data retrieval and data index known to the owner of meter.

4.10.5.9 Monthly meter reading and collection of data

The RVPN and concerned Vitran Nigams/Utpadan Nigams shall jointly read the meters through thier authorized representative on first day of every month at 12 hours and shall retrieve meter reading data. A copy of meter reading sheet duly signed will be supplied by RVPN to Vitran Nigam or RVUN, as the case may be, and one copy shall be kept sealed for future reference. Wherever meters are in position or in operation, the tele-metered data shall be retrieved from the optical communication port of the meter.

4.10.5.10 System for Joint Inspection, Testing and Calibration

- i) The metering points between RVPN, RVUN and Discoms shall be regularly inspected twice in a year or at an interval as mutually agreed jointly by both the agencies involved for dispatch and receipt of energy. Since the static tri-vector meters are calibrated through software at the manufacturers works, therefore, during joint inspection, only accuracy of the meters and functioning shall be verified and certified jointly by both the agencies. In case of any doubt or defect, the meter shall be replaced then and there or calibrated. In later case, error correction as, determined will be applied to the meter reading . for the purpose of billing as per contingency referred as class 21 and comparing their readings. To covet for loss of time, spare meters shall always be kept available with the agency to which the meter/metering point belongs. After testing, the meter shall be sealed and a joint report shall be prepared giving details of testing work carried out, old seals removed, new seals affixed, etc. The agency, in whose premises the meter is located, shall be responsible for proper security, protection and sealing arrangement of the metering equipment.
- ii) Joint inspection shall also be carried out as and when difference in meter reading (so corrected) exceeds the sum of maximum error as per accuracy class of main & back up meter. The meters provided, at the sending end as well as at the receiving end, shall be jointly tested / calibrated on all loads and power factors as per relevant standard through static phantom load.

4.10.5.11 Sealing

- i) All tariff-metering system shall be jointly sealed by the representatives of the concerned parties as per the procedure agreed upon.
- ii) No seal, applied pursuant to this metering code, shall be broken or removed except in the presence of or with the prior consent of the agency affixing the seal or on whose behalf the seal has been affixed, unless it is necessary to do so in circumstances where (a) both main and check meters are malfunctioning or there occurs a fire or similar hazard and. such removal is essential and such consent can not be obtained and, (b) such action is required for the purpose of attending to the meter failure. 'Where verbal consent is given. it must be got confumed in writing forthwith. ,
- iii) Each party shall control the issue of its own seals and sealing pliers and shall keep proper register/record of all such pliers and the authorized persons to whom these are issued.

4.10.5.12 Access to Equipment & Data

Each constituent of the agency (utility) on request with advance notice, shall grant full right to metering equipment for other agency's employees, agents/duly authorized representative for inspecting, testing, calibrating, sealing, replacing the damaged equipment, collecting the data, joint reading recording and other functions necessary and as mutually agreed.

4.10.5.13 Operation & Maintenance ofthe Metering System

- i) The operation and maintenance of the metering system includes proper installation, regular maintenance of the metering system checking of errors of the CI's, VTs and meters, proper laying of cables and protection thereof, regular/daily reading meters

and regular data retrieved through MRI & BCS, attending any breakdown/fault on the metering system etc.

- ii) The maintenance of the meters shall be the exclusive responsibility of the owner of the meters; the ownership of meters has been indicated at clause 6 above.

4.10.5.14 Procedure for Assessment of Consumption in case of Defective and/or Stopped Meters.

Whenever a meter goes defective, the consumption recorded by the check meter! back up meter/secondary back up (i.e. receiving end meters) shall be referred. The details of the malfunctioning along with date and time and snaps shot parameters along with load survey shall be retrieved from the main meter. The exact nature of the mal-functioning shall be brought out after analyzing the data so retrieved and the consumption /losses recorded by ~e main meter shall be assessed accordingly. If main as well as back up metering systems become defective, the assessment of energy consumption for the outage period shall be done from the backup meters by the concerned parties as mutually agreed or at the level of Metering Committee.

4.10.5.15 Replacement of Defective or Stopped Meter

The owner of the meter shall maintain spare inventory of meters in sufficient quantity, so that down time is minimized.

4.10.5.16 Two part and ART capability

- i) The ABT compliant meter will have provision to compute and store average active and reactive energy and load data with respect to system frequency and the integration of the data i.e. average Wh & Varh, and average frequency for 15 minutes block will be available in each meter:

Minimum acceptable specification of these meters shall be as per column 1 and 2 of Annexure 1.

Meters shall also have reactive high and reactive low volt-ampere hour registers for total drawl, high and low system voltage drawl. The Discom- wise summation of kWh, kW, PF, demand scheduled interchangel unscheduled interchange will be done at the main computer station provided at central billing station or at Load Dispatch Centre.

- ii) The metering arrangement between RVPN and Discom
The metering arrangement between RVPN and Discom shall comprise of static tri-vector meter on the LV side of EHV Transformer.
- a) Frequency based ABT compliant meters shall be provided on 220 kV/132 kV lines feeding each Discom. The function of these meters will be as under:
 - i) To measure Discom-wise schedule and unscheduled interchange of energy.
 - ii) To monitor and measure Discom-wise kWikV AI, kVA demand, hourly power, factor and MW Ar flow including MV Ar exchange above 103% and below 97% of rated system voltage.

For this purpose, the voltage parameters shall be integrated at one centrally located. station preferably at load dispatch centre at Jaipur through computer and suitable software.

- b) Static tri-vector meters should be provided on LV secondary . side of all EHV transformers. The function/duty of this meter will be as sunder:
 - i) Measurement of kWh energy supplied to Discoms for billing purpose.
 - ii) kW/kVA demand and power factor, hourly as well monthly drawls caused by Discom on each EHV transformer. .

Note: For further details on metering code for Rajasthan Grid please refer Part-III of Grid Code fmalized by RRVPNL as per RERC order dated 28.10.2002

4.10.6 Central Electricity Authority Regulations 2004 on Meters.

Some of the important provisions of CEA regulations are given below:

- A) Regarding Harmonics
 - 1) The metering system shall be totally immune to harmonics
 - 2) The meter should be capable of providing harmonic stations.
 - 3) The accuracy of the meter shall not be effected by harmonics circulating in the system of magnitudes within permissible limits stipulated by CEA agreed standards and regulations.
 - 4) For distribution systems, the licensees shall monitor harmonics at different points in the distribution system.The total harmonic current drawn from the transmission system at any point shall not exceed 8% of the fundamental frequency current. -
 - 5) For bulk consumers, total harmonic component of current drawnfrom the transmission system shall not exceed 12%. The consumers shall install filters to reduce harmonics generated by their equipment.
- B) Provisions regarding voltage unbalance
 - i) The voltage unbalance is defined as deviation between voltage of highest and lowest phasesjgverage voltage of three phases).
 - ii) The voltage unbalance, as defined at i), shall not exceed the following units:

At33kV	3%
At 11 kV	3.5 %
- C) Requirement regarding calibration of CTs for interface tariff

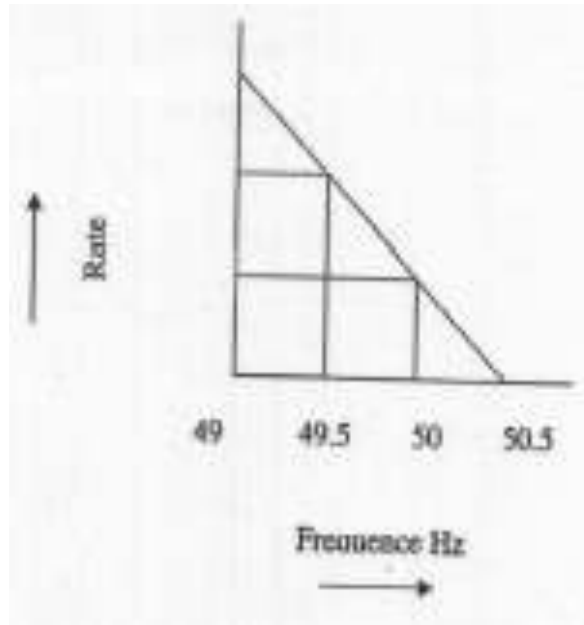
Instrument transformers shall be calibrated once at the time of commissioning. The calibration results shall be compared with the test certificate issued by the manufacturers. The ratios available an adopted shall be written meter registers on a label fastened to the meter. The instrument transformer shall be tested once in a five-year or whenever a party suspects an internal fault or degradation of accuracy due to magnetic core deterioration
- D) Standards on installation and operation of meters Regarding current and voltage transformers
 - i) The accuracy class of the CIs and VTs shall not be inferior to that of the meters.
 - ii) The rated burden of the CIs and VTs shall be adequate for connection . to the meters, other instruments and telecom . equipment at each location and CI's and VIs shall not be overloaded.

- iii) The CTs and VIs shall be tested once in a five years. If they are not replaced after elapsing of the normal life expectancy period, they shall be tested once in every six months thereafter for accuracy of ratio and burden.

4.11 SALIENT FEATURES OF AVAILABILITY BASED TARIFF INTRODUCED FROM 1.12.2002

Smooth grid operation warrants that generation should balance the loads plus losses in which case system frequency remains steady near 50 Hz. The tariff structures are designed so as to discourage the constituents to over draw when frequency is low because demand is already higher than the generation. On the other hand, generators are required to back down when frequency is high i.e, there is less demand as compared to the total generation. Salient features of ABT tariff structures are as under:

- 1) In the ABT system (applicable from 1.12.2000), there are three types of charges-
 - a) Energy charge for the scheduled generation as per respective rates.
 - b) The prescribed energy charges for deviations from scheduled i.e. for unscheduled interchanges (UI charges).
 - c) Fixed charges for the declared availability of generators. Although, ABT is presently binding on Central generating stations, financial implications arising out of unscheduled draws are still to be borne by SEBs/Utilities.
- 2) Energy charges as per scheduled draws (as requisitioned by the constituents in advance) are now booked as per rates for the respective generating stations.
- 3) Unscheduled energy over draws/under draws are booked as per the energy rates applicable for the frequency bands in which the energy is exchanged.
- 4) Every state is required to pay its monthly fixed charges (including incentive/disincentive as applicable) as per its entitlements / allocations from the central generating stations irrespective of energy draws.
- 5) The state load dispatch centers are now required to indicate their demand on 15 minutes interval basis demand to Northern Regional Load Dispatch Centre (NRLDC), a day in advance, which can be modified up to 10 p.m. of the previous day. The requirement is indicated by LD, based on day-ahead generation conveyed by NRLDC to SLDCs.
- 6) The energy metering shall be done on 15 minute interval at inter state metering points. This is being separately integrated for the month for various frequency bands. The least count will be 0.02 Hz.
- 7) In case of unforeseen variations in the load demand from the schedule sent to RILC, the SLDC can request for change in its schedule within its entitlement. This can be applicable from the sixth block i.e. after about one and half hours from the time the request is made i.e. request for revision of schedule has to be made at least one and half hour in advance.



- 8) The State under drawing energy from its schedule has to pay to the generating station for the scheduled energy and recover the cost of energy under drawn from the states which had over drawn energy on the rates applicable for the frequency bands as mentioned above. Therefore, if under draws are at low frequency, the board/fransco. is benefited by surrendering the surplus energy at higher rates to others and if under draws are at higher frequency, the recovery is very low and even may be zero at frequencies of 50.5 Hz or above. If RVPNL over draws at 50.5 Hz, by backing down its generation at (KTPS/ISTPS), the extra energy so drawn from the NREB grid is almost free of cost.

4.12 HIGHLIGHTS OF MAIN FEATURES OF TECHNICAL SPECIFICATION FOR 3 PHASE, 4 WIRE 0.2 S CLASS AC STATIC INTER UTILITY AVAILABILITY BASED TARIFF TRIVECTOR METER FOR EHV SYSTEM OF RVPN AND OTHER ASSOCIATED EQUIPMENT SUITABLE FOR TARIFF METERING AS WELL FOR ENERGY ACCOUNTAL

4.12.1 The metering system shall have following features:

- a) The feature of CTIPT error compensation should be feasible to configure and incorporate in the metering at later stage whenever required.
- b) Modem interface connectable and compatible to communication system for transfer of data to remote stations.
- c) For transfer of data. system should have multiple communication ports for local reading and remote communication facility.
- d) Meter shall be draw out type modular unit with facility of automatic CT shorting.
- e) The meter shall be capable of powered with 230 V AC auxiliary supply and 220 V DC or 110 DC supply of the sub station so the metering core of Pf/CVT is never

loaded and in case of shut down on feeder/breaker, meter can be interrogated locally or remotely. It will normally be powered by AC auxiliary supply and will be switched over to DC supply only when AC auxiliary supply fails.

4.12.2 STANDARDS APPLICABLE

S.No	Standard No	Title
1.	IS 14697- 1999 With latest amendments	AC-static-transformer-operated Watt-hour . and VAR-Hour meters, class 0.2 S.
2	CBIP technical report No. 88 With latest amendments	Specification for AC static electrical energy meters to be referred for immunity against AC & DC magnetic induction of external origin as per revised values given at Cl. 4.6.2 Tb-15-under influence quantities
3	IEC-60687-2000 With latest amendments	AC static Watt-hour meters for active energy, class 0.2S
4	CBIP technical report With latest amendments	No. 111 Specification for common meter reading instrument.
5	18-9000 With latest amendments	Basic environmental testing procedures for electronic and electrical items.

4.12.3 PRINCIPAL PARAMETERS

1.1 Supply system:

Rated voltage (Vref) $3 \times 110/\sqrt{3}$ V (phase to neutral) .

(Through PT) (3 phase, 4- wire system)

3×110 V (phase to phase)

Meter shall be programmed for

$-\sqrt{3} \times 110$ V (ph.-Ph.)

$-\sqrt{3} \times 110$ V (ph.-N).

Rated current (basic current I_b)

3×1 Amps or

(Connected through CT)

3×5 Amp, as specified

Multiplying factor to arrive at actual primary values wherever applicable, shall be calculated from the CT and PT ratio of the installed CTs and PTs.

4.12.4 GENERAL TECHNICAL REQUIREMENTS:

- i) The micro processor based 3-phase, 4-wire metering system shall conform to class 0.2 S as per IEC 60687-2000 and meter shall be draw out modular unit with facility of automatic CT shorting.

- ii) The active energy measurement (Wh) shall be carried out on 3- phase, 4- wire principal with accuracy as per class 0.28 of IEC 60687 - 2000. In the meters, the energy shall be computed directly in CTIPT secondary quantities and indicated in Watt-hours. The meters shall compute the active energy (Wb) import and export and average frequency from the sub station during each successive IS-minute block and stored in its memory. It shall also display on demand the Wh import and export during the previous 15 minutes block.
- iii) Further the meter shall continuously integrate and display on demand the accumulative active energy import and export from the sub station upto date time. The cumulative Watt-hour reading at each midnight shall be stored in the meter memory. Separate register shall be maintained for active energy import and export.
- iv) The meter shall count the number of cycles in PT output during each successive 15-minute block and divide the same by 900 to arrive at the average frequency. This shall be available in the report generated as a two-digit code, which shall be arrived at by subtracting 49 from the average frequency, multiplying by 50 and neglecting all decimals. For example 49.89 Hz. shall be recorded as 44. In case the average frequency is less than 49 Hz. it shall be recorded as 00. In case it is 51.0 Hz. or higher it shall be recorded as 99. The average frequency of the previous is-minute block shall also be displayed on demand in Hertz.
- v) The meter shall continuously compute the average of the RMS value (fundamental only) of the 3 lines to neutral IT secondary voltage as the percentage of 63.51 V and then display the same on demand.
- vi) The meter shall also compute the reactive power (V Ar) on 3-phase, 4-wire principal. Limits of error shall conform to IS 14697 to class 0.5S and integrate the reactive energy (V Arh) algebraically in two separate registers, one for the period for which RMS voltage is 103% or higher and the other for the period for which the RMS voltage is below 97%. The current reactive power rv Ar) with a minus sign if negative, and cumulative reactive energy (V Arh) reading of the two registers shall be displayed on demand. The readings of the two registers at each .. midnight shall also be restored in.the meters memory. In the meter the reactive power and reactive energy transmittals shall be computed in V Arl V Arh directly calculated in PT and CT secondary quantities. When lagging reactive power is being sent out from the sub 'station V Ar display shall have no sign and V Arh registers shall move forward. When reactive power flow is in the reverse direction, V Ar display shall have a negative sign and V ARrh registers shall move backwards.
- vii) Four cumulative energy registers for active energy should be available for viewing at BCSand on meter display.
 - a) Reactive energy lag, while active energy import.
 - b) Reactive energy lag, while active energy export.
 - c) Reactive energy lead, while active energy import.
 - d) Reactive energy lead, while active energy export.
- viii) Each meter shall have a built in calendar in clock, having an accuracy of 1• minute per month or better. The calendar and clock shall be correctly set at the manufacturer's works. The date (day - month- year) and time' (hour- minute- seconds) shall be

displayed on the meter front on demand. Clock adjustment shall be possible at site using the common meter reading instrument (CMRI) or remotely using time synchronization signal through modem and PSTNN -satJ GSM communication system. For the purpose of getting standard time, the computer from where the meter will be read shall be equipped with GPS signal receiver. This GPS receiver shall be built-in the scope of this specification.

- ix) Each meter shall have a unique identification code, which shall be marked permanently on the front as well as in its memory. All meters supplied to RVPNL as per this specification shall have their identification code starting with RVP, which shall not be used for any other supply. RVP shall be followed by a 5 digit-running serial number.
- x) Each meter shall have a non-volatile memory in which the following shall be automatically stored. The non-volatile memory should retain data for a period not less than 10 years, under un-powered condition. Battery back up memory will not be treated as NVM.
 - a) Average frequency for each successive IS-minute block up to second decimal.
 - b) Wh transmittal during each successive 15-minute block upto second decimal for import and export separately. It should be possible to calculate net Watt-hour for each 15-minute block at BCS end.
 - c) Cumulative Wh transmittal at each mid night.
 - d) Cumulative V Arh transmittal for voltage high condition at each mid night.
 - e) Cumulative V Arh transmittal for voltage low condition at each mid night.
 - f) Failure of VT supply on anyone phase as a star (*) mark in load survey data.
 - g) Battery backed memory shall not be accepted.
- xi) The meter shall store all the above listed data in their memories for a period of 75 days .The data older than 75 days shall get erased automatically.
- xii) The whole system shall be searched as to provide a print out (both from the local PC and the remote central computer) of the following form:

Date: Time	Coded Frequency	Wh. (import)	Wh (Export)	Wh (Net)
00:15	23	12.22	25.22	-13.00
00:30	34	13.91	23.91	-10.00
-				
-				
-				
24:00	55	37.23	27.23	+10.00

- xiii) All meters shall be totally identical in all respects except for their unique identification codes. They- shall also be totally sealed with no possibility of any adjustment at site except for clock correction.
- xiv) The meters shall safely withstand the usual fluctuation arising during faults in particular, VT secondary voltage 115% of rated applied continuously and 190% of rated for 3 seconds and CT secondary current 120 % of rated applied continuously

and 20 times of maximum current applied for 0.5 seconds, shall not cause any damage to or the mal operation of the meters.

- xv) Individual meter should derive operating power from AC or DC auxiliary supply and should not load the measurement PI's for their operation. It should automatically switch between the AC/DC auxiliary supply based on its availability. The standard auxiliary voltages available at the sub station are 220 V AC and 220 V DC or 110 V DC. The voltage regulation of the auxiliary supply shall be within +/- 20%,
- xvi) An automatic back up for the continued operation of the offered meters clock and calendar shall be provided through a long life battery which shall be capable of supplying the required power for at least two years under meter un-powered conditions. The offered meters shall be supplied duly fitted with the battery that shall not be required to be changed for at least 10 years, as long as total VT interruption does not exceed two years.
- xvii) Power Factor Range: The meter shall be suitable for full power factor range from zero (lagging) through unity to zero (leading). The meter should work as an active energy import and export and reactive (lag and lead) energy meter.
- xviii) Power Supply Variation: The meter should be suitable for working with following-supply variations:-

Specified operating range	0.8 to 1.1 Vref.
Limit range of operation	0.7 to 1.2 Vref
Frequency	50Hz±5 %.

- xix) Accuracy: Class of accuracy of the meter shall be 0.2S for measurement of active, energy and 0.5 s for reactive energy and as per formula for apparent energy. The accuracy should not drift with time.

4.12.5 SALIENT FEATURES:

The meter shall have the following additional salient features:

- i) The 3 line to neutral voltages shall be continuously monitored by individual phase wise LEDs and in case of these voltages falls below 60% the normally flashing/steady lamp provided on the meters front becomes steady/off. The time blocks in which such a voltage failure occurs/persists shall also be recorded in the meters memory. The lamp shall automatically resume normal function when corresponding VT secondary voltage is healthy again. The two V Arh registers specified in clause 5.6 shall remain stay put while VT supply is unhealthy.
- ii. The meter shall be capable to connect auxiliary power supply for AC - and DC voltages. The design should enable to aux. supply to be switched automatically between the-AC or DC voltage depending upon which is available. Typical aux. Voltages required are 110 Volt AC and 220 V DC to power up the unit. The system shall have a provision for minimum two such aux. supplies and shall continue to work even if one of the above is present.
- iii. It should be possible to check the healthiness of phase voltages by displaying all the voltages on the meter display.

- iv) The meter should work accurately irrespective of phase sequence of the mains supply.
- v) It should be possible to check the correctness of connections of CT and PI to the meter with proper polarity. This feature may be made available on the meter display or on CMRI. For this purpose, suitable software for field diagnosis of meter connections with the help of meter and CMRI should be supplied as per Annexure - G-15 of IS 14697-1999.
- vi) The meter should remain powered up and functional even when either of any two phases or anyone phase along with neutral is available to the meter.
- vii) The meter should continue to record accurately as per prevailing electrical conditions even if the neutral of potential supply gets disconnected.
- viii) The meter shall be provided with adequate magnetic shielding so that any external magnetic field (At electro magnet or DC magnet) as per the values specified in CBIP Technical report No.88 (with latest 'amendments) applied on the meter shall not effect the proper functioning. and recording of energy as per error limits prescribed by CBIP.
- ix) It shall not be possible to change the basic meter software by any means in the field. Moreover, critical events like time set, MD reset operation, tariff change, etc. shall be logged by the meter. 20 such events shall be logged in roll over mode for maximum ten events.
- x) Display of Measured Values:
 - a) The measured value(s) shall be displayed through Liquid Crystal Display (LCD backlit) or Light Emission Diode (LED) display.
 - b) The data should be stored in Non Volatile Memory. The non-volatile memory should retain data for a period of not less than 10 years under un-powered condition. Battery backup memory will not be considered as NVM;
 - c) It should be possible to easily identify the single or multiple displayed parameters through symbols! legends on the meter display itself or through display annunciation along with a separate legend plate fixed on the front face of the meter cover.
 - d) The register shall be able to record and display starting from zero, for a minimum of 1500 hours, the energy corresponding to rated maximum current at reference voltage and unity power factor. The register should not roll over in between this duration.
 - e) Any interrogation/read operation shall not delete or alter any stored meter data.
- xi) Meter Serial Number:

In addition to providing serial number of the meter on the display plate, the meter serial number shall also be programmed into meter memory for identification through CMRII meter reading print out, and optionally on meter display.
- xii) Display Sequence:

The meter shall display the required parameters on suitable selection through keypad:

-

 - a) LEDILCD segment check.
 - b) Real time.
 - c) Date - dd,mm,yy.
 - d) Meter serial number (optional).
 - e) Power On hours.

- f) Cumulative MD reset count.
 - g) Active energy import (Wh). (Wh on 15 minutes block basis for previous block)
 - h) Active energy export (Wh). (Wh on 15 minutes block basis for previous block)
 - i) Average frequency of previous block in Hz.
 - j) Average percentage voltage with respect to Vref.
 - k) Cumulative Reactive energy for voltage high condition. (i.e. net V Arh when RMS voltage is $\geq 103\%$ Vm).
 - l) Cumulative Reactive energy for voltage low condition. (i.e. net V Arh when RMS voltage is $< 97\%$).
 - m) Energy registers of active, reactive and apparent energies for True import! export cumulative readings:
 - i) Cumulative Active energy import (Wh).
 - ii) Cumulative Active energy export (Wh).
 - iii) Cumulative Reactive energy lag (V Arh lag), while Wh import.
 - iv) Cumulative Reactive energy lag (V Arh lag), while Wh export.
 - v) Cumulative Reactive energy lead (V Arh lead), while Wh import.
 - vi) Cumulative Reactive energy lead (V Arh lead), while Wh export.
 - vii) Cumulative Apparent energy (V Ah), while Wh import.
 - viii) Cumulative Apparent energy (V Ah), while Wh export
 - ix) High resolution energy registers (Minimum 4 digits after decimal).
 - i) Wh **.****
 - ii) V Arh lag **.****
 - iii) V Arh lead **.****
 - iv) Yah **.****
- Note: - If energy readings upto 4 decimal or more digits are provided on the main registers, then high-resolution energy registers as given at sequence (n) will not be required separately. Alternatively, the same can be given on the CMRI.'
- n) Instantaneous power factor with sign for lag/lead.
 - o) Cumulative maximum demand (V A)
 - p) Instantaneous phase voltage.
 - i) R phase voltage
 - ii) Y phase voltage
 - iii) B phase voltage
 - q) Instantaneous line currents (Amps.)
 - i) R phase line current
 - ii) Y phase line current.
 - iii) B phase line current
 - r) Frequency
 - s) Phase sequence of voltages (alternatively, this may be provided at CMRI I BCS end).
 - t) Instantaneous load in
 - i) W
 - ii) VA
 - iii) VAR
 - u) Maximum demand in V AIW since last reset

- v) Anomaly data:
 - i) Present status of anomaly
 - a) Missing potential with phase identification
 - b) CT polarity reversal with phase identification
 - c) Current unbalance.
 - ii) Date and time of last anomaly occurrence with type of anomaly.
 - iii) Date and time of last anomaly restoration with type of anomaly.
 - iv) Cumulative anomaly count of all types of anomalies and all phases.

Detailed phase wise anomaly information should, however, be logged in the meter memory and be capable of down loading to the BCS through the CMRI and be available for viewing at the BCS end.

Note: Apparent energy should be based on reactive lag/lead.
 i.e. App. energy = $\sqrt{(\text{active imp. energy})^2 + [\text{react. Energy (lag+ lead)}]^2}$

 - v) a) Cumulative active energy import reading (Wh) of predefined date and time for monthly billing purpose (BP Wh).
 - b) Cumulative active energy export reading (Wh) of predefined date and time for monthly billing purpose (BP Wh).
 - c) Cumulative apparent energy reading (V Ah) , during Wh import of predefined date and time for billing purpose (BP V Ah),
 - d) Cumulative apparent energy reading (V Ah) during Wh export of predefined date and time for billing purpose (BP V Ah).
 - e) Maximum demand (V A) up to predefined date and time of the month for billing purpose (BP V A) import mode.
 - f) Maximum demand (V A) up to predefined date and time of the month for billing purpose (BP V A) export mode.
 - g) Average power factor of the consumption month up to predefined date and time for billing purpose (BP PF) import mode.
 - h) Average power factor of the consumption month up to predefined date and time for billing purpose (BP PF) export mode.

Alternately information corresponding to g & h above shall be available on the base computer software.

(Note: The average power factor displayed for billing purposes should exactly match the average power factor worked out through Wh/V Ah).

xiii) Output Device:

The meter shall have a test output accessible from the front and be capable of being monitored with suitable testing equipment. The operation indicator, if fitted, must be visible from the front. Test output device shall be provided in the form of one common LED/LCD for Wh, V ARh and optionally V Ah with the provision of selecting the parameter being tested. Alternatively, test output device in the form of separate LED/LCDs for Wh, V ARh and optionally V Ah is also acceptable.

The relation between test output and the indication on display shall comply with the marking on the name plate (imp. per Wh/V Arh/V Ah).

The manufacturer shall state the necessary number of pulse count(s) to ensure measurement accuracy of at least 1/10th of class of the meter at the different test points.

The resolution of the test output pulse(s) should be sufficient to enable conduction of the starting current in less than 10 minutes and accuracy test at the lowest load with desired accuracy within 5 minutes.

xiv) Time Synchronization:

The meter shall support one-minute advance and retard command from CMRI through password protected security system, which shall be adjusted in six 15 minutes blocks with an adjustment of 10 seconds each block. One time advance/retard command is accepted than meter shall not accept time adjustment command for next seven days. The clock adjustment correction shall be registered in the meters memory and suitably shown on print out survey data. The time synchronization should also be possible from remote BCS through PSTNN sat! GSM system and modem. The base computer and its software shall be equipped with GPS signal receiver for the purpose time synchronization of all meters connected to 220 kV GSS and its associated 132 kV GSS using time synchronization signal through PSTNN sat! GSM system and modem. As a standby measure the CMRI will be used for time synchronization of individual meter. There should be provision in the base computer system to synchronize time at preset time daily with respect to GPS clock of SLDC or central billing station.

xvi) Maximum demand (MD) registration:

The meter shall continuously monitor and calculate the average demand in VA during the integration period set and the maximum, out of these shall be stored along with date and time when it occurred in the meter memory. The maximum registered value shall also be made available on meter display.

An LED glow or pulse output to incident with end of each demand period shall be provided in the meter.

The integration period shall be set as 15 minutes, on real time basis, which shall be capable to change to other integration period also, if required.

Energy measurement in demand period shall be such that the sampling is synchronized with the end of demand period otherwise energy measured in a demand period but not stored in that demand period shall be carried forward.

The principal of maximum demand calculation used by the bidder should be explained in the offer.

xvii) Maximum demand reset:

Facility for auto reset of MD at predefined date and time shall be provided. The meter shall display the maximum demand reset count.

xviii) Load survey capability and billing point requirements:

The meter shall be capable of recording 15 minutes average of active energy import, active energy export, V A import, V A export, demand and frequency, for last 75 days. It shall be possible to select either demand or energy view at the BCS end.

The average frequency should be logged with a marking of time advance I retard and voltage low event if occurred in that survey . integration period. Voltage low marking should be locked when average voltage goes below 60% of Vref.

The load survey data should be available in the form bar charts as well as in spreadsheets. The BCS shall have the facility to give the complete load survey data both in numeric and graphic form.

The figures of 24 hourly Wh import, Wh export and V A import, V A export should also be made available under each date in the load surveyor otherwise, it should be possible to calculate such figures through BCS.

The predefined date and time for registering the billing parameters of Wh import, Wh export, V Ah import, V Ah export, PF import, PF export and V A MD import, V A MD export shall be 00 .00 hours of the first day of each calendar (billing) month. All billing parameters shall be transferred to billing registers and shall be displayed on display mode referred to as 'BILLING PARAMETERS'.

The above billing data, load survey data, anomaly information and instantaneous parameters data shall all be retrievable as stored in present cyclic order through the meter's communication port through a common meter reading instrument (CMRI)IPSTNN satigSM and shall be transferred (down loaded) to a PC with windows based software to get complete details in numerical and/or graphic form. The necessary base-computer-software (BCS) with complete details, for this purpose, shall be provided by the supplier

Further, apart from instantaneous parameters like voltage, current, PF and readings of billing parameters, energy registers etc" the following additional parameters should be made available at the BCS end:

- a) MD reset count
- b) Billing parameters for last three months

xix) Harmonics measurements:

The meter should be capable of measuring fundamental energy as well total energy i.e. fundamental plus harmonics energy. Fundamental energy should be made available on meter display and the same only shall be used for billing purpose.

The supplier shall indicate the sampling rate so that it shall be sufficient for the user to determine the accuracy of total energy.

The values of total energy shall be made available either on meter display or on CMRI with proper resolution.

The supplier shall state as to how he will meet the above requirement and finally the above requirement shall be mutually agreed between user and supplier.

The total energy shall be logged in the meter memory and be capable of down loading to the BCS through the CMRIJPSTNN satlGSM services as per communication system and be available for viewing at the BCS end.

xx) Self- Diagnostic feature:

The meter shall be capable of performing complete self-diagnostic check to monitor the circuits for any malfunctioning to ensure integrity of data memory location all the time. The meter shall have indications for unsatisfactory Inonfunctioning/malfunctioning of the following:

- a) Time and date and
- b) All display segments as per the requirement under G 19 of IS 14697.

The details of malfunctioning of time and date should be recorded in the meter memory. The bidder should furnish the details of self-diagnostic capability feature.

xxi) Tamper and Anomaly detection features:

The meter should have features to detect the occurrence and restoration of, at least, the following common ways of tamper/anomaly:

- a) Missing potential: The meter shall be capable of detecting and recording occurrences and restoration of missing potential (1 phase or 2 phases) which can happen due to intentional / accidental disconnection of potential leads, along with the total number of such occurrences for all phases. Absence of one or more phase voltage from mains side should not be recorded as missing potential.
- b) CT polarity reversal: The meter shall be capable of detecting and recording occurrences and restoration of CT polarity reversal of one or more phases.
- c) Current and voltage unbalance: The meter shall be capable of detecting and recording occurrences and restoration of current and voltage unbalance separately as an anomaly event.
Snap shorts (numerical values) of voltage, current, power factor and energy (0) readings as well as the date and time of logging of the occurrence and restoration of all anomaly events, subject to meter-memory space as described herein under, should be logged in the meter memory and available for retrieving through the meter's optical port via CMRI and down loading to the BCS.
- d) Power On/Off: If all the voltages are not available, power off event should be logged and power ON event should be logged when supply is available. The power on and off event should be logged with date and time.

Minimum hundred (100) events (occurrence and restoration) of all types of anomaly with date and time shall be available in the meter memory on first-in, first-out basis. It shall be possible to retrieve the anomaly data along with all related snap shorts data through the meter's optical port with the help of a CMRI and down load the same to the BCS where it shall be available for viewing. All this information shall be available in simple and easily understandable format.

The threshold values for voltage, current and PF etc. for the purpose of logging occurrence and restoration of various types of anomaly will be mutually decided by the purchaser and supplier. The supplier should, however, propose these values in their offer.

xxii) Anomaly detection logic:

Properly designed meter anomaly logic should be provided. The anomaly logic should be capable of discriminating the system abnormalities from source side and load side and should not log I record anomaly due to source side abnormalities.

There shall be four separate compartments for logging of different type of anomalies as follows:

Compartment No.1:

20 events of CT polarity reversal

Compartment No.2:

20 events of missing-potential anomalies.

Compartment No3:

40 events shall be allocated for current/voltage unbalance anomalies.

Compartment No.4:

20 events of power On/Off .

The logging of various anomalies in each compartment should be as under:

Once one or more compartments have become full, the last anomaly event pertaining to the same compartment will be entered and the earliest (first one) anomaly event should disappear. Thus, in this manner each succeeding anomaly event will replace the earliest recorded event, compartment wise. Events of one compartment/category should overwrite the events of their own compartment/ category only.

Bidders may indicate alternate proposals for the anomaly detection and logging scheme.

Anomaly count should increase as per occurrence (not restoration) of anomaly events. The total No. of anomaly counts should also be provided on the meter display as well as at the BCS end.

xx) Anomaly persistence time:

The persistence time for logging/registration of an occurrence of an anomaly should be 5 minutes \pm 10 seconds. The persistence time for logging of restoration of anomaly should not be more than 120 seconds.

xxi) Accuracy Requirement:

The accuracy of parameters measured by meters shall be tested in accordance with the relevant standards described in clause 2.0 of this specification. For apparent energy, accuracy testing shall be done in accordance with the provisions of annexure G 7 of IS 14697-1999. Time accuracy of the meter should be as per annexure G 18 of IS-14697 -1999.

xxii) Electrical Requirement:

4.12.6 SOFTWARES:

4.12.6.1) Software for reading, down loading data, time setting and TOD programming in the meter, normally resident in the Common Meter Reading Instrument (CMRI). The software of latest version shall be installed in the CMRI as well as supplied separately in the form of CDs. Software. should be suitable and configurable to other kind of tariff within the recorded parameters !data provided by the meter.

Time setting and ABTrOD programming should be enabled at BCS under multi level password protected security system for specified meter(s).

4.12.6.2) Window bases Base Computer Software (BCS) for receiving data from CMRI or other specified communication system and downloading instructions from base computer to CMRI. This BCS should have, amongst other requirements and features and facilities described in detail at Cl. No. 7 in this specification, the facility to convert meter reading data into user definable format so that it may be possible for the user to integrate the same with the users billing data and process the selected data on line in desired manner. The necessary training, if required, and documentation for this purpose shall also be provided free of charge.

4.12.6.3) Necessary software for loading application program via CMRI serial port be made available separately.

4.12.6.4) Any other special application software of the manufacturer for the meter.

Any future up gradation made by the supplier in any of the above software shall also be provided free of cost.

4.12.7 COMMUNICATION SYSTEM

The communication system as referred in the specification shall be either or combination of radio frequency/PLCC (power Line Carrier Communication)/PSTN (Public switched

Telephone network)N sat! Mobile! other means of telemetry like private network of Transco or low power radio.

i) COMMUNICATION PROTOCOL:

The meter shall open communication protocol or protocol as per relevant mc for data retrieval and data telex. The protocol software and memory map of the same should be made available to RVPN. The meter should also be capable to transmit data to RT Us, base computer system as well as to IED.

ii) MODEMS:

The modems will be required with metering system for remote data transfer through communication system. The modem shall conform to BABT standard for data communication and shall communicate with system at 1200 Baud and above. The modem shall conform to V.22 data transmission standard recommended by cern, suitable device to protect the metering system from surge on communication system shall be provided with the metering system. The device shall protect the system for upto 6 kV surge on common mode and differential mode. The modem will be suitable for 56 kbps or faster.

4.12.8 PRINCIPAL PARAMETERS OF CMRI:

For down loading data of HTILT Tn-vector meters, the meter reading device shall be portable, compact and battery powered. It should be capable of reading! gathering data from various makes of Tri-vector Meters equipped with suitable communication ports and transferring them on to a base computer system.

The capability of the CMRI shall be designed for the number of meters it can read at one time with and without load survey data. However, CMRI shall be suitable for reading at least 20 meters for billing and tamper data but without load survey and minimum 10 meters for billing and tamper data with load survey CMRI should be able to display phasor/vector diagram of phase currents, phase voltage with respective phase angles and phase sequence of voltage at site when these data are read from the meter.

4.12.8.1 GENERAL TECHNICAL REQUIREMENTS OF CMRI:

PHYSICAL CHARACTERISTICS:

i) Size:

CMRI shall be handy and small in size for ease of portability. The maximum dimensions shall not exceed 200x100x60 mm (LxWxH). However the display portion could be wider.

Weight: Weight of CMRI including batteries shall not exceed 1 Kg.

ii) Enclosure:

The casing shall be of electrical insulating material of high thermal stability and mechanical strength.

Its degree of protection shall be level (2) IP 67 depending upon requirements as per IEC 52911S 12063.

The CMRI enclosure shall be solvent resistant.

The CMRI shall be provided with a suitable holding strap for proper gripping and carrying case.

- iii) **Ruggedness:**
The CMRI shall be able to withstand harsh field environment without physical damage or loss of data. The tests for this requirement are given in the testing procedures as detailed in the specification.
- iv) **Display:**
The display of the CMRI shall have the following characteristics:
 - a) Easy readability in varying ambient light conditions.
 - b) A minimum of 4 lines and 20 characters per line on the screen.
 - c) Size of the upper case alpha character to be minimum 4 mID.
 - d) Contrast and intensity control to get a clear display in varying ambient light.
- v. **KEY BOARD :**
The keyboard of the CMRI shall have the following attributes:
 - a) Long operational life i.e. minimum 100,000 operations.
 - b) Feedback for key press acknowledgement to user.
 - c) Legible and non-fading keypad imprints.
 - d) Each English alphabet should have a separate key.
- vi) **INPUT/OUTPUT PORTS (I/O PORTS) :**
The CMRI shall have serial input/output port (s). One port shall be serial port, RS 232 C compatible.
Another port may be used for convenience of connecting peripherals such as bar-code reader printer, battery charger, loader-charger etc.
- vii) The CMRI shall be able to provide power supply for optical sensor used for meter reading application.

4.12.8.2 PHYSICAL INTERFACE OF CMRI:

- i) **Interface between meter and CMRI.**
The interface between a meter and CMRI shall consist of 2 parts.
 - a) Meter optical sensor terminating into a 9 pin D type male connector with a cable of 500 mm +/- 10 mm, length.
 - b) CMRI cable should have matching 9 pin D type female connector of 1500 mm +/-10 mm length.
- ii) **Interface between CMRI and Base Computer Station:**

Suitable cable for communication between CMRI and base computer system shall be provided. This communication shall be serial RS-232C. On the BCS end of the cable, a 9 pin D type female connector shall be provided.

- iii) Both connecting cables described above in 10.5.1 & 10.5.2 shall be made of flexible material and shall be shielded. The two ends of each type of cable shall be stress relieved.

4.12.8.3 HARDWARE AND SOFTWARE REQUIREMENT OF CMRI

- i) **Operating Systems:**
To facilitate use of various meter specific CMRI programs in one CMRI, latest operating system shall be used. The facility to upgrade the BIOS\OS by a CMRI bidder shall be available without exposing the hardware of the CMRI.
The additional programs necessary to transfer application programs with serial ports shall be provided by the bidder.
- ii) **Memory:**
 - a) The CMRI shall have a minimum memory capacity of 3 MB with battery backup and up gradable.
 - b) BIOS\OS on FLASH\EEPROM Memory.
- iii) **Communication:**
The CMRI shall be required to communicate in three different modes.
 - a) Downloading \ Uploading data from \ to the meter.
 - b) Uploading \ Downloading data to \ from the base computer station.
 - c) The CMRI shall be capable to read bar coded information using a bar code scanner from barcodes of AC static \ electromechanical electricity meters by using appropriate scanner and barcode software.
 - d) The CMRI shall have flexible baud rate ranging from 300 Baud to 19,200 Baud and optionally to higher baud rates to cater to communication needs stated above.
- iv) **Real time clock:**
A real time Clock shall be provided in the common meter reading instrument and shall have the following features:
 - Power requirement The clock shall have a minimum of 15 days battery back up.
 - Calendar - The clock shall have minimum 20 years calendar.
 - Time drift. The time drift of the real time clock, considering all influencing quantities shall not exceed 20 seconds per day.
- v) **Time Setting Facility:**
The common ammeter-reading instrument shall have the facility to get its time set from the base computer station. Proper security for this shall be ensured. The meter specific CMRI programs shall have the ability to use CMRI real time clock to tag all time related events.

- vi) **Power Supply (Battery):**
The common meter-reading instrument shall have the following features for its power requirements:
 - a) The common meter-reading instrument shall be powered by rechargeable battery housed within its enclosure.
 - b) The average capacity of a charged battery shall be sufficient to communicate with meters and base computer station for at least:
 - i. FOUR HOURS while communicating through optical interface of meters and
 - ii. SIX HOURS without powering I/O ports for optical interface or printer etc.
 - c. To reduce the equipment down time and inventories, there shall be provision to charge the CMRI battery without being removed from the equipment. A suitable battery charger for automatic charging of CMRI battery shall be provided, e.g. Loader-charger. The extra cost, if any, for such accessory should also be indicated.
 - d. There shall be a provision for AUTO POWER SAVE, which shall force the instrument in the power saving mode in case of no-activity within 5 minutes.
 - e. The battery used for data retention in SRAM shall have a minimum of 3 years backup capacity.
 - f. The CMRI shall have battery low indication and automatic cut off to avoid further drain of the battery.

4.12.8.4 COMMUNICATION PROTOCOL AND SOFTWARE OF CMRI:

Software

- A) The CMRI bidder shall provide following software:
 - i) Embedded latest operating system,
 - ii) Necessary software for loading application programs via a serial port for uploading and down loading between CMRI and Base Computer Station.
- B) The following software shall be made available by each meter manufacturer, whose meters are to interface with the CMRI:
 - i) Software to be resident in CMRI for the purpose of reading and programming the specific make(s) of static meters.
 - ii. BCS software for accepting data from CMRI. processing, generating reports and down loading instructions from BCS to CMRI.
 - iii) The CMRI should have graphics capability.
- C) Special requirements:
A third party software may also be loaded for special applications such as manual meter, reading, data entry, printing. display of balance memory etc.
- D) The CMRI should have facility to draw/display vector diagram of the electrical conditions existing at site to check the healthiness of the connections.

- E) The CMRI should have provision to read the energy registers so that accuracy testing can be done at site with standard calibrating equipment.
- F) The CMRI should have provision to read the various instantaneous electrical parameters at site like voltages, current, PF, phase angles, power (kW, kV Ar, kVA), frequency etc.
- G) The CMRI should have facility to estimate the memory space available before reading the meters.
 - i) Support display:
There should be 'user friendly' approach for viewing meter data for the reading collected now or for the reading collected in the past All information about a particular consumer should be segregated and available at one place so that locating any consumer's past data is easy. It should be possible to locate/retrieve data on the basis of one of the following particulars:
 - a) Consumer ID/number
 - b) Meter Sr. No.
 - c) Date of meter reading
 - d) Location
 - ii) The data transfer:
It should be possible to transfers the data to and fro from CMRI through serial interface.
 - iii) Configurability:
It should be possible to have selective printing out of all the available data of the meter. Print out should not include anything and everything available . with the BCS. The software should support the 'Print Wizard' or similar utility whereby user can decide what to print out. The user of the software need not revert back to the supplier of the software for modifying the software just to print what he desires.

It is very important that the BCS has the feature to export available data for integrating with the RVPN's billing system. Here again an 'Export Wizard' or similar utility should be available whereby user can select file format, what data to export, the field width selection (whether 8 characters or 10 characters, to include decimal point or not, number of digits after decimal point) etc.
 - iv) Security:
The BCS shall have multi level password for data protection and security. The first level should allow the user to enter the system. The different software features shall be protected by different passwords. The configuration of passwords should be user definable. The software installed on one PC should not be copiable on to another PC.

4.13 GENERAL GUIDELINES FOR OVERALL ACCURACY OF METERING EQUIPMENTS AT RELATIVE ACCURACY OF CTs AND VTs WITH RESPECT TO THE ACCURACY OF THE ENERGY METER.

Thus it is necessary to think about overall higher accuracy in bulk energy metering instead of meter accuracy only. In order to decide level of over-all accuracy of metering, we have to refer to different guide line provisions made in various standards related to the metering equipments as detailed below

4.13.1 IS 11448:2000 Application Guide for A.C. Electricity Meters:

This provides clear guidelines on ranges of measurement and accuracy requirement as under.-
Clause 5: Metering Arrangements for various Tariffs.

Recommendations of accuracy class for different consumers.

Class 0.5 Accuracy : These meters are generally recommended for registration of energy supplied to consumers at extra high voltages. Consumers supplied at high voltages but meters of this accuracy class may also meter having considerable off-take.

Class 0.2 accuracy:

These meters are generally recommended for registration of energy in bulk supply, that is, transfer or exchange of considerable amount of power at sending/receiving ends of an interconnected extra high voltage network. Meters of this accuracy class may also meter consumers supplied at extra high voltages but having considerable off-take

Note: If energy drawl is low (not zero) for appreciable period of time, meters of special measuring range designated by "s" after the class index, namely 0.2s and Class 0.5s are recommended in place of class 0.2 and 0.5 respectively. Static meters of class 0.2S and 0.5S conforming to IS 14697 are available.

4.13.2 As per IEC 687 Clause 1 Scope:

Para 3rd "Note:- me 185 describes transformers having a measuring range of 0.05 In to 1.2 In or of 0.05 In to 1.5 In or of 0.05 In to 2 In and transformers having a measuring range of 0.01 In to 1.2 In for accuracy classes 0.2 S and D.5S. As the measuring ranges of a meter and its associated transformers have to be matched and as only transformers of classes 0.2 Sand 0.5S have the accuracy required to operate the meters of this standard, the measuring ranges of the meter will be 0.01 In to 1.2 In".

4.13.3 As per IS 14697:1999 for A.C Static Transformers operated watt-hour and Var. Hour Meters, Class 0.2s and Class 0.5s

-Specification recommends for following in its FORWARD at part No. 5 as under

" The letter'S' denotes special measuring range designated for transformer operated applications, generally for large power measurements. Current transformers are also'S' designated.

As per IS 27U5 (part 2): 1992 "Current transformers: Part 2 Measuring current transformers (second revision) " have measuring ranges comparable to those of static meters covered by this standard. For the sake of overall accuracy throughout the measuring range, static meters covered by this standard should preferably be connected with 's' designated current transformers. For example, class 0.5 S meter is used with 0.2 S CT and class 0.2 S meter is used with 0.2 S CT."

4.13.4 As per IS 11448: 2000 Application Guide for A.C. Electricity Meters clause 5.7: Selection of Instrument Transformers.

"The current Transformers conforming to IS 2705 (part 2) used for metering of a particular category of tariff are recommended to have accuracy class generally one index better than that of the meter. The voltage transformer conforming to IS 3156 (part 2) and used for metering of a particular category of tariff, are required to have the accuracy class similar to that of the meter."

The following may be taken as guideline>

Meter Acc. Class	2.0	1.0	0.5	0.5 S	0.2 S
CT Accuracy class	1.0	0.5	0.2	0.2 S	0.2S
			or 0.1		
VT Accuracy Class	-	1.0	0.5	0.5	0.2

" It is important to note that measuring range of current transformer used should preferably be compatible to the measuring range of meter. Also, the connected burden of each current I voltage circuit should preferably be within the operating range of instrument transformer, that is between 25 percent and 100 percent of the rated output of each CT/VT".

4.13.5 As per IS 2705 (part 2): 1992 Current Transformer specifications Part 2 Measuring Current Transformer, Clause 3.2 Special Application, Accuracy Classes as per which:-

"For the special application in connection only with special electricity meters which measure accurately at a current between 50 mA and 6 A (that is between 1 percent and 120 percent of the rated current of 5 A), the special application accuracy classes shall be 0.28 and 0.5S. These classes shall apply only for the rated secondary current of 5 A and for the ratios 25/5, 50/5 and 100/5 and their decimal multiples.

With the above recommendations it becomes necessary to take care of the following two factors for achieving over all accuracy of special class metering for bulk energy

- (A) Matching range of measurement of CT's with that of special class meter.

(B) Matching Accuracy of measurement of CT's & PT's (VT's) with that of special class meters.

a (1) The range of measurement of special class meters has been specified in IEC60687, Table 9 and IS 14697 (1999) table n

The range of measurement of 0.2S and 0.5S class energy meters is 1 %Ib to 120%Ib as given below:-

Meter Class	Accuracy %Ib	Current I min to I max (Ib=1A)	Current I min to I max (Ib = 5A)
0.25 and 0.5S	1 % Ib to 120% Ib	10 mA to 1.2A	50 mA to 60 Amp

a (2) Range of measurement of normal Current Transformers and Special class Current Transformers

As per me 185: 1987, Section 9, clause 27 table IV and IV A and IS 2705 Part 2 (1992), clause 3.3.3 table 1 e, the range of measurement for CT's of different accuracy class is as under:-

CT's	%Ib CT Ace. class	Value of I min to I max for 1A Ib	Value of Current I min to I max for 5AIb
Normal crs	0.2 S And 0.5 S 120%	5% to 1.2 A.	50 mA to 1.2 A.
Special Class crs	0.2 S And 0.5 S 120%	1% to 1.2A	10 mA to 1.2A

Please note that the normal CT's can measure from 5% Ib to 20% Ib within specified accuracy, whereas special class CT's can measure from 1 % to 120% of Ib within specified accuracy.

Therefore the CT's of class S should be used with class S (special class) meters, so that small amount of energy can also be measured Accurately with the help of metering equipment suitable for measurement of bulk energy (having high CT PT ratio).

b. Matching Accuracy of measurement or CT's & VT's (PT's) with that of special class meters.

b(i) Measurement accuracy of 0.28 & 0.58 energy meters:-

As per IEC 60687 International Standard for A.C. Static watt-hour meters for active energy (class 0.25 and 0.55) clause 4.6, table 9 and IS 14697:1999 for A.C. Static transformer operated watt-hour and VAR-Hour meters, class 0.25 and 0.55 clause II, Table II for Accuracy Requirements the percentage error limits i.e. limits of error due to variation of current are given below: -

Value of Current	PF	Accuracy class	
		0.25	0.55
0.01 In ~ I < 0.05 In (5%)	1	+/- 0.4	+/- 1.0
0.05 In s I s I max (5% to I max)	1	+/- 0.2	+/- 0.5
0.02 In ~ I < D. I In (10%)	0.5 Lag 0.8 Lead	+/- 0.5	+/- 1.0
0.1 In s I s I max (I max)	0.5 lag 0.8 lead	+/- 0.5	+/- 0.6

b(ii) Accuracy requirements of CT's: Limits of error as specified in IEC 185:1987 and IS 2705 (Part 2) 1992 for percentage current ratio error and phase displacement error of Current Transformers of various accuracy classes as under:-

Limits of error for normal Current Transformers

Accuracy Class	+ / - Percentage Current (ratio) error at percentage of rated Current shown below				Phase displacement at percentage of rated Current shown below							
					Minutes				Centiradians			
	5	20	100	120	5	20	100	120	5	20	100	120
0.1	0.4	0.2	0.1	0.1	15	8	5	5	0.4	0.2	0.1	0.1
0.2	0.75	0.35	0.2	0.2	30	15	10	10	5	4	5	5
0.5	1.5	0.75	0.5	0.5	90	45	30	30	0.9	0.4	0.3	0.3
1.0	3.0	1.5	1.0	1.0	180	90	60	60	2.7	5	0.9	0.9
									5.4	1.3	1.8	1.8
									5			
									2.7			

Limits of error of Current Transformers for special applications

This table is applicable only to transformers having a rated secondary current of 5 A

Ace. Class	+ / - Percentage Current (ratio) error at percentage of rated current shown below					Phase displacement at percentage of rated Current shown below									
						Minutes					Centiradians				
						1	5	20	100	120	1	5	20	100	120
0.28	0.75	0.35	0.2	0.2	0.2	30	15	10	10	10	0.9	0.45	0.3	0.3	0.3
0.55	1.5	0.75	0.5	0.5	0.5	90	45	30	30	30	2.7	1.35	0.9	0.9	0.9

B (iii) Comparison of errors of 0.2 S Class Meter with errors of different classes of eT's for proper matching to achieve best possible overall accuracy of measurements in metering of bulk energy.

4.14 READING AND, RESETTING VARIOUS NUMERICAL RELAYS INSTALLED IN RVPN SYSTEM

A) 400/220 kV Distance Protection Schemes

1) EPAC Distance Scheme (M/s Alstom)

a) How to read fault record.

Once operated, relay indicates Zone, Kilometer, Currents, voltages, resistance, phase, date, time etc. Press Lower 'V' key again and again to read above data.

- To read data in memory, press 'Set' key and bring cursor on 'EVEN' menu by pressing left < and right> keys .
- Then press lower 'V' key enter in 'Even' menu.
- It will indicate EV1, EV2, and EV3 etc. latest fault record is in EV1.
- To see latest fault details bring cursor on EV1 by using <> keys then press 'V' down key again and again all parameters will be available on display one by one.
- Press (↑) Up Key again & again for Normal display.

b) Trip contact – self reset

c) Resetting of fault LED

Press 'set' key and bring cursor on 'LED' by pressing left < and right > keys then press lower 'V' key. The trip LED's will stop glowing.

Note: All contacts are self reset hence breaker closing is possible without resetting of relay/LED's. Reset external trip relays.

2) MICOM P 442 Distance Scheme (M/s Alstom)

a) How to read fault record.

Once operated relay indicate Zone, Kilometer, Currents, voltages, resistance, phase, date, time etc. Press 'Book marked' key again and again to read all above data.

- To read data in memory press lower 'V' key then move by pressing > right key. View record appears on display then press lower 'V' key again and again. Fault No. zero is latest fault. All parameters will be available one by one by pressing 'V' down key.

b) Trip contact – self reset

c) Resetting of fault LED

Press 'Book marked' key again and again. 'Clear fault' will appear on display, then press 'C' key. The trip LED's will stop glowing.

To reset alarm LED, enter on VIEW RECORD as above. Reset 'NO' will appear. Press enter key. No start blinking, make 'YES' by pressing up or down key & then enter key. Then press 'C' key again and again for normal display.

Note: All contacts are self reset hence breaker closing is possible without resetting of relay/LED's.
Reset external trip relays.

3) 7SA 522 Distance scheme (M/s Siemens)

a) How to read fault record.

Operate key pad as follows:

	Sequence of Operation	Display
1	Press 'MENU' key	Annunciation
2	Press >(R) key	Event log
3	Press V(D) key	Trip log
4	Press >(R) key	Last fault
5	Press >(R) key	Date and time
6	Press V(D) key Again and again	Complete parameters regarding faults
7	Press 'Esc' (R) key Again and again	Original display
b)	Trip contact – self reset	
c)	To reset LED : Press 'LED' key The trip LED's will stop glowing.	

Note: All contacts are self reset hence breaker closing is possible without resetting of relay/LED's.
Reset external trip relays.

4) REL-100 Distance Scheme (M/s ABB)

a) How to read fault record

Operate key pad as follows:

	Sequence of Operation	Display on relay
1	Press → (Right) key	Display Information
2	Press (Enter) key	Fault
3	Press (Enter) key	Distance report
4	Short Press (Enter) key	Complete parameters
5	Long press (Enter) key	Next menu

See Next Sub Menu and short press to see details of following menu:

- i) Distance to 'F'
- ii) Clear LEDs
- iii) Clear Dist. Report

After taking complete parameters press ↑ up key to reach original display.

- b) Trip contact-self reset
- c) How to reset LED

Press clear LED's sub menu to reset the LED's. The trip LED's will stop glowing.

Note: i) All contacts are self reset hence breaker closing is possible without resetting of relay/LED's. Reset external trip relays.

- ii) Menu tree attached at Appendix 'A'.

5) SEL 321 Distance Protection Scheme (M/s E/R)

- a) How to read fault record

Operate key pad as follows

Push the fault button to display event history. Use (↑) and (↓) buttons to scroll between event records and (←) and (→) buttons to scroll between fields within a record. Push the exit or cancel button to return to the default display. The select button has no effect in this mode.

Button Pushed	Result Displayed	Description
Fault	1 date : 12.1.05 Time: 2342: 51.732	Displays date/time of latest event record.
→	1 Date: 12.1.05	
Type: LABC		Displays details of latest event record. Showing event faulted Phase and type.
→	1 date : 12.1.05	
Dist. 75.13		Shows distance to fault
↑	2 date : 12.1.05 Time: 2356: 31.238	Displays second event record date and time (Pressing (↑) for next and (↓) for previous event record.
Exit	Default display	Default display

- b) Trip contact-self reset
- c) How to reset LED - Press target reset button after clearance of fault. The trip LED's will stop glowing.

Note: All contacts are self reset hence breaker closing is possible without resetting of relay/LED's. Reset external trip relays.

B) 132 kV Distance scheme

- i) PD 521 Distance Scheme (M/s Alstom)

- a) How to read fault record

Operate key pad as follows

Take complete fault parameters as per enclosed address list at Appendix 'B' before resetting by operating the key pad of the relay. Important addresses are given below:

0396	time
0397	date
0421	Op- time
0422	Fault location Km.
0427	Fault location percentage
3601	A phase
3602	B phase
3603	C phase
3604	Ground fault
0423	Fault impedance

b) Trip contact-self reset

c) How to reset LED – Reset 'R' push button. The trip LED's will stop glowing

Note: All contacts are self reset hence breaker closing is possible without resetting of relay/LED's.

Reset external trip relays.

C) Differential Relay

i) KBCH Differential Relay (M/s Alstom)

a) How to read fault record.

Operate key pad as follows

1 Sequence of Operation Display

111 1 Press 'F' key System Data

2 Press 'k' key Fault record

3 Press 'F' short again

& again Complete

parameters regarding faults

4 Press 'F' long & 'O' keys original display

b) Trip contact-self reset

c) To reset LED : Press 'O' key. The trip LED's will stop glowing.

Note: i) All contacts are self reset hence breaker closing is possible without resetting of relay/LED's.

Reset external trip relays

ii) When 'clear fault record' '=' '0' available on display, do not press 'O' key otherwise all fault records will disappear from the memory.

ii) 7UT 51 Differential Relay (M/s Siemens)

- a) How to read fault record.
Operated key pad as follows

Type DA5200E for direct address block of fault annunciation. Then press (↑) and (↓) keys to scroll the fault-I, II or the last.

Press (↑) and (↓) keys to look into the record.

	Sequence of Operation	Display
↑	5200 Last fault	Beginning of the block 'fault annunciation of the last system fault.
↓	001 31.5.2002	
	System fault	The date of the system fault is indicated in second line consecutive no. of system fault indicated.
↑	002 16: 17:28:359 fault : C	Time of beginning of fault is given .
↓	003 OMS differential general fault : C	The following item indicated all fault annunciation which have occurred
↑	004 OMS differential > trip : C	From fault detection until drop of the devices in chronological sequence
↓	005 85MS Dev. : drop off : C	

- b) Trip contact-self reset
c) To reset LED : Press RESET button to reset LED's . The trip LED's will stop glowing

Note: All contacts are self reset hence breaker closing is possible without resetting of relay/LED's.
Reset external trip relays

iii) MICOM Differential Relay (M/s Alstom)

- a) How to read fault record

Operate key pad as follows

	Sequence of Operation	Display on relay
1	Press 'V' (down) key	Parameters
2	Press >(right) key	Operation
3	Press >(right) key	Events
4	Press 'V' (down) key	Event counter
5	Press >(right) key	Measured fault data
6	Press >(right) key	Events recording
7	Press 'V' (down) key	OL R. C
8	Press >(Right) key	FTRC

- 9 Press V(Down) key Fault recording
- 10 Press V(Down) key Event number
- 11 Press >(Right) key again and again Total details regarding fault

- b) Trip contact-self reset
- c) How to reset LED Press 'book marked' key again and again. 'Clear fault' will appear on display and then press 'C' key to reset LED. The trip LED's will stop glowing.

Note: All contacts are self reset hence breaker closing is possible without resetting of relay/LED's.
Reset external trip relays

D) Over Current & Earth Fault Relay

i) KCEG / KCCG Over Current & Earth Fault Relay (M/s Alstom)

- a) How to read fault record

Operate key pad as follows

Sequence of Operation

Display on relay

- 1 Press (F) key System Data
- 2 Press (-) key Fault records
- 3 Press (F) key Select fault number
- 4 Short Press & release (F) key again and again Complete parameters

Regarding faults

- 5 Long press (F) key then (O) key Normal display

- b) Trip contact-self reset
- c) To reset LED : Press 'O' key. The trip LED's will stop glowing

Note: i) All contacts are self reset hence breaker closing is possible without resetting of relay/LED's. Reset external trip relays

- ii) When 'clear fault record' '=' '0' available on display. Do not press 'O' key

WARNING:

- 1) NEVER WITHDRAW RELAY/CARD FROM CASING WITHOUT DISCONNECTION OF DC SUPPLY.
- 2) DON'T ENTER IN OTHER MENU EXCEPT FAULT RECORD.

4.15 MAINTENANCE MANUAL FOR PROTECTION & METERING

4.15.1 PROTECTION

GENERAL

The protection scheme basically consists of protective relays, functions as a sensing device and switching circuit (i.e. circuit breaker), which after getting command from relay disconnects only the faulted element(s) promptly and reliably thereby saving the rest of the system from being affected due to fault.

The protection scheme is, therefore, a very important and vital component of the power system and hence, proper care is necessary for its selection, operation and maintenance.

NEED FOR PROPER COORDINATION OF RELAYS

The protective relays minimize the damage to the system and interruption duration by immediately locating / detecting the fault as well as isolating the faulted circuit / part of the power system. Hence, the reliability, fast action, selectivity and coordinated operation of the protective relays are the desirable features of the protective system, particularly the coordinated operation of the relays is a must in the vast integrated and interconnected modern grids to minimize the duration of the interruption caused to the system and also loss of generation as well as distribution.

NUMERICAL RELAYS

Latest numerical relays are microprocessor based; a single relay has many features. These compact multi functioned relays cost less and save additionally on space and assembly/wiring cost compared to traditional relaying schemes. These are practically maintenance free.

These relays have memory, communication capability and higher level control system. The protective relay scheme has undergone changes from formerly stand-alone devices to coordinated or integrated components of an overall sub station automation system.

Control panels and panel wiring are getting obsolete which computer terminals and serial communication links are replacing. User friendly and fail-safe sub station operation by fully graphic HMI terminals with comprehensive state indication contribute to a higher level of power system quality.

The high function integration of numerical relays calls for new design and redundancy of concepts. In most cases, only one unit provides all protection functions to one feeder/breaker, of course a second relay package has to be provided for the Main -2 or back up protection functions. The International trend is going for standardization of hardware design and modular software.

In general, these relays contain a user interface with LCD display and keypad, but normally more comfortable setting and read out of data by PC is used.

Load monitoring as well as sequence of events and fault / disturbance recording are now, in general, provided as add-on functions.

The modern numerical relays are widely self-monitored from the measuring inputs to the tripping command outputs.

The maintenance strategy, therefore, is to be changed from regular or routine testing to condition based testing. As self-monitoring cannot cover 100% of the protection system, a combination of self monitoring and on-site testing at longer time intervals guarantees the highest availability.

In this way, self-monitoring leads to economy in test amount and to a considerable reduction in the total life cycle maintenance cost.

Merits and demerits of numerical relays:

Numerical relay technology is from the main stream and is for the designers to provide users with the functions they need at the prices they have come to expect.

Now engineers want to work only with microprocessors, data communications, PC's etc.

Benefits

Numerical relays have:

- Intelligent functions and features.
- Related functions in one package
- Non – fault monitoring and information.
- Detailed fault recording and information.
- Data by remote communication.
- Supports network- based sub station control (SCADA).
- Self-monitoring, no routine maintenance.
- Less panel space, battery power, CT PT burden.

Merits of computer based relaying.

- These are standard products and are configured via settings as per system requirement.
- No custom system engineering or wiring is required.
- Supply period is very short.
- Fewer inventories are required.
- Very less maintenance spares are required.
- Fast field repair by swap – out.

Demerits of computer based relaying.

- Microprocessor based devices including protective relays have short life cycle.
- While each generation of Microprocessor based devices increases the functionality compared with the previous generation, the pace of change makes the equipment obsolete in shorter times. This makes it difficult for the users to maintain expertise in using the latest designs.
- Another point of this shortcoming is in the form of changes in the software used on the existing hardware platforms.
- Sometimes these changes effectively generate newer relay designs. This requires that a software tracking system be used for each device own by a utility.

- The multifunction Microprocessor based relays have a significant number of settings. The increase in number of settings may pose problems in managing the settings and conducting functional tests.

Multiple functions

Microprocessor relays provide many functions that were not available in electromechanical or solid state relays. These features include multiple setting groups over programmable logic, adaptive logic, self monitoring, self testing, and sequence of events recording, oscillography and ability to communicate with other relays and control computers. While these features make these relays very powerful, they also introduced factors such as complexity that were not associated with earlier relays.

Cost

The cost per function of microprocessor-based relays is lower compared to the cost of their electromechanical and solid-state counter parts. The lower cost of components, cost of protection equipment and protection technology has resulted.

Custom logic schemes

A major feature of micro- processor based relays that was not available in previous technologies is the ability to allow users to develop their own logic schemes, including dynamic changes in the logic. This benefit, however, comes at a cost because of this capability increases the complexity of the system.

Panel space

Micro processor base protection systems require significantly less panel space than the space required by the electromechanical and solid state relays that provide similar functions. The reduction in size is a result of the high level integration of the hardware and the ability of using one physical device for performing multiple protection functions, such as, over current and multiple zone distance relaying for phase and ground fault protection. The shortcoming of the benefit is that it increases the susceptibility to common mode failure of protection schemes.

Burden on Instrument Transformers.

Microprocessor based relays impose significantly less burden on instrument transformers than the burden imposed by the relays of the previous technologies. In addition, micro processor based relays can be programmed to detect saturation of instrument transformers for minimizing incorrect operations they also require few CT and PT connections because some operating quantities, such as zero sequence currents and voltages are derived by numerical technologies.

Sequence of events and oscillography

Reporting features, including sequence of events recording and oscillography are a natural by product of micro processed based protection system. These features make it possible to better analyze the performance of the relays as well as system disturbances at minimal additional cost.

Self monitoring and self testing

Another advantage of microprocessor-based relays is their ability to perform self-monitoring and self-testing functions. These features reduce the need for routine maintenance because of the relays automatically take themselves out of service and alert the operators of the problem when they detect functional abnormalities.

Important Recommendations of NREB Protection Committee

Recommendations

- i) Some of the system fault occurrences are due to bus fault. To facilitate faster clearance of the bus fault, faster bus bar protection should be provided at all 400 kV and 220 kV sub stations and also at important 132kV sub stations in the region or those directly connected to generating stations or tie-lines with the Regional Grid.
- ii) One of the reasons for bus fault in old stations was due to lower rupturing/withstand capacity of the sub station equipment like breakers, CTs, isolators, etc. The equipments need to be replaced as per increased fault level in a phased manner.

Other Suggestions

- i) For old inter-state 220 kV lines, the existing electro-magnetic distance relays need to be replaced by static (latest numerical) non-switched carrier-aided distance relays.
- ii) The existing over current and earth fault IDMT relays should be retained with revision of plug setting and TMS settings as and where necessary for proper discrimination.
- iii) Proper directional feature should be ensured and correct directional check on load should be carried out on all overcurrent, earth fault and distance relays under suitable load conditions.
- iv) All the 400 kV distance protection relays should be used in permissive under-reach inter-trip mode so long as no series capacitor is installed in the line. Wherever power swing blocking/tripping feature is provided, its setting should be arrived at after carrying out system studies
- vi) It is felt that the winding, oil temperature setting for tripping of the transformer should be set as per the manufacturers' recommendations and advice.
- vii) The setting of the over-fluxing relay should be kept as per the over fluxing capability of the transformer protected and as per the manufacturer recommendations and advice. The existing definite-time over-fluxing relay should preferably be replaced by IDMT over-fluxing relays to match with the over-fluxing capability curves of the transformer. It is suggested that over-fluxing relay should be provided on LV side in addition to HV side. Whenever only the over-fluxing relay is used, it is preferable to provide on LV side.

Corrective Measures:

Following corrective measures should be taken to control over-voltage problems: -

- i) Some of the occurrences are caused due to improper operation of the cooling system of the transformers. To avoid this, the following measures are suggested:
- ii) Cooling system must be maintained properly in all grid transformers.
- iii) Switching of fans and pumps should be kept on auto-mode.

- iv) The upper limit in respect of the allowable temperature of transformer as advised by the manufacturers should neither be exceeded nor be lowered under any circumstances.
- v) All fans and pumps should be periodically checked/tested for trouble-free problem.
- vi) Monitoring of hot spots and current carrying clamps and connectors should be carried out particularly by either contact or non-contact methods.
- vii) Whenever possible, operation of the winding and oil temperature monitoring should not be A.C. supply dependent.
- viii) In some of the tie lines, over current relay setting has been kept at a level well below the line (thermal) capacity causing tripping of the line whenever flow exceeds the set limit. This is against the norm of integrated operation and may cause grid disturbance. It is recommended that an over-current tripping should be provided at thermal limit of the conductor (or at 120% of line CT ratio whichever is low).
It is suggested that LBB protection should be incorporated in all the major sub stations.
 - The directional check for earth fault and over current relays should be done for correct directional operation under appropriate power factor and percentage load conditions as recommended by relay manufacturers.
 - In some of the transformers, Buchholz relays may operate during switching of pumps. This check should be included in the pre-commissioning check list.
 - In order to identify and analyse the correct sequence of operations disturbance recorder/sequence event recorder should be provided at major stations (latest numerical relays have this as a built in feature).
 - The committee suggests that on all important interconnected sections, redundancy should be available to meet the outage of single lines. In cases of over loading, efforts should be made to regulate the flow on the line immediately.

System Security

It is desired that:-

when frequency drops slowly, under-frequency relay could shed the load and save the system. However, under disastrous conditions, df/dt relays would be used. A suitable combination of both could save the system.

the lines should not trip unless there is a fault and hence, over-current setting should be adopted as per the thermal capacity of the line.

bus bar protection along with the LBB should be provided at all main stations. Particularly at those GSS, which are directly connected to generating stations.

Emergency supply for station auxiliaries:

- a) Large and important GSS must be provided with DG set of adequate capacity to give emergency supply to the station auxiliaries. Trial run should be taken at least once in a week to keep it in readiness.
- b) Emergency lighting should be provided in control room and switchyard and this should be automatically switched on when there is power failure.
Adequate fire protection for all the oil-filled equipment shall be provided.

Oil sump shall also be provided for transformers and shunt reactors.

Maintenance & Testing Procedures of protective relays / equipments and Earthing practices

Maintenance and testing procedure

- i) Maintenance and testing procedure given by manufacturers of relays and equipments are generally found to be sufficient and adequate and, therefore, are to be strictly followed by the utilities. The periodicity of maintenance and testing as recommended by the manufacturers may, however, be reviewed by utilities depending on the working environment, site conditions, frequency of faults, behavior and operation of relays/equipments and type of relays etc. However, it is suggested that periodic testing of relays should be done once in a year. Sub committee also recommends on-line testing facilities for important protections/equipments.
- ii) Sub committee noted that in some of the cases, water entered the junction boxes for switchyard equipment like isolator, breaker, MK's etc. and these created faults. To avoid this, the committee recommends that:
 - a) Junction box should be water and vermin -proof and should preferably be located well above the ground level.
 - b) Pre-monsoon check on outdoor junction boxes should be carried out.
 - c) In carrier-aided distance protection scheme, end-to-end tests should be done regularly.

Earthing Practice For Protection Equipments;

- i) All the protective devices including CT, PT, relay panels etc. should be earthed properly. Earthing of PT primary separately and adequately must be ensured. Earthing of star point of PT secondary/CT secondary must be done effectively. However, earthing of CT PT secondary at only one point should be adopted.
- ii) Multiple earthed CT/PT secondary winding are a source of trouble and responsible for mal-operation of protective relays.
- iii) Where CT paralleling is a compulsion, earthing of only one star point may be adopted. The star point for other CTs may be kept floating.
- iv) Proper earthing of the relay panel should be ensured. This is very important from the point of operation of static relays.
- v) Armouring of all 400 kV control cables shall be earthed at both ends through cable glands.
- vi) For co-axial cable used for PLCC it is preferable to install flash guards at the control room end for discharge of high voltage developed, during switching operation of HV equipment.
- vii) PVC insulated, stranded copper-armoured control cables should be used in conjunction with static (as well numerical) relays and control circuits.
- viii) **Terminal blocks-** Non-disconnecting stud type terminal blocks shall be used for all circuits except CT PT circuits in the panels. For CT & PT circuits in the panel, either test terminal block (having facilities for automatic shorting of CTs) or disconnecting stud-type terminal blocks are to be used.

For all switchyard equipments, terminal blocks are to be of non-disconnecting stud type.

PT Supervision Selection Scheme

Whenever, two sets of PTs are used (for bus bars) and change over of PT supply from one PT to another is affected. 3-phase-4-wire selection scheme should be adopted. Sub-committee suggested that making a common neutral and running a single neutral wire of PT supply for both the PTs should be avoided because this may result in mal-operation/operation of distance protection relay provided specially for protection of short lines.

Note: - Secondly improper operation or non operation of isolators auxiliary contact may cause non switching of VT supply to Distance Protection Schemes which may result in mal-operation of the DPR's. It has therefore to be ensured that the isolator auxiliary contacts are always maintained in perfect working condition. Apart from VT selection, they play important role in various controls and interlock circuits.

PRACTICE OF ON LOAD CHANGE OVER OF FEEDER SUPPLY FROM ONE BUS TO OTHER BUS BY CLOSING BOTH ISOLATORS AT A TIME MUST BE AVOIDED BECAUSE THIS MAY RESULT IN PARALLELING OF VT SUPPLIES AND THEREBY CAUSING VT FUSES IN SWITCH YARD TO BLOW AND FINALLY RESULTING IN TRIPPING OF FEEDERS CARRYING LOAD DUE TO OPERATION OF DISTANCE PROTECTION RELAYS.

Bus Bar Protection Scheme

Whenever high impedance bus bar protection schemes are in service, stabilizing resistance range should be reviewed. In future, the stabilizing resistance range should be adopted as 0-1000 ohms, however, in the existing bus bar protection scheme, where the stabilizing resistance is within the range of 0-200 ohms, the position should be reviewed and feasibility of providing higher resistance should be explored depending of fault level.

- Transformer should be made to trip from both sides on operation of bus bar protection instead of tripping the breaker connected to faulty bus alone.
- In case of 400 kV lines, bus bar protection should trip remote end line breaker also.
- Wherever CT switching is involved in bus bar protection, it should be through latch type switching relay and not through direct auxiliary contacts. In the present schemes, wherever the CT switching is through direct auxiliary relay contact, it should be reviewed and modified accordingly.
- If isolator contacts are used for energizing the CT switching relay, three pole contacts should be always connected in parallel for the operating coil and in series for resetting coils. The present schemes need to be reviewed and modified accordingly.

Disturbance recorder/Event Sequence Recorder

The sub committee recommends that disturbance recorders and event sequence recorder should be provided in all the 400 kV and major 220 kV sub stations.

Long Term Policy

The sub committee recommends regular load flow studies, short circuit studies and system stability studies to be carried out and revision/ modification/improvement in protection system (including periodic review of the protective relay setting) based on these studies.

Sub committee also recommends the following points:

- a) On-line testing facility of the protective relays with self-diagnostic feature.
- b) Microprocessor numerical based relays and control system.
- c) Integration of control with protection and use of SCADA system.
- d) Use of CTs & PTs with guaranteed transient performance.
- e) Completion of database on regional basis and the Performance of protective relays used in the system. For this, grid disturbance reports, test results, analysis, review shall consolidated.
- f) Possibility of using dry cell battery may be explored.
- g) All major sub stations control rooms, relay/PLCC rooms shall be air-conditioned.
- h) Setting up of well-equipped testing laboratory for protective relay.

Sub committee recommends that adequate training facilities need to be created by utilities for protection engineers with the help of installations like power system testing institution Bangalore and other educational Institutions and also with relay manufacturers/consultants.

CONCEPT OF BACK UP PROTECTION

CONCEPT

The role/function of back up protection in the overall protection system plays a very important part. It has to be adopted and applied very intelligently and carefully in the existing system. Generally the existing relay/schemes can be made to play a proper role of back up protection by way of its proper application in the system by revision of time setting, reach setting and direction setting and by selecting proper carrier signal application.

The back up protection requirement encompasses a number of aspects. Of primary importance for an EHV transmission network is the requirement to ensure correct, or best possible, operation of the over all fault clearance system even in the event of the failure of one of the components within the protection scheme itself or the failure of an external component within the overall fault clearance system.

The method usually adopted to accommodate failure of a primary relay is to back this relay up by inclusion of a second primary relay. **Complete protection equipment back up is achieved by fully duplicating the main protection systems, and not just the primary protection relays.**

What is necessary, therefore, is a philosophy which clearly defines the role of the different elements of back up protection, sub categorized into those which provide **local backup**, and those which provide **remote backup**, and how they coordinate to provide the best overall solution for the transmission system from a microscopic perspective.

PERFORMANCE

i) SYSTEM REQUIREMENTS

It is the requirement of the system to match the performance capability of the protection equipment to what is needed for adequate protect of the power system.

ii) MAINTENANCE REQUIREMENT

It is the prime requirement to carry out routine maintenance on protection equipment without taking the item(s) of the plant out of service. When testing of the relay is necessary, the protection equipment to be tested can be isolated, keeping the alternative main protection system undisturbed and hence, the primary equipment is in service. This also supports the argument of the employing two main protection systems of identical type.

iii) SELF TESTING FEATURES

This feature is available in latest numerical relays. The development of latest relays has evolved self-checking features built into the protection equipment. As confidence in the feature grows, less and less reliance need be placed on having autonomous back up functions as well as testing frequency. Should one of the primary relays fail due to an internal failure, this would be flagged immediately and the defective relay could be repaired / replaced within

a short period of time. Previously, an internal relay fault could go undetected until the relay was called upon to operate for a fault on the power system, if the power system fault occurred before the next scheduled routine testing.

CODE OF PRACTICE FOR PROTECTION

Circuitry

- The entire wiring of control circuit for indications, alarm, metering and protection should be of permanent nature.
- There is no place for temporary wiring or adhocism in control and protection circuit.
- The leads should be identified by ferrules near terminals.
- Every lead should end at a terminal point and no junction, by twisting, is allowed. If two wires are to be jointed, both ends should be connected at a common terminal or both ends are to be terminated at two different terminals and a loop be provided.
- The wiring should be by copper leads for CT secondary for all cores, i.e. metering as well as protections.
- The wiring should be by copper leads for PT secondary also, wherever they are intended for protection.
- The copper leads should be preferably stranded but not single lead type.
- Where PTs are employed for commercial metering, stranded copper wires should be used.
- The terminals should be lugged by ring shape ‘O’ lugs. ‘U’ shape lugs should be avoided.
- For CT secondary terminals, two (2) nuts with one spring washer and two plate washers are to be compulsorily used.
- The terminal strips should be stud type with nuts and not screw-in type.
- Wherever two station batteries are available, the primary protection and back up protection should be from different batteries.
- Where there is only one battery at a power sub station, the primary and back up protections should be given DC supply through individual/main circuits with independent fuses run from DC bus.
- When CBs have two trip coils: they must be connected for operation by primary and back up protections.
- DC and AC supplies should not be taken through different cores of the same cable.
- Independent DC cables should be run to each equipment in the yard and looping of DC supply, either in the yard or in control room, from one equipment to the other is not permitted.
- The DC yard lighting for emergency lighting should be through independent cables, which must NEVER be mixed up with protection, and other circuit cables.
- For indications, alarms, annunciations, controls (closing coil, trip coil etc. NEGATIVE of DC supply is always given direct and POSITIVE is supplied through commands like close, trip, protection- trip etc.
- Standard color codes for leads in control cables of different sizes should be used.
- CTs with 1 amp. Secondary rating should be used compulsorily where distance of control room is adjustable from switchyard. .
- The CT ratios available and adopted with No. of cores shall be displayed on each panel as follows.
 - 400-200-100/1-1-1
 - The selected ratio should be underline.
- Wherever CT cores are not used ‘SHORTING LOOPS’ should be provided near CT secondary terminals and not in the marshaling boxes or at panels.

- The cable entries near equipment marshalling boxes and panels should be by use of appropriate size glands leaving no scope for entry of lizards/reptiles etc.
- The wiring inside the panels should be neat and clean and well dressed and also fastened avoiding loose wires.
- All spare wires, not in use, should not only be disconnected but also removed from panels.
- Few cells from station battery should not be used for separate low voltage DC circuits e.g. PLCC etc. Instead, DC-to-DC converters only should be employed utilizing full DC voltages of the entire battery as input.

Equipment wise relaying practices and nomenclatures

S.No	Equipment	Protection	Philosophy	Indication
1	Power Transformer	a) Main protection	Differential, REF, High Impedance Differential	87
		b) Back up	O/C & E/F	50/51: 64, 64R/M /NX
		c) Over fluxing & NDR	V/f Residual Voltage	99
		d) Gas or surge Operated	Buchholz	63
		e) Thermal	i) Winding temp. high/trip	49/T
			ii) Oil temp. high/trip	26/T
			iii) P.R.D.	30P
			iv) OLTC out of step	OST
2	Line	a) Main protection	i) Distance / impedance relay	21
			ii) Distance / impedance relay	21
		b) Back up	Directional O/C, E/F relay	50/67
			i) Carrier send	85x 1
			ii) Carrier received	85 x 2
			iii) Carrier lock out trip	85 LO
3.	Bus Bar	a) Main protection	Differential,	87

			LBB	50-Z (Timer 2/50Z)
4.	Circuit Breaker	b) Back up breaker stuck		95
		a) Trip circuit supervision/ healthy/indication relay		195/295
		b) Trip circuit-1/Auto re- closure Indication relay)		62
		c) Pole Discrepancy timer		162/162X
		d) Pole Discrepancy lock out relay		96
		e) Auto re-closure blocking relay		197
		f) Auto Re-closure timer for single phase re - closing		
5.	Miscellaneous	a) Supply (DC/AC) supervision relay		80
		b) Under/over frequency relay		81
		c) DC over current relay		76
		d) VT selection relay		75
		e) Tripping relay		86/186/28 6
		f) Check Synchronizing relay		25
		g) VT selection (use failure relay)		27/97
		h) Alarm relay		74
		i) Auxiliary relay/Indicator Relay		30
		j) Remote Close/Remote Trip	K15R/K5L	
		k) Local close/Local trip	K15R/K5L	

4.5.3 STANDARD LEAD NUMBERS.

Certain lead numbers are standardized, as followed, and should be compulsively adopted with ferrules at terminals of leads.

J1 DC Positive
J2 DC Negative

Controls & Alarms

Remote close:	K15R
Remote trip	K5R
Local close	K15L
Local trip	K5L
O/C	Relay trip K3, Master trip K9
Trip	Relay trip K3, Master trip K9
E/F trip	Relay trip K3, Master trip K9
Diff. Trip	Relay trip K3, Master trip K9
OSR/OLTC trip	163T
Buchholz	63T
O.T. trip	26T
W.T. trip	49 T
Over-fluxing trip	99
PRV trip	
TER-ALA trip	149T
Buchholz Alarm	63A
WT alarm	49A
OT alarm	26A
TER alarm	149A
Bus bar protection trip	96
Pole discrepancy trip	162
Indication +ve – L	
OFF L3	
ON L5	
Semaphore OFF L7	
Semaphore ON L9	
CB trip alarm	L21
Bus AB switch remote OFF – L11	
Bus indication ON L13	
Line/equipment	OFF L15
	ON L17
	ON L19
	OFF L21

Norms for transformer protection.

- No Buchholz relay for transformers below 500 KVA capacities.
- Transformers up to 1500 KVA shall have only horn gap protection.
- Transformer 1500 KVA and 8000 KVA and above – Differential protection in addition to Buchholz relay.

SYMBOLS AND NUMBERS USED IN METERING, PROTECTION AND CONTROL CIRCUIT WIRING

Symbol	Used for
A	C.T. wires for main protection
B	C.T. wires for Bus bar protection
C	C.T. wires for back up protection (over current / earth fault protection)
D	C.T. wires for metering
E	PT/CVT wires for Protection & metering

G	PT/CVT wires for synchronizing
H	A.C. supply main wires
J	D.C. supply main wires
K	Control supply wires
L	Indication and Annunciation wires
M	A.C. supply wires
N	A.C. Control supply (e.g. Tap changer)
P	D.C Control supply for bus bar protection /Local breaker back up protection.
U	Spare Contract
X	
Odd numbers 1, 3, 5 etc. for D.C positive/A.C. phase.	
Even numbers 2, 4, 5 etc for. D.C Negative/A.C. Neutral	
Numbers	Used For
11 to 30	R phase
31 to 50	Y phase
51 to 70	B phase
71 to 80	Neutral
81 to 91	Open delta / residual voltage
90	Earthing

Abbreviations of Indications /relays/Flags

Indication	Used For
1	Timer
2	2Z or 2/50Z - Timer for local breaker backup Protection
3	Checking or interlocking relay
6	Circuit breaker, connection or switch
12	Over Frequency/Over Speed Relay
14	Under Frequency/Under Speed Relay
21	Impedance relay/ Distance Relay
25	Synchronizing/paralleling relay
27	Under voltage relay
30	Auxiliary relay for Indicator relay
32	DC Reverse Power/Directional Power Relay
37	Under current or under power relay
40	Field failure/Loss of excitation relay
43	Transfer switching relay/changeover relay
46	Negative Sequence Relay/Phase balance Current Relay
47	Phase sequence voltage relay
48	Incomplete sequence relay
49	Machine or transformer thermal relay
50	Instantaneous Over current relay 50 A local breaker back up protection relay
51/51 N	Over current /Earth fault relay- IDMTL
52	AC Circuit Breaker
52a	AC Circuit Breaker auxiliary contact N/O

52b	AC Circuit Breaker auxiliary contact N/C
54	High Speed DC Circuit Breaker
55	Power Factor Relay
56	Field application relay
59	AC Over Voltage Relay
60	Voltage or current balance relay
62	Circuit breaker pole discrepancy timer 162 x pole discrepancy lock out relay alarm
63	Gas operated or surge operated relay 63 T Bucholz trip 63 A Buchholz Alarm 163 TC/OLTC trip circuit
64	Earth fault relay 64 R Restricted earth fault relay 64 N Earth fault relay 64 NX Auxiliary relay for Directional earth fault relay
67/67 N	Directional O/C + E/F relay 67 ABC phase of relay Reverse power relay
68	Blocking Relay
74	Alarm relay
75	VT selection relay 75 A Bus I side 75 B Bus II side
76	DC over current relay
78	Phase angle measuring relay or out of step protection relay
79	AC Re-closing Relay
80	DC Supply supervision relay
81	Frequency relay
83	Automatic selective control or transfer relay
85	Carrier signal aux. relay 85x1 carrier send relay 85 x 2 carrier receive relay
86	Tripping and Lockout relay 86 A, B, C single phase tripping relay phases wise 86 T three phase tripping relay 186 A, B auto reclose block trip relay 186 Lockout relay 286 trip re-closing
87	Differential relay
91	Voltage directional relay
92	Power Directional Relay
95	Trip circuit healthy Supervision relay/ indication relay. 195 Trip circuit-I 295 Trip circuit-II
96	Auto re-closure blocking relay or bus bar protection tripping relay
97	VT fuse failure relay
99	Over- flux relay 99A – Alarm 99 T- tripping

	<p>Note: Suffix- X is used for Auxiliary relay for contact multiplication of main relay Z- local breaker back up protection relay Prefix 2 timer for main relay</p>
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Abbreviations for type nomenclature of relays

Symbol	First letter	Second letter	Third letter
A	Phase angle comparison	Attracted Armature	Auxiliary
B	Balanced current	Buchholz	Testing
C	Current (Amperes)	Induction cup	Carrier or counting
D	Differential	Induction disc	Directional
E	Direction	-	Earth (ground)
F	Frequency	-	Flag & Alarm Indicator
G	-	Galvanometer (Moving coil)	General /Generator
H	-	-	Harmonic Restraint
I	Directional current	Transactor	Inter locked or Industrial
J	-	Mixed types	Tripping
JE	-	-	Tripping (Elec. Reset)
JH	-	-	Tripping (Hand - reset)
JS	-	-	Tripping (self- reset)
JC	-	-	Control
K	Rate of rise of current	-	Check alarm
L	-	-	Load limiting
M	Manual	Magnet (Polarized)	Semaphore or motor
N	-	-	Negative sequence
O	Oil pressure	-	Out of step
P	Poly phase VA	Plug	Potential failure
Q	-	-	Alarm
R	Reactive VA	Rectifier	Re-closing
S	Slip frequency	Synchronous motor	Synchronizing
T	Temperature	Transistor	Timer or transformer
U	-	-	Definite time
V	Potential (volts)	-	Voltage restraint
W	Watts (Power)	Weight (Gravity)	Pilot wire
WA	-	-	Inter posing
WJ	-	-	Inter tripping
X	Reactance	-	Supervisory
Y	Admittance	-	Flash back (back fire)
Z	Impedance	-	Special application
ZS	-	-	Zero sequence

First figure - Indicates the number of units in the relay essential to its operation-not including seal-in auxiliary units.

Second figure- Indicates a particular characteristic of one of a group of similar relays e.g. CDG11, CDG12, CDG13 and CDG14 are all inverse time over current relays but with different characteristic curve such as Inverse time (IDMT), Inverse time (long time delay), very inverse, Extremely inverse etc.

RELAY INDICATION CODE

1)	Operating Quantity
A	Phase angle comparison
B	Balance current
C	Current
D	Differential
E	Direction
F	Frequency
G	Gauss
I	Directional current
K	Rate of rise of current
M	Manual
O	Oil pressure
P	Poly phase volt ampere
R	Reactive volt ampere
S	Slip frequency
T	Temperature
V	Voltage
W	Power
X	Reactance
Y	Admittance
Z	Impedance
2	Basic measurement
A	Attracted Armature
B	Buchholz
C	Induction cup
D	Induction disc
G	Galvanometer
I	Transactor
J	Mixed type
M	Sensitive balanced armature
P	Plug
R	Rectifier
S	Synchronous motor
T	Static circuit
W	Weight or gravity
3	Indication of application
A	Auxiliary

B	Testing
C	Carrier or counting
CB	Capacitor bank
D	Directional
E	Earth
EF	Earth fault
F	Flag or indicator
G	General organization
GF	Generator field
H	Harmonic restraint
I	Inter locked or industrial
IG	General or generator (instantaneous)
J	Tripping
JE or JX	Tripping (ELE-reset)
JH or JY	Tripping (hand reset)
JA or JS or JZ	Tripping (Self-reset)
JB	Control (Tripping)
K	Check alarm
L	Load limiting
M	Motor or semaphore
N	Negative phase sequence
O	Out of step
P	Potential or fuse failure
Q	Alarm
R	Re-closing
S	Synchronizing
T	Transformer or timer
U	Definite timer
V	Voltage control
W	Pilot wire
WA	Interposing auxiliary
WJ	Inter-tripping
X	Supervisory
Y	Special application
ZS	Zero phases sequence
4	No. Of Units The first No. Indicates the no. Of relay units excluding sealing reinforcing auxiliary units e.g. CMM 42 relay consists of a thermal o/c unit, an instantaneous O/c unit, an E/F unit and an instantaneous unbalance unit.
5	Characteristics The second No. Indicates the particular characteristic of one of a group of relays e.g. CMM 41, CMM42 relays are of the same type and composition but differs in their time delay characteristics.
6	Case size
A	Size 1 draw out single ended 10 terminal
B	Size 1 draw out double ended 20 terminal

C	Size 2 draw out single ended 10 terminal
D	Size 2 draw out double ended 20 terminal
E	Size 3 draw out single ended 10 terminal
F	Size 3 draw out double ended 20 terminal
L	Size ½ non draw out (Type VAK relay)
M	Size ½ draw out single ended 10 terminal
P	Size 1½ draw out single ended 10 terminal
R	Size 1½ draw out double ended 20 terminal
S	Size 1½ draw out double ended 40 terminal
T	Size 4½ draw out single ended 30 terminal
U	Handle locked plug in
Y	Size ¼ moulded non draw out 10 terminal
Z	Size 1/2 moulded non draw out 12 terminal
7	Case Mounting
F	Flush vertical
D	Flush Horizontal
8	Identification
	This may be one or more Nos. or letters and enables to identify rating, contact arrangement etc.
9	Suffix
	Last letter regarded as a part of identification above if last No. is 5 for 50 Hz. 6 for 60 Hz.
10	Distance Protection Scheme An Exemption to the rules are dist. Protection schemes which have a group of prefix letters to identify type, measurement etc.
M	For MHO characteristic
R	For reactance
SS	Switched scheme
Note	Digit denotes No. of time distance steps and final letter V or T indicates the scheme is electromagnetic or static.
	MM3V means 3 step electromagnetic disc scheme with 3 MHO measuring unit for Ph-ph and 3 for ph-N.
	ANSI TERMINOLOGY
No.	Function
3TC	Trip coil circuit monitoring
21	Distance Protection
25	Synchronism check
27	Under voltage protection
32	Directional power protection
37	Under current protection
40	Field loss protection
46	Reverse – phase or phase – balance current protection
47	Phase-sequence voltage protection
49	Machine thermal protection
50	Instantaneous phase O/c protection
50bf	Breaker failure protection
50T	Transformer tank protection
50hr	Instantaneous O/c with harmonic restraint

50N	Instantaneous ground O/c protection
50Ns	Instantaneous sustained ground O/c protection
50N/ 50Ns	Instantaneous ground/ sustained ground O/c protection
50Nu/51 Nu	Ground current unbalance protection
500 u/510u	Capacitor bank phase current unbalance
51	Time phase O/c protection
51N	Time ground O/c protection
51N/51Ns	Time sustained ground/ ground O/c protection
51br	Time O/c protection against blocked rotor
59	Over voltage protection
59N	Neutral Over voltage protection
66	Excessive NO. of start – UPS protection
67	Directional phase O/c protection
67N	Directional ground O/c protection
67Nus	Directional neutral protection (ungrounded system)
78	Out of step protection
79	Re-closer
81	Over/under frequency protection
87	Differential protection
95	Special ground O/c protection
95R	Special ground O/c protection

Standards for the different tests on relays

	Insulation test IEC 255-5
	Between circuit and ground 2kV, 50/60 Hz. For 1 min.
	Between independent circuits 2kV, 50/60 Hz. For 1 min.
	Impulse test IEC 255-5
	5 kV 1, 2 μ s: 0.5 J
	1M Hz. – Disturbance test IEC 255-22-1 class III
	Common mode 2.5 kV
	Differential mode 1.0 kV
	Fast transient test IEC- 255-22-4 class IV
	4 kV \pm 10%
	Radiated electromagnetic field disturbance IEC 1000-4-3
	Amplitude modulated 10V/M
	Pulse modulated 10V/M
	Electrostatic discharge test IEC 255 – 22 – 2 lass III
	8 kV \pm 10%
	Radio frequency emissivity
	EN 55011
	Temperature IEC 255-6
	Operating range – 10 deg. C to + 55 deg. C
	Storage range – 25 deg. C to + 70 deg. C

	Humidity 95% (Non condensing)
	Power supply ripple IEC 255 – 11
	< 20%

Test Plug and Universal Test block

Type MPB/ MPG

Features:

- On load testing of relays and meters without disturbing panel wiring.
- Reduced cost of commissioning and routine measurement.
- Simplified and safer testing

Application

Type MPB test plug is used for testing relays and meters in draw out cases. In conjunction with type MPG test block, it can be used for testing relays and meters in non draw out cases of any manufacture.

MAINTENANCE SCHEDULE FOR DIFFERENT PROTECTION SCHEMES

S.No.	Activity	Condition	Period
I	Line Protection		
A	Distance Protection		
a	Check for all zones (includes Z1, Z2, Z3 and Z3 reverse)	W S/D	5 Y
b	Time measurement	W S/D	5Y
c	Power Swing blocking (PSB) check	W S/D	5Y
d	SOTF	W S/D	5Y
C	LZ-96		
a	Op to coupler inputs check (where provided)	W S/D	5Y
b	Self diagnostic signals check	W S/D	5Y
2	Common test for distance and unit protection		
a	Trip contacts check	S/D	5Y
b	Annunciation check	S/D	5Y
c	Check for carrier send/receive	S/D	5Y
d	Auxiliary relay healthiness	S/D	5Y
e	Over voltage relay	S/D	5Y
f	LBB	S/D	5Y
g	STUB protection	S/D	5Y
h	Fault locator initiation check	S/D	5Y
i	DR, EL initiation check	S/D	5Y
j	Auto re-close check	S/D	5Y
k	DC logic	S/D	5Y
3	Auto transformer protections		
a	Over fluxing relay	S/D	5Y
b	Over load	S/D	5Y

c	Directional over current	S/D	5Y
d	LBB	S/D	5Y
e	Auxiliary relays (Buchholz, PRV winding temperature oil level etc.	S/D	5Y
f	Fuse failure check	S/D	5Y
g	Transformer differential protection	S/D	5Y
h	Restricted earth fault	S/D	5Y
4	PLCC system		
a	Checking of return loss	S/D	Y
b	Power supply measurements	S/D	Y
c	Transmitter checks	S/D	Y
d	Receiver checks	S/D	Y
e	Checks of alarms	S/D	Y
r	Reflex test	S/D	Y
g	LMU composite/ return loss	W S/D	Y
5	Bus bar protection		
a	Primary injection test	S/D	SOS
b	Protection stability and sensitivity checks	S/D	SOS

W S/D Without shutdown
S/D With shutdown
Y Yearly
HY Half Yearly
M Monthly
SOS Emergency / Contingency

LIST OF SPARE RELAYS/ RELAY SPARES TO BE MAINTAINED AT VARIOUS GSS

S.N O.	NAME OF ITEM	400 KV/220 KV	220 KV/132 KV	132 KV	REMARKS
1	Trip Relay Hand Reset/ Lock out Type	2 for each D.C. rating per GSS		2 relays per GSS	No. of NO/NC contacts and DC rating shall be specified by the indenting officer/ Incharge GSS
2	i) Trip Relay Self Reset/ Non Lock out Type	2 for each D.C. rating per GSS		2 relays per GSS	To be kept at each GSS
	ii) Master Trip Relay	2 for each D.C. rating per GSS		2 relays per GSS	To be kept at each GSS
3	Auxiliary Relay H/R Type for _____	2 for each D.C. rating per GSS		2 relays per GSS	To be kept at each GSS
4	Auxiliary Relay S/R Type for _____	2 for each D.C. rating per GSS		2 relays per GSS	To be kept at each GSS

5	Trip circuit Supervision Relay	One set of relays per five breakers			To be kept at each GSS
6	2 Over Current+1 Earth Fault Relay (set) a) Directional a) Non-Directional	(a) 2 of each model (b) 2 of each model	a) 1 of each model for 220 kV side b) 1 of each model for 220 kV side a) 1 of equivalent type for 132 kV side a) 1 of equivalent type for 132 kV side	1 of equivalent type for 132, 33 & 11 kV 1 of equivalent type for 132, 33 & 11 kV	Equivalent relay shall be numerical having approved make. Preferably, equivalent relay may have universal rating of current & auxiliary supply
7	Distance Protection Relay (Scheme) including Power Swing Blocking Relay	1 scheme/10 feeders of each type	1 scheme/10 feeders for 220 kV and 1 scheme/20 feeders for 132 kV	1 scheme /20 feeders	One relay of each model/type for each voltage level i.e. 400 / 220/132kV to be maintained at circle level.
8	Differential Relay	One relay each type per GSS	One relay each type per GSS	One relay/ 10 feeders each type	To be kept at 400/220 kV GSS 2(Two) at division level
9	Universal ICT suitable for both 1 A as well 5 A	1 Set (3 Nos.)	1 Set (3 Nos.)	1 Set (3 Nos.)	To be kept at 400/220 kV GSS 2(Two) at division level
10	Over Flux Relay	2	2	2 relay per division	To be kept at 400/220 kV GSS 2(Two) at division level
11	NDR	One relay per GSS	One relay per GSS	One relay per division	To be kept at each GSS
12	Over Voltage Relay	One relay per GSS	One relay per GSS	One relay per division	To be kept at each GSS
13	Under Voltage Relay	One relay per GSS	One relay per GSS	One relay per division	To be kept at each GSS
15	Trip/ Alarm contact assembly units for over current and E/F relays E/M type.	One unit per breaker	One unit per breaker	One unit per breaker	To be kept at each GSS

CHAPTER-5

5.1 GENERAL INSTRUCTIONS FOR SWITCH YARD EQUIPMENTS

A **Purpose**

The equipments shall be inspected at regular intervals in line with general guide lines or manufacturer's recommendations shall be followed.

B **General checks /maintenance instructions**

1. **External cleaning**

The insulators of the breaker / CT/CVT / isolators shall be cleaned for salt and dirt/dust deposition as well as cleaning of the other insulators in the sub station. The time interval for this cleaning shall be based on the atmospheric pollution or the periodicity mentioned in this document .

2. **Rust Protection:**

Some parts of the mechanism in the operation 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 strong corrosive surroundings. The rust stains shall be cleaned with emery paper away and new rust protection shall be painted or sprayed on. As rust protection, grease G or Tectyl 506 is recommended.

3. **Tightness check**

The breakers are provided with density monitor switches (temperature compensated pressure gauges). Every density monitor switch is provided with an alarm contact which gives an electrical signal if abnormal leakage takes place. With the first inspection, the bolted joints on the breaker and operating mechanism shall be tightened up. All the wiring joints in the terminal blocks of the operating mechanism shall be re-tightened at regular intervals. It is not necessary to repeat this tightening, only after bigger overhauls. SF-6 gas leakages are to be detected using suitable gas leak detector .

4. **Lubrication**

For lubrication, the lubricants recommended shall primarily be used. The bearings of the breaker and operating mechanism of isolator and breaker are to be lubricated with grease G and they normally do not need lubrication before the major overhauls / larger revisions.

5. **Treatment of Gas kits and Sealing Surfaces**

Whenever any gasketed part is opened, always the gasket is to be replaced with new one.

General

- Sealing surfaces and O rings shall be sparsely greased to accomplish a better sealing against this surface and at the same time protecting against corrosion.
- Material for de-greasing and cleaning : **Trichloroethane**
- Material for greasing of O ring : **Grease G**
- Material for greasing of O ring and Nitrate rubber in moving sealing : **Grease G**
- Material for removal of contact glue: **Acetone**
- Material for rust protection of untreated or phosphatised steel : **Valvolilnetectyl – 506**

6) **Treatment of Fixed contact surfaces**

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

- A. Silvered contact surfaces** - Silver contact surfaces shall be cleaned, if necessary, with a soft cloth and solvent (trichloroethane). **Steel brushing or grinding is not allowed.**
- B. Copper surfaces** – Copper surfaces shall be cleaned and made oxide/sulphate free. If necessary they shall be cleaned with cloth and solvent (trichloroethane) or steel brushing. After steel brushing, the surface shall always be cleaned from loose particles and dust with dry cloth/solvent.
- C. Aluminum Surfaces** Aluminum contact surfaces shall be cleaned with steel brush or emery cloth directly afterwards the surface should very thoroughly cleaned from particles and dust with a dry cloth. After this, a thin layer of Vaseline is applied. This shall be done within 5 minutes after cleaning. The joint shall be assembled within 15 minutes.

7) **Moving contact surfaces**

Silvered : Cleaned if necessary, with soft clothe and solvent (Tri-chloroethane). No steel brushing .

Non silver- Cleaned as silvered surfaces , can also be steel brushed.

After steel brushing, these shall be thoroughly cleaned for loose particles and dust.

Lubrication: Lubricant- grease K is applied in a very thin layer on the surfaces of the male contact and puffer cylinder. The superfluous grease is to be carefully removed.

8. **Tools for General Maintenance:**

The tools required for general maintenance as well as overhauling of breaker/insulator/ground switch etc. are as follows:

1. **Tools:**

- A normal tool kit like torque wrenches (10-300 Nm) etc.
- Lifting equipment like crane and slings etc.
- Special tools as prescribed in the overhaul instructions of the breaker.

9) **Safety reference:**

Refer chapter on safety instructions.

Testing shall be carried out during shutdown period and all testing which require removal of earth switch/earthing, shall be done under PTW

5.2 Isolators & Earth switches

1. Insulator – Insulation

They should be cleaned and inspected; porcelain insulation should be examined for cracks and other defects. Maintenance as given under bushings in sections 1.5.10 and 2.1.4 under transformers and OCB should be followed:

2. Contacts – fixed and moving

Contacts should be examined, over heating and / or other damages. They should be reconditioned or renewed as required. Fixed and moving copper contacts may be dressed by using a fine file or fine glass paper. Evmy or corborundun paper should not be used Earth connections of the isolator with earth blades should be checked and tightened. If the isolator is provided with sparking tips (arching horns) , they should be checked and ensured that sparking tips touch before the main contacts close these

tips and replace if badly damaged. Check auxiliary contacts for correct alignment lightly spray with petroleum jelly.

3. Mechanism Cleaning;
Examine the isolator control mechanism and renew parts. Lubricate and check for correct operation. In case motor operated mechanism, check operation of motor, motor brakes, limit switches etc.
4. Indicating devices and interlocks
Examine 'ON' and 'OFF' indicators and also interlocks, padlocking devices and test the same, whenever necessary.
5. Check supporting structure for loose nuts & bolts.
Check earthing connections of supporting structure and metallic parts of the isolator including operating handle.
6. Caution: Mechanical/electrical interlocks of earth switches with circuit breaker closing circuit and line isolators must always be kept in proper working condition.

5.3 BUS BARS

Bus bar of a sub station is the only part which has to carry maximum load current during normal operation as well during fault conditions.

Any poor joint or loose jumper in this part may create heating, voltage drop and current unbalance in three phase system during normal operation. Some loose jumper or a poor joint may open or fail during fault condition when heavy fault current is being fed by a bus bar section, this may result in 'bus fault'. And a bus fault is the worst kind of fault in a power system.

Thus a bus bar itself and all other components located in the 'bus bar zone ' like jumpers isolators, CTs, PTs, breakers etc. form a critical part of power system which if fail may create a bus fault. Thus it is very important to maintain this part of power system in perfect condition.

5.3.1 BUS BAR SUPPORTING INSULATORS:

The surface should be properly cleaned and examined for cracks etc. during every shutdown of Bus Bar.

5.3.2 JOINTS (Clamps and terminal connectors etc):

At the same time, it is necessary to check tightness of all nut bolts of various clamps at joints of all current carrying parts with a spanner gently but firmly. Use of toque wrench is more suitable. Remember, that a poor contact will develop enormous heat when in operation, which may ultimately cause a burn out or crack the insulators. A good method of identifying a bad joint is to make a habit of touching all joints soon after a shut down to see if it is hot, a good joint should not be hotter than the rest of the conductor or bus bar.

5.3.3 EARTH SHIELDS:

Check condition of earth shields for rusting, damage, loose strands, improper sag etc. Repair, renew or replace as required. Check the tightness of nuts and bolts of strain and suspension clamps of the earth shield. Check copper bonds to tower and earth lead of earth conductor of various peaks.

5.4 OPERATION AND MAINTENANCE OF CURRENT TRANSFORMERS

5.4.1 Construction:

- Generally the EHV instrument transformers in use are of ‘oil minimum’ type. Oil with quartz is filled inside the CTs.
- CTs are generally hermetically sealed and therefore practically free from maintenance.
- Expansion chamber is filled with Nitrogen, in some old CT’s bellows were provided in place of Nitrogen.
- All external iron parts are ‘hot dip galvanized ‘
- Facility for Selection of different ratios is provided on either primary side or on secondary side or a combination of both.

5.4.2 Testing of CT’s

5.4.2.1 IR MEASUREMENTS

- 1. EQUIPMENT AND TEST NAME** – Insulation Resistance measurement for EHV class current transformers.
- 2. PURPOSE** - IR measurement of 400, 220 kV and 132 kV current transformer between HV (Primary) winding and Test tap (for CTs having test taps) and between HV and earth (for CTs not having test taps).
- 3. DEFINITION**
INSULATION RESISTANCE: is defined as ratio of applied voltage (D.C.) to total leakage current (capacitive, absorption and conduction currents).
- 4. TESTING SCHEDULE AND FREQUENCY**
As per maintenance schedule.
- 5. TEST EQUIPMENT**
5kV megger and associated accessories like test leads etc.
- 6. ISOLATION REQUIRED**
 - a. CB should be in open position
 - b. Isolators from both sides of CT should be in open position
 - c. Earth switch should be opened at the time of IR measurement
- 7. SAFETY REFERENCE-** See safety instructions.
- 8. PRECAUTIONS**
 - a. Ensure that PTW is taken as per norms
 - b. There should be no joints in testing cables
 - c. Test leads should not touch any live part

- d. Megger body should be earthed
- e. Surface/terminals should be cleaned
- f. IR measurement should be carried out preferably in dry and sunny weather
- g. Never connect the test set to energized equipment
- h. The ground terminal must be connected first and removed at last.
- i. High voltage plugs should be free from moisture during installation and operation.
- j. If oil traces are found on the surface of CT, the same should be cleaned by Methyl Alcohol/CTC etc. Petrol and diesel should never be used.
- k. It should be ensured that whole testing equipment along with testing procedures are available at testing site. Testing must be carried out in presence of testing engineer only.
- l. After testing with high voltage (5 kV) test terminals must be grounded before being touched by any personnel.
- m. Test lead connecting the HV terminals should not touch the ground.
- n. Test leads should be properly screened/shielded

9. TESTING PROCEDURE

Connect the Megger. Connect the HV terminal to the Primary terminal of CT by using crocodile clip for firm grip. Carry out the measurement as per standard procedure given by the kit supplier. Note down the values as per format.

10. EVALUATION OF TEST RESULTS

Changes in the normal IR value of CT may occur due to abnormal conditions such as presence of moisture, dirt, dust crack in insulator of CT and degradation of insulation. Changes in the IR value of CT are also based on the weather conditions. It is advised to carry out IR measurement during sunny and dry weather preferably. Insulation Resistance changes with deterioration in insulating properties. Absolute value of IR is important to monitor but the size of change is equally important.

Measure capacitance and Tan Delta and compare with prescribed limits and previous results.

11) INSULATION RESISTANCE MEASUREMENT:

The IR values given below are just rough guide lines. Actual values will depend on the condition of the instrument transformer, weather condition, temperature, cleanliness of insulator and test equipments.

	<i>With 5 kV Insulation Tester</i>		
	400 kV	220/132 kV	33/11 kV
Primary to earth	> 400M Ω	> 250 M Ω	>100M Ω
Primary to secondary	> 400M Ω	> 250 M Ω	>100M Ω
Primary to Tertiary winding	> 400M Ω	> 250 M Ω	>100M Ω
	<i>With 500 V Insulation Tester</i>		
Secondary to earth	> 2 M Ω	> 1 M Ω	> 1 M Ω
Between secondaries	> 2 M Ω	> 1 M Ω	> 1 M Ω

Note: Take following measures while measuring insulation resistance with high voltage (5 kV) megger.

1. When meggering between primary and earth connect all the secondary windings together along with tertiary winding D3 and earth the same.
2. The bushing surface should be thoroughly cleaned and dried, before taking reading
3. The lead wire of megger should not touch ground or any part of CT.
4. When the megger reading stabilizes after 30 seconds the IR value should be taken.
5. While carrying the test a CT in service, the primary and secondary connections should be disconnected from all circuits.

5.5 OPERATION AND MAINTENANCE OF CVTs AND PTs

5.5.1 CVT

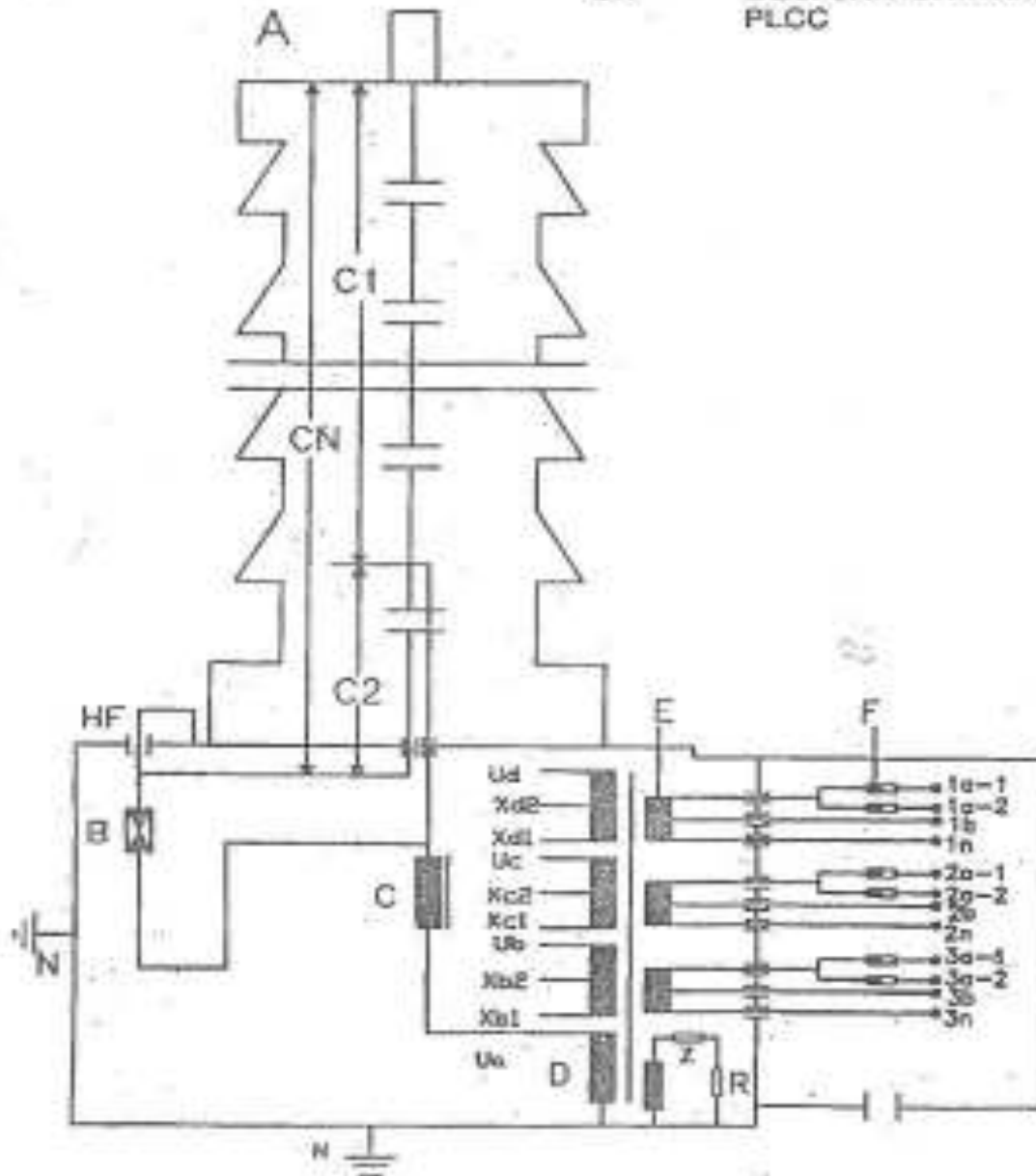
5.5.1.1 Brief Description of Capacitor Voltage Transformer:

The Capacitor Voltage transformer consists of a capacitive potential divider and an inductive medium voltage circuit. The inductive part is immersed in mineral oil and sealed with an air cushion inside a steel tank; One, two or three capacitor units are mounted on the tank and are used as capacitive potential divider. They consist of capacitor stacks made from paper or paper and PP film dielectric impregnated in transformer oil with an inert Nitrogen gas Cushion or metal bellow respectively and are hermetically sealed.

The steel tank with its lowest capacitor unit mounted in it is to be handled as a composite unit for transport since the cover of tank acts as bottom flange of the capacitor unit also.

The schematic diagram of the CVT is as show in fig.1

A	- H. V. Terminal	R	- Resistor
B	- Sparkgap	Z	- F. R. Circuit
C	- H. V. Choke	UD-Xd	} Compensating windings
D	- Primary Winding	UC-Xc	
E	- Secondary Winding	Ub-Xb	
F	- Fuses	Ua-	Lead connecting C. D.
HF	- H. F. Bushing (PLCC)	C1-	PRI. CAPACITANCE
N	- Earthing	C2-	SEC. (INTERMEDIATE) CAPACITANCE
		CN	EQU. CAPACITANCE FOR PLCC



TYPICAL SCHEMATIC DIAGRAM

Fig. 1

5.5.1.2 Main Equipment and Accessories:

For Capacitor Voltage Transformer with multi unit construction for higher voltage rating, the fitting and accessories are provided along with CVT units as shown in fig. 1.

5.5.1.3 Maintenance

- a. At check the earth connection of the tank once in a year.
- b. Depending upon atmospheric conditions clean outside surface of the insulator.
- c. The units are harmonically sealed hence oil does not deteriorate in service. In no case oil sample should be drawn for testing the dielectric strength or any other purpose.
- d. In case of fuse failure, the reason for the same should be investigated and fault should be rectified before fuses of proper rating are replaced. Fuses of too high a rating will not protect the CVT. On the other hand too low a rating will add to the burden of the CVT and the CVT may go out of accuracy class.
- e. Oil level shall be checked regularly.

5.6 LIGHTENING ARRESTOR

Various phenomena which may occur in the EHV power system may be responsible for EHV equipment failures. which are protected by providing L.A.

5.6.1 Health monitoring of the Lighting Arrester:

The lightning arresters normally do not require any maintenance during their life time. However a careful maintenance and monitoring can give good results and prevent system disturbances and damages. Measurement of the resistive component of the continuous leakage current provides the most accurate method for checking of the arrester condition in service. Under normal system conditions the arrester conducts less than 1 mA. The leakage current of an arrester is known to increase with time and hence it dictates the life of the arrester. Increased leakage current increases the temperature of zinc oxide elements which in turn increases the leakage current further. Once the leakage current reaches a critical level, the arrester would result in a thermal run away condition resulting the failure. The rate of change of leakage current is therefore an important parameter from the view point of liability.

Monitoring of leakage current on regular basis would help to identify any abnormal behavior of the arrester before it enters into the thermal run away conditions. Hence protective measure can be taken to avoid the failure of arrester that could lead to disruption in the operation and the damage to the other equipment. This can be achieved either by connecting permanently a surge monitor consisting of counter and leakage current indicator or by using portable leakage current analyzer.

5.6.2 Surge Monitor

- i. The primary function of the discharge counter is to count the surge that appears across the arrester. The surge counter operates only at impulse currents above a certain amplitude of 100 Amp. and above.
The surge monitor is an instrument used in conjunction with lightning arrester to continuously keep track of the condition of the arrester while it is energized. It is electrically connected in between the surge arrester and the earth. It consists of an ammeter and the discharge counter. Ammeter indicated the leakage current drawn by the arrester under steady state voltage condition, while the counter indicates the number of operations undergone by the arrester.

5.6.3 Surface leakage currents.

As with any other outdoor insulator, external surface leakage currents may temporarily occur on the arrester housing in rain or in conditions of high humidity combined with surface pollution. In addition internal surface leakage currents may appear due to moisture penetration. During measurements, the surface currents, may interfere with the leakage current of the resistors, however, the sensitivity to external and internal surface currents may be different for the various measurement methods. The influence of the external surface currents can be avoided, either by performing the measurements in dry conditions or any other suitable method, e.g. by passing the surface current to ground.

5.6.4 Measurement of the total leakage current

The total leakage current depends mainly on the capacitive current, since the resistive part is only a fraction of the capacitive current component. Further more the capacitive and resistive current components differ in phase by 90° , therefore a large increase in the resistive current of the metal-oxide resistors is needed before a significant change can be noticed in the total leakage current level. In addition the total leakage current is sensitive to the installation, since the capacitive current depends on the actual stray capacitances.

5.6.5 Checking of Surge Monitor

Check operation of Surge Monitor if found defective that shall be bypassed.

CHAPTER-6

6.1 Valve Regulated Lead Acid (VRLA) batteries

6.1.1 General Information

The power stake batteries are maintenance free type and work on oxygen recombination principal. The oxygen gas generated at the positive plate is transported in the gas phase through a highly absorbent and porous glass mat separator to the negative plate. The microporous glass separator is not completely saturated with electrolyte and the void space thus available allows an unimpeded access of oxygen to the negative plate. The oxygen gas gets reduced at the negative plate surface, thereby effectively suppressing the evolution of hydrogen. Consequently, power stake cells do not lose any water under normal operation and therefore, no topping – up is required.

Power stake valve regulated lead acid (VRLA) batteries use a patented MFX alloy for the positive grid which exhibits excellent deep discharge performance in combination with a universally acclaimed maintenance free lead-calcium alloy for the negative grid. Power stake cells give very long life if float service, in addition to deep discharge capability. The power stake batteries made are generally ranging from 100 AH to 5000 AH.

i. Voltage:

Power stake cells are 2V units which are assembled in modular racks to get 2V, 6V and 12V modules. These racks are mounted horizontally and can be stacked one above the other. For maximum service life, the recommended float voltage is 2.23 V per cell. Power stake cells are normally rated to an end cell voltage of 1.75 volts per cell, where it is necessary to terminate discharge at higher end cell voltage due to reasons of equipment compatibility. It can be done providing higher rated capacities.

ii) Charges:

Power stake cells should be charged with constant potential charges. The charging current should be limited to a maximum of $0.2 C_{10}$ the widely accepted charging methods use a current of $0.1 C_{10}$. Float charging is at 2.23 VPC and the recommended boost charge voltage is 2.30 VPC. If the charger does not have a float-cum-boost mode, it is important to switch over to float after boost not later than 24 hrs. under steady current condition.

iii) Applications

Power stake cells are designed specially for standby applications. The deep discharge cycle performance combined with excellent float characteristics make power stake the ideal choice for a wide range of industrial applications like telecom, power generating stations and sub stations, uninterrupted power supply, railways and solar photo voltaic.

6.2 OPERATION AND MAINTENANCE OF VRLA BATTERIES- SYSTEM MONITORING

6.2.1 GENERAL

The battery should be monitored regularly for obtaining satisfactory performance through out its operating life. These batteries do not require watering or specific gravity measurement. The following give the routine monitoring and visual checks for the trouble free operation.

The VRLA battery set should be checked for its healthiness by switching off the AC supply to the battery charger for 2 minute daily however if DC fail happens immediately after switching off the AC supply of the battery charger the supply should be switched ON and the battery set should be checked immediately.

6.2.2 PILOT CELL

A Pilot cell is selected in the series string to reflect the general condition of all cells in the battery. The cell selected should be the lowest cell voltage in the series string following the freshening charge. Reading and recording pilot cell voltage monthly serves as an indicator of battery condition between scheduled overall individual cell readings.

6.2.3 RECORDS

A complete recorded history of the battery operation is most desirable and helpful in obtaining satisfactory performance. Good records will also show when corrective action may be required to eliminate possible charging, maintenance or environment problems.

The following surveillance data must be read and permanently recorded for review by supervisory personnel so that any necessary remedial action is taken.

- A. Upon completion of the freshening charge and with the battery on float charge at the proper voltage for one week, read and record the following.
 - 1. Individual cell voltage
 - 2. Battery terminal voltage
 - 3. Ambient temperature
- B. Every 3 months, a complete set of readings as specified in paragraph A above must be recorded in the format.

6.2.4 EQUALIZE CHARGING

When non-uniformity in voltage has developed between cells, an equalize charge is given, it is given to restore all cells, to a fully charged condition.

An equalizing charge should be given when the following conditions exist:

- A. The float voltage of the pilot cells is atleast 0.05V below the average float voltage per cell in the bank.
- B. A recharge of battery is required in a minimum time period following an emergency discharge.
- C. Accurate periodic records of individual cell voltages show an increase in spread since the previous readings.

Whenever the battery given an equalize charge, an additional set of readings should be taken and recorded.

6.2.5 UNIT CLEANING:

Periodically clean cell covers with a dry 50mm paintbrush to remove accumulated dust. If any cell parts appear to be damp with electrolyte or show signs of corrosion contact the supplier for maintenance.

CAUTION;

Do not clean plastic parts with solvents, detergents, oils, minerals, spirits or spray-type cleaners as these may cause crazing or cracking of the plastic materials.

6.2.6 CONNECTIONS CHECKING

Battery terminals and inter-cell connections should be corrosion free and tight for trouble free operation. Periodically these connections should be inspected.

If corrosion is present, disconnect the connector from the terminal.

Gently clean the affected area using a brush or scouring pad. Apply a thin coating of petroleum jelly to the cleaned contact surfaces, after making the connections.

While tightening the inter-cell connections, extreme care should be taken so that neither any interconnecting strip nor any spanner / tool falls on any cell / group of cells which may short them in the process. This may damage the cell / group of cells and can even cause an accident.

ALL TERMINALS AND INTERCELL CONNECTIONS SHOULD BE RETORQUED AT LEAST ONCE EVERY SIX MONTHS TO 11N.m.

6.2.7 EQUALIZING CHARGE

i. GENERAL

Under normal operating conditions an equalizing charge is not required. An equalizing charge is a special charge given to a battery when non-uniformity in voltage has developed between cells. It is given to restore all cells to a fully charged condition. Use a charging voltage higher than the normal float voltage and for a specified number of hours, as determined by the voltage used.

Non-uniformity of cells may result from low float voltage due to improper adjustment of the charger or a panel voltmeter which reads an incorrect (higher) output voltage. Also variations in cell temperatures greater than 3°C in the string at a given time due to environmental conditions or module arrangement can cause low cells.

ii) EQUALIZING FREQUENCY

An equalizing charge should be given when the following conditions exist.

- A. The float voltage of the pilot cell is atleast 0.05V below the average float voltage per cell in the bank.
- B. A recharge of battery is required in a minimum time period following an emergency discharge.

iii) **EQUALIZING CHARGE METHOD**

Constant Voltage charge is the method for giving an equalizing charge. Determine the maximum voltage that may be applied to the system. This voltage, divided by the numbers of cells connected in series will establish the maximum volts per cell that may be used to perform the equalizing charge in the shortest period of time. Refer to Table for voltage and recommended time periods.

TABLE

Temperature	Cell Volts	Time
Below 15°C	2.30	30hrs.
15-32° C	2.30	20hrs.
above 32°C	2.30	12hrs.

Note: Time periods listed in Table are for different ambient temperature. For temperatures less than 15°C double the number of hours.

Raise the voltage to the maximum value permitted by the system equipment or recommended equalizing charge voltage whichever is lower. When charging current has tapered and stabilized (no further reduction for three hours), charge for the hours shown in table or until the lowest cell voltage ceases to rise. Monitoring of cell voltages should be started during the final 10% of the applicable time period to determine lowest cell voltage in the battery system.

iv) **DO’S & DONTS**

DO’S

1. Upon receipt of shipment unload and store the batteries in covered area.
2. Read “Installation and operating instruction Manual” prior to installation of the batteries.
3. Clean the batteries as and when dust accumulates.
4. The batteries if placed in cubical provide sufficient ventilation.
5. The terminal bolt connections to be torqued to 11Nm(100lb inch)
6. Restorque the connections once every six months.
7. Keep the batteries away from heat sources, sparks, fire etc.
8. Charge the batteries once every six months, if stored for long periods.
9. After a discharge recharge the batteries immediately.
10. Note down individual cell voltage readings once every one month.
11. Charge the batteries only at 2.23 volts per cell.

DONTS

1. Do not locate batteries in places exposed to direct sunlight, rain dust storm etc.
2. Do not ad water or acid.

3. Do not attempt to dismantle the battery.
4. Do not tamper with safety valves.
5. Do not over tighten the terminal bolts.
6. Do not allow any metal objects to rest on the battery or fall across the battery terminals.
7. Do not boost charge the batteries for more than 12 hrs.
8. Do not mix the batteries of different capacity or makes.
9. Do not mix ordinary conventional/low maintenance batteries with maintenance free VRLA Batteries.

Open circuit voltages for percentage charge of battery

STATE OF CHARGE OF VRLS TYPE MAINTENANCE FREE BATTERY SET WITH REFERENCE TO THE OPEN CIRCUIT VOLTAGE OF INDIVIDUAL CELLS.

TABLE -1	
%State of Charge	Open Circuit Voltage +0.05 -0.02
100	2.15
90	2.13
80	2.11
70	2.09
60	2.07
50	2.05
40	2.03
30	2.01
20	1.99
10	1.97
0	1.95

Open circuit voltages shall be measured after at least 3 hours of disconnecting from charging or 1 hour of disconnecting from discharging.

6.3 Common instructions for operation and maintenance of battery sets

- 6.3.1 Float charger should ALWAYS BE KEPT ON even when the battery set is being boost charged.
- 6.3.2 In case of failure of A. C. supply to the battery charger for more than two hours, the battery set should be boost charged at the equalizing current rate specified for the battery set for the number of hours the A. C. supply remained failed.
- 6.3.3 The exhaust fan(s) should be in working condition in the battery room. Equally sufficient air inlet should be provided to the battery room to prevent negative pressure developing in the battery room. When the exhaust fan is running, the door of the battery room should always be kept open in case there is no separate entry provided for air inlet to the battery room.

- 6.3.4 If the float voltage is correctly maintained as specified at item No. 1, the charging of the battery set at the equalizing current rates specified for the battery set is expected to be required once in every three months.
- 6.3.5 The cells between which intercell connector is to be removed, is first bypassed so that in the event of failure of A. C. supply to the battery charger during this work, the battery voltage will be available to meet the D. C. load. (Refer Appendix - A)
- 6.3.6 After boost charging make the battery set open circuit and allow the voltage of battery set to be reduced to value nearly equal to float voltage and then switch OFF the boost A.C. supply switch.

6.4 Common instructions for conventional type battery set.

- 6.4.1 Add only distilled water as per IS – 1069 to maintain cell electrolyte level. NEVER ADD ACID.
- 6.4.2 The formula for temperature correction of specific gravity is :

$$SG (27^{\circ}C) = SG (t) + 0.7 (t - 27^{\circ}C)$$
 where t = temperature of the cell.

Example :

- a) Suppose the temperature of battery cell is 32°C and the reading of the hydrometer is 1205, then the corrected specific gravity at 27°C will be

$$1205 + 0.7 \times (32 - 27) = 1208.5.$$
- b) Suppose the temperature of battery cell is 22°C and the reading of the hydrometer is 1205, then the corrected specific gravity at 27°C will be

$$1205 + 0.7 \times (22 - 27) = 1201.5.$$
- 6.4.3 If inspite of repeated charging, the specific gravity or voltage of some cell(s) does not improve, these are to be considered weak cells. These should be removed from the battery set one at a time and charged independently at the specified recharging current for the battery set until gassing starts. The recharging current is reduced to the finishing current specified for the battery set till the cell appears to be fully charged, i.e., the specific gravity of the cell becomes stationary. Then charging should be stopped for one hour and then be resumed at the finishing current rate until free gassing again takes place. A further stop of one hour duration should be made and charge should again be resumed at the finishing current rate. These stops of one hour duration alternated by charging at the finishing current rate should be repeated until gassing starts simultaneously with switching on of the charging current. If in spite of this special charge, the cells do not pick up the specific gravity or voltage, the cells are to be replaced.
- 6.4.4 Premature gassing in any cell(s) is due to negative plates of low capacity because of sulphation. Such cells should be removed from the battery set and given prolonged charging at very low rates at half the finishing rate of charge specified for the battery set. As soon as the premature gassing is noted, the rate of charge should be reduced to a point where the gassing ceases.

- 6.4.5 During charging, if the temperature of the electrolyte tends to rise beyond 45°C, the current should be reduced to one third of the value. If necessary, charging can be suspended for some time to allow the temperature to come down.
- 6.4.6 Adjustment of the specific gravity should be done only after the battery set has been given a long duration boost charging at the current(s) specified for the battery set and the cells show signs of being charged. The specific gravity should be adjusted only near the end of such charging, replacing electrolyte with distilled water in cells having high gravity, or replacing electrolyte in cells having low gravity with electrolyte from cells having high gravity.
- 6.4.7 Excessive gassing and progressive increase in the specific gravity during floating conditions indicate that the floating voltage is high. Check accuracy of the voltmeter in the charger & take remedial action if necessary.
- 6.4.8 Progressive lower values of the specific gravity during floating conditions indicate that the floating voltage is set low. Check accuracy of the voltmeter in the charger & take remedial action if necessary. Grounded circuits also circulate leakage currents thereby discharging the battery. Check for the leakage of the electrolyte or grounding of the current carrying conductors in the charger as well as in the battery circuit.
- 6.4.9 Continuous lowering of the electrolyte level may be due to leakage of the electrolyte or loss of water in electrolyte because of evaporation by too high a floating voltage or excessive charging. Replace container immediately in case of leakage. Also check accuracy of the voltmeter in the charger & take remedial action if necessary.
- 6.4.10 Never store acid, i.e., electrolyte of specific gravity higher than 1200.

6.5 Common instructions for maintenance free VRLA type battery sets.

- 6.5.1 Temperature compensation lead should always be connected to charger and its sensor must be placed in the battery room. So that the charger can maintain constant voltage according to temperature variation in the battery room. The temperature compensation is 3 mV/cell/deg C. for variation in battery room temperature.
- 6.5.2 Voltmeter of precision 0.01 Volt should always be used to take battery voltage readings.
- 6.5.3 The formula for temperature correction of battery voltage is :

$$V (27^{\circ}\text{C}) = V (t) - 0.003 (t - 27^{\circ}\text{C})$$

where t = Ambient temperature of the battery room.

Example :

- a) Suppose the temperature of battery room is 32°C and the reading of the voltmeter is 2.20 V, then the corrected voltage at 27°C will be
 $-0.003 \times (32 - 27) = 2.185 \text{ V.}$
- b) Suppose the temperature of battery room is 22°C and the reading of the voltmeter is 2.20 V, then the corrected voltage at 27°C will be
 $-0.003 \times (22 - 27) = 2.215 \text{ V}$

CHAPTER-7

7.1 Repair and Maintenance of Capacitor Banks

7.1.1 REPAIRS OF MINOR DEFECTS IN CAPACITORS

1. It is important that few points be considered for obtaining satisfactory performance and long useful life of capacitors. Do not attempt any repairs which may open the sealed internal assembly or which may cause the impregnant to come to contact with air or other materials. Any leakage that has been caused to a unit due to mechanical damaged should be stopped, as soon as possible, by soldering (using only resin alcohol flux) or by plugging the hole. Do not attempt to add any impregnating liquid to such units. Following are few faults, which are likely to develop, and necessary quick repairs required to be done.

7.1.2 Table for Minor defects, cause and Repairs

Symptoms	Cause	Remedy/Repair
Leakage of impregnant This should be stopped immediately as and when noticed.	a) Leak in welded & soldered portion.	a) Clean the portion thoroughly, rub with emery cloth, dry and solder with acid free resin core solder.
	b) Leak from terminal cap and collar.	b) Clean the portion, dry and apply 'Araldite 1 or M. seal
	c) Leak from sealing holes.	c) Re-solder the place
	d) Leak from broken terminal bushing.	d) Discard the unit.
B) Overheating the unit	a) Poor Ventilation	a) Find the cause & improve the free circulation of air.
	b) Excessive ambient temperature	b) Arrange for forced ventilation.
	c) Over voltage	c) Reduce voltage if possible otherwise switch off the capacitor.
	d) Harmonic in supply	d) Remedy for excessive overloads could be relocation of the capacitors (location away from harmonic generation), using 6% series reactor, if possible.
	e) High frequency oscillations caused by bad contacts in capacitor circuit.	e) High frequency oscillation giving rise to overheating and overstressing the capacitor must be avoided by maintaining tight and good electrical contacts in the capacitor circuit. Regular inspection of all contacts of the capacitors equipment is, therefore, recommended.
c) Fuse blowing	a) Short circuit unit(unit defective)	a) Remove the unit and check IR value (not below 50 megaohms as per ISO, check the clanging current by applying LT supply. If these values are not within limits, reject the unit.

	b) Fuse defective or not of correct rating.	b) Replace with suitable fuse link.
	c) Overcorrect due to over voltage & harmonics.	c) Reduce voltage and control harmonics.
	d) Short external to the unit.	d) Check and remove the short and ensure the unit is OK before re-commissioning..
D) Current below normal value	a) Low voltage	a) No repair (No harm)
	b) Unit fuse blown	b) Disconnect the unit & Check IR value and charging current.
	c) Some units out of circuit or open	c) Check & see individual unit.
	d) Loose connection	d) Tighten them carefully.
E) Abnormal bulging	a) Impregnate almost leaked out	Reject the unit.
	b) Gas formation due to internal arcing	b) Reject the unit.
F) Crackling noise	Partial Internal Faults	Cases are very rare.
		Check IR value and charging current.

Note :

- a. In all the above cases, please ensure that phases are balanced with equal number of units and phase capacitance (for the capacitor bank without series reactors).
- b. When the minor repairs are done on the capacitor unit, then this particular unit should be removed and shifted to the outer ends of the row and should be kept under constant observations/watch (e.g. noting charging current, IR values at periodical intervals).

7.2 INSPECTION AND PREVENTIVE MAINTENANCE OF CAPACITOR BANK

Actually the capacitor units are a sealed one and do not require any maintenance. A periodic check of a few important parts of capacitor units/bank is very necessary to avoid any sudden failure. Table 1 gives the recommended schedule for inspection and preventive maintenance of capacitor banks which should be meticulously followed:

Schedule for Inspection & Maintenance

Recommended Schedule for Inspection and Preventive Maintenance of Capacitor Bank.

Table-1

Equipment/ item whose inspection/ maintenance is required		Points to be checked / noted and details of maintenance work to be done		Frequency of inspection /Maintenance	Remarks
1		2		3	4
1	Capacitor unit	a	Check of leakage of impregnant form terminals	Monthly	If necessary the capacitor unit may be checked by testing (The

			/ lid , welded seams		IR values and charging current should be within acceptable limits). Repairs may be carried out if possible otherwise it should be removed from the circuit to avoid damage to other healthy units in the proximity.
		b	Check for cracks or bulging of the relay of capacitor units.	Weekly	
		c	Terminal bushings I Examine for cracks and other damages II Remove all dirt, paint and other deposits	Monthly	
		d	Check for general cleanliness	“	Capacitor units should be properly cleaned as and when the surface condition deteriorates and warrants repainting.
		e	Repaint capacitor units and supporting structures.	As and when necessary	
		f	Check IR values of the capacitor units		The insulation resistance of the capacitor units between bushing to earth shall be checked half yearly with a megger of not less than 500 volts (preferably 2500 V) output. The other bushings should be shorted during test. The readings are compared with those taken at the time of commissioning and on the previous occasions. For capacitor designed and manufactured as per ISS the insulating resistance so determined shall not be less than 50 M.ohms. In case the value measured is less than 50 M. ohms, the unit should not be put in service. For the capacitors manufactured according to other specifications, the minimum insulation resistance should be as specified in the supplier's' technical literature.
			Check charging current	Half yearly	The current drawn by the unit at specified voltage giving LT supply is measured with the help of ammeter and volt meter (or AVO meter) and compared with

				the design current (rated current of unit) in similar condition. Lower current indicates partial failure. The capacitance of the units be checked with the help of capacitance meter wherever available instead of nothing the charging currents.
2	Capacitor fuse (if external fuses are provided).	Check for continuity and tightness	Weekly	In case of capacitor units protected through external fuses, it should be ensured that the fuses are of proper design and rating and are properly fitted. They should be fitted in such a way as not to cause unnecessary tension at the joint, where the terminal bushing is fitted at the top of the container. Ensure for the availability of spare fuses of correct ratings.
3	Capacitor bank, bus bar connections and rack.	Post-insulation used for bus for support. Estimate for cracks and other damages. Remove all dirt, Paint. And other deposits.	Monthly	
		b) The bus bar should be checked for tight connections, deformation and clearances. The bus bar should not be allowed to get rusty.		
		c) The racks should be checked for corrosion and dirt.		
		d) Causes for developing hot spots in the system on account of loose jointing, improper sizes of equipments are checked up and remedial measures taken.	“	Tighten up all screws and nuts specially electrical connections so that there are no loose contacts. Tighten the bushing terminal nuts just sufficient to make good electrical contacts. Avoid over tightening as it may result in rotation of bushing rod and in leakages from the soldered bushings due to excessive stress on the soldered joints
		e) earthing of the capacitor bank Check	Monthly	Adequate earthing of capacitor units/ rack should be ensured. Capacitor unit case should be properly screwed with the supporting channel making good electrical contacts . It should be

				ensures that neutral of star connected capacitor bank is not earthing.
		f) Check IR value of the capacitor bank bus.	Half yearly.	
4	Voltage transformer (RVT)	a) Check terminal connections for tightness	Monthly	
		b) Check oil level	Monthly	
		c) Check dielectric strength of oil.	Half yearly.	
		d) Check RVT fuses for their healthiness	Monthly	
		e) Check IR Value	Half yearly.	Sudden drop in IR value needs to be investigated.
		f) Voltage across open delta winding of RVT at the C&R panel	Monthly	Voltage across open delta winding of RVT should be checked monthly. Normally it should be the same as was recorded during first commissioning. However, if there has been an increase, it will mean some unbalance is there although the limit has not reached to trip the breaker. The reasons of unbalance should be investigated and remedial measures taken accordingly.
5	Series reactor	Where the series reactor are installed with the capacitor banks, their inspection and maintenance be done as per prevalent practice for that of the transformer according to the 'MSE Manual' of Punjab State Electricity Board.	As per MSE manual	
6	Circuit breaker	Inspection & maintenance be done according to the MSE Manual of PSEB.	After	After every tripping of capacitor bank on fault or once a month whichever is earlier.
7	C&R panel	Maintenance and periodical testing on the control and relay panel be done according to the MSE manual of PSEB.	As per MSE Manual	

Note: The work on the capacitor bank should be done after switching 'OFF' the capacitor bank fully discharging to a safe value with the insulating earthing rod (wait for 5 minutes before handling) and after providing temporary earth which is left intact till the work is finished. Ensure that no hardware or tools are left inside the assembly.

CHAPTER-8

8.1 Inspection and maintenance of Transmission Lines

8.1.1 Inspection from ground:

Normal patrolling of transmission line from ground is recommended to be carried out twice in a year, once in a month of April/May and again in the month of September/October and critical lines once in a month by a team of Engineer/Junior Engineer/Lineman with the help of binocular. All the possible items shall be inspected as per format-II. The condition of the various visible items shall be recorded in this format.

Once the total line is patrolled, the report of defect observed in the line is to be prepared in format III and copy sent to Executive Engineer / Superintending Engineer.

Work of minor nature which are easily accessible, such as shortage of members, tightening of nuts & bolts and providing of step bolts can also be taken up. Safety items and T&Ps such as Hunter shoes, water bags, binoculars, torch, stick, rain coat, required spanners, nut and bolts of assorted size, step bolts etc. should also be carried by the patrolling team. Trees, shrubs, bushes etc. which infringe on the clearance are to be cut during patrolling.

In case of rectification/maintenance which is required to be done under shutdown, the Assistant Engineer in charge of the line shall prepare a program for taking shutdown/shutdowns and arrange to the same through the Executive Engineer/Superintending Engineer.

Night patrolling of the lines may also be carried out for detecting the hotspots etc. once in a year on some locations on sample basis.

8.1.2 Precautions & General Instructions during patrolling

- i. Poles, towers or structures should not be climbed up under any circumstances during normal patrol.
- ii. If any snapped conductor/earth wire is found lying on the ground, the nearby residents should be cautioned that no humans, animals, bullock carts, tractor trolleys, camel carts should be allowed to go near the snapped conductor/earth wire. The matter should be immediately reported by the patrolman to the Assistant Engineer for asking remedial measures.
- iii. Any abnormal observation should be reported to the Assistant Engineer immediately by the patrolman.

8.1.3 Ground patrolling :

The following points are to be checked and attended during patrolling :-

General

- i. Adequacy of clearance of trees, shrubs, bushes, etc. from the line conductors is to be checked. All trees, shrubs, bushes etc. which infringe on the clearances are to be cut. Small bush growth, shrubs and trees whose height is not expected to rise beyond 3 meters may be allowed to remain. Grass growth on the boundary walls (Dola) of farms which can grow to a height such as to infringe on the clearance should be cut. Trees outside right of way but of such height as may infringe on line clearance should be trimmed accordingly. Trees or bushes growing inside or very close to the legs of towers should be cut/removed.

The vertical clearance of conductor from trees / shrubs / bushes etc. should be checked when atmospheric temperature is high and the line is adequately loaded.

- ii. Vertical and horizontal clearances between the lowest or nearest conductor & any part of buildings/structures under construction below or adjacent to the line, etc. is to be checked and should not be less than the values given below as per IE rules 1956 :-

66 kV 132 kV 220 kV 400 kV

a) Vertical Clearance 4.0 m 4.6 m 5.5 m 7.30

b) Horizontal clearance 2.3 m 2.9 m 3.8 m 5.60

(on the basis of maximum deflection due to wind pressure) In case the clearances are less than those given above action should be taken to stop all such new constructions works.

- iii. Ground clearance infringement due to construction of roads, ditches and channels or due to earth and refuge dumped near or under the line or due to shifting sand dunes should be checked and arrangements made such that the minimum ground clearances given below are maintained as per IE rules 1956.

a. 66 kV lines - 5.5 m

b. 132 kV lines - 6.1 m

c. 220 kV lines - 7.0 m

d. 400 kV lines - 8.8 m

- iv. Clearance of lowest conductor from power lines or telecommunication lines should be checked, if necessary, by the-odolite. The following are the minimum clearances, as per Rule 87 IER 1956.

a. From 400 kV lines - 5.49 m

b. From 220 kV lines - 4.58 m

c. From 132 kV lines - 3.05 m

d. From 66 kV lines - 2.44 m

Contact concerned authority for maintaining required clearance.

8.1.4 Tower

- i. Check the backfilling of the foundation of tower. Also check that the earth around the tower footing has not sunk or got eroded or water logged or is in any way causing danger to the tower footing or exposing the foundation. Take remedial measures to restore tower footing including provision of revetment if necessary.

- ii. The earth around the tower footing should not be above the concrete level. i.e., above the chimney so as to cause damage to the tower leg. The excess earth should be removed.
- iii. Check that the concrete of the chimney is not cracked or the coping is not damaged. Take measures to rectify the defect.
- iv. For tower locations provided with revetment, check that the retaining wall is neither broken nor is in danger of failing. Take remedial measures.
- v. Check that the earthing on the tower leg is intact. If damaged, repair is to be undertaken and if missing, then it should be replaced. Measure the Earth Resistance of each Tower.
- vi. Check that all the tower members are intact and in place and not damaged due to any reason. All missing and damaged members are to be replaced at the earliest. Check that the nuts & bolts are not loose or missing. Nuts & bolts found loose or missing should be immediately tightened. replaced.
- vii. Check that the numberings on the tower and markings on the danger plates or phase plates are readable. Take remedial measures.
- viii. Check that the galvanizing or painting of the tower members is in proper condition. Take remedial measures to restore galvanizing or painting to good condition.
- ix. Check that there is no corrosion of any part of the tower. Immediate measures should be taken to rectify the defect.
- x. Check that the anti climbing devices and barbed wire are fixed and in place. If missing or damaged or incomplete, take suitable action.
- xi. Check that there are no bird nests on the tower or cross arms. Remove which are existing.
- xii. In the case of H Poles, TPS structures, four pole structures or fabricated cut point structures, check the fixing of the guys and their foundations. Any shortcomings (Loose/disconnected) should be rectified. If missing, arrange for replacement.

8.1.5 Insulators & Hardware

- i. Check that the insulators have not flashed over or have got chipped. Note down details and arrange replacement.
- ii. Check that the arcing horns are not loose or touching the conductor or missing. Arrange rectification.
- iii. Check that the vibration dampers are not damaged. Arrange replacement. Also check that the vibration dampers are in their proper position i.e. they have not shifted along the conductor/earth wire and away from the tower.

The following are the recommended distances:

1. ACSR Moose –	Suspension Tower	- 1.35 M
	Tension Tower (2 nos.)	- 1.35 & 2.70 M
2. ACSR Panther		- 1.14 M
3. ACSR Zebra		- 1.45 M
4. 7/3.15 mm E/W		- 0.63 M
5. 7/3.66 mm E/W		- 0.65 M & 1.3 M
5. 7/4.00 mm E/W		- 0.68 M

(Clarification: In case of suspension towers, the distance is from the center of the suspension clamp. In case of bolted type tension hardware, the distance is from the end of the clamp. In the case of compression type tension hardware, the distance is from the end of the aluminum / steel portion). In the case of Bates damper, check that P.G. clamps and the conductor are in their proper place. Arrange to attend shortcomings, if any.

- iv. QCheck that the armor rods are not damaged and that they are not damaging the conductor. Arrange replacement/rectification.
- v. Check the jumpers at tension points. There should not be any damage to the conductor or the P.G. clamps or the compressed ends. Arrange rectification/replacement.
- vi. Check that the tension clamps/suspension clamps of the conductor & earth wire are not damaged/rusted. In case of earth wire, check that the earth wire has not become free from the suspension clamps and is lying on some tower member.
- vii. In the case of tension towers check with binoculars that the pins of the D-shackles of the hardwares have not worn out. Arrange replacement, if necessary.
- viii. Check that the earth bond provided on the suspension and tension hardware of earth wire is intact and connected to the tower. Arrange rectification/replacement.

8.1.6 Conductor & Earth wire (Between towers)

- i. Check for visible damages like cut strands, deposits, burn marks, corrosion etc. Take remedial measures.
- ii. Check that the conductor/earth wire has not moved out of mid span joints.

8.1.7 Schedule of inspection & maintenance activities :

There is a need to decide the frequency of carrying out inspection of various items with and without shut down. The schedule for maintenance and attending the defects noticed during normal patrolling is also given for guidance at format-I.

8.1.8 Fault inspection of line :

Apart from the normal inspection of the line, detailed inspection of the line is required to be carried out in case of occurring of fault of minor/major nature. This includes the failure of

towers, conductors/ earth wire and insulators/hardware etc. The fault inspection report shall be prepared as per format V.

8.1.9 Inspection/check report for major maintenance work :

It is utmost important that required inspection/testing/checks are carried out during maintenance work and also after completion of maintenance activities so as to ensure smooth charging of line. This check list including testing details is indicated in format VI.

While replacing the insulators, it should be ensured that the mechanically as well as electrically healthy insulators should only be used. The insulators should be meggered at ground using 5 kV megger and their IR value should be above 1000 Mega ohms under dry condition. The results may be recorded as per format VI.

Carryout scanning through through thermovision camera of Lines which are critical
On Line cleaning of insulators for lines Passing through polluted /fog affected area.

8.2 SCHEDULE AND FORMATS

8.2.1 MAINTENANCE SCHEDULES OF TRANSMISSION LINES

Format-I

<i>Sl.No.</i>	<i>Name of the activity</i>	<i>Frequency</i>	<i>Nature</i>
A	Ground inspection by lineman/team	Half yearly (Pre-monsoon+ after monsoon)	Non S/D
B	Inspection of critical line/critical Section	Annually	Non S/D
C	Thermo-vision scanning of critical lines/critical locations (spacer-dampers/jumpers/Insulators)	Annually	Non S/D
D	Punctured Insulator Detection of critical location	Annually	Non S/D
E	Attending of defects	Annually	Non S/D
1	Foundation-backfilling/soil erosion	Immediately	Non S/D
2	Attending of crack of chimney	Immediately	Non S/D
3	Replacement of Danger/number /Phase/Circuit plate	Within 3 months	Non S/D
4	Replacement of missing/damaged tower components	Immediately	Non S/D
5	Trimming/cutting of trees which do not require S/D	Immediately	Non S/D
6	Trimming/Cutting of trees which require S/D	Immediately	S/D
7	Replacement of broken/damaged insulator in normal area (two or less/string)	Yearly	HLM or S/D
8	Replacement of broken/damaged insulator in normal area (three/string)	Immediately	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 (two/string)	Immediately	HLM or S/D
11	Cleaning of insulators in polluted area a. Critical pollution	Half yearly (after-monsoon & pre	S/D S/D

	b. Normal pollution	winter) Yearly	
12	Attending of damage to conductor by temporary method	Half yearly	HLM or S/D
13	Attending of damage to conductor by permanent method	Yearly	S/D
14.	Attending of failed spacer-dampers a. Causing conductor damage b. Hanging/dislocated spacer-dampers	Half yearly Yearly	HLM or S/D
15	Attending of hot spots	Immediately	HLM or S/D
16	Temp .measures for land slide/sinking of foundation	Immediately	Non S/D
17	Tightening of B&N/Anchor bolts	Immediately	Non S/D or HLM
18	Re-fixing of vibration dampers of conductor/earthwire	Yearly	S/D or HLM
19	Measurement of tower footing resistance Normal locations / Critical locations	Once in two year / Yearly	Non S/D Non S/D

HLM - Hot Line Maintenance

Criteria for critical lines :

1. No. of failures in past
2. Affected by natural reasons i.e. pollution/flood/land slides etc.
3. Evacuation lines for power projects
4. Inter region lines

8.2.2 Format - II

Name of Sub-Division
 :
 Name of the line
 :
 Member of Team (Lineman/Jen/Executive)
 :
 Date of Patrolling
 :

Name of
 Division :

	Location	1	2	3	continued
	Span	1_2	2_ 3	3	as reqd.
1)	Clearance of line conductors from trees, shrubs, bushes, etc.				
2)	Vertical & horizontal clearance of neighboring buildings & structures under construction.				
3)	Ground clearance from roads, ditches, channels, earth, refuge dump, shifting sand dunes.				
4)	Clearances from power lines & telecommunication lines.				
5)	Tower foundation free from erosion, water logging or sinking.				
6)	Earth around tower footing below concrete level.				
7)	Concrete of chimney or coping.				
8)	Retaining valve of revetment & general condition of revetment				
9)	Earthing of tower leg.				

- 10) Tower members and nuts & bolts.
- 11) Number plates, phase plates & danger plates.
- 12) Galvanising / painting.
- 13) Anti-climbing devices & barbed wire.
- 14) Bird nests.
- 15) Guy wires.
- 16) Insulator arching horns.
- 17) Vibration dampers.
- 18) Armour rods.
- 19)
- 20) Jumpers.
- 21) Suspension/Tension clamps.
- 22) Pins of D-shackles of tension hardwares.
- 23) Earth bond.
- 24) Conductor.
- 25) Earth wire.

Signature & Date

:

8.2.3 Format - III

Name of Sub-Division :
 Name of the line :
 Member of Team (Lineman/Jen/Executive) :
 Date of Patrolling :

Name of Division :

Details of Defects / Shortcomings and their Rectification

Loc. No. or Span	Nature of defects or shortcomings	Remedial action to be taken	Remedial action taken	Reason for not taking remedial action	Remarks
1	2	3	4	5	6

8.2.5 INSPECTION REPORT FOR MAJOR MAINTENANCE/BREAKDOWN WORKS

Format V

NAME OF REGION :
 NAME OF LINE :
 MEMBER OF TEAM (LINEMAN/JE/EXECUTIVE) :
 DATE OF PATROLLING :

TYPE OF MAINTENANCE	DESCRIPTION		STATUS
Insulator Replacement	1	Whether IR value of insulators checked in stores	Yes / No
	2	Check all bolts & pins for their correct sizes, all nuts, lock nuts, washers and split pins are fitted correctly	
	3	Check verticality of insulator string (for susp. Tower), in good condition with correct number of insulators in string	
	4	Check conductor clamps ensuring that all nuts and spring washers are fitted and clamp has no signs of cracking	
Collapse of tower/conductor replacement	1	Check point no.1,2,3 and 4 above for Insulator replacement	
	2	Check damper positions are correct	
	3	From tower, visually check spacers in adjacent spans	
	4	Check ACD, Step bolts, correct plates and no damaged steel work.	

Signature & Date

8.2.6 IR VALUE AND OTHER DETAILS OF INSULATORS

Format - VI

Name of Region Area/Zone :
Name of Line :
Members of Team (Lineman/JE/Executive) :
Date of activity :
Make and Sl.No.of megger used :
Location No/Phase :

Sl.No.	Batch No.	Manufacturer	IR Value in Mega Ohms	Remarks
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				
11				
12				

Signature & date :

8.3 PROBABLE CAUSES OF FAILURE OF THE TRANSMISSION LINE COMPONENTS

8.3.1 Introduction

In the power system, transmission lines play a very vital role in transmission of power. For a healthy/reliable power system, it is desirable that there are minimum power break-downs/outages on the transmission lines. For avoiding break-down on the lines planned preventive maintenance is considered to be absolutely necessary. This aspect not only reduces the outage period of the transmission lines but 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 as lack of knowledge of 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 snap due to loose nuts and bolts on dead end compression type clamps etc.

8.3.2 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. Some times, split pins of hardwares/security clips of disc. insulators are also found broken or 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. In case earthing of tower is not proper, back flashover due to lightning strokes, direct lightning 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.
4. Excessive vibrations on conductor.
5. Dropping of birds/ refuse/ defecation by birds on insulators where bird's guards are not provided.
6. Throwing of stones missiles, shooting practices 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.

8.3.3 Probable Causes of Failure of Conductor and Conductor Accessories

Conductor and conductor accessories form 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 of voltage rating up to 220kV, single ACSR or Aluminum Alloy conductor and in transmission lines of voltage rating 400kV and above, twin or quad ACSR or Aluminum Alloy Conductors are used. 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 can 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 lightning 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 / Helicopters 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.

8.3.4 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 loses 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.

iv. 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.

Due to vibrations, 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

Due to vibration, 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

8.3.5 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, bolts and 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 drawing, 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. Failure due to inefficient earthing and also due to number of 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.

8.3.6 Probable Causes for Failure of Towers

The tower and hardware is the main component 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.

Tower structure is a main component of transmission system. The failure/collapse of a tower can cause interruption of power supply for prolonged periods. The erection of a new tower or setting right 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 weightage to the aspect not only from the point of preventive maintenance of tower but also to know the causes leading to its failure.

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

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 (surficial and sub surficial flow).
5. Other causes including opening of gates of the spillways on upstream side of the tower etc.

8.3.7 Probable Causes of Damage of Earthing Electrode and Earthing strip Etc.

The earthing system of the transmission towers play a major role during normal working as well as during abnormal working of transmission lines. 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).

8.4 MAINTENANCE PROCEDURES OF EHV TRANSMISSION LINES

8.4.1 INTRODUCTION

Today, RVPNL is maintaining transmission lines of Voltage class upto EHV AC 400 kV. These lines criss-cross the entire length and breadth of the Rajasthan and power is transmitted on these lines to the remotest corner. A very high degree of availability is therefore required which consequently gives break down maintenance of these elements paramount importance.

Breakdown maintenance is not a desired phenomenon. RVPNL try their utmost to carry out preventive maintenance in such a fashion so as to avoid break down maintenance to the extent possible. No amount of effort, however, is sufficient so as to ward off breakdowns altogether.

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
- iv. Conductor snapping & breakages
- vi. Insulator failure
- vii. Reduction in clearance due to swing/Falling and growth of tree & branches
- viii. Hardware failure

Although there are minor/major modification in the design of towers ranging from 66kV to 400kV 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 :

8.4.2 METHODOLOGY

Declaration of Break-down on line

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

8.4.3 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.

8.4.4 Patrolling and scheduling

Patrolling is carried out and a schedule is prepared for the restoration of the line at the earliest taking in to account various factors like importance of the line (evacuation line, link line, inter regional 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 can not be a hard and fast rule or even a

thumb rule to determine the restoration time of a broken down line. It all depends on factors mentioned above as also many other reasons.

After getting a message of location of breakdown, a responsible engineer shall immediately visit the site. He shall inspect :

- The approach to the location and list out the activities to be carried out to clear the approach for truck, tractor & light vehicle
- Inspect the spot and list out the activities to be carried out to clear the site from bushes and other hindrances for easy handling of T&P and material required
- Inspect the failed part of the line and list out the materials and T&P required for the hob
- 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 be formed activity-wise and their transportation arrangement to the site be made.

The scope of above activities will widen as per the nature of break down and controlling officer will be the best judge for planning. Similarly, meals are to be arranged at site only to avoid wastage of time. First aid and seasonal medical drugs shall be available for the maintenance of health of the workers. There should always be some vehicle available at workspot 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 perfect ness. Site camps for the convenience of the workers can be arranged in local Gram Panchayat halls etc. as per the facility available.

8.4.5 ANTI CORROSIVE MEASURES

It is observed that there is rusting of tower super structure, anti-climbing devices, stubs at concrete joints etc. since the transmission line passes through open fields the tower super-structure has to face all the climatic abnormalities/pollution effects due to chemical industries etc., as such tower super structure may get rusted at some specific locations.

8.4.6 Preventive measures/anticorrosive measures

1. Apply two coats of black bitumen paint of good quality on the tower stub/legs above ground level and also around the concrete muffs.
2. remove the soil from the stubs/tower legs and cut down the heavy growth of grass/bushes to avoid rusting
3. Apply red oxide and aluminum paint on the rusted tower super structure and anti climbing devices. This should be cleaned with wire brush etc. before applying the paint of the rusted structure.
4. The tower super structure and all other accessories used on the tower should be of galvanized steel for avoiding corrosion etc.

Generally, it is seen that maximum number of tower failures are due to failure of its foundations. This is due to design deficiency and not maintaining the quality of work of foundation during construction stage and wrong soil classification and sometimes due to negligence in maintenance.

- a) It is the experience that very less maintenance is possible for the foundation underground. However, following is the maintenance to be carried out for the portion above ground level, which is mostly a chimney part and muffing. The soil around chimney gets disturbed due to cultivation and various types of quarrying/digging by various departments for buildings, roads, railways, dams and for other construction purposes. Land sliding/hill sinking etc. takes place due to diverted water from nallahs, rivers etc. and other natural causes. Hence the only remedy remains to take care of all these soil erosions in time and due to necessary works such as building of retaining walls, diversions for water wherever required.
- b) Similarly, bushes should not be allowed to grow nearby foundations which cause storage of more water near foundation and if some hair cracks are there in the foundation, it causes water seepage in the concrete and results in rusting. This is practical experience observed.
- c) Similarly, soil should not be above muffing level to avoid rusting of the stub. If any cracks are there in chimney, it should be repaired by using cement slurry. In case of field where chemical fertilizers are much in use or near factories where factory water comes near the chimneys shall be given protective coating to avoid deterioration of chimney concrete.

The condition of the foundation can be assessed by non destructive methods and accordingly the foundation strengthening or repair is to be carried out as per result. If some cracks are found in chimney, the repair work is to be done. If only chimney is damaged, except healthy portion of the chimney the upper portion is to be dismantled and re-done with fresh material after observing routine procedure and precautions. If superficial cracks are there, it should be attended by grouting with cement slurry.

8.5 TREE CUTTING

8.5.1 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, 132 KV, 220 KV, 400 KV on AC transmission 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 the 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.

Taking into consideration on theoretical requirement of right-of-way and transport requirement of maintenance, the following right-of-way widths are recommended :

Transmission Voltage (kV)	Recommended Width of Right-of-Way (M)
132	27
220	35
400	52

8.5.2 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 to way as per IS 5613 before commissioning the lines.

8.5.3 Reasons for tree cutting during Maintenance of lines

To avoid tripping on the transmission lines :

The trees have moisture in them and because of deep roots in the soil the trees 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.

8.6 List of T & P and spares to be maintained by the AEn Incharge of the line :

T & P			Spares (for every 40 kms of length)		
1.	Electronic fault locator	1 No.	1.	Conductor joint sleeve (aluminium and steel)	2 Nos.
2.	Megger 5000 Volts	1 No.	2.	Earthwire joints	2 Nos.
3.	Hydraulic joint machine for conductor joints with aluminium and steel core dyes.	1 No.	3.	Pre-fabricated armor rods	4 Sets.
4.	Binocular	1 No.	4.	Suspension insulator string with hard wire fitting and clamp	Nos.

5.	Mobile telephone (BSNL)	1 No.	5.	Tension insulator string with hardware fitting and clamp	2 Nos.
6.	Jeep with trolley	1 No.	6.	Intermediate tower complete	1 No.
7.	Earth rod	3 Nos.	7.	Angle tower (For 80 kms.)	1 No.
8.	Conductor cutter	1 No.			
9.	Charge line detector	1 No.			
10.	Two-way Three-way pulley with rope	1 Set			
11.	Safety belt, helmet, shoes, etc.	10 Nos.			

CHAPTER-9

9.1 GENERAL:

Earthing of system performs two distinct functions.

1. Earthing of non current parts from the point of view of safety of personnel.
2. Earthing of generator and transformer neutral to provide for an operative protected system.

The common earthing bus is employed to which are connected the frames of all electrical machines, the cases of instrument transformers, switch board , earthing lines, insulator base, buildings, structures etc. Thus, if the earthing system is effective, a zero or nearly zero earthing potential will be established on all metal parts which may otherwise develop a dangerous potential with respect to earth in case of an earth fault.

The potential, which the earth parts may develop on the occurrence of an earth fault, will naturally depend upon the magnitude of the current for example the resistance of 0.1 ohm will develop a potential difference of 100 volts for an earth fault current of 1000 Amps. The resistance of earth electrodes, the joints etc.(complete earthing system) should be brought to a minimum level so as to avoid dangerous touch and step potentials.

It is, therefore, necessary to check the earth resistance of earth electrodes and inspect earth connections for proper contact etc.

An earthing wire or terminal of a sub-station should never be disconnected from its ground rod because if the structure has a leaking insulator, a high voltage across the disconnected ground lead and its ground rod may be fatal. It is necessary to disconnect a ground lead, it must be securely by passed with a temporary heavy stranded copper wire before working on the permanent connect in.

Ensure connectivity in between existing mesh and extended mesh in case of Bay augmentation.

Records of the ground resistance value measured half yearly, at each sub-station ,along with date of the test are to be kept.

With a view to appreciate the various factors which affect the resistance of the earthing system, a note on earthing is as follows:-

Main design considerations for earthing are:

- i. Low electrical resistance to earth.
- ii. Good corrosion resistance of earthing material.
- iii. Ability to carry high fault currents repeatedly.
- iv. Reliable life of at least 30 years.

9.1.1 Need for an earthed system:

Purpose/Objective

- i. To provide sufficiently low impedance path to fault currents to facilitate satisfactory operation of protective equipments under fault conditions.
- ii. To ensure that living beings in the vicinity of sub stations are not exposed to unsafe potentials under steady state and during fault conditions.
- iii. To retain system voltages within reasonable limits under fault conditions (such as lightning, switching surges or in advertent contact with higher voltage systems) and ensure that voltage is not exceeded upto insulation break down level.
- iv. Graded insulation can be used in power transformers in solidly earthed system.
- v. To limit the voltage to earth on conductive materials which enclose electrical equipments.
- vi. To stabilize the phase to earth voltages on lines under steady state conditions e.g. by dissipating electro static charges which could be built up due to clouds, dust, sleet etc.
- vii. A means of monitoring the insulation of the power equipments.
- viii. To eliminate persistent arching ground faults.
- ix. To ensure that the fault which develops between high and low voltage windings of a transformer can be detected by primary protection.
- x. To provide an alternative path for induced current and thereby minimizing the electrical `noise' in cables.
- xi. To provide an equi-potential platform on which electronic equipments can operate.

CHAPTER-10

10.1 POLICY, PHILOSOPHY, PRINCIPLES AND AUDIT

10.1.1 POLICY

- i. The RVPN Safety Rules & Safety Instructions are drawn up to comply with the requirement of the Indian Electricity Rules, 1956.
- ii. The RVPN recognizes and accepts its statutory and moral responsibilities for ensuring safe design, construction, operation and maintenance of equipment and for the provision of safe methods of work and healthy working conditions. These requirements rank equally with other objectives of the Company.
- iii. The success of the Policy relies on all employees complying with safety requirements relevant to their responsibilities.

10.1.2 PHILOSOPHY

- i. Transmission of electrical power at Extra High and High Voltage is carried out using the RVPN's electrical and mechanical items of equipment, interconnected to form electro-mechanical systems. These systems contain inherent dangers but are designed so that they are safe when operated normally.
- ii. When work or testing is to be carried out on or near to these systems, rules need to be specified to achieve safety from the inherent danger.
- iii. These Safety Rules are based on a philosophy that persons will be protected from the inherent dangers. This is achieved by making persons "safe from the system".
- iv. The inherent dangers are those arising from a system. The RVPN Safety Rules and Safety Instructions define the procedures and responsibilities for achieving safety of persons from inherent dangers.
- v. The Safety Rules are supplemented by the RVPN Safety Instructions which define the actions to be taken to apply the provisions of the Safety Rules.
- vi. The Safety Rules and Safety Instructions together form a system to provide a safe procedure for work or testing on the system and can be summarized as follows:
 - a. Making available the equipment concerned for the maintenance work or testing work.
 - b. Establishing safe conditions for maintenance work or testing work. This can be achieved by either limiting the area of work or testing or by isolating and discharging the contents to a safe working level.
 - c. Authorizing the maintenance work or testing to commence.
 - d. Receiving the authority to carry out maintenance work or testing, carrying out the work or testing while maintaining those safe conditions.
 - e. Cancelling the authority to work or test on completion of the work or testing
 - f. Restoring the system to normal.

- vii. Further dangers are those arising from the environment in which persons undertake work. The way in which these dangers are managed is specified in the Safety Rules and Safety Instructions.

10.1.3 PRINCIPLES

The principles supporting the Policy and Philosophy for the Safety Rules and Safety Instructions are as follows:-

- a. The Safety Rules and Safety Instructions are only designed to protect people.
- b. The primary method of achieving safety from the system is by isolation, followed by earthing for EHV and HV equipment. In the case of mechanical equipment, this shall be followed by draining, venting, purging and discharging stored energy systems (as appropriate). Where reasonably practicable, all points of isolation, vents and earths should be locked.
- c. The application of specific instructions / procedures where these Rules cannot be applied (e.g., Live / Hot Line Working).
- d. The safety precautions for all work and testing shall be maintained across all internal and external control boundaries.
- e. Training of all staff and monitoring / authorizing certain staff that will carry out specific duties in the application of the Rules.
- f. Ensuring compliance by a regular and systematic audit.

10.1.4 SAFETY AUDIT

It is essential that safety standards are maintained at all times and although all staff must comply fully with the Rules, a regular check will assist in maintaining the highest possible level of safety.

This audit process must not be seen as an investigation into a person's performance, but rather as an aid to implementing, maintaining and improving high levels of safety throughout the RVPN. The way in which this Audit is to be conducted is described in Section 10.22.0.

10.2 DEFINITIONS

Additional Earth(s):	Temporary, portable Earth(s) which are issued to the recipient of the Permit to Work or Permit to Test and are included in an Earthing Schedule. They are applied within an Isolated Zone in order to discharge any induced voltage. Additional Earth(s) shall be minimum 35 sq. mm copper equivalent.
Approved Procedure:	RVPN Safety Instructions or other specialized procedures approved by CE / SE.
Authorized Person:	Maintenance / Testing Engineer. Maintenance Engineer: Responsible for carrying out maintenance works of EHV & HV equipments, transmission lines & LT systems. Testing Engineer: Responsible for carrying out testing of protective systems, PLCC panels and other related equipments.
Caution Notice:	A notice in prescribed form to be placed at all points of isolation , or attached to all vents and drains and to Primary Earths where practicable and to control and operating devices to indicate that work or testing is being carried out.
Certificate of No Back Feed:	A certificate which records the details of Isolation carried out at a remote substation in order to achieve safety from EHV/HV systems and from test supplies.
Certificate of Earthing	A certificate which records the details of Isolation& earthing carried out at a remote substation in order to achieve safety from EHV / HV systems and from test supplies.
Company:	RAJASTHAN RAJYA VIDYUT PRASARAN NIGAM LTD. (RRVPL, or, in short, RVPN).
Competent Person:	A person not below the level of Supervisor or Technician.
Danger:	A risk to health, or of bodily injury, or to life.
Danger Notice:	An approved notice reading “Danger” in Hindi and English with a sign of skull & bones.
Dead:	Not electrically Live or Charged.
Earthing Device:	An approved means of providing a connection between an electrical conductor / equipment and earth, being either a “Primary Earth” or an “Additional Earth”.
Earthing Schedule:	A schedule indicating the requirements of Additional Earth(s) for each stage of the work or testing. It must show the number of earths required and either describe or show pictorially their position in the Isolated Zone.
Equipment:	Electrical and mechanical apparatus / equipment used to protect, control, measure, generate, transmit and distribute electricity to which the Safety Rules apply.
Extra High Voltage (EHV):	Any voltage in excess of 33,000 volts (AC/DC).
General Safety:	Those actions required to maintain a safe environment / place for work / testing, e.g., safe access and safe methods of work & testing and the correct use of personal protective equipment.
High Voltage (HV):	A voltage between 650 volts and 33,000 volts.
Isolated:	Disconnected from associated Equipment by Isolating Device(s) in the isolated position, or by adequate physical separation.
Isolating Device:	A device for rendering Equipment Isolated.

Isolated Zone:	All items of equipment contained within a work / testing area for which isolation has been achieved at all points of supply.
Keys(Safety Key):	The key from a unique lock (at a location) which is used for locking / interlocking an Isolating Device, Earth or Drain / Vents.
Key Safe:	A designated lockable cabinet for the safe custody of all Safety Keys.
Live:	Charged / Energized at a voltage by being connected to a source of electricity.
Lock / Locks:	A device used for immobilization of an item of Equipment.
Lock Closed:	To secure an item of Equipment with padlocks or other device such that it is immobilized in the closed position.
Lock Open:	To secure an item of Equipment with padlocks or other device such that it is immobilized in the open position.
Low Voltage (LV):	A voltage not exceeding 250 volts.
Medium Voltage (MV):	A voltage between 250 and 650 volts.
Northern Region Load Dispatch Center (N R L D C):-	The center where the operations of Northern Regional Electricity grid constituting the power systems of the constituents of Northern Region are monitored & coordinated.
Point(s) of Isolation:	The point(s) at which Equipment has been Isolated and, when practicable, the Isolation Point must remain immobilized and Locked. Caution Notices shall be attached to all Points of Isolation.
PRASARAN NIGAM:	RRVPL - Rajasthan Rajya Vidyut Prasaran Nigam Limited.
Primary Earth(s):	Earth(s) {Either fixed earth Switch(es) or Portable Earth(s) with sufficient / suitable electrical capacity} applied between the point of work and all points of EHV / HV isolation before the Permit To Work or Permit To Test is issued. <u>Primary earth(s) shall be minimum 95 sq. mm copper equivalent.</u>
Permits To Test (PTT):	A safety Document specifying the EHV / HV Equipment and the testing to be carried out and the actions taken to avert / avoid the disturbance of the system during the testing.
Permits To Work (PTW):	A Safety Document specifying the Equipment / Area and the work / testing to be carried out and the actions taken to achieve Safety from the system.
Purged:	A condition of Equipment from which any dangerous contents have been removed.
RSI:	RRVPL Safety Instructions.
Safe Electrical Clearance:	A minimum distance of 1.5 meters which must be maintained by lineman / workman from the conductors or jumpers of a de-energized overhead line which has been Isolated & Primary earthed and for which a Safety Document has been issued before connection of Additional Earths under the terms of that Safety Document.
Safety Document:	A Document specifying the Equipment / Area and the work / testing to be carried out and the actions taken to achieve Safety from the system (Permit To Work), or to safeguard the disturbance of the system during the testing (Permit To Test).
Safety from the System:	That condition which safeguards persons working on or near to Equipment from the Dangers which are inherent in a System.

Safety Working Clearance:	The minimum clearance to be maintained in air between the live part of the equipment on one hand and earth or another piece of equipment or conductor on which it is necessary to carry out the work, on the other.
Senior Authorized Person / Shift In charge:	Engineer responsible for all operations and activities in substations.
State Load Despatch Centre (SLDC):	The RVPN's control room is at Heerapura (Jaipur) for operation round the clock for the purpose of managing the operation of the State Transmission System and co-ordination of State generation and Drawal on a real time basis.
Supervision:	Supervision, Personal / direct, by an Authorized Person who is available at the point of work or testing at all times during the course of that work or testing.
System:	Items of Equipment which are used either separately or in combination to generate transmit or distribute electricity.
Vented:	Allowing a closed space to have an outlet to atmosphere so that the pressure has equalized to atmospheric.

10.3 GENERAL PROVISIONS

10.3.1 GENERAL SAFETY.

- i. In addition to the requirements for establishing Safety from the System specified in these Safety Rules and Safety Instructions, General Safety shall be established and maintained at all times.
- ii. General Safety shall be established by the person holding the Safety Document before work / testing starts. The person responsible for establishing General Safety shall be specified in the Safety Instructions.
- iii. During the course of work, the person in charge of the work / testing shall ensure that each & every member of the working party maintains General Safety.
- iv. It is the responsibility of all members of the working party, overseen by the person in charge of the work / testing, to ensure that their activities do not affect other work areas.

10.3.2 SAFETY RULES, SAFETY INSTRUCTIONS AND PROCEDURES.

- i. These Safety Rules, Safety Instructions and Procedures are mandatory.
- ii. Relevant Safety Rules issued by other Authorities should also be considered mandatory when designated as in Basic Safety Rules.

10.3.3 SPECIAL INSTRUCTIONS.

Maintenance Work or testing carried out on or near to a System to which these Safety Rules cannot be applied, or for special reasons should not be applied, shall be carried out in accordance with an Approved Procedure. (e.g., EHV / HV Live Line / Hot Line working which cannot be covered in these Safety Rules).

10.3.4 OBJECTIONS ON SAFETY GROUNDS.

Any person who has objections on safety grounds in the application of these Safety Rules and Safety Instructions shall explain their reasons to the person holding the Safety Document. If their objections cannot be resolved immediately, then the matter should be referred to the Shift - In - Charge. If the objections are still not resolved then the matter should be referred to the Sub Station – In - Charge.

10.4 THE BASIC SAFETY RULES.

10.4.1 APPLICATION OF RULES.

- i. The Rajasthan Rajya Vidyut Prasaran Nigam Limited Safety Rules and Safety Instructions shall be applied when working on or near to items of Equipment which are part of a System described in 10.4.1(ii).

- ii. The System to which these Safety Rules and Safety Instructions apply is all those items of Equipment owned by RVPN Limited and located within the Company's Sub Station fences or on its transmission lines.
- iii. Equipment shall be added to and removed from a system only in accordance with an Approved Handing over / Taking over Procedure. The same procedure will determine when the Safety Rules and Safety Instructions shall apply, or cease to apply.
- iv. Equipment located on another company's premises and on which RVPN personnel work, may be subject to RVPN Safety Rules and Safety Instructions, or to the owning Authority Safety Rules and Safety Instructions.

10.4.2 APPROACH TO EXPOSED EXTRA HIGH VOLTAGE AND HIGH VOLTAGE CONDUCTORS AND INSULATORS.

- i. Persons shall not allow any part of their body or objects / tools & plant to approach within the specified Safety Clearance to exposed EHV / HV conductors which are Live. The only exception to this is during Live / Hot line work carried out on EHV / HV equipment in accordance with Approved specialized procedure.
- ii. **SAFETY WORKING CLEARANCE.**

Highest system Voltage (kV)	Safety working Clearance (in meters)
12	2.6
36	2.8
72.5	3.1
145	3.7
245	4.3
420	6.4

- iii. When Points of Isolation have been established **but** exposed conductors could be subject to Extra High Voltage or High Voltage, the only object permitted to approach within Safety **Working** Clearance shall be Approved voltage measuring devices or Earthing Devices.
- iv. When Points of Isolation have been established by the application of Earthing Devices, approach is allowed under an appropriate Safety Document within the specified Safety Clearance.

10.4.3 SAFETY PRECAUTIONS FOR WORK OR TESTING ON OR NEAR TO EXTRAHIGH VOLTAGE OR HIGH VOLTAGE EQUIPMENT.

- i) (a) When work or testing is to be carried out on or near to EHV / HV equipment, the means of achieving safety must be assessed according to Safety Instructions 01.
- (b) The EHV / HV equipment must be identified.
- ii) Safety Documents.

- a. When work or testing is to be done on the normally energized part / primary side of the EHV / HV equipment and it is necessary to provide Primary Earths, a Permit To Work (PTW) shall be issued. In case it is required to remove the Primary Earth for the purpose of testing (such as meggering), this shall be done after taking due precautions as required.
- b. When work or testing is to be done on the normally not energized part / secondary side of the EHV / HV equipment, such as for relay testing or CB operation testing or work on secondary side of CT's / PT's, and does not require the de – energization of the equipment or the providing of Primary Earths, Permit To Test (PTT) shall be issued.
- c. The Safety Document must show the Safety Precautions taken to achieve safety from the EHV / HV system and also further precautions required to protect persons from inherent dangers in other systems. (e.g., purging for the removal of substance injurious to health, venting, draining and removal of stored energy as quoted in safety rule 10.4.5(iii) and LV / MV supplies).
- d. Within any Isolated Zone, any number of PTWs may be issued after consideration of 10.4.3(ii)(g).
- e. Within any Isolated Zone, only one Permit To Test shall be in force at any time. PTWs may be permitted in the same Isolated Zone at the same time as the Permit To Test is in force provided the different scopes of work or testing do not pose any danger to the working personnel and the equipment(s). The recipients of the PTT and PTW shall concur and be informed of the status.
- f. When the restoration of motive power is required for work or testing, the supplies required must be stated on the Safety Document in accordance with Safety Instruction 01.
- g. If motive power supplies have been made available, no other PTWs shall be issued on the same equipment.
- iii. When Danger from induced voltages could arise during the course of work or testing, Additional Earths shall be applied.

10.4.4 SAFETY PRECAUTIONS FOR WORK ON OR NEAR TO MEDIUM AND LOW VOLTAGE EQUIPMENT

- i. Where reasonably practical, work on or near to Medium and Low voltage equipment should be carried out with that equipment in Dead condition.
- ii. When work or testing is to be carried out on or near to MV / LV Equipment, then the means of achieving safety must be assessed according to Safety Instruction 04 and shall also comply with the following rules.
 - a. The MV / LV Equipment shall be identified.
 - b. The MV / LV Equipment shall be Isolated and those Points of Isolation secured.

- c. The method of instructing how the work or testing is to take place can be either a Safety Document or Personal Supervision.
- iii. When it is unavoidable to carry out work or testing on MV / LV equipment which is not Dead, then suitable precautions to avoid Danger must be followed as detailed in Safety Instructions 04.

10.4.5 SAFETY PRECAUTIONS FOR WORK OR TESTING ON OR NEAR TO MECHANICAL EQUIPMENT.

- i. When work or testing is to be carried out on or near to mechanical equipment, the means of achieving safety must be assessed according to Safety Instructions 01.
- ii. Safety Documents.
 - a. For work or testing with the Equipment Isolated and either non - operational or with limited restoration of motive power supplies, the Safety Document issued will be a Permit To Work.
 - b. When testing of mechanical Equipment involves the application of test pressures, the Safety Document issued will be a Permit To Test.
- iii. When the work or testing requires the issue of a Permit To Work according to Safety Rules 10.4.5(ii)(a), the precautions will be specified in the Permit To Work and must include the following:-
 - a. The Mechanical equipment must be Isolated and Points of Isolation established for the work.
 - b. Further precautions taken to protect persons from inherent dangers in mechanical systems. This must include draining, venting, purging and removal of stored energy.
 - c. Venting emissions shall be dissipated so as to avoid Danger. Where reasonably practicable, vents shall be locked open and Caution Notices fixed.
 - d. The removal of the stored energy must be carried out in a manner to contain or dissipate that stored energy safely.
 - e. Where internal access is required and the residue of the contents could cause Danger, the mechanical equipment must be purged and that residue disposed of safely according to an Approved Procedure.
- iv. Where work or testing is to be carried out on mechanical Equipment and it is essential to restore motive power for that work or testing while the Permit To Work is in force, then the following additional precautions shall be applied.
 - a. All supplies required must be stated on the Permit To Work in accordance with the Safety Instructions 01.

- b. If motive power supplies have been made available, no other PTWs shall be issued on the same Equipment.
- v. When the testing requires the issue of a Permit To Test according to Safety Rule 10.4.5 (ii) (b) then the procedures will be as described in Safety Instructions 01 and 10.

It is essential that the risks of testing are properly assessed by the Maintenance / Testing Engineer. This procedure should only be used when such testing is an operational necessity.

10.4.6 OPERATION OF EQUIPMENT

The operation of any Equipment to achieve Safety from the system shall never involve pre - arranged signals or the use of time intervals.

The operation of the equipment and / or its isolation and / or earthing shall be confirmed before the issue of Permit To Work or Permit To Test.

10.4.7 DEMARCATION OF WORK AND TESTING AREAS.

- i. The work and testing area shall be clearly demarcated.
- ii. Where necessary, physical protection must be provided to prevent Danger to persons in a demarcated area from adjacent System hazards.

Earthing by three earth rods, on both side shall be done.

10.4.8 IDENTIFICATION OF EQUIPMENT

Equipment shall be clearly marked with a unique code and / or description, which must be the information used on Safety Documents and in switching instructions.

10.4. A

RAJASTHAN RAJYA VIDYUT PRASARAN NIGAM LTD.

In Person/On Telephone
(In duplicate)

_____KV Grid Sub Station, _____

PERMIT TO WORK

Permit No _____

Date _____

REQUEST:

Work Area:

Work to be done:

Period of PTW: (From)Date _____ (To) Date _____

Time _____ Time _____

Details of isolation required:

PTW Requested by:

Name:

Designation:

Date:- _____ Time:- _____

Signature

ISSUE of PTW

Precautions taken to achieve Safety:

i)

ii)

iii)

2. Work area is isolated / earthed and it is safe to work on. Additional earths may be provided at the place of work.

3. Further precautions to be taken to achieve Safety:

i)

ii)

4. "No Back Feed" / "Earthing" certificate No. _____ dt. _____ issued by _____ at (Time) _____.

5. PTW allowed: (From) Date _____ (To) Date _____

Time _____ Time _____

Entry made in PTW register on page No. _____.

PTW Approved by:

Name:

Designation of Shift – In - Charge:

Date:- _____ Time:- _____

Signature

RECEIPT:

I hereby declare that I have inspected and have satisfied myself that such equipment where the work is to be carried out has been switched off and isolated / earthed. I also accept responsibility for carrying out work only on equipment detailed on this permit and that no attempt will be made by me or by any man under my control, to carry out work on any other equipment.

Name:

Designation:

Date:- _____ Time:- _____

Signature

RETURN OF PERMIT TO WORK:

Details of work done:

Restrictions / changes, if any, on the equipment being returned to service:

CLEARANCE CERTIFICATE:

I hereby declare that all men, material & earthing have been withdrawn and all personnel warned that it is no longer safe to work on the equipment specified in this permit and all tools and additional earths are clear and equipment is ready for charging.

Name:

Designation:

Date:-

Time:-

Signature

CANCELLATION OF PERMIT TO WORK:

PTW cancelled and entry made in PTW register on page No. _____.

SEQUENCE OF NORMALIZATION :

i)

ii)

iii)

Name:

Designation of Shift – In – Charge:

Date:-

Time:-

Signature

10.4 B

RAJASTHAN RAJYA VIDYUT PRASARAN NIGAM LTD.

(In duplicate)

_____ KV Grid Sub Station, _____

PERMIT TO TEST

Permit No. _____

Date

REQUEST:

Test Area:

Testing to be carried out:

3. Period of PTT: (From) Date _____ (To) Date _____

Time _____ Time _____

Details of isolation if required:

PTT Requested by:

Name:

Designation:

Date:- _____ Time:- _____

Signature

ISSUE:

Precaution(s) taken to safeguard the system:

i)

ii)

Further precautions to be taken to safeguard the system:

Test area is identified and it is safe to carry out test.

4. PTT allowed: (From) Date _____ (To) Date _____

Time _____ Time _____

Entry made in PTT register on page No. _____.

PTT Approved by:

Name:

Designation of Shift – In - Charge:

Date:- _____ Time:- _____

Signature

C. RECEIPT:

I hereby declare that I have personally inspected and have satisfied myself that such equipments where the test(s) are to be carried out has been switched off and isolated. I also accept responsibility of carrying out test(s) on equipment detailed on this PTT and that no attempt will be made by me or by any man under my control to carry out tests on any other equipment.

Name:

Designation:

Date:- _____ Time:- _____

Signature

D. RETURN OF PERMIT TO TEST:

Details of tests carried out:

Restrictions / changes, if any, on the equipment being returned to service:

CLEARANCE CERTIFICATE:

I hereby declare that all men and material have been withdrawn. The original settings of equipment/ relays have been restored. Relays have been put in their cases with covers. Test plugs have been restored. CT, PT & DC circuits have been made through.

The following exceptions are recorded:

- i)
- ii)

Name:

Designation of Shift - In - Charge:

Date :- _____ Time:- _____

Signature

E. CANCELLATION OF PTT:

PTT cancelled and entry made in PTT register on Page No. _____.

SEQUENCE OF NORMALIZATION :

- i)
- ii)
- iii)
- iv)

Name

Designation of Shift - In - Charge:

Date :- _____ Time:- _____

Signature

RVPN SAFETY INSTRUCTIONS (RSI) – INDEX.

- RSI – 01. EXTRA HIGH VOLTAGE AND HIGH VOLTAGE SWITCHING, EARTHING AND SAFETY DOCUMENT PROCEDURE.
- RSI – 02. DEMARCATION OF WORK AND TESTING AREAS IN SUBSTATIONS.
- RSI – 03. TESTING OF EHV AND HV EQUIPMENT.
- RSI – 04. LOW VOLTAGE AND MEDIUM VOLTAGE EQUIPMENT.
- RSI – 05. EXTRA HIGH VOLTAGE OVERHEAD LINES SAFETY PRECAUTIONS.
- RSI – 06. ACCESS TO HV / EHV COMPARTMENTS AND STRUCTURES.
- RSI – 07. EQUIPMENT CONTAINING SULPHUR HEXAFLUORIDE (SF₆).
- RSI – 08. MOBILE ACCESS EQUIPMENT, VEHICLES, CRANES AND LONG OBJECTS IN SUBSTATIONS.
- RSI – 09. EHV AND HV STATIC CAPACITOR BANKS.
- RSI – 10. PRESSURE SYSTEMS.
- RSI – 11. STATION STORAGE BATTERY
- RSI – 12. FIRE PROTECTION AREAS.
- RSI – 13. PROCEDURE FOR WORKING ON SF₆ FILLED EQUIPMENT.
- RSI – 14. APPOINTMENT (WORK ALLOCATION) OF PERSONS (RRVPL SAFETY RULES).
- RSI – 15. PROCEDURE FOR ADDING / REMOVING EQUIPMENT TO FROM THE EHV / HV SYSTEM.
- RSI – 16. PROCEDURE FOR WORK IN GENERAL CONFINED SPACES.
- RSI – 17. PROCEDURE FOR WORK INSIDE TRANSFORMER / REACTOR TANKS.

10.5 RVPN SAFETY INSTRUCTIONS 01 (RSI – 01)

EHV AND HV SWITCHING, EARTHING AND SAFETY DOCUMENT PROCEDURE.

10.5.1 PURPOSE

When maintenance or testing is to be carried out on RVPN's EHV / HV System, procedures need to be specified to achieve safety from the system.

10.5.2 SCOPE

This RVPN Safety Instructions set down the procedure to be adopted when carrying out EHV / HV switching, isolation from other supplies, earthing, issue of Safety Document and control on RVPN's EHV / HV Transmission System.

10.5.3 PROCEDURE

- i. **When work is to be** carried out on or near EHV / HV equipment, the Maintenance Engineer and the Shift - In - Charge will assess the means of achieving safety from the system. Refer Safety Rule 10.4.3(i) (a).
- ii. When the work on the substation equipment / transmission line requires the providing of primary earths, then the safety document issued must be a Permit To Work. Refer Safety Rule 10.4.3(ii) (a).
- iii. When the work / testing on the substation equipment/ transmission line do not require the providing of primary earths, then the safety document issued must be a Permit To Test. Refer Safety Rule 10.4.3(ii) (b).
- iv. Within any isolated zone, any number of PTWs may be issued at the discretion of the Shift Incharge. Refer Safety Rule 10.4.3(ii) (d).
- v. Within any isolated zone, only one PTT shall be in force at any time. No PTWs are permitted at the same time as the PTT is in force in the same isolated zone. Refer Safety Rule 10.4.3(ii) (e).
- vi. After agreement has been reached between the Sub Station Shift – In - Charge and the SLDC that the shutdown on the specified substation equipment / transmission line can be availed, the Maintenance Engineer requests the shutdown by completing all items of Request for the Permit To Work or Permit To Test (Part A).
- vii. The SLDC will confirm to the Shift – In - Charge that the shutdown can be availed and both will record the instructions in their log sheet(s) together with the message number, date and time that the instruction was given.
- viii. The Shift – In - Charge will carry out switching operations as per the instructions of SLDC. He shall also give a message to the Shift – In – Charge of the Sub Station at the other end(s) for carrying out such switching operations as are necessary for isolation of the work / test area. These switching operations will be recorded in the substation log sheet(s) together with message number, the date and time.

- ix. If, during a switching operation, a piece of equipment shows any sign of distress, switching must cease immediately and the Sub Station – In - Charge notified. All persons must be warned that a potential hazard exists.
- x. In the case of lines or equipment where isolation and / or earthing is required from the other end, the Shift – In – Charge of the Sub Station where PTW / PTT has been applied for shall obtain the ‘Earthing Certificate’ / ‘No Feed Back Certificate’ / PTW / PTT from the other end(s).
- xi. The Shift - In - Charge of the Sub Station where the PTW / PTT has been applied for will then carry out all isolation and will Lock Open these points of isolation. In case of Line, the Shift - In - Charge shall give a message to the Shift – In – Charge of the Sub Station at the other end(s) for carrying out isolation and locking open the points of isolation. The Shift – In – Charge of the Sub Station at the remote end will then isolate and Lock Open all points of isolation and confirm back to the Shift - In - Charge of the Sub Station where the PTW / PTT has been applied for. Any isolation of the secondary side of voltage transformers and auxiliary transformers (tertiary winding where applicable) will also be carried out including locking. These switching operations will be recorded in the substation log sheet(s) together with message number, date and time that instruction was given.
- xii. Once all isolation including voltage transformers and auxiliary transformers (tertiary winding where applicable) has been completed, including remote ends where necessary, and confirmation has been received that the isolation has been completed at the remote end, earth switches shall be closed and Locked. Caution Notices shall be fixed on all control handles on the control panel and also attached to the padlocks used to Lock Open all points of Isolation and Lock Closed all earth switches. These switching operations will be recorded in the Sub-station log sheet together with message number, date and time.
- xiii. ‘No Back Feed Certificate’ / ‘Earthing Certificate’ must be obtained from all concerned Sub Stations. All details of the ‘No Back Feed Certificate’ / ‘Earthing Certificate’ must be entered in the Sub Station log sheet along with message number, date and time. The message number, date and time must also be recorded on the PTW / PTT.
- xiv. The Shift – In - Charge at the Sub Station(s) where the Permit(s) to Work or Permit(s) To Test are to be issued shall record the isolation and earthing in Part B.1 of the Permit To Work or Permit To Test (Sequence of Isolation).
- xv. All Safety Keys, fuses and links, etc, which have been used to Lock all points of isolation and earth switches, etc. will be Locked in a Key Safe under the safe custody of the Shift - In - Charge.
- xvi. The Shift - In - Charge will specify the following in Part B of the Permit To Work or Permit To Test before issue:

- a. Any further precautions which are required to be taken later by the Incharge holding the Permit To Work or Permit To Test to achieve Safety {Refer Safety Rule 10.4.3(ii) (b)}.
 - b. The power supplies that can be resorted for the particular work being carried out {Refer Safety Rule 10.4.3(ii) (e)} and issue the Approved written procedure.
 - c. The number of Additional Earths required. The use of these Additional Earths will be specified on an Earthing Schedule drawn up by the Maintenance Engineer.
- xvii. The Shift - In - Charge will issue the Permit To Work or Permit To Test to the Person requesting for PTW / PTT who will retain the Safety Document in his possession until all work has been completed. The Shift - In - Charge will record all the details in the substation log book and Permit To Work or Permit To Test register. In cases where PTW / PTT has been requested over telephone, the confirmation of conveying the approval of the PTW / PTT shall be recorded by the Shift – In – Charge.
- xviii. a) The Person requesting for PTW / PTT will sign Part C (Receipt) to accept the responsibility for carrying out the work / testing on the Sub Station equipment / transmission line. The Person responsible for the work / testing will draw up the Earthing Schedule, if required, to show the position and use of Additional Earths.
- b) IMPORTANT:- In cases where PTW / PTT has been requested over telephone, the person responsible for the work / testing shall give confirmation of receipt of the approval of the PTW / PTT by giving a “code name” which shall be not be recorded by the Shift – In – Charge. The Shift – In – Charge shall verbally convey the “code name” to the next Shift–In–Charge.
- xix) a) In substations, Additional Earths must be applied in a manner similar to primary portable earths using the same earthing equipment.
- b) On overhead transmission lines, Additional Earths can be applied within Safety Clearance but at not less than Safe Electrical Clearance as specified in Safety Instructions 05.
- xx) a) On completion of the work, the person who has obtained the PTW / PTT will sign the Return of Permit To Work or Permit To Test (Part D) to declare that all work / testing is completed. The person who has obtained the PTW / PTT over telephone shall convey the above alongwith the “code name” given by him at the time of obtaining the PTW / PTT.
- b) While returning the PTW / PTT, any restrictions applicable / changes made shall be described in part D. It shall also be confirmed that all men, tools, plant and Additional Earths have been removed.
- xxi) The Shift - In - Charge will receive / accept the cleared Permit To Work or Permit To Test and record receipt in the substation log sheet. He will also record the receipt / acceptance in the Permit To Work or Permit To Test register together with date and time, and mention this in Part E.1 of the PTW / PTT.

- xxii) The Shift - In - Charge will verify the local status and then carry out the removal of all the Primary Earthing and switching operations after consultation with SLDC and remote end(s), recording these in the substation log sheet together with date and time. He will complete Part E.2 of the Permit To Work / Permit To Test to describe the sequence of normalization.
- xxiii) The Shift – In – Charge shall cancel the PTW / PTT by signing in Part E. The PTW / PTT shall then be kept for record.

10.6 RVPN SAFETY INSTRUCTIONS 02 (RSI – 02).

DEMARCATIION OF WORK AND TESTING AREAS IN SUB STATIONS.

10.6.1 PURPOSE.

Before any work / testing is carried out in or adjacent to a charged substation area, the work or test area is to be clearly demarcated. (Refer Safety rule 10.4.7).

10.6.2 SCOPE.

This RVPN Safety Instructions sets down the procedures to be adopted for the demarcation of work / test areas in substations.

10.6.3 EQUIPMENT IDENTIFICATION.

Equipment on which work or test is to be carried out must be readily identifiable. Where necessary, a means of identification must be fixed to it. This will remain effective throughout the course of the work.

10.6.4 DANGERS.

The main Dangers to personnel working in substations are electric shock, burns or falls arising from:

- i. The possibility of mistaking Equipment on which it is unsafe to work for that on which it is safe to work.
- ii. Inadvertently infringing Safety Clearance.
- iii. Taking inadequate precautions to suppress or safely discharge any induced or other impressed voltages on the Equipment.
- iv. Insecure hand and footholds.
- v. Failure to make proper use of personal protective equipments.
- vi. Sudden rush of flying insects, viz., Bees, flying ants, etc.

10.6.5 WORK / TESTING.

- i. When work or testing is to be carried out on or near to Equipment in a substation, the area demarcation is to be determined by the Maintenance Engineer / Testing Engineer to the satisfaction of the Shift - In - Charge.
- ii. Work / testing in a substation must be carried out under the supervision of a Maintenance Engineer / Testing Engineer.

10.6.6 DEMARCATION OF WORK / TESTING AREAS.

- i. Where work is to be carried out near to Equipment which may be Live, or must be regarded as Live, then the limits of the work area must be defined as per Rule 10.6.5 (i) above and followed for Safety Distance as per Rule 10.4.2 (ii) of the Safety Rules.
- ii. Boundary marks must be clearly identifiable and easy to see. They must be fixed or moved by maintenance personnel under the supervision of the Maintenance Engineer / Testing Engineer and Shift - In - Charge.
- iii. Boundary marking
 - a. should be properly fixed / supported.
 - b. may be attached to any structure supporting Equipment.
 - c. should not carry any notice.
- iv. In general, the boundary marking must be arranged so that it is impossible to climb, from within the work area, on structures supporting Equipment which is Live. Where this is not possible, red Danger notices must be attached at working level, before work commences, to identify the structures.
- v. The boundary of the work / test area must be identified by using red and white plastic chain or nylon rope / tape of about 12 mm diameter /width.
- vi. Safety Distance must be maintained at all times to Equipment on which it is unsafe to work. This includes any overhead conductors that pass over the work area or adjacent live equipment on which work is not to take place.
- vii. The demarcation equipment can be erected after safety precautions have been established but must not be erected before the issue of the PTW / PTT.
- viii. The demarcation equipment shall be removed only after the clearance of the PTW / PTT.
- ix. Consideration should be given, if thought necessary by the Maintenance Engineer / Testing Engineer, for providing physical protection to personnel from hazards in the System adjacent to the demarcated area.

Earthing by three earth rods ,on both side of work area shall be done

10.6.7 DANGER NOTICES.

- i. Danger Notices must be placed to inform personnel that adjacent Equipment is not included in the specified work area. The notices must be attached to or fixed adjacent to adjoining Equipment in sufficient numbers to be visible from the work area at all times.
- ii. Danger Notices must only be fixed or moved by maintenance personnel under the supervision of Maintenance Engineer / Testing Engineer and Shift - In - Charge.

10.6.8 HAZARD AREAS.

Hazard Areas may be barricaded off by using yellow and black plastic / nylon chain / rope / tape.

10.7 RVPN SAFETY INSTRUCTIONS 03 (RSI – 03).

TESTING OF EXTRA HIGH VOLTAGE AND HIGH VOLTAGE EQUIPMENT.

10.7.1 PURPOSE.

When testing is to be carried out on EHV / HV Equipment, procedures need to be specified to achieve safety from inherent Dangers.

10.7.2 SCOPE.

This safety instruction applies the principles established by the safety precautions to achieve safety from the system for personnel during the testing of EHV / HV Equipment.

10.7.3 EQUIPMENT IDENTIFICATION.

Equipment on which testing is to be carried out must be readily identifiable. Where necessary, a means of identification must be fixed to it that will remain effective throughout the course of testing. Refer Safety Rule 10.4.3(i) (b).

10.7.4 DANGERS.

The main dangers to personnel during the course of testing are electric shock, burns and other injuries arising from

- Accidental contact with LIVE Equipment.
- Electrical energy, mechanical pressures and forces derived from testing sources.

10.7.5 PREPARATIONS FOR TESTING.

- i. Testing must be carried out by competent trained Personnel.
- ii. Testing which requires the application of primary earth must be carried out under a Permit To Work.

- iii. Testing which does not require the application of primary earth may be carried out under a Permit To Test.
- iv. Further precautions, e.g., “Fire Fighting equipment to be immobilized”, must be stated on the Safety Document in accordance with RVPN Safety Instruction 01 (RSI 01).
- v. The test area and its boundaries and limits must be identified in accordance with the Safety Instruction “Demarcation of Work and Testing Areas in Substations.”(RSI - 02)
- vi. Points of Isolation must be maintained from all supplies other than those required for the tests.

10.7.6 TESTING

- i. The Competent Person in receipt of the ng at the other end.

10.7.7 COMPLETION OF TESTING.

When a safety document which includes testing as part of the work activity is to be cleared, the competent person must ensure that any safety precautions that were varied / modified for the testing and are not restored to the original state are listed as exceptions.

10.8 RVPN SAFETY INSTRUCTIONS 04 (RSI – 04)

LOW VOLTAGE AND MEDIUM VOLTAGE EQUIPMENT

10.8.1 PURPOSE

When work or testing is being carried out on LV / MV Equipment, procedures need to be specified to achieve safety from inherent danger.

10.8.2 SCOPE

These RVPN Safety Instructions apply the principles established by the Safety Rules to achieve Safety from the System for personnel working or testing on Low / Medium Voltage (LV / MV) Equipment.

10.8.3 EQUIPMENT IDENTIFICATION

Equipment on which work or testing is to be carried out must be readily identifiable. Where necessary a means of identification must be fixed to it which will remain effective throughout the course of the work. Refer Safety Rule 10.4.4(ii) (a).

10.8.4 DANGERS

The main Dangers to personnel working or testing on LV/MV Equipment are electric shock or burns arising from

- i. The possibility of personnel mistaking Equipment on which it is unsafe to work for that on which it is safe to work.
- ii. The possibility of the Equipment being worked on accidentally or inadvertently being made Live.
- iii. Dangerous voltages on open - circuited current transformer.
- iv. Vicinity of the LV / MV circuit / conductor due to less clearance specially in LT switch gear.

10.8.5 GENERAL REQUIREMENTS.

- i. Where reasonably practicable, the preferred method is to work on or near to LV / MV Equipment which is Dead. Refer Safety Rule 10.4.4 (i). Work on Live LV / MV Equipment should rarely be permitted, but where no alternative method is possible, work can be carried out as in section 5 of this Safety Instruction. Refer Safety Rule 10.4.4(iii).
- ii. A Sub Station - In - Charge must carry out an assessment to determine under what conditions the work is to take place and if a Safety Document is to be issued. When Safety Document is issued, type & shape of Safety Document shall be as per Safety Rule 10.4.4(ii) (c).
- iii. When work is to be carried out on LV / MV Equipment which is part of Extra High Voltage / High Voltage Equipment, adequate precautions must be taken to achieve Safety of such LV / MV equipments from the EHV / HV Equipment.
- iv. When tests are to be carried out on LV / MV Equipment which is in proximity to exposed EHV / HV Equipment which may be Live, or may become Live, the relevant requirements of RVPN Safety Instruction “Demarcation of work and testing areas in Substations” (RSI - 02) must be met.
- v. When work on live equipment requires portable instruments to be used for voltage or resistance measurements, the instruments must be provided with insulated probes.
- vi. When working on protection or metering equipment, extreme care must be taken not to open circuit the secondary winding of current transformers. These must be short - circuited before work is carried out.

10.8.6 Work / Testing on / or Near to Dead LV/MV Equipment.

- i. Sub Station – In – Charge must assess the work required on / or near to the dead LV/MV equipment and decide whether it must be carried out under:
 - a. Permit To Work, or
 - b. Personal supervision
 Refer Safety Rule 10.4.4(ii) (c).
- ii) Equipment must be isolated. Time switches, float switches, thermostats, sequence switching devices or similar automatic switching devices are not isolating devices.

- iii) Points of isolation must be established. Any fuses and links and / or safety keys used to secure the points or isolation must be retained in a key safe. Refer Safety Rule 10.4.2.
- iv) Where work is to be done on portable or hand held LV / MV equipment, isolation must be achieved by the removal of the plug from the socket outlet.
- v) The work must be carried out by a competent person.
- vi) Before commencing work, the competent person must check, by means of an approved voltage testing device that the LV / MV equipment on which he is to work is not live. The device must be tested immediately before and after use.
- vii) If the work is interrupted, the competent person who is to continue the work must recheck, as described in 10.8.6(vi) above, that the equipment is not live.
- viii) Before commencing work on exposed LV / MV overhead conductors which have been isolated, in addition to proving that they are not live, the conductors including the neutral, must be short circuited and earthed.

10.8.7 WORK OR TESTING NEAR TO LIVE LV / MV EQUIPMENT

- i. Work near to live LV / MV equipment must only proceed after a satisfactory assessment by Sub Station – In - Charge.
- ii. The work must only be done by a competent person.
- iii. The competent person who is to do the work must first remove all metallic objects such as wrist watch, rings, wristlets, cufflinks and pendants, etc. from his / her body.
- iv. When necessary to prevent injury, approved insulated tools, insulating stands, mats or gloves as appropriate must be used.
- v. Only suitable test instrument with insulated test probes must be used.
- vi. Consideration must be given to the competent person being accompanied by another competent person if the presence of such a person could contribute significantly for ensuring that injury is prevented. Any accompanying competent person must be trained to recognize danger and if necessary to render assistance in the event of an emergency.
- vii. Before commencing work in areas where there is a possibility of the presence of gas which might be inadvertently ignited by electric sparks, the Sub Station – In - Charge must be consulted.

10.8.8 WORK ON LIVE LV / MV EQUIPMENT

Refer Safety Rule 10.4.4(iii)

- i. Work on live LV / MV equipment is to be avoided as far as practicable.

- ii. “If there is no alternative to working live”, then the following procedure must be adopted:
 - a. The Sub Station – In - Charge and the Maintenance Engineer must thoroughly review the requirement of the work.
 - b. A written procedure for the live work must be drawn by the Sub Station – In - Charge and the Maintenance Engineer in such a way that the procedure will comprehensively describe the precautions required to carry out the work.
 - c. Approved insulated tools and equipment must be specified and provided.
 - d. The work will be carried out only under the direct supervision of the Maintenance Engineer.
- iii. When this work also involves working on or near to EHV / HV or mechanical equipment, the requirements of Safety Rules 104.2, 10.4.3, 10.4.5 and 10.4.7 must be met.

10.9 RVPN SAFETY INSTRUCTIONS 05 (RSI – 05)

WORK ON EXTRA HIGH VOLTAGE OVERHEAD LINES.

10.9.1 PURPOSE

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

10.9.2 SCOPE

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

10.9.3 DEFINITIONS

- i. 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.
- ii. Line End Clamp – The End Clamp of an Additional Earth which is to be connected with the conductor or jumper.
- iii. Earth Lead – A lead made of copper or aluminum strands protected with a cover for connection between the Line End Clamp and the Earth End Clamp.
- iv. Socket – The sliding socket for holding and operating the Line End Clamp which is a part of a Telescopic Pole or Bridging Pole.

- v. 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.
- vi. Working Phases – The conductor phases on which Linemen will carry out work.
- vii. Field Equipment Earth – Approved connections for bonding of items of field and access equipment such as scaffold, hydraulic platforms, mobile cranes, winches, etc. to earth. The earths are coloured 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 sq. mm copper equivalent. An additional earth can be used in the form of field equipment earth.

10.9.4 DANGERS

The main Dangers when working on transmission lines are:

- i. The possibility of personnel mistaking identification of the circuit on which it is safe to work with the one that is still energized.
- ii. Infringing Safety Clearance before Additional Earth is applied.
- iii. Inadequate precautions to exclude any induced voltages present on the conductors or fittings.

10.9.5 GENERAL PRECAUTIONS TO BE TAKEN BEFORE CLIMBING OR WORKING ON TRANSMISSION LINE TOWERS OR WORKING ON CONDUCTORS.

These general safety precautions are to be taken in addition to the safety precautions detailed in Schemes 1 to 5.

- i. One responsible officer (supervisor/ engineer) should always be present at the site of work.
- ii. 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.
- iii. All Linemen who work on the transmission line towers, conductors or fittings, shall wear and make use of all safety belts / harnesses and other safety equipment provided for their safety and protection.
- iv. The Supervisor/ Engineer shall keep a constant vigil on the linemen climbing on the towers and give them directions in a manner to ensure that they climb only on the side/ portion of the tower on which it is safe to carryout work.

- v. Additional earths shall be carried on the tower in gunny / suitable bags to avoid any damage to the additional earths. Alternatively, the additional earths can be carried manually by the Linemen on their shoulders or raised up by using rope.
- vi. Safe electrical clearance shall be maintained by all Linemen until all the additional earths are correctly connected to conductors or jumpers of circuits under shut down.
- vii. All earth end clamps of additional earths shall be connected first to the tower / cross arm member at the point where the Lineman is standing or sitting in order to apply the additional earths. This earth end clamp shall, as far as possible, be connected at a point between the Lineman and the line end clamp.
- viii. After connection of the earth end clamps with the tower / cross arm members, all line end clamps shall be connected to conductor or jumper from the point where lineman is sitting or standing.

(NOTE) To ensure that a proper connection of the line end clamps with the conductor or jumper has been made, a check of the tightness by attempting to rotate the line end clamps on the conductor or jumper should be made by use of the earthing pole.

- ix. The earthing pole / bridging pole shall be kept suitably on the tower after connection of the line end clamps until disconnection of all additional earths.
- x. 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, the Lineman must shift away from tower / cross arm members to maintain safe electrical clearance. He must not touch the disconnection 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 / disconnected earth. Then the disconnected additional earth shall be removed by the use of the earthing pole.
- xi. After completing the work, all tools, plant and men shall be removed from the conductors and fittings. The last Lineman shall remove the line end clamps from the conductors / jumpers while sitting or standing at the point of or behind the 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.
- xii. On completion of work, the additional earths shall be carried to the ground from the tower in gunny / suitable bags or lowered to ground using rope to avoid any damage to the additional earths. To avoid damage, the additional earths should not be thrown from the tower.
- xiii. While coming down from the tower, the Linemen shall remove the red flags and the green flags.
- xiv. One No. spare additional earth should be carried to the working tower to provide a spare in case of any contingencies.

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

10.9.6 SCHEME 1

WORK ON TOWERS WHICH DOES NOT INVOLVE THE DISCONNECTION OF CONDUCTORS OR JUMPERS

A Work

For work on the de - energized circuit of transmission line which does not involve the disconnection or lowering of any conductors to the ground. This scheme is to be followed during carrying out the following works:

- i. Changing suspension insulators.
- ii. Any other work on a suspension string.
- iii. Fixing / replacing of spacers or vibration dampers adjacent to the suspension or tension string.

B Procedure

- i. Apply general procedures as in section 10.9.5 of this Safety Instructions.
- ii. Apply additional earths to all phases and to all sub conductors (wherever applicable) at the working tower of the de - energized circuit.
- iii. As an extra safety measure, both sub conductors of working phase(s) may be bridged with an additional earth.
- iv. Carry out the maintenance of strings and vibration dampers as per normal procedure. However, if a winch is used for replacement of insulators, the winch must be earthed by the use of a fitted equipment earth attached to an earth spike driven to the ground. All line pulleys used should have good electrical connection with the tower. The pulleys should not have any insulation, i.e., rubber lining, etc.

(NOTE) Conductors can also be earthed at adjacent towers instead of bridging the sub conductors as extra safety measures.

10.9.7 SCHEME 2

BREAKING AND REMAKING JUMPER CONNECTIONS

A Work

For work on the de - energized circuit which does not involve the disconnection or lowering of conductors between towers to the ground. This scheme is to be followed after earthing for the following work on tension towers:

- Breaking or remaking jumper connections, including lowering and raising a jumper.

B Procedure

- i. Apply general procedures as in section 10.9.5 above.
- ii. Even if only one end of the jumper is to be disconnected, additional earths must be provided on both side of the tower at both ends of the conductors on line side of the dead end compression joints.
- iii. Apply additional earths to all phases and to all sub conductors (wherever applicable) on the jumpers at the working tower of the de - energized circuit.
- iv. Apply additional earths on all working phases and on all sub conductors (wherever applicable) on adjacent towers.
- v. Disconnect the jumpers from one or both ends as applicable.
- vi. If the jumper is to be lowered to the ground, disconnect the line end clamp of the additional earth from the jumper before lowering the jumper to the ground. The disconnected additional earth shall be kept suitably at tower cross arm.
- vii. Lower the jumper in such a way that safety clearance is maintained from all live conductors.
- viii. Before any person on the ground touches the jumper, it should be discharged by the use of an additional earth connected to the tower leg or fixed to an earth spike driven into the ground.
- ix. Carry out the maintenance work on the jumpers as per normal procedure.
- x. Raise the jumper to the cross arm maintaining safety clearance from all live conductors. Precautions shall be taken so that the jumper is not raised in the horizontal position.
- xi. The additional earth shall be applied to the jumper for connecting it to the dead end compression joints.
- xii. Connect the jumper at both ends with dead end compression joints.

10.9.8 SCHEME 3

WORK ON CONDUCTORS BETWEEN TOWERS:

A WORK

For work on the de - energized circuit which does not involve the disconnection or lowering of conductors to the ground. This scheme is to be followed after earthing for the following works.

- i. Fixing / repair of line spacers.
- ii. Fixing / repair of rigid spacers.
- iii. Fixing / repair of line spacer dampers.

B Procedure

- i. Apply general procedures as in section 10.9.5 above.
- ii. Apply additional earths on all phases on towers at both the ends of working zone. These towers should not be more than 10 spans apart. At tension tower(s) within the working zone, apply additional earths to the jumpers.
- iii. Carry out the maintenance work as per normal procedure. While working, following safety precautions shall be taken.
 - a. The men on the conductor shall always maintain safe electrical clearance from tower steel parts or any other material at earth potential at those towers where conductor is not earthed.
 - b. If any tool or plant is required by the Lineman on the conductors, they shall be lifted to the working position by using a poly propylene / insulated rope/ bag.
 - c. If access to any tower is required, all the conductors at that tower shall be earthed with additional earths.
 - d. If, before work commences, there is a risk of thunder / lightning stroke, no work shall be started. If during the course of work, there is a risk of thunder / lightning stroke, all work shall immediately stop and all men shall return to the ground.

10.9.9 SCHEME 4

PAINTING OF TOWERS WHICH DOES NOT INVOLVE ANY DISCONNECTIONS AND ANY ACCESS TO CONDUCTOR

A Work

For work on the de - energized circuit which does not require any contact with insulators, associated fittings or conductors. This scheme is to be followed after earthing for the following works:

Painting of:

- i. Single circuit towers.
- ii. Double circuit towers upto vertical centre line of tower towards the de - energized circuit.

B Procedure

- i. Apply general procedures as in section 10.9.5 above.

- ii. Apply additional earths on all phases on sub conductors (wherever applicable) of the de-energized circuit not more than ten towers apart. At tension tower(s), the additional earths shall be connected to the jumpers.
- iii. In case only one or two towers are to be painted, only the working towers need to be earthed as per normal procedure of earthing for suspension or tension towers as the case may be.
- iv. Carry out the painting work on towers as per normal procedure.

10.9.10 SCHEME 5

RAISING AND LOWERING PHASE CONDUCTORS AT SUSPENSION TOWERS. FITTING REPAIR SELEEVES/ JOINTS TO PHASE CONDUCTORS.

A Work

For work on the de - energized circuit of a transmission line which involves raising and lowering phase conductors and the fitting of repair sleeves / joints to the phase conductors. This scheme is to be followed after earthing for the following works:

- i. Lowering of conductor at suspension tower.
- ii. Raising of conductor at suspension tower.
- iii. Providing the repair sleeves on the lowered conductor.
- iv. Cutting and jointing of lowered conductor.

B Procedure

Apply general procedures as in section 10.9.5 above.

- i. **LOWERING AND RAISING CONDUCTORS.**
 - a. Additional Earths shall be fixed on all phases of conductors at the suspension towers and at both the adjacent towers.
 - b. If a manual winch is used, it shall be earthed to the tower using a Field Equipment Earth.
 - c. All the pulleys used should have good electrical connection with the tower. The pulleys should not have any insulation, i.e., rubber lining, etc.
 - d. Connect the rope with the conductor through pulley at suitable places in the tower and through winch.
 - e. If scaffolding is used in the span below conductor, the scaffolding shall be earthed by providing an earth spike.
 - f. Before lowering the conductor, the Additional Earth(s) shall be removed from that conductor and the Additional Earth(s) shall be kept suitably at the tower.

- g. When the lowered conductor is at approx. four meters from ground, additional earth(s) shall be applied from ground spike / tower on to the lowered conductor(s).
- h. When on the ground and the conductor has to be cut, Bridging Earth(s) shall be provided on both sides of cutting point with ground spike or tower legs. Then as per working procedure, the conductor shall be cut and joined. After joining the conductor, the Additional Earth(s) shall be removed.
- i. The conductor(s) shall be raised up to 4 meters height from ground and additional earth(s) shall be removed.
- j. Raise the conductor(s) up to the cross arm level and apply the additional earths on the conductors.
- k. On completion of work, remove all additional earths.
- ii) **RAISING CONDUCTOR FOLLOWING BREAK DOWN**
 - a. Additional Earths with ground spike shall be fitted to all conductor phases at the towers on either side of break down point and either side of work area. In case lowering of conductors from adjacent suspension towers is required, follow the procedure of lowering the conductors given at 10.9.10 (B)(i) of this procedure above. If conductor is required to be lowered from tension towers, then follow Scheme No.6.
 - b. If a manual winch is used for lowering or raising conductor(s), it must be earthed on the tower or by the use of a Field Equipment Earth attached to an earth spike driven into the ground. All the pulleys used should have good electrical connection with the tower. The pulleys should not have any insulation, i.e., rubber lining, etc.
 - c. After raising the conductor up to 4 meter from ground, remove additional earths from the conductors.
 - d. After raising the conductor up to the cross arm level, all Additional Earth(s) should be attached to the conductor.
 - e. After completion of work, additional earths shall be removed.

10.9.11 Scheme 6

LOWERING AND RAISING OF CONDUCTOR AT TENSION TOWERS

A Work

For work on the de - energized circuit of a transmission line which involves lowering and raising phase conductors and the fixing of repair sleeves / joints to the phase conductors. This scheme is to be followed after earthing for the following works:

- i. Lowering of conductor at tension tower.
- ii. Raising of conductor at tension tower.

- iii. Providing the repair sleeves on the lowered conductor.
- iv. Cutting and jointing of lowered conductor.

B Procedure:

LOWERING AND RAISING OF CONDUCTOR

- i. Apply general procedures as in section 10.9.5 above.
- ii. Follow Scheme 2 for disconnection of jumpers. While following Scheme 2, care shall be taken for providing bridging earth which shall be connected to the tower side yoke plate / maintenance block and on to conductors.
- iii. Provide long additional earths from ground spikes on the conductor of the phase wire which is to be lowered / raised. Remove the additional earths connected from the tower to the conductor.
- iv. Lower the conductor to the ground alongwith the additional earths connected to the ground spikes.
- v. Provide additional earths on either side if cutting of the conductor is to be done for jointing purpose.
- vi. After repair work, raise the conductor up to cross arm level alongwith the additional earths connected to the ground spikes.
- vii. Connect the additional earths provided on the towers and remove all additional earths connected to the ground spikes.
- viii. Follow Scheme 2 for making jumper connections.
- ix. After completion of work, remove all additional earths.

10.9.12 Scheme 7

WORK ON EARTH WIRE

A Work

Replacement of vibration dampers & copper bonds, and tightening of bolts and nuts of clamps, etc.

B Procedure

- i. No earthing procedure is required in case of Double Circuit towers or single circuit towers in delta configuration as no shutdown is to be taken for climbing on these types of towers.

- ii. For 400 KV single circuit towers with horizontal configuration of conductors, follow the earthing requirements as per Scheme 1 for both suspension towers and tension towers.

10.9.13 Scheme 8

WORK ON EARTH WIRES AFTER BREAK DOWNS

A Work

Jointing and raising of earth wire after break down.

B Procedure

- i. Obtain the shut down of the affected circuit in case of 400 KV double circuit line, and shut down of the line(s) in case of single circuit lines and other double circuit line.
- ii. Provide earthing as per Scheme 1 on all towers which are required to be climbed.
- iii. Provide additional earths connected to earth spikes on the earth wire ends (2 Meters away from ends) before starting the job for mid span joints.
- iv. During rigging, the pulley used at the cross arm / peak end shall be provided with additional earth connected to the cross arm / peak. This is required if fibre round / polypropylene rope sling has been used in place of wire rope sling for fixing the pulley.
- v. Carry out the repair and maintenance work on the earth wire.
- vi. Raise the earth wire upto 4 meters height from ground and then remove additional earths connected to earth spikes.
- vii. Use extreme caution when raising the earth wire in case of 400 KV double circuit lines so that the required safety clearance is always maintained.
- viii. Raise the earth wire upto cross arm / peak level.
- ix. Remove all additional earths on completion of work.

10.9.14 Scheme 9

INSPECTION / PATROLLING OF TOWERS AND LINE MATERIALS / FITTINGS

A Work

- i. Inspection of complete single circuit towers under shut down.
- ii. Inspection of towers upto vertical centre line of double circuit towers towards circuit under shut down (only one circuit under shut down).

- iii. Inspection of all insulators, fittings, accessories, etc. of de – energized circuit of single circuit & double circuit lines.
- iv. Tightening of bolts & nuts, fixing split pins in suspension / tension hardware, etc.

B Procedure

- i. Follow system of earthing procedure as per Scheme 3 if inspection is being done by trolley work.
- ii. Follow system of earthing procedure as per Scheme 1 in case access to any conductor point is needed from tower cross arm.
- iii. Carry out minor works like tightening of bolts and nuts, fixing split pins, relocation of vibration dampers, etc.
- iv. Remove additional earth after completion of inspection & minor works.

10.10 RVPN SAFETY INSTRUCTIONS 06 (RSI – 06)

ACCESS TO EHV / HV COMPARTMENTS AND STRUCTURES

10.10.1 Purpose

To control the access of personnel to EHV / HV compartments and structures.

10.10.2 Scope

These RVPN Safety Instructions set down the procedures to control the access of personnel to enclosures, chambers, cubicles, cells containing exposed extra high voltage / high voltage conductors. It also includes access to towers, gantries or other means of supporting or giving access to such conductors.

10.10.3 Definitions

Access key:	A unique key for locking a device for preventing access to a compartment or structure.
Compartment:	An enclosure, chamber, cubicle or cell designed to prevent and control access to equipment having exposed EHV / HV conductors.
Structure:	A tower, gantry or other means of supporting or giving access to EHV / HV equipment / conductor.

10.10.4 Equipment Identification

Each compartment or structure must be readily identifiable.

10.10.5 Dangers

The main dangers to personnel working in compartments and on structures are electric shock, burns or falling. These can arise from accidental or unauthorized access and proximity to live EHV / HV conductors.

10.10.6 Access to Compartments.

- i. Devices designed to prevent access to compartments must normally be kept locked.
- ii. Access keys for the locks must normally be kept locked in a box or cupboard under the control of Shift - In - Charge.
- iii. Only the Shift - In - Charge or operating personnel under his personal supervision must have access to a compartment in which the exposed EHV / HV conductors are live.
- iv. When work is to be done on EHV / HV equipment in a compartment, all the exposed EHV / HV conductors must have been isolated, points of isolation established, primary earths applied and a Permit To Work or Permit To test issued for the work. The lock controlling access to the compartment must be unlocked by the Shift - In - Charge.

10.10.7 Access to structures

- i. Devices designed to prevent the climbing of structures must normally be kept locked or bolted.
- ii. Access devices must be opened only by the Shift - In - Charge under a specific PTW / PTT.

10.11 RVPN SAFETY INSTRUCTIONS 07 (RSI – 07)

EQUIPMENT CONTAINING SULPHUR HEXAFLUORIDE (SF₆)

10.11.1 Purpose

To control inherent dangers involved in equipment containing SF₆.

10.11.2 Scope

These RVPN Safety Instructions apply the principles established by the Safety Rules to achieve safety from the system for personnel working on equipment which contains or has contained sulphur hexafluoride (SF₆) gas.

10.11.3 Definitions

Gas zones:	Discrete pieces of equipment which may be independently isolated and drained of SF ₆ . A gas zone may comprise of:
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- A single phase enclosure.
- A single enclosure containing the three phases of an item of equipment.
- Three single phase enclosures of a common item of equipment connected by inter phase pipe work.

“Point of Access” Notice:	An approved notice identifying initial points of entry to isolated and vented equipments (relevant to GIS only).
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10.11.4 Equipment Identification

- i. Equipment on which work is to be carried out must be readily identifiable. Where necessary, a means of identification must be fixed to it which will remain effective throughout the duration of the work.
- ii. Gas zones must be identified as per the layout of GIS.

10.11.5 Dangers

The main dangers to personnel from equipment containing SF₆ gas are:

- i. Asphyxiation or suffocation.
- ii. Electric shock.
- iii. Burns.
- iv. The release of stored mechanical energy or pressure.
- v. Toxic breakdown products which can be formed within the equipment.

10.11.6 Preparation for Work

- i. **Demarcation of work area:**
The boundaries of the equipment on which it is safe to work must be clearly identified. This must be done in accordance with the requirements of RVPN Safety Instructions 02 (RSI - 02): “Demarcation of Work / Testing Areas in Sub Stations”.
- ii. **When depressurization is not required:**
If depressurization is not required to allow work to be done, necessary precautions must be taken to achieve safety from the System by applying appropriate safety precautions followed by the issue of a Permit To Work or Permit To Test.
- iii. **When depressurization is required:**

When depressurization is required, the following precautions must be taken to achieve safety from the system.
 - a. The equipment must be drained of SF₆. This must be carried out in accordance with the approved procedures relating to sulphur hexafluoride (SF₆) gas.
 - b. A point of access notice must be displayed at each initial entry point (applicable for GIS). These notices must be fixed or moved only by maintenance personnel under the supervision of a Maintenance / Testing Engineer (Refer RSI – 02).

- c. A Permit To Work or Permit To Test must be issued for the work to proceed and, where appropriate, the recommendations for general safety report must specify the further precautions to be taken to deal with any arc products which may be present. The removal and disposal of any arc products must be in accordance with the approved procedure relating to sulphur hexafluoride (SF₆) gas.

10.12 RVPN SAFETY INSTRUCTIONS 08 (RSI - 08)

MOVEMENT AND OPERATION OF MOBILE ACCESS EQUIPMENT, VEHICLES, CRANES AND LONG OBJECTS IN SUB STATIONS.

10.12.1 Purpose

To provide safety from the hazards arising from movement of mobile cranes, vehicles, etc. within a charged switchyard.

10.12.2 Scope

These RVPN Safety Instructions apply the principles established by the Safety Rules to achieve safety from the system when mobile access equipment, vehicles, cranes and long objects are being moved or used within Sub Stations containing exposed live EHV / HV equipment.

10.12.3 Definitions

Field equipment earths:	Approved connections for bonding items of field and access equipment such as scaffold, hydraulic platform, mobile crane, winches, etc. to earth. The earths are coloured orange to identify them from additional earths and not included on an earthing schedule. They shall have a minimum cross sectional area of 35 mm sq. copper equivalent.
Long objects:	Items of equipment such as ladders, scaffold, poles, ropes, measuring tapes, etc. which, if not controlled during handling, could infringe safety clearance.
Operator:	A person trained, assessed and appointed to use specific type of mobile access equipment, vehicle or cranes within energized Sub Stations.

10.12.4 Equipment identification

Equipment on which work is to be carried out must be readily identifiable. Wherever necessary, a means of identification must be fixed to it which will remain effective throughout the duration of work.

10.12.5 Dangers

The main dangers to personnel during the movement and use of access equipment, vehicles, cranes and long objects in Sub Stations containing exposed live EHV / HV conductors are electric shock, burns or falling arising from:

- Infringing safety clearance.
- Induced voltages.

10.12.6 USE OF MOBILE ACCESS EQUIPMENT, VEHICLE AND CRANES IN SUB STATIONS.

- i. When mobile access equipment, vehicles or cranes are to be used in Sub Stations, Maintenance / Testing Engineer on site must assess the risks.
- ii. The Maintenance / Testing Engineer shall ensure that the mobile access equipment is operated by a trained operator only.

10.12.7 MOVEMENT OF MOBILE ACCESS EQUIPMENT VEHICLES AND CRANES TO AND FROM THE DEMARCATED WORKING AREA.

- i. When mobile access equipment, vehicles or cranes are to be moved to and from the safe working area, and any part of this equipment in the transport position is higher than 2.3 meters from ground level, then a Maintenance / Testing Engineer must assess the risks.
- ii. The Maintenance / Testing Engineer must specify on site the route to be followed with adequate protection.
- iii. The Maintenance / Testing Engineer may also specify when during the movement, the mobile access equipment, vehicle or crane must be bonded to earth using field equipment earths.
- iv. The Maintenance / Testing Engineer, when deciding on the route to be taken, must also ensure that the bus bar zone protection wherever provided and adjacent circuit protection is in service.
- v. The Maintenance / Testing Engineer must provide personal supervision during the whole period of movement.
- vi. At no time must safety clearance be infringed.

10.12.8 OPERATION OF MOBILE ACCESS EQUIPMENT, VEHICLES AND CRANES WITHIN THE DEMARCATED WORKING AREA.

- i. Working area must be identified in accordance with RVPN Safety Instructions RSI – 02 ‘Demarcation of work / testing areas in Sub Stations’.
- ii. Approach to within safety clearance of equipment by mobile access equipment, vehicle or crane is only allowed under Permit To Work or Permit To Test.

- iii. The operator must ensure that effective use is made of any equipment stabilizing devices or outriggers.
- iv. The Maintenance / Testing Engineer holding the safety document must consider whether it is necessary to consult an appropriate qualified specialist (e.g., Civil Engineer) to ensure that safe ground bearing pressures will not be exceeded. This is particularly important where wheels, stabilizing legs or outriggers may need to be positioned over ducts. Where necessary, load spreading devices must be used.
- v. The recipient of the safety document must ensure that, as soon as practicable after reaching the demarcated working area, a field equipment earth is connected to the equipment.
- vi. The recipient of the safety document must satisfy himself that the operator knows what work is to be done and that the equipments controls are operating correctly.
- vii. The recipient of the safety document must consider whether to select member(s) of his working party as Safety Observer(s). He must assess the risks in relation to the work being done, the equipment being used, the field of vision of the operator and the proximity of exposed live EHV / HV equipment.
- viii. The Safety Observer(s) must use agreed signal for halting the movement of crane to avoid Danger.
- ix. Equipment provided for personnel access must be electrically bonded to the earthed EHV / HV equipment as near to the point of work as practicable to provide an equipotential zone. This can be achieved by connecting the access equipment through a field equipment earth to the same point as the primary earth or additional earth attached to the EHV / HV equipment. It is essential that there is an adequate bond between the access platform and the vehicle chassis.

10.12.9 SCAFFOLDING

- i. The Maintenance / Testing Engineer must finalize, on the site, the movement route of scaffolding.
- ii. Subsequent movement of scaffolding to the required location must be carried out under the personal supervision of the Maintenance / Testing Engineer.
- iii. When moved in a Sub Station, long scaffolding components must be carried in a horizontal position and as near to the ground as possible.
- iv. Before scaffolding is erected or dismantled, the Maintenance / Testing Engineer must assess the risks in relation to the proximity to exposed live EHV / HV equipment.
- v. Field equipment earths must be applied to scaffolding erected near to the live EHV / HV equipment as soon as it is practicable to do so. As erection proceeds, Field Equipment Earths must be applied at approximately 5 metres (15 feet) intervals, vertically or horizontally or as determined by the Maintenance / Testing Engineer.

- vi. The recipient of the safety document must assess the risks in relation to the method of erection and the proximity to exposed live EHV / HV equipment. He must consider whether to select Safety Observer(s).
- vii. No bamboo / wooden scaffolding is to be used.

10.12.10 MOVEMENT AND USE OF LONG OBJECTS

- i. Long Objects must be stored, moved and used in a controlled manner to ensure that they do not infringe Safety Clearance.
- ii. Umbrellas must not be carried in switchyard areas.

LADDERS

- i. Only Approved ladders must be used which are of no greater length than is required for the work.
- ii. When not in use all ladders within substations must be securely Locked to a suitable anchorage.
- iii. Ladders for operational purpose must not be used without the permission of a Shift Engineer.
- iv. The movement and erection of ladders must be carried out under the Personal Supervision of Shift Engineer / Maintenance Engineer.
- v. When moved in a substation, ladders must be carried in a horizontal position and as near to the ground as possible.
- vi. If ladders have to be moved within a defined safe working area after the initial placement, the movement must be carried out in accordance with the specific instructions of the Maintenance / Testing Engineer.
- vii. Before use portable ladders provided to give access to fixed ladders which terminate above ground level must be Locked in position by a maintenance / testing engineer. These must remain Locked in position during the period the ladders are in use.

10.13.0 RVPN SAFETY INSTRUCTIONS 09 (RSI – 09)

EXTRA HIGH VOLTAGE / HIGH VOLTAGE STATIC CAPACITOR BANKS

10.13.1 Purpose

The safety of personnel working on or testing EHV / HV static capacitor banks has to be ensured by the removal of stored energy.

10.13.2 Scope

These RVPN Safety Instructions apply the principles established by the Safety Rules to achieve safety from the system including the removal of stored energy for personnel working on EHV / HV static capacitor banks.

10.13.3 Definitions

Rack:	An individual framework containing capacitors connected together.
Capacitor Bank:	A group of capacitors consisting of a number of racks connected together. If the equipment consists of only one rack, the term capacitor bank will also apply.
Shorting switch:	A fixed device for short circuiting the capacitors in racks to dissipate stored energy safely. It may also provide a direct connection to earth.
Short Circuiting Lead:	An approved (6 sq. mm, copper equivalent 1.1 KV insulation) lead with insulated clips or a standard lead supplied by the manufacturer for this purpose. This is used for short-circuiting an individual capacitor. This can be a clip – on type lead used during the disconnection of a capacitor or a bolt – on type lead used during removal and temporary storage.
ContinuityLead:	An approved lead or a standard lead supplied by the manufacturer which is used as a temporary means of maintaining continuity of the connections between other capacitors during the disconnection of a capacitor.
Discharge Stick:	An approved device used for the purpose of discharging any residual charge in a capacitor / Capacitor Bank .

10.13.4 Equipment Identification

Equipment on which work is to be carried out must be readily identifiable. Wherever necessary, a means of identification must be fixed to it which will remain effective throughout the duration of work.

10.13.5 Dangers

The main dangers to personnel are electric shock or burns arising from:

- The discharge of electrical energy retained by the static capacitors after they have been isolated.
- Inadequate precautions to guard against any induced voltages in the conductors or associated fittings.

10.13.6 Preparation of Work / Testing

- i. The capacitor bank must be isolated, points of isolation established and primary earths applied.
- ii. Shorting switches, where installed on the racks must be closed. The control of shorting switches is the responsibility of the Maintenance / Testing Engineer.
- iii. A Permit To Work or Permit To Test must be issued.

10.13.7 Work / Testing

- i. No capacitor **unit** must be **handled** unless it is short – circuited.
- ii. The Maintenance Engineer requesting the safety document must specify the position for application of clip - on short circuiting leads and continuity leads. Short circuiting leads and continuity leads must be applied to the appropriate capacitors under the personal supervision of the Maintenance / Testing Engineer.
- iii. Before the application of short circuiting leads to a capacitor provided with externally fuse, it must be discharged using the discharge stick under the personal supervision of the Maintenance / Testing Engineer.
- iv. Before an individual capacitor is removed from a rack,
 - a. The clip – on short circuiting lead must be replaced by a bolt – on short circuiting lead.
 - b. The bolt – on connection must be made before the clip - on lead is disconnected.
 - c. The continuity of the connections of adjacent capacitors must be maintained using the continuity leads.
 - d. During storage and transport, capacitors must be short -circuited using at least two complete turns, between terminals, of tinned copper fuse wire of not less than 30 amp. rating.
 - e. When work activity requires the opening or removal of shorting switches and specifies special requirements for subsequent access to capacitors, these actions must be carried out under the personal supervision of the Maintenance / Testing Engineer.

10.14.0 RVPN SAFETY INSTRUCTIONS 10 (RSI - 10)

PRESSURE SYSTEMS

10.14.1 Purpose

To protect all personnel against the dangers of pressurized systems.

10.14.2 Scope

These RVPNL Safety Instructions apply the principles established by the Safety Rules to achieve safety from the system for personnel working on pressure systems.

10.14.3 Definitions

Pressure system:

- a) A system comprising of one or more pressure vessels of rigid construction, any associated pipe work, protective devices and associated equipments.
- b) The pipe work with its protective devices to which a portable gas container is, or is intended to be, connected.
- c) A pipe line in its protective devices which contains or is liable to contain a relevant fluid/ gas at some pressure.

Safe operating limit:

The operating limits (incorporating a suitable margin of safety) beyond which system failure is liable to occur.

10.14.4 Equipment Identification

Equipment on which work is to be carried out must be readily identifiable. Wherever necessary, a means of identification must be fixed to it which will remain effective throughout the duration of work.

10.14.5 Dangers

The main dangers from pressure systems arise from:

- The uncontrolled release of pressurized substances, e.g., compressed air / gas / fluids, etc.

10.14.6 Work / Testing

- i. When work is to be carried out on pressure systems, a competent person (Maintenance / Testing Engineer) must assess the means of achieving safety from the system. Work may be carried out under one of the following conditions:
 - a. With the system isolated and points of isolation established, pressure drained, air / gas / fluids vented and purged, and cooled, where necessary.
 - b. With the system isolated and points of isolation established but containing pressurized substances, e.g., SF₆ gas / hydraulic oil in case of circuit breakers.
 - c. With the equipment operational.
 - d. With the equipment partly isolated and partly in its operational mode.
 - e. All equipment must be clearly demarcated according to RVPN Safety Instructions 02 (RSI – 02) while a safety document is in force.

10.14.7 Work with the Equipment Isolated and Non Operational.

- i. The equipment must be isolated from all external sources of energy and points of isolation established.
- ii. A non-return valve must not be considered as a shut off valve unless it is capable of being locked in the closed position.
- iii. Electrically and manually operated valves must be adjusted to the required position and locked. The electrical supply to electrically operated valves must be isolated or the mechanical drive disconnected.
- iv. Hydraulic and pneumatic control valves must be locked in the appropriate position.
- v. The contents of the equipment must be adjusted to a safe level, which will avoid danger.
- vi. The equipment must be Vented and Purged as appropriate.
- vii. Pressure vessels must be regarded as confined spaces. When access is necessary the requirement of RVPN Safety Instructions 16 (RSI – 16) ‘General Confined Spaces’ must be applied.
- viii. A Permit To Work must be issued. Refer Safety Rule 10.4.5 (ii) (a).

10.14.8 WORK / TESTING WITH THE EQUIPMENT IN AN OPERATIONAL OR PARTLY OPERATIONAL MODE

- i. The following work can be carried out with the equipment in a fully operational or **partly** operational mode:
 - On-load repairs of leaks: On-load repair of leaks on compression joints (e.g., ermetto / threaded / flange joint etc.) may be carried out under the supervision of Maintenance / Testing Engineer.
- ii. If the work of testing requires the limited restoration of motive power (e.g., compressor motor electrical supplies), then the safety document issued will be a Permit To Work. Refer Safety Rule 10.44(i) (a).
- iii. The requirements and precautions for the restoration of those supplies will be as described in RVPN Safety Instructions 01 (RS –01).
- iv. The following activities may be carried out by the issue of a Permit To Test. Refer Safety Rule 10.4.3 (ii) (b).
 - a. Testing of safety valves:
The testing of safety valves or hydraulic testing must be carried out under the personal supervision of the Maintenance / Testing Engineer.
 - b) Testing of pressurized air / gas / fluid:

The testing of quality of compressed air / gas / fluid, pressurized system and testing equipments shall be carried out under the personal supervision of a Maintenance / Testing Engineer.

10.14.9 Inspection and Hydraulic Testing

A hydraulic test at a pressure in excess of the safe operating limit is an over pressure test. Such a test must only be done in accordance with a written procedure approved by the Sub Station – In – Charge and with the issue of a Permit To Test.

10.15 RVPN SAFETY INSTRUCTIONS 11 (RSI – 11)

STATION STORAGE BATTERY

10.15.1 Purpose

To specify procedures needed to achieve safety from inherent dangers when testing / maintenance is being carried out on station storage batteries.

10.15.2 Scope

These RVPN Safety instructions apply the principles established by the Safety Rules to achieve safety from the system for personnel working on station storage batteries.

10.15.3 Definitions

A battery bank: All battery cells, connections and stands comprise a battery bank.

10.15.4 Equipment Identification

Equipment on which work is to be carried out must be readily identifiable. Wherever necessary, a means of identification must be fixed to it which will remain effective throughout the duration of work.

10.15.5 Dangers

The main dangers to personnel working on a battery bank are electric shock or burns arising from:

- The possibility of personnel inadvertently shorting battery terminals.
- Dangers spilling of electrolyte on body.
- Asphyxiation or suffocation due to the fumes of storage battery acid.

10.15.6 General requirements

- i. The Sub Station – In – Charge must carry out an assessment to determine the conditions under which the work is to take place and if a safety document is required to be issued.

- ii. When work is to be carried out on a battery bank, adequate precautions must be taken to achieve safety from the danger of DC voltage and spilling of electrolyte.
- iii. When work on live equipment requires portable instruments to be used for impedance or voltage measurements, the instruments must be provided with insulated probes.
- iv. When handling acid, extreme care must be taken and personnel protective equipment like face shield, apron, gloves, etc. must be used before work is undertaken.
- v. Proper ventilation alongwith water supply in washbasin shall be ensured in or near the battery room.
- vi. While preparing electrolyte, always ADD ACID TO WATER. NEVER ADD WATER TO ACID.
- vii. Always clean spilled acid immediately.
- viii. During handling of acid, sufficient quantity of water must be available nearby.

10.15.7 Working / Testing on Station Battery Bank.

- i. Wherever required, points of isolation must be established. Any fuses and links and / or safety keys used to secure the points of isolation must be retained in key safe.
- ii. Sub Station – In – Charge must assess the work required to be done on a battery bank and decide whether it must be carried out under:
 - a. Permit To Work, and/or
 - b. Personal supervision.
- iii. The work must be carried out by competent person(s).
- iv. The competent person(s) who shall do the work must first remove all metallic objects such as wrist watch, rings, wristlets, cufflinks, pendants, etc. on their person.
- v. Where necessary to prevent injury, approved insulated tools, insulating stands, mats, gloves, apron, face shields, as appropriate, must be used.
- vi. Only suitable testing instruments with insulated test probes must be used.
- vii. Consideration must be given to a competent person being accompanied by another competent person if the presence of such a person could contribute significantly to ensuring that injury is prevented. Any accompanying competent person must be trained to recognize danger and if necessary to render assistance in the event of an emergency, e.g., accidental spilling of acid on eyes, unconsciousness due to inhalation of toxic gases, etc.

10.16 RVPN SAFETY INSTRUCTIONS 12 (RSI – 12)

FIRE PROTECTION AREAS

10.16.1 Purpose

To ensure safety of personnel from the effects of fixed automatic fire protection / fighting systems

10.16.2 Scope

These RVPN Safety Instructions apply the principles established by the Safety Rules to achieve safety from the system for personnel working in, or entering areas protected by fixed fire protection / fighting systems.

10.16.3 Equipment Identification

Equipment on which work is to be carried out must be readily identifiable. Wherever necessary, a means of identification must be fixed to it which will remain effective throughout the duration of work.

10.16.4 Dangers

The main dangers to personnel from the operation of fixed fire protection / fighting systems are:

- Asphyxiation / suffocation as a result of operation of fixed fire fighting systems.
- Falling or striking against objects due to poor visibility after the release of contents of fire extinguishers.

10.16.5 PRESSURIZED SYSTEMS (HYDRANT / HIGH VELOCITY WATER SPRAY SYSTEMS)

- i. Before work commences in an area protected by a water emulsifier fire protection system, the system must be isolated.
- ii. The following precautions must be taken:
 - a. The automatic control of the fire protection system must be rendered inoperative and the control kept on 'Manual'. Valves should be closed for the particular equipment for which PTW / PTT is being issued in order to isolate it from the rest of the system. These actions must be recorded in accordance with RVPNL Safety Instructions 01 (RSI – 01), 03 (RSI – 03) and 10 (RSI – 10).
 - b. Notice(s) indicating that the control is on 'Manual' must be fixed to the automatic / manual selector switch and at point(s) of access to the area.
 - c. Precautions taken to render the automatic control inoperative must be noted on any Permit To Work/ Permit To Test issued for work / testing in the protected area.
- ii. Automatic control of the fire protection system can be restored after all persons have withdrawn from the area / all access doors have been locked.

10.16.6 Access to Areas Following Operation of Fire Protection Systems

Before persons are permitted to enter an area into which a fire protection system has been discharged, whether following a fire or accidentally, the area must be thoroughly checked and verified as safe by the Shift - In - Charge. If the atmosphere cannot be verified as safe and it is essential to enter the area, approved breathing equipment and protective apparel must be worn.

10.17.0 RVPN SAFETY INSTRUCTIONS 13 (RSI – 13)

PROCEDURE FOR WORKING ON SF₆ GAS FILLED EQUIPMENT

10.17.1 Purpose

To protect all personnel against inherent hazards / dangers while working on SF₆ gas filled equipments.

10.17.2 Scope

These RVPN Safety Instructions lay down procedures for working on SF₆ gas filled equipments and to protect all personnel against inherent dangers / hazards of SF₆ gas.

10.17.3 Definitions

Impurities:	Impurities (toxic or non toxic) contained in SF ₆ gas filled in EHV equipments.
Decomposition products:	Electrical discharge decomposes SF ₆ gas into SF ₄ , SF ₂ , etc. These are called decomposition products. In some cases, sulphur fluoride gas is also formed due to electric discharges.

10.17.4 Equipment Identification

Equipment on which work is to be carried out must be readily identifiable. Wherever necessary, a means of identification must be fixed to it which will remain effective throughout the duration of work.

10.17.5 Dangers

Following are the dangers which the personnel may be subjected to while working on SF₆ gas filled equipments:

- Since SF₆ gas is heavier than air, there is danger of asphyxiation (suffocation) in the storage / work area in the absence of proper ventilation.
- Decomposition products, e.g., sulphur fluorides and other toxic gases having pungent or unpleasant odour may cause irritation in nose, mouth and eyes.

10.17.6 Working Procedures

- i. A Permit To Work must be issued before starting the work.
- ii. The equipment on which work is to be done must be electrically isolated from other equipments.
- iii. The equipment must be earthed at two points.
- iv. Using gas evacuation trolley, SF6 gas should be taken out from the equipment and evacuation upto about 50 mbar should be achieved.
- v. After ensuring that total gas has been evacuated / removed, then only the equipment should be opened / dismantled.
- vi. In general, a mask or other protective measures are not necessary when no appreciable amount of dust (fluoride powder) or odour exists. However, during internal inspection of the interior path of apparatus, personnel should take precautions to avoid exposure to the break down products and suitable protective equipment like gas mask (preferably incorporating molecular filter, etc.), industrial type goggles (SF6 gas dust can some times attack the glass of goggles, spectacles, etc.) and rubber gloves shall be used.
- vii. After completing the work on the equipment, the equipment should be reassembled.
- viii. Before refilling SF6 gas, evacuation upto 5 m bar should be carried out for about two hours. Thereafter, SF6 gas should be filled in the equipment.

10.18.0 RVPN SAFETY INSTRUCTIONS 14 (RSI – 14)

AUTHORISATION (WORK ALLOCATION) OF PERSONS.

10.18.1 Purpose

To define guidelines for **authorising** persons for carrying out maintenance works in EHV Sub Stations or on transmission lines.

10.18.2 Scope

These RVPN Safety Instructions set down procedures for **authorisation** of personnel such as Maintenance Engineer, Testing Engineer, Shift - In - Charge, Sub Station – In – Charge, Line – In - Charge, Operator and Authorized Person.

10.18.3 Definitions

Maintenance Engineer:	Engineer responsible for carrying out maintenances works of EHV equipments, transmission lines and HV / MV / LT systems.
Testing Engineer:	Engineer responsible for carrying testing of protective relays & systems, PLCC panels and other related equipments
Shift - In - Charge:	Engineer responsible for all operations / activities in Sub Stations.

Sub Station – In - Charge:	Engineer responsible for all operation and maintenance activities being done / to be done in the Sub Station.
Line – In - Charge:	Engineer responsible for patrolling of and maintenance activities being done or to be done on the transmission line.
Lead Shift - In Charge:	Shift - In - Charge of the Sub Station where PTW /PTT has been applied for and who shall be responsible for coordination of operation activities involved for carrying out line maintenance.
Operator:	Person authorized to carry out operations of EHV equipment or to use specific type of vehicles or cranes within Sub Station.
Authorized Person(s):	Person(s) authorized to carry out operation / maintenance work on EHV equipments / transmission lines.

10.18.4 Procedures

- i. Only **authorised** persons shall be allowed to carry out operation and maintenance activities in Sub Stations / on transmission lines.
- ii. Safety guidelines during O&M of Sub Stations shall be issued by Sub Station - In - Charge. All operation and maintenance activities shall be carried out under the control of Sub Station - In - Charge.
- iii. For carrying out maintenance work, issue of safety document (PTW / PTT) shall be approved by Sub Station - In - Charge.
- iv) Sub Station - In - Charge shall **authorise** Shift - In – Charge & Maintenance Engineer for carrying out O&M activities. Maintenance Engineer shall also be Testing Engineer for local testing. Engineers of the Protection Wing & other fields who have been assigned specific testing tasks shall also be designated as Testing Engineers. Sub Station safety documents, i.e., PTW / PTT shall be filled by Maintenance Engineer / Testing Engineer for carrying out maintenance / testing activities in Sub Stations. PTW / PTT are to be approved by Sub Station - In - Charge before being issued by Shift - In - Charge.
- v) All operations including isolation and earthing of equipments shall be carried out by the Operator in the presence of Shift - In - Charge.
- vi) Only after personally confirming isolation and earthing in the work area, the Shift – In – Charge shall issue the PTW / PTT. After receipt of PTW / PTT, the Maintenance Engineer / Testing Engineer shall advise the Authorized Persons for carrying out maintenance / testing activities. All Authorized Persons shall be **selected** by Maintenance Engineer / Testing Engineer.
- vii. Maintenance Engineer / Testing Engineer shall be responsible for taking all safety precautions during maintenance testing works including use of Personnel Protective Equipment (PPEs).

10.19 RVPN SAFETY INSTRUCTIONS 15 (RSI – 15)

PROCEDURE FOR ADDING TO / REMOVING FROM THE EHV / HV SYSTEM

10.19.1 Purpose

To define procedure for safely adding / removing equipments (new / old) to / from the EHV / HV system.

10.19.2 Scope

These RVPN Safety Instructions define procedures to achieve safety of personnel and / or transmission system safety while adding / removing equipments to / from the EHV system.

10.19.3 Definitions

Bay:	An array of switching and protective equipments (such as circuit breaker, current transformer, isolators, wave trap, control and relays panels, etc.) for control and protection of a feeder, i.e., transmission line or transformer / reactor, etc. which are to be commissioned or added to / removed from the transmission system.
Bay equipment:	Circuit breaker, current transformer, wave trap, control and relay panels, etc. which are part of the bay.
Inter Linking Transformer (ILT):	Transformer used to step up / step down the system voltage and are synchronized with the system on both the HV and LV sides
Reactor:	Line or bus reactor used for controlling the system voltage.
Maintenance Engineer:	Engineer responsible for carrying out maintenance works of EHV equipments, transmission lines and HV/ MV / LT systems.
Erection Engineer:	Engineer responsible for all erection activities related to addition/removal of equipment to / from the bay.
Sub Station - In - Charge:	Engineer responsible for erection, operation and maintenance activities being done / to be done in the Sub Station.

10.19.4 Procedures

- i. **Adding Complete Bay to EHV / HV System.**
 - a. When a new bay is to be added to existing EHV / HV system, safety precautions as per RSI – 08, including maintaining safe electrical clearance, need to be taken during movement of crane for carrying out erection / dismantling work.
 - b. Before connecting the new equipment, pre-commissioning checks are to be completed first.

- c. Once pre-commissioning checks are completed, necessary PTW / PTT is to be requested by Erection Engineer which shall be approved by Sub Station - In - Charge. Work of connecting jumpers, etc. is to be completed taking safety precautions as per RSI - 01. After connecting to the existing EHV system, all commissioning checks are to be performed.
- d. All control cables & protection relays are to be connected while taking all safety precautions.

ii. Adding Bay Equipment to EHV / HV System

- a. When old bay equipment is to be replaced by new type/ design of equipment, then work shall be carried out only after issue of safety documents, i.e., PTW / PTT duly approved by Sub Station - In - Charge and taking safety precautions as per RSI - 01.

iii. Removing complete Bay from EHV / HV System

- a. When any bay is to be removed from EHV / HV system, then PTW / PTT is to be issued which shall be approved by Sub Station - In - Charge. Safety precautions as per RSI - 01 are to be taken during dismantling work.
- b. The bay which is to be removed shall be identified / isolated from the rest of the system.
- c. Safety precautions as per RSI – 08, including maintaining safe electrical clearance, need to be taken during movement of crane for carrying out dismantling work.

iv. Removing Bay Equipment from EHV / HV System

- a. When any bay equipment is to be removed from EHV / HV system, then PTW / PTT is to be issued which shall be approved by Sub Station - In - Charge. Safety precautions as per RSI - 01 are to be taken during dismantling work.
- b. Bay Equipment which is to be removed shall be identified/ isolated from the rest of the system.
- c. Safety precautions as per RSI – 08, including maintaining safe electrical clearance, need to be taken during movement of crane for carrying out dismantling work.

10.20.0 RVPN SAFETY INSTRUCTIONS 16 (RSI – 16)

PROCEDURE FOR WORK IN GENERAL CONFINED SPACES

10.20.1 Purpose

To define procedures for precautions to be taken to prevent Danger when entry into a confined space is required.

10.20.2 Scope

These RVPN Safety Instructions define procedures to achieve safety of personnel when it is necessary to enter a confined space either for inspection or work.

10.20.3 Definitions

Confined space is one of the following:

- i. A normally sealed tank for which entry is **through** a manhole or inspection window or similar point of access, e.g., as in transformer tank, shunt reactor tank, GIS, etc.
- ii. Open topped pits, sumps or trenches which may contain dangerous substances **or reptiles**.
- iii. Inverted bottom spaces which may contain dangerous substances **or reptiles**.
- iv. Rooms, buildings or other enclosures which contain gases that have displaced air.

10.20.4 Dangers

- i. The main Dangers to personnel in confined spaces are:
 - a. Asphyxiation or suffocation.
 - b. Poisoning due to toxic atmosphere / **biting by reptiles**.
 - c. Fire causing an explosion or burns to personnel.
 - d. Effect of excessive noise.
 - e. Falling or getting trapped within the confined space.
- ii. Danger in confined spaces can also be caused by work such as application of heat to the surface which may cause ignition of the contents or cause a chemical reaction between the contents or the residue.
- iii. Danger in confined spaces can also be present in open topped pits, sumps or trenches which may contain trapped gases which are heavier than air, e.g., SF₆, LPG, Chlorine or sump solvents. Similarly, inverted open bottom spaces may contain gases which are lighter than air, e.g., Hydrogen.
- iv. Danger in confined spaces can also be due to gases which have density similar to air, e.g., Nitrogen and CO₂, but which displace air.

10.20.5 Procedures

- i. **CONFINED SPACES WHICH HAVE NOT CONTAINED TOXIC OR ASPHYXIATING / SUFFOCATING AIR OR FLAMMABLE SUBSTANCES.**

- a. In case of EHV / HV / MV / LV equipment and wherever considered necessary in other cases, a Permit To Work shall be issued specifying the precautions to be taken to achieve safety and any additional precautions to be taken during the duration of the work.
- b. Before any work is commenced, all supplies of gases, liquids, etc. must be isolated and the confined space vented to atmosphere.
- c. Maintenance Engineer shall give consideration to the provision of forced ventilation within the confined space for the duration of the work.
- d. Oxygen should not be used to “sweeten” the atmosphere in the confined space. Oxygen enriched atmosphere can make substances such as grease liable to spontaneous combustion.
- e. If it is essential to use gas or electrical welding equipment inside the confined space, additional precautions must be taken to eliminate Danger from the heat or flame or electrical sparks and / or gases caused by such operations.
- f. If entry to or access within the confined space is restricted or there is possibility of slipping or falling within the confined space, provision must be made to safely evacuate any personnel who are overcome by fumes or are injured. The provision of a suitable harness (safety belt) with ropes and staff stationed outside the confined space shall be provided.

ii. CONFINED SPACES WHICH HAVE CONTAINED TOXIC OR ASPHYXIATING / SUFFOCATING AIR OR FLAMMABLE SUBSTANCES.

- a. In case of EHV / HV / MV / LV equipment and where considered necessary in other cases, a Permit To Work shall be issued specifying the precautions to be taken to achieve safety and any additional precautions to be taken during the duration of the work.
- b. Before any work is commenced, all supplies of gases, liquids, etc. must be isolated and the confined space vented to atmosphere.
- c. A suitably qualified person, e.g., a Chemical Engineer should be consulted and requested to test the atmosphere to ensure that no toxic, asphyxiating / suffocating or flammable substances are present within the confined space and that there is a sufficient quantity of air to support life.
- d. The suitably qualified person should specify at what regular intervals such tests as at 10.20.5 (ii) (c) above should be repeated for the duration of the work.
- e. The provisions of 10.20.5 (i) (c) to 10.20.5 (i) (f) shall be followed.
- f. If it is not possible to exclude all the Dangers, then breathing apparatus must be used by all persons entering the confined space. Only staff trained to use such apparatus shall be permitted to enter the confined space.

10.21 RVPN SAFETY INSTRUCTIONS 17 (RSI – 17)

PROCEDURE FOR WORK INSIDE TRANSFORMER / REACTOR TANKS

10.21.1 Purpose

To define procedures for precautions to be taken to prevent Danger when entry into the tank of a transformer / reactor is required.

10.21.2 Scope

These RVPN Safety Instructions define procedures to achieve safety of personnel when it is necessary to enter the tank of a transformer / reactor for the purpose of internal inspection or for erection.

10.21.3 Dangers

- i. The main Dangers to personnel inside the tank of a transformer / reactor are:
 - a. Asphyxiation or suffocation.
 - b. Fire causing an explosion or burns to personnel.
 - c. Falling or getting trapped within the tank of a transformer / reactor.
- ii. Danger inside the tank of a transformer / reactor can also be caused by work such as application of heat to the surface which may cause ignition of the oil vapours present in the tank.
- iii. Danger inside the tank of a transformer / reactor can also be present in inverted open bottom spaces which may contain gases which are lighter than air, e.g., Hydrogen.
- iv. Danger inside the tank of a transformer / reactor can also be due to gases which have density similar to air, e.g., Nitrogen and CO₂, but which displace air.

10.21.4 Procedures

- i. A Permit To Work shall be issued specifying the precautions to be taken to achieve safety and any additional precautions to be taken during the duration of the work.
- ii. Before any work is commenced, all possible inspection windows and man holes shall be opened and the tank of the transformer / reactor vented to atmosphere.
- iii. Maintenance Engineer shall give consideration to the provision of forced ventilation (and injection of dry air where required for limiting effect of moisture on winding insulation) within the tank of the transformer / reactor for the duration of the work.
- iv. Oxygen should not be used to “sweeten” the atmosphere in the tank of the transformer / reactor. Oxygen enriched atmosphere can make substances such as grease liable to spontaneous combustion.

- v. If it is essential to use gas or electrical welding equipment inside the tank of the transformer / reactor, additional precautions must be taken to eliminate Danger from the heat or flame or electrical sparks and / or gases caused by such operations.
- vi. If entry to or access within the tank of the transformer / reactor is restricted or there is possibility of slipping or falling within the tank of the transformer / reactor, provision must be made to safely evacuate any personnel who are overcome by fumes or are injured. The provision of a suitable harness (safety belt) with ropes and staff stationed outside the tank of the transformer / reactor shall be provided.

10.22.0 SAFETY AUDIT

10.22.1 INTRODUCTION

- i. It is essential that the highest Safety Standards are maintained throughout the company and that the quality of these standards is assured by an audit.
- ii. Safety Audit is to be used solely as a means for establishing the quality of safety standards so that procedures can be reviewed and if necessary, improved to ensure that safety practices are satisfactory throughout the Company.
- iii. Safety Audit should not be seen as a means of judging an individual's performance.

10.22.2 The audit process will be in **four stages:-**

- i. The Sub Station - In - Charge and transmission line – In – Charge will personally audit at random one working situation per month. The records are to be kept at site, but a list of audits carried out and their results are to be sent to the Safety Officer (nominated by the Superintending Engineer) at the Circle Level.
- ii. The Safety Officer at the Circle Level will personally audit at least two Sub Stations and two transmission line working situations per annum. The records are to be kept in the Circle office, but a list of the audits carried out by the site staff and the Circle Level staff, with their results, is to be sent to the Safety Officer at the Zonal level.
- iii. The Safety Officer at the Zonal level (nominated by the Zonal Chief Engineer) will audit two Sub Stations and two Transmission lines working situations in the Zone per annum. The records are to be kept in the Zonal office, but a list of the audits carried out by the Circle Level staff and the Zonal Level staff, with their results, is to be sent to the Safety Officer at the Corporate level.
- iv. The Safety Officer at the Corporate level (nominated by the Management Representative) will maintain a record of all the audit results and review them annually.
- v. The Safety Officer at the Corporate level will review Safety Rules and Safety Instructions and, if required, issue revisions based on the review of the annual audit.
- vi. The format for audit is attached to this section as Appendix – A.

Rajasthan Rajya Vidyut Prasaran Nigam Limited

Audit of Compliance of RVPN Safety Rules

Sub Station _____

Equipment / Bay / Line _____

Safety Document: PTW / PTT _____

Date of Issue _____

Date of Audit _____

AUDIT CHECKPOINTS:

Item	Description	Comments
1.0	ISSUE OF SAFETY DOCUMENT	
1.1	Whether correct document issued for work / testing	
1.2	Whether isolation & earthing of work / testing area done as per requirement	
1.3	Whether demarcation of work / testing area done as per requirement	
2.0	STAFF	
2.1	Did recipient have sufficient knowledge of work / testing area	
2.2	Did recipient have sufficient knowledge of work / testing being carried out	
2.3	Whether required Additional safety measures were applied	
2.4	Whether other staff was carrying out work / testing in the same area	
3.0	GENERAL SAFETY	
3.1	Whether awareness of hazards in / near work / testing area was mentioned in the PTW / PTT	
3.2	Whether required Protective Clothing was used	
3.3	Whether required Personal Safety Equipment was used	
4.0	DOCUMENTATION	
4.1	Was Switching recorded	
4.2	Whether issue & return of Safety Documents was recorded in the PTW / PTT Register	

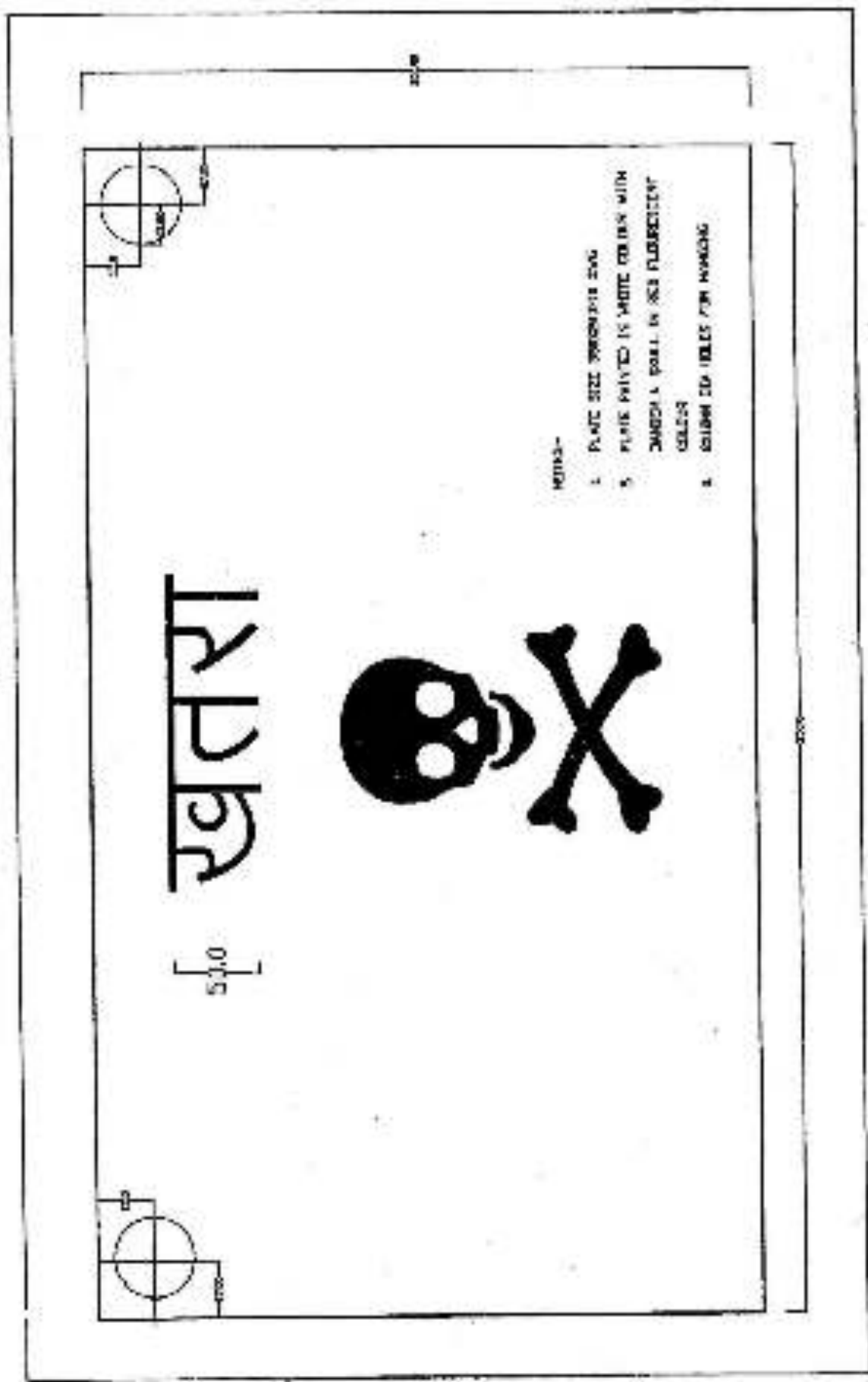
Audit carried out by

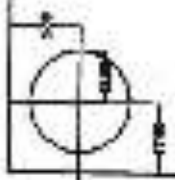
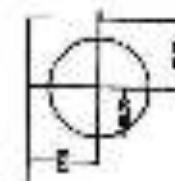
Name _____

Designation _____

Address _____

Signature





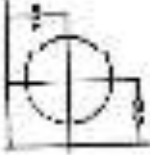
25.0 [DO NOT OPERATE
25.0 [MEN AT WORK

NOTES-

1. M.S. PLATE SIZE 250X300X10 SWD
2. EXAMIN FOR HOLES FOR MOUNTING



कार्य प्रगति पर है।
चालू नहीं करें।

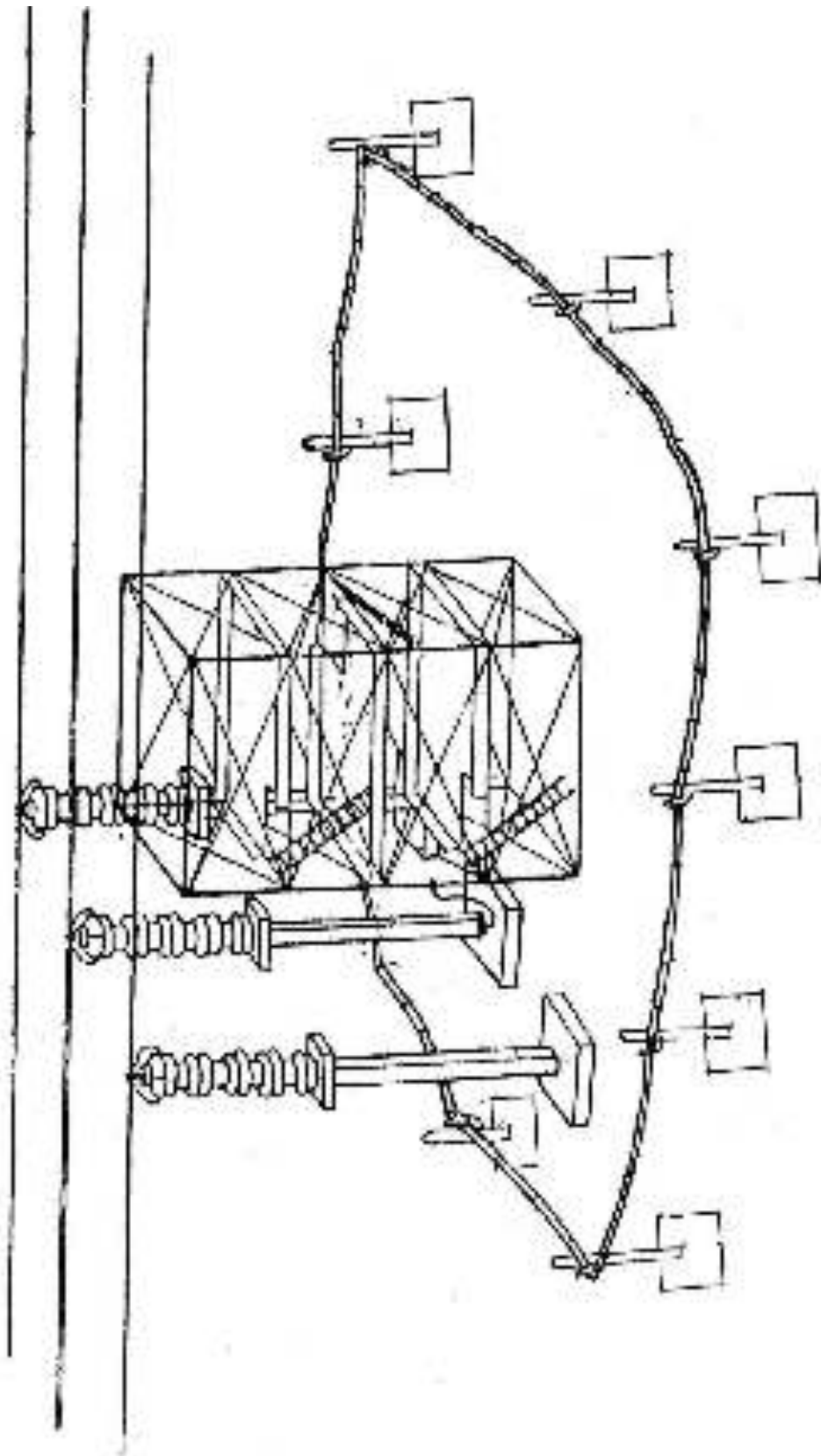


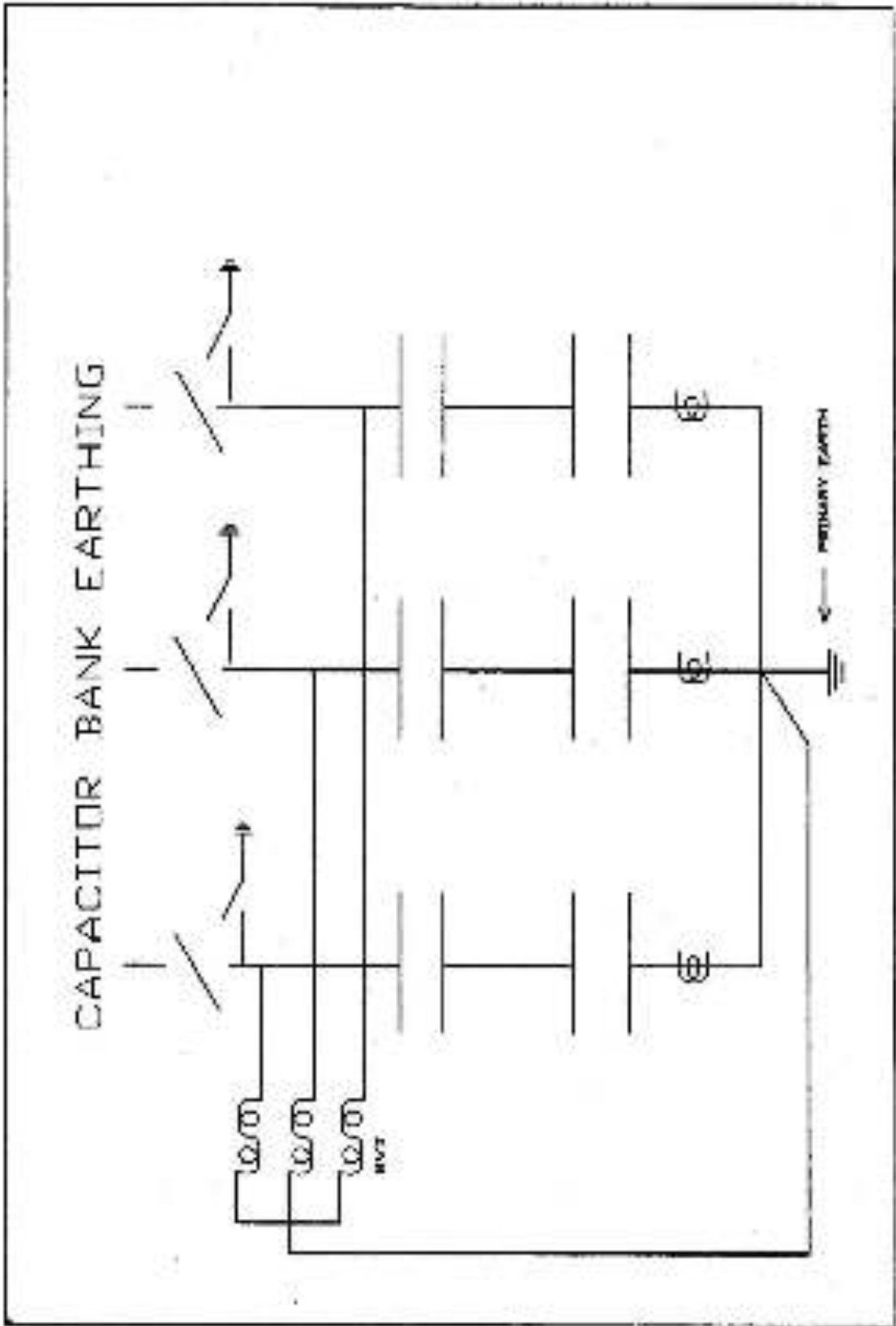
चालू
चालू

NOTES-

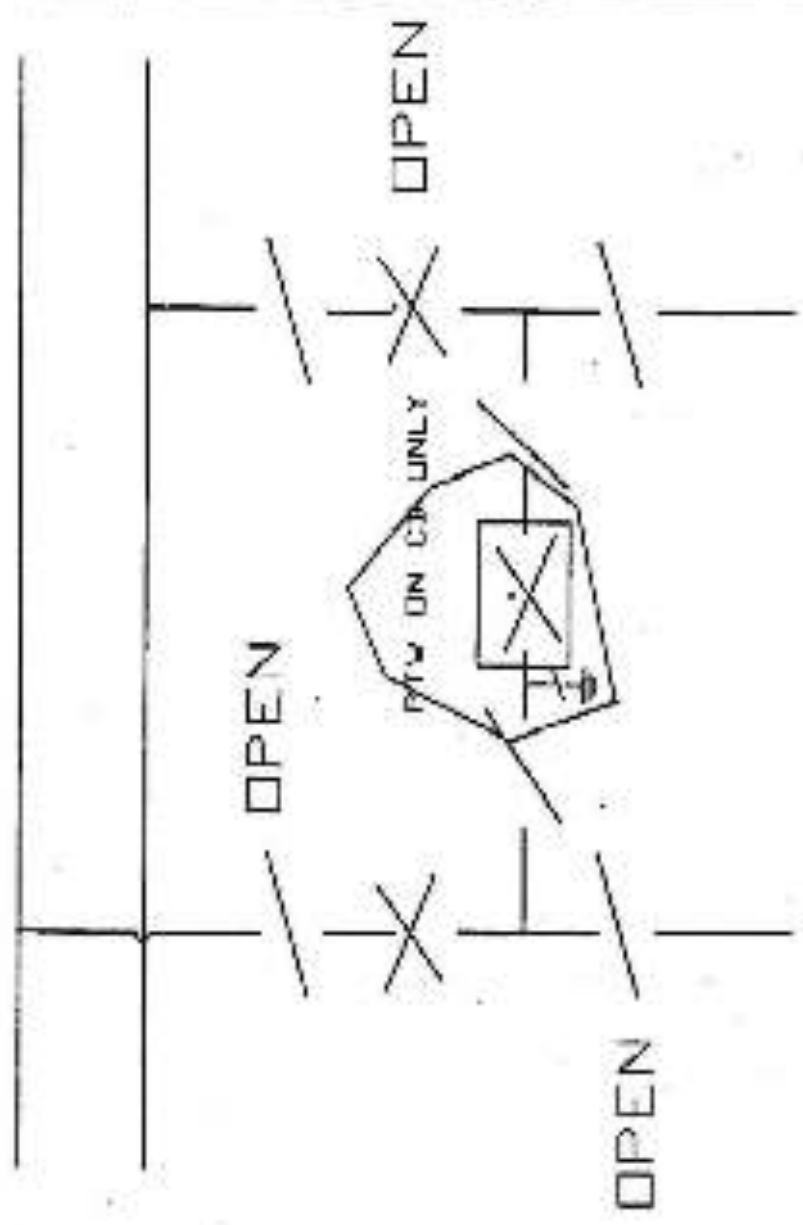
1. IS. PASTE SIZE RECOMMENDED ONLY
2. PASTE IS TO BE MIXED FOR HANDING

GENERAL SAFETY

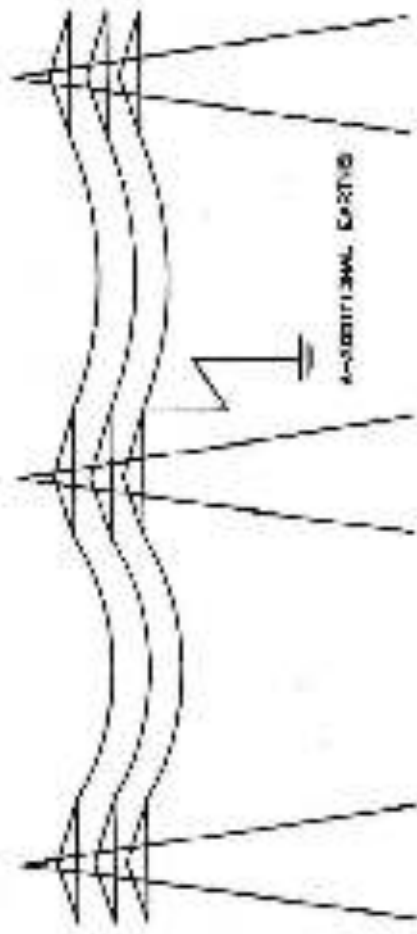




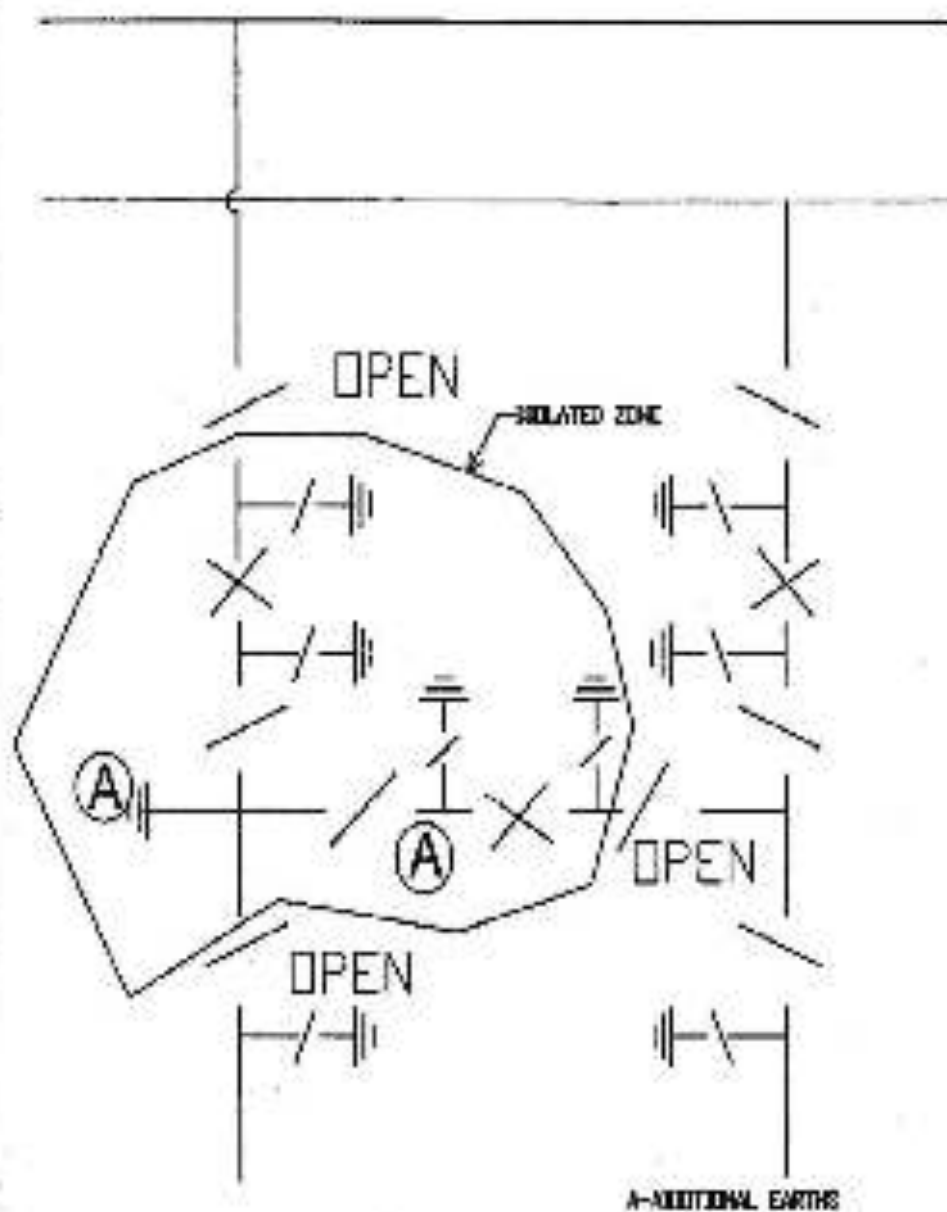
DEMARCATION OF ISOLATED ZONE



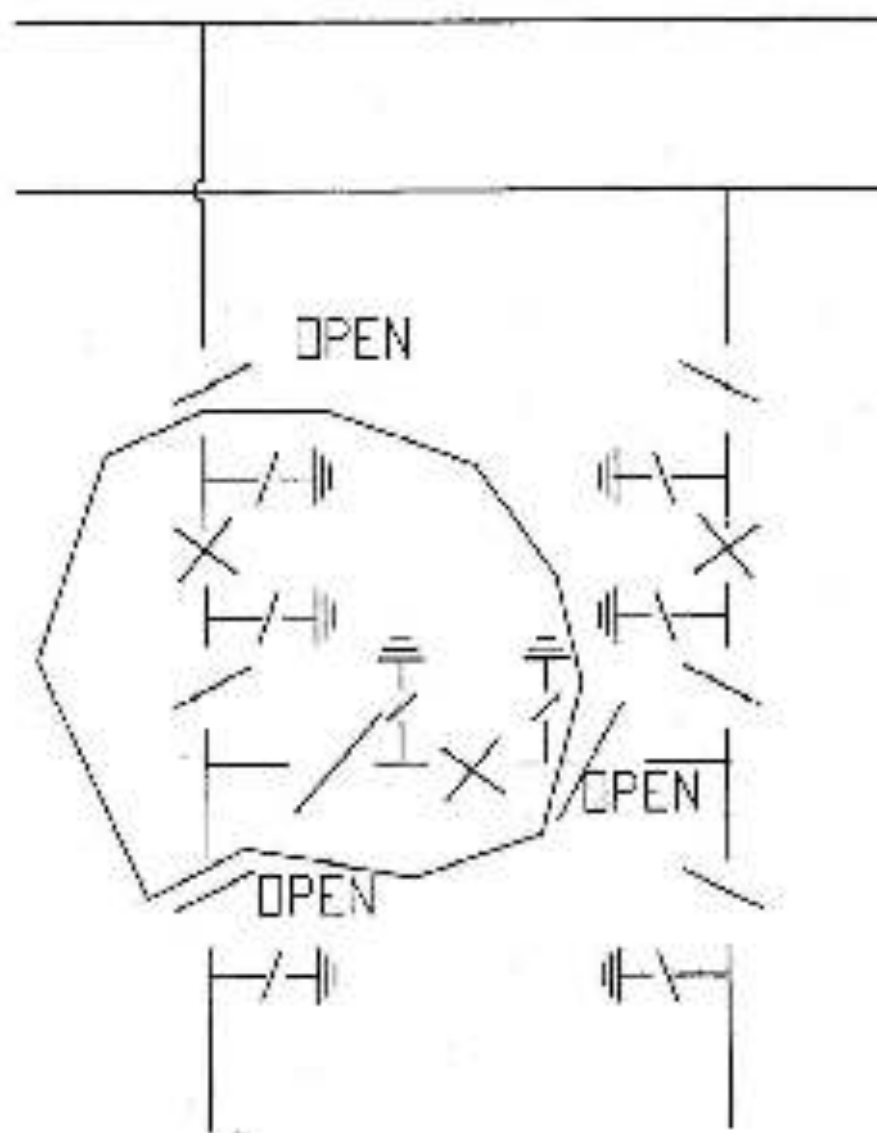
EARTH SWITCHES CLOSED AT BOTH SUBSTATIONS
WORK ON MIDDLE TOWER CONDUCTOR (NO DISCONNECTIONS)



APPLICATION OF ADDITIONAL EARTHS AT REQUIRED POINTS



ISOLATED ZONE



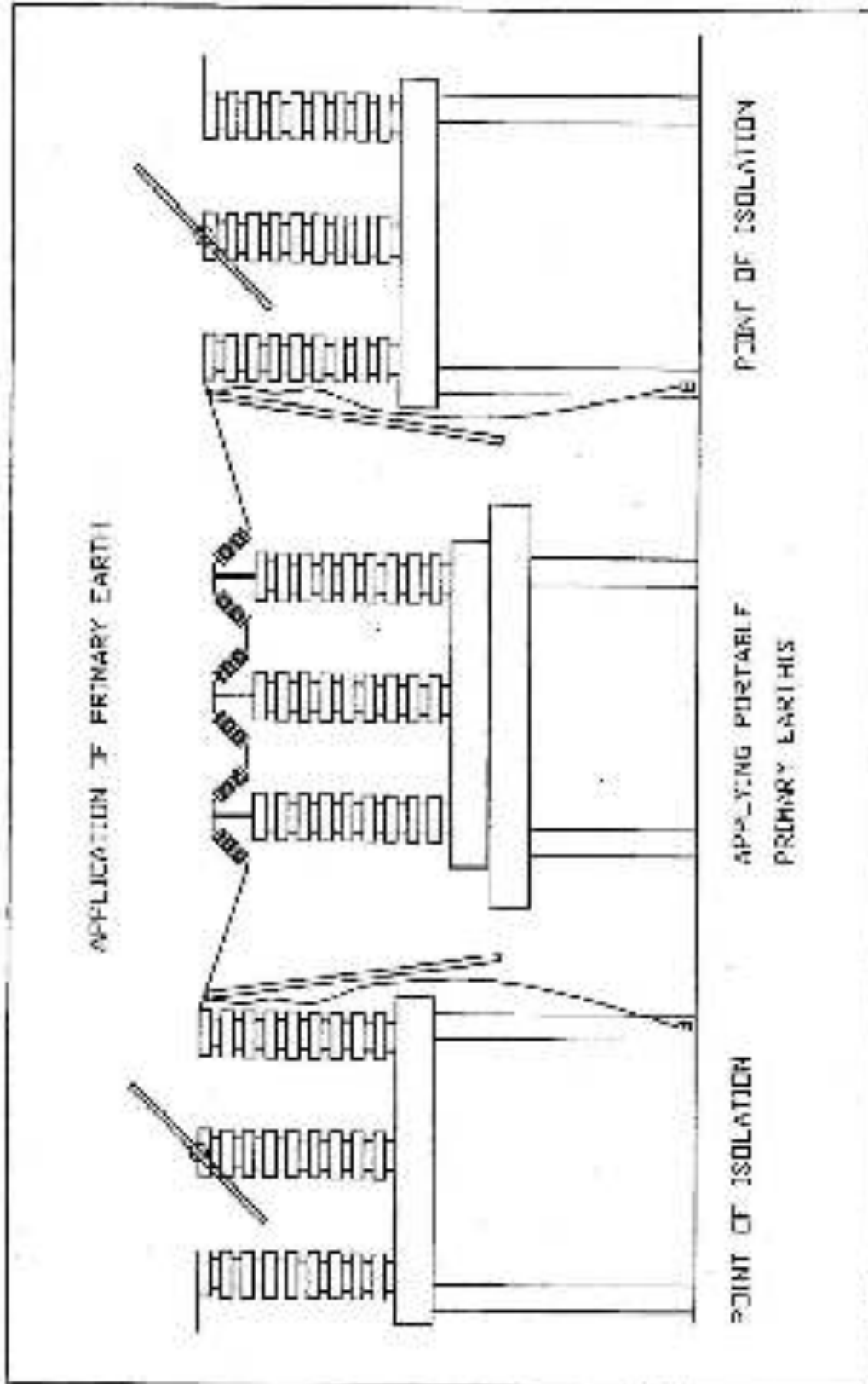
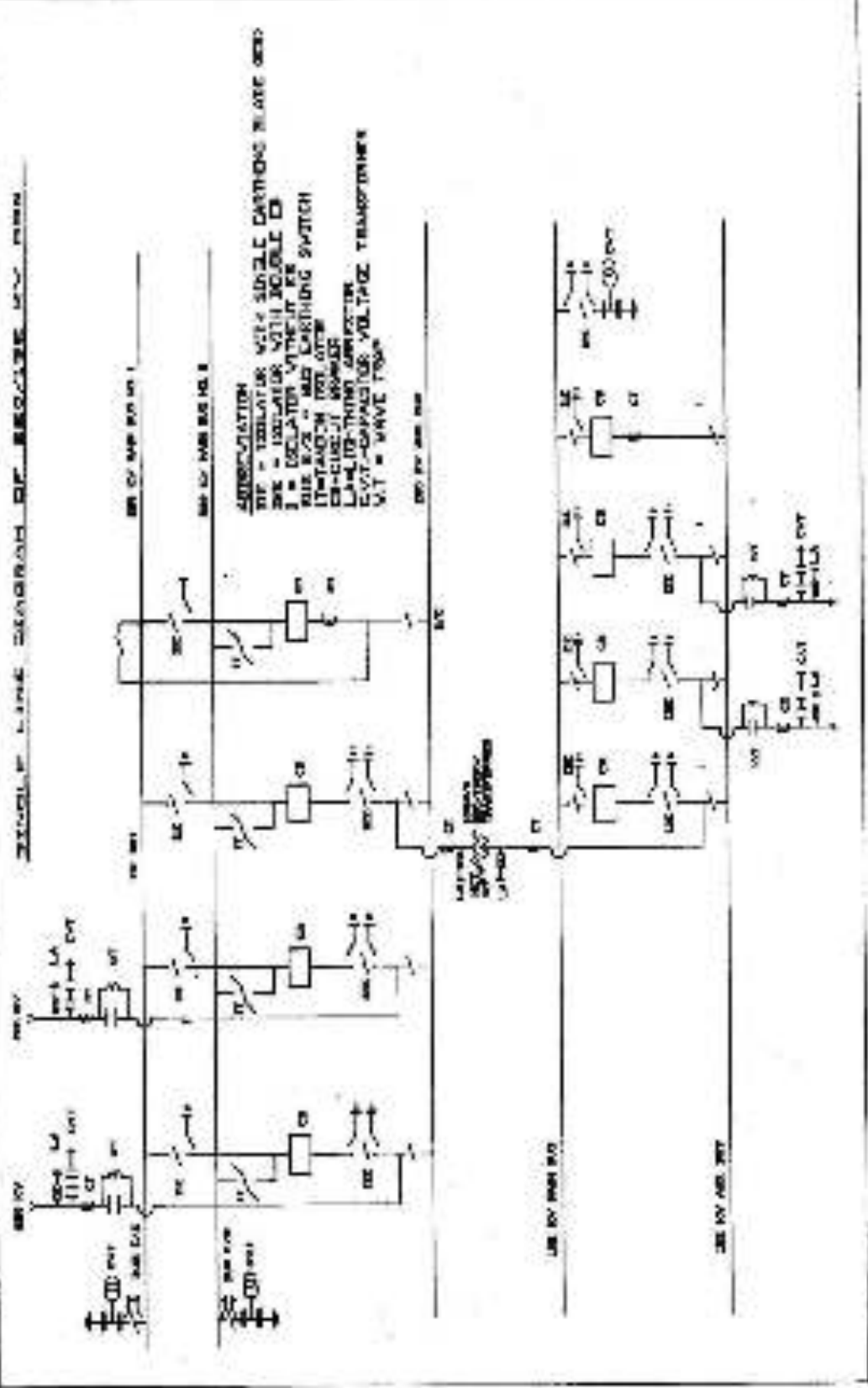
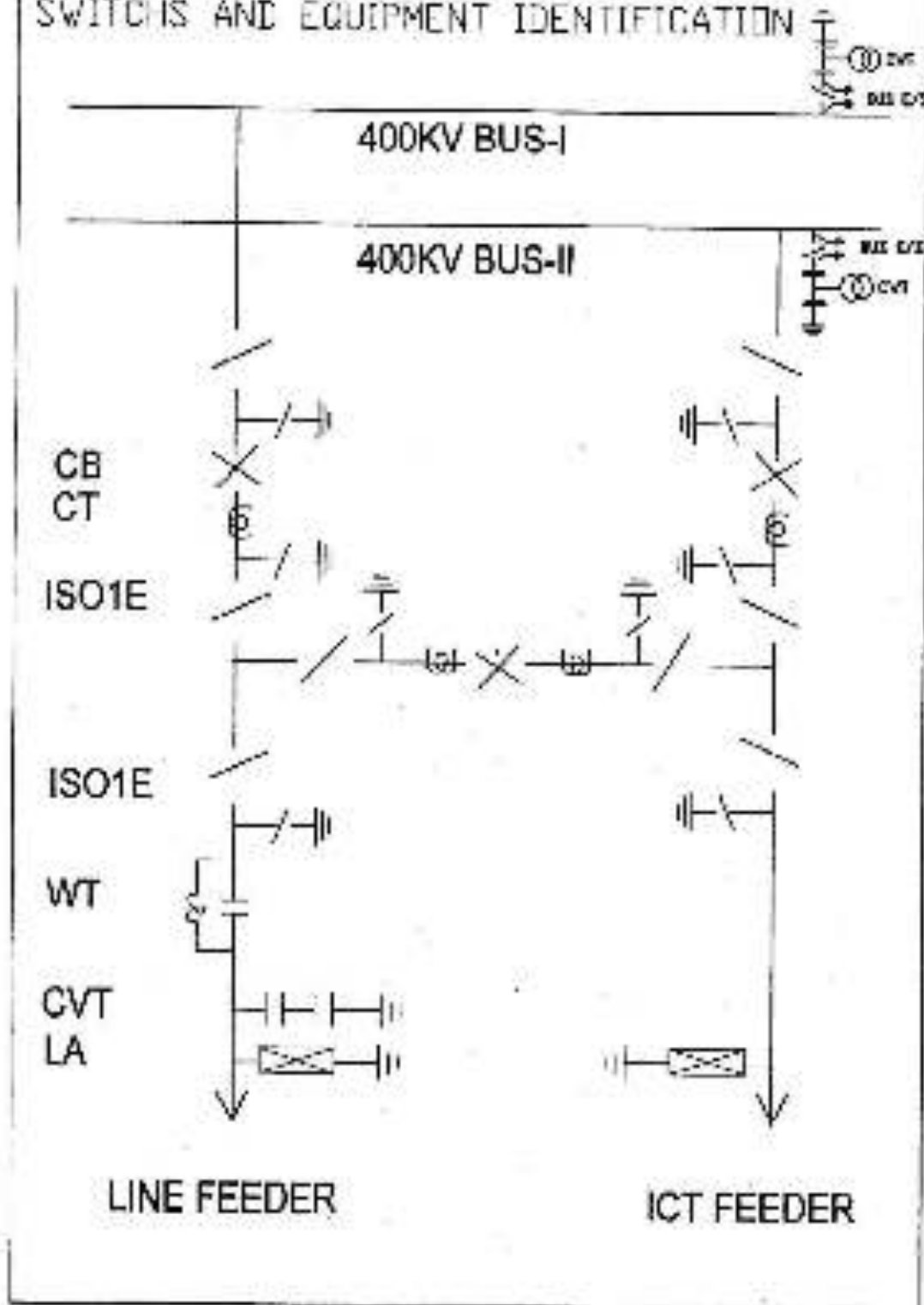


FIGURE 1. LINE SCHEMATIC OF BECULITE HV LINE



TYPICAL COMPLETE DIAMETER OF 400KV GSS
 SHOWING EARTHING USING ISULATOR EARTH
 SWITCHS AND EQUIPMENT IDENTIFICATION



TRANSFORMER MAINTENANCE ACTIVITIES

Activities to be performed once in a month(monthly maintenance):-

- (i) Check oil level in the Main Conservator tank.
- (ii) Check oil level in breather between lower and upper marking at glass.
- (iii) Check condition of silicagel(change if required).
- (iv) Check oil level in the OLTC conservator tank.
- (v) Observe air in the Main Conservator oil(if oil level in oil sight glass is not full, air is present).
- (vi) Check auto starting of cooler oil pumps and fans in local/remote/auto modes.
- (vii) Cleaning of marshalling box/control cubicle & tightening of connections therein.
- (viii) Check Nitrogen Pressure in case of transformers provided with fire protection system

Activities to be performed once in three months(quarterly maintenance):-

- (i) Check bushings for cracks & clean dirt deposit.
- (ii) To check oil level in the bushings.
- (iii) Record the counter reading of OLTC.
- (iv) Check the OLTC driving mechanism for any loosening of nuts & bolts etc.

Activities to be performed once in six months:-

- (i) Electrical checking/testing of P.R.D., Buchholz Relay and OLTC Surge Relay.
- (ii) Measure the Insulation Resistance(IR) of the windings with the help of a 5KV Megger.
(The winding temperature at the time of measurement of IR is also to be mentioned).
- (iii) Tightening of nuts & bolts of clamps, fixtures, jumpers etc.
- (iv) Perform BDV and DGA tests of the oil of the main tank(Two sample – Top & Bottom). The samples should be taken during clear weather.
- (v) Check and adjust(if required) temperature settings for the operation of cooling fans and oil pumps.
- (vi) Maintenance of OLTC driving mechanism, i.e., motor, shaft, gear, coupling etc.

Activities to be performed once in a year(Yearly Maintenance):-

- (i) External cleaning of Radiators.
- (ii) Check oil in the temperature pockets and calibrate the WTI & OTI meters.
- (iii) Measure Earth Resistance of neutral(it should be less than one ohm).
- (iv) Test Buchholz relay by draining oil from it & the PRD for its healthiness by operating of its plunger.
- (v) Perform mock drill operation of fire protection system.

Activities to be performed once in two years:-

- (i) Replace the oil of the diverter compartment, irrespective of its condition, with fresh and filtered oil.
- (ii) Measure Capacitance And Tan Delta of the Bushings of Transfermer.

Activities to be performed once in four years:-

- (i) Clean and check the diverter contacts for any wear and tear. Replace the worn out contacts.

CIRCUIT BREAKER MAINTENANCE ACTIVITIES

Activities to be performed once in a month(monthly maintenance):-

- (i) Record the counter reading.
- (ii) Cleaning and checking of Control Cubicle and tightening of connections therein.

Activities to be performed once in three months(quarterly maintenance):-

- (i) Measurement of Insulation Resistance between the upper & lower terminals of the same pole(in case of V.C.B.) when the Circuit Breaker is in open position(it should be $> 50 \text{ G Ohm}$).
- (ii) Check air leakage from storage tank and pipe joints etc in case of pneumatic operated circuit breakers. To check V-belt tension(of air compressor) and replace it if required
- (iii) Check Alarm & Indication circuits.
- (iv) Check/clean/tight control & relay panel wiring.
- (v) Check operation of Circuit Breaker(through protection system) if it has not operated during the last three months.

Activities to be performed once in six months(half yearly maintenance):-

- (i) Tightening of clamps, fixtures, jumpers etc and that of linkages and rods in the mechanism.
- (ii) Maintenance of Air Compressor.

Activities to be performed once in a year(yearly maintenance):-

- (i) Check the pole discrepancy relay(220KV & above)
- (ii) Check the operation times(C, O, C-O).
- (iii) Check all operational lock outs.
- (iv) Measurement of Contact Resistance.

Note:-In addition to the routine maintenance as mentioned above, overhauling of circuit breakers is to be done as per its O&M manual provided by the manufacturer.

CAPACITOR VOLTAGE TRANSFORMER(CVT)/PT MAINTENANCE ACTIVITIES

Activities to be performed once in three months(quarterly maintenance):-

- (i)Check oil level.
- (ii)Visual checking of earthing of HF point.
- (iii)Measure voltage at CVT junction box and at C&R panel.

Activities to be performed once in six months(half yearly maintenance):-

- (i)Tightening of terminal connections.
- (ii)Cleaning of Bushing and checking it for cracks etc.

CURRENT TRANSFORMER(CT) MAINTENANCE ACTIVITIES

Activities to be performed once in three months(quarterly maintenance):-

- (i)Check oil level.
- (ii)Cleaning of marshalling box/junction box and tightening of terminals.

Activities to be performed once in six months(half yearly maintenance):-

- (i)Cleaning terminal box(at the bottom of the CT) and tightening of terminals. Ensure that the no hole in the plate cover is open which was not needed for wiring.
- (ii)Measurement of Insulation Resistance(IR).
- (iii)Tightening of primary clamp, jumper etc.
- (iv)Cleaning of Bushing and checking it for cracks etc.

Activities to be performed once in two years:-

- (i)Capacitance and tan delta measurement.

LIGHTENING ARRESTER(LA) MAINTENANCE ACTIVITIES

Activities to be performed once in a month(monthly maintenance):-

- (i)Record the surge counter reading.
- (ii)Check the leakage current indicator.

Activities to be performed once in six months(half yearly maintenance):-

- (i)Check healthiness of the surge counter.

Activities to be performed once in a year(yearly maintenance):-

- (i)Measurement of earth resistance.
- (ii)Cleaning of Insulator stack and checking for cracks etc.
- (iii)Tightening of clamps.
- (iv) Checking the health of LA by LA Analyser.

ISOLATOR & EARTH SWITCH MAINTENANCE ACTIVITIES

Activities to be performed once in three months(quarterly maintenance):-

- (i)Cleaning of operating box, auxiliary contacts etc.
- (ii)Check the contacts for tightness.

Activities to be performed once in six months(half yearly maintenance):-

- (i)Tightening of Clamps, jumpers etc & cleaning of insulators & check them for cracks etc.
- (ii)Cleaning of main contacts(Male and Female) by CCL4 or other suitable agent to minimise the rusting effect. Immediately replace the contacts with deep pitting/burning.
- (iii)Check and correct(if required) the alignment of the isolator& earth switch.
- (iv)Check mounting bolts for tightness.
- (v)Greasing/lubrication of moving parts.

Activities to be performed once in a year(yearly maintenance):-

- (i)Maintenance of motor, coupling etc in case of motorized Isolators & earth switches.

MAINTENANCE SCHEDULE FOR STATIONARY BATTERY SET AND BATTERY CHARGER

Item No.	Frequency of Inspection	Item to be Inspected	Inspection	Action required, if inspection shows unsatisfactory condition
1	2	3	4	5
1.	Daily	Float charger Auto Mode	Float charger output voltage should be between the values given below: <u>110 V Battery Set</u> <u>220V Battery Set</u> 118 V to 121 V 236 V to 242 V	Defect should be located & rectified. If necessary, charger manufacturer may be called. Meanwhile, the float charger be operated in manual mode & voltage maintained within specified limits.
2.	Daily	Battery set connected to load.	Switch off the battery charger. Observe D.C. voltage: In case D.C. voltage disappears as soon as the float charger is switched off, or, instead of full D.C. voltage, the battery tap voltage is observed, and then the float charger is to be switched ON immediately.	a)(i) If the DC voltage disappears, this indicates some open circuit, or blown fuse, or open isolating switch in the battery circuit. (ii) If the battery tap voltage is observed, it could be due to any of the following reasons: -- Boost charger AC and / or DC supply switch is / are in ON position. Return both to OFF position. DC contactor in the battery charger is not energized (coil damaged or discontinuity in the control circuit), or the main contacts do not make properly. Investigate and rectify fault.
			b) Check that the battery is discharging to the load by observing the charge / discharge ammeter which should show current on discharge side. Return charger to normal operation.	b) If the battery set is not discharging into the load, it means that either there is some resistance in the battery circuit or the batteries have become discharged. Investigate and rectify fault.

3.	Daily	<p><u>Conventional Battery Set.</u> Specific gravity of cell nos. 1, 28, 55, 82, 110 as relevant.</p> <p><u>Maintenance free VRLA type Battery Set.</u> Voltage of cell nos. 1, 28, 54, 82, 110 as relevant.</p>	<p>Check the specific gravity of the cells and temperature of cell no.55 / 110 & convert the specific gravity to 27°C as given at Instruction no. 8.</p> <p>(ii) Check the voltage of the cells and the temperature of the Battery Room & convert the voltage to 27°C as given at Instruction no. 19.</p>	<p>If specific gravity is not within the limits specified at item no. 4 below, take remedial action accordingly.</p> <p>(ii) If the voltage of any of these cells is below the average float voltage per cell by 0.05 V, then charge the battery set at 2.30 V per cell till the charging current tapers down and stabilizes (no reduction for 3 hours).</p>																										
4.	Weekly	<p><u>Conventional Battery Set.</u> Specific gravity, electrolyte level and voltage of all the cells.</p>	<p>After switching off the charger {Follow precautions at item No. 2 (a) above}, check specific gravity and voltage of all the cells and the temperature of cell No. 55 / 110. Return charger to normal operation. Convert specific gravity readings to 27°C by the formula : $\{SG\ 27^{\circ}C = SG\ t + 0.7 (t - 27^{\circ}C)\}$ <p>The values of specific gravity at 27°C & voltage should be as below :</p> <table border="0" style="width: 100%;"> <tr> <td style="text-align: center;">Specific Gravity</td> <td style="text-align: center;">Voltage</td> </tr> <tr> <td style="text-align: center;">Sl. No.</td> <td style="text-align: center;">per cell</td> </tr> <tr> <td style="text-align: center;"><u>No.MAKEat 27°C(min.)</u></td> <td></td> </tr> <tr> <td style="text-align: center;">i) STANDARD</td> <td></td> </tr> <tr> <td style="text-align: center;">1210±5</td> <td style="text-align: center;">2.0 V</td> </tr> <tr> <td style="text-align: center;">ii) AMCO</td> <td></td> </tr> <tr> <td style="text-align: center;">1200±5</td> <td style="text-align: center;">2.0 V</td> </tr> <tr> <td style="text-align: center;">iii) EXIDE</td> <td></td> </tr> <tr> <td style="text-align: center;">1200±5</td> <td style="text-align: center;">2.0 V</td> </tr> </table> </p>	Specific Gravity	Voltage	Sl. No.	per cell	<u>No.MAKEat 27°C(min.)</u>		i) STANDARD		1210±5	2.0 V	ii) AMCO		1200±5	2.0 V	iii) EXIDE		1200±5	2.0 V	<p>a(i) If specific gravity is higher than the upper limit, replace a little quantity of electrolyte by an equal quantity of distilled water by using judgement. (See Instruction No. 13)</p> <p>a(ii) If the specific gravity or voltage of any one or more cells is lower than the lower limit (See Instruction No. 14 also), charge the battery as a whole for a short duration at the current given below so that the lower specific gravity of the cells could improve to the required value.</p> <table border="0" style="width: 100%;"> <tr> <td style="text-align: center;"><u>Sl.No.MAKE</u></td> <td style="text-align: center;"><u>CHARGING CURRENT</u></td> </tr> <tr> <td style="text-align: center;">STANDARD</td> <td style="text-align: center;">2.5 % OF AH CAPACITY</td> </tr> <tr> <td style="text-align: center;">AMCO</td> <td style="text-align: center;">2.5 % OF AH CAPACITY</td> </tr> <tr> <td style="text-align: center;">EXIDE</td> <td style="text-align: center;">2.5 % OF AH CAPACITY</td> </tr> </table> <p>a(iii) If the specific gravity in a majority of the cells has fallen below 1195 (27°C) for Standard make battery cells and below 1185 (27°C) for EXIDE & AMCO make battery cells or the voltage has fallen below 2.0 V, then the battery set should be charged as per the procedure at</p>	<u>Sl.No.MAKE</u>	<u>CHARGING CURRENT</u>	STANDARD	2.5 % OF AH CAPACITY	AMCO	2.5 % OF AH CAPACITY	EXIDE	2.5 % OF AH CAPACITY
Specific Gravity	Voltage																													
Sl. No.	per cell																													
<u>No.MAKEat 27°C(min.)</u>																														
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1210±5	2.0 V																													
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1200±5	2.0 V																													
iii) EXIDE																														
1200±5	2.0 V																													
<u>Sl.No.MAKE</u>	<u>CHARGING CURRENT</u>																													
STANDARD	2.5 % OF AH CAPACITY																													
AMCO	2.5 % OF AH CAPACITY																													
EXIDE	2.5 % OF AH CAPACITY																													

				item no. 11.
			b) Check the electrolyte level.	<p>a(iv) If in spite of charging as given a(ii) and a(iii) above, the specific gravity or voltage of some of the cells does not attain the required value, then these cells are to be considered as weak cells and treated in accordance with Instruction No.9.</p> <p>b(i) If the electrolyte level is below the given mark (See Instruction no. 15), top up with only pure distilled water. NEVER ADD ACID. Whenever distilled water is added to any cell, the battery set should be given a boost charging at the current given at item no. 4 a (ii) above until distilled water and electrolyte get mixed thoroughly.</p> <p>b(ii) In case of overflowing in cells due to increase in electrolyte level even without addition of distilled water, this is due to damp atmosphere in the battery room causing condensation on the cell covers. Improve ventilation in the battery room (See Instruction No.3).</p> <p>If the voltage of some cell(s) is below the average float voltage per cell by a value of 0.05 Volt, then charge the cell(s) at a constant voltage of 2.30 Volt per Cell until the current tapers down and stabilizes.</p>
		<p><u>Maintenance free VRLA type battery set.</u> Voltages of all cells</p>	<p>After switching off the float charger {follow precaution at item No. 2 (a) above}, check the voltage of all cells and ambient temperatures. Convert voltage readings to 27°C by the formula: $V_{27^{\circ}\text{C}} = V_t - 0.003 (t - 27^{\circ}\text{C})$.</p> <p>The minimum value of voltage at 27°C should be 2.15 volts per cell.</p>	
5.	Weekly	Battery Cells.	Check for cleanliness & dust / moisture deposits & leakage.	Clean all the cell containers, stand and insulators and attend leakage, if any. Apply Vaseline / petroleum jelly on terminals, intercell connectors and nuts and bolts wherever necessary.

				<p>Alternatively, use CRC (Bharat Bijlee or any standard make) instead of Vaseline / petroleum jelly.</p> <p>b) In case of conventional type battery set ensure that the rubber seal at the base of the terminals & on cell lid is fitted properly. Replace if damaged.</p>
6	Monthly	Battery Set Capacity Status.	<p>Switch off the float charger for one hour {Follow precautions at item no. 2 (a) above} & observe drop in battery voltage.</p> <p>The battery Voltage should not drop below 107 V for 110 V battery set & below 214 V for 220 V battery set.</p> <p>If the voltage does not fall below the values given above, switch on the float charger & then give boost charge to the battery set as below.</p> <p><u>Conventional battery set.</u> At a current given at item No.4 a (ii) for 2 hours.</p> <p><u>Maintenance free VRLA battery set.</u> Charge at 2.30 Volt per cell for 2 hours or till charging current becomes negligible, whichever is earlier.</p>	<p>Rapid fall in voltage could be due to loose connections or corroded terminals. Switch on battery charger. Clean corroded parts with warm water as per procedure at Item No. 7 and tighten loose connections. Switch off the float charger again for one hour. If the battery voltage still drops below the limits given, recharge the battery set as per instructions given at Item No. 11 given below. Switch off the float charger again for one hour. If the battery voltage still drops below the limits given, this could be due to weak cells. Check the voltage of all the cells keeping the float charger off. Return charger to normal operation.</p> <p><u>For conventional battery set</u> If the voltage of majority of the cells is below 2.0 V, then the battery set should be considered to have lost its capacity and battery set should be replaced. However, if the voltage of only some of the cells is below 2.0 V, then such cells are to be considered as weak cells and treated in accordance with Instruction No. 9. The treated / replacement cells should be refitted in the battery set.</p>
				<p><u>For Maintenance free VRLA battery set</u> The cell(s) having lowest voltage is / are to be taken out and the remaining set is then discharged such that the individual cell</p>

				<p>voltage becomes equal to voltage of the cells which have been removed. The cell(s) which were removed are again connected to the battery set and the complete set is then charged at a constant voltage of 2.3 Volt / cell until the charging current tapers down and stabilizes to a minimum value, and 3 consecutive hourly readings of voltage of each cell remain constant.</p> <p>d) Switch off the float charger again for one hour. If the battery voltage still falls below the limits given then the discharge capacity test should be conducted as given at item no. 12 below and the battery immediately recharged as given therein. If the capacity of the battery set is below 100 AH for 120 AH & 200 AH capacity battery sets, and below 200 Ah for 400 AH battery set, then the battery set shall be replaced. If it is not possible to conduct discharge capacity test, the battery set should be replaced.</p>
7.	Monthly	Corroded terminals	<p>a) Check for sulphate deposits on terminals of cells, inter-cell connectors and nuts & bolts. Inter-cell connector using robust & reliable connection.</p>	<p>a) For removing sulphate deposits, temporarily by-pass the inter-cell connector using robust & reliable connection. One inter-cell connector should be attended at a time. The inter-cell connector which has been by-passed should then be removed and cleaned with warm water, dried, re-fixed and then coated with Vaseline / petroleum jelly / CRC (See Instruction No. 6 for by-passing inter-cell connectors).</p>
			<p>b) Check for corroded / damaged terminals, inter-cell connectors, and nuts & bolts.</p> <p>c) Check nuts & bolts for tightness.</p>	<p>b) Replace damaged inter-cell connectors and nuts & bolts after providing by-pass arrangement as at (a) above.</p> <p>c) Tighten nuts & bolts found loose.</p> <p>d) Wash all vent plugs by immersing in a bucket of water,</p>

			d) Check vent plugs.	wipe them clean and re-fix.
8.	Monthly	Battery Charger	<p>Check for cleanliness.</p> <p>Check for loose connections.</p> <p>Check operation of float charger by putting it in manual mode and slightly raising the float output voltage. The charge / discharge ammeter should show current on the charge side. Return charger to auto mode.</p> <p>d) Check the operation of the boost charger by switching on the boost input & output switches / MCB (with coarse & fine switches in minimum position) & slowly increasing the boost output voltage by operating the coarse & fine switches till the charge / discharge ammeter shows current on the charge side. Switch off the boost charger and return the coarse and fine switches to minimum position.</p>	<p>Clean with blower.</p> <p>Tighten connections found loose.</p> <p>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 & corrected. In case of failure of float charger, the boost charger can be used as float charger with a Keyed push button provided in the battery charger. For this purpose, first switch off the float Charger and then switch on the Keyed push button. The boost charger should then be switched ON and output voltage adjusted to maintain near about the voltage given at Item No. 1 above. In case Keyed push button is not provided, then the circuit for the D. C. is to be disabled.</p> <p>If the charge / discharge ammeter does not show the current on the charge side, then the boost charger is not giving output. Defect should be located and rectified.</p>
9.	Quarterly. (Applicable for	Open circuit voltage of battery cells.	Disconnect the battery set from the float charger by switching ON boost A.C.	The D.C. voltage of all cells should be measured. This gives an indication of the conditions of

	VRLA battery set only)		supply in the charger. As the load is connected to float charger, the battery set is in open circuit condition. Boost output D.C. switch should be kept OFF and coarse and fine selector switches should be at minimum position during this time. Check the voltage of the cells after 3 Hours.	the cells as indicated in Table-1. (i) If voltage of all cells is 2.15 Volt or above, then switch OFF boost A.C. supply switch and float the battery set at float voltage keeping the current drawn by the battery set within limits. (ii) If voltage is below 2.15 Volt, then charge the battery set at 2.30 Volt / cell until the current tapers down and stabilizes to minimum value.
10.	Half Yearly or as Required. (Applicable for VRLA battery set only)	Battery Set	Check the voltage of all the cells with the float charger ON.	If the difference between the maximum & minimum cell voltages is between 0.05V to 0.1V, charge the battery set at a constant voltage of 2.30 V / cell until the charging current tapers down and stabilizes to a minimum value & the voltage of each cell remains constant for three consecutive hours. (ii) If the above difference in cell voltage is more than 0.1V, then equalizing of cell voltages is required. For this purpose a shutdown of complete sub - station is to be arranged. All cells must be discharged to a voltage of 1.75V by removing one by one those cells which attain 1.75V. Then charge the complete set at a constant voltage of 2.30 V / cell, at a current equal to 20% of AH capacity of the battery set but limited to charger capacity, until the current taken by set is reduced to zero or a constant minimum value, and three consecutive hourly readings of voltage of each cell remain constant.

11.	Yearly (Conditional)	Curative Discharge (to be conducted if conditions permit shutdown of the sub-station & after arranging back feed supply for recharging the battery set).	<p>After switching off the float charger, discharge the battery at its 10 hour rate discharge current (12 Amps for 120 AH, 20 Amps for 200 AH, & 40 Amps for 400 AH capacity battery set respectively) for a period of 2 hours.</p> <p>Recharge the battery set as given below.</p> <p><u>Conventional battery set</u> At the recharge current till the cells start gassing freely. Then reduce current to the finishing rate & charge until the specified value of specific gravity is attained and remains constant for three consecutive hourly readings. Also refer Instruction No. 12.</p> <p><u>Maintenance Free VRLA Battery Set</u> At a constant voltage of 2.30 V / cell till the current reduces and stabilizes to a minimum value and three consecutive hourly readings of voltage of all the cells remain constant.</p>	<p>By this discharge, the battery set has a higher probability of longer life. This discharging and charging help to correct some imbalances also.</p> <p><u>Values of Recharge & Finishing Currents, & Specific Gravity :</u></p> <p>Specific Gravity : Sl. No. Make & Capacity Current Recharge Current at 27°C</p> <p>i) Standard-400 AH 40 Amp 20 Amp 1210 ± 5</p> <p>ii) Standard-200 AH 20 Amp 10 Amp 1210 ± 5</p> <p>iii) Standard-120 AH 12 Amp 6 Amp 1210 ± 5</p> <p>iv) AMCO-400 AH 56 Amp 28 Amp 1200 ± 5</p> <p>v) AMCO-200 AH 28 Amp 14 Amp 1200 ± 5</p> <p>vi) AMCO-120 AH 17 Amp 8 Amp 1200 ± 5</p> <p>vii) EXIDE-400 AH 40 Amp 24 Amp 1200 ± 5</p> <p>viii) EXIDE-200 AH 20 Amp 12 Amp 1200 ± 5</p>
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12.	If monthly inspection of capacity status as per item No. 6 above shows unsatisfactory condition.	Capacity check (to be done under shutdown only, & after arranging back feed supply for recharging battery set).	<p>The discharge should not be done when electrolyte temperature exceeds 35°C unless it is unavoidable.</p> <p>After switching off the float charger, discharge the battery set at its 10 hour rate discharge current as given in item no. 11 above till the following values are reached :</p> <p><u>220 V battery set :</u> For conventional type battery set: Close circuit voltage across battery set falls to 203.5 V or voltage across any one cell falls to 1.70 V whichever is earlier. (b) For VRLA type battery set: Close circuit voltage across battery set falls to 192.5V, or voltage across any one cell falls to 1.75V whichever is earlier.</p> <p>ii) <u>110 V battery set :</u> For conventional type battery set: Close circuit voltage across battery set falls to 101.75 V or voltage across any one cell falls to 1.70 V whichever is earlier. (b) For VRLA type battery set: Close circuit voltage across battery set falls to 96.25 V, or voltage across any one cell falls to 1.75V whichever is earlier. Time in hours elapsing between beginning and end of discharge shall be taken as the period of discharge. Recharge the battery set as given in Item no. 11 above.</p>	<p>The temperature of the electrolyte of cell no. 55 (for conventional battery set) & ambient temperature of Battery room (for VRLA battery set shall be noted at hourly intervals during discharge.</p> <p>The average temperature (t°C) of the electrolyte or that of ambient temperature of Battery room during discharge is the average of these hourly readings for conventional battery set & VRLA battery set respectively.</p> <p>The period of discharge in hours multiplied by the current is the capacity Ct of the set at the average temperature discharge (t°C) during discharge. The capacity shall be corrected to 27°C by the following formula : Capacity at 27°C = Ct + $\frac{Ct \times 0.43}{27 - t}$ (100</p> <p>SHUTDOWN OF THE SUB STATION SHOULD BE RETURNED ONLY AFTER THE BATTERY SET HAS BEEN CHARGED TILL : FOR CONVENTIONAL BATTERY SET, THE CELLS ATTAIN A VOLTAGE OF 2.4 V, (B)FOR VRLA TYPE MAINTENANCE FREE BATTERY SET, THE CELLS ATTAIN A VOLTAGE OF 2.0 VOLTS.</p> <p>CHARGING IS TO BE CONTINUED TILL THE BATTERY SET IS FULLY CHARGED AS AT ITEM NO. 11 ABOVE.</p>
13.	Yearly	Battery Stand	Clean the stand and insulators under the battery cells.	Replace / repair damages. Paint stand, if required, with electrolyte resistant paint.

MAINTENANCE SCHEDULE FOR CAPACITOR BANK

Equipment/ item whose inspection/ maintenance is required		Points to be checked / noted and details of maintenance work to be done		Frequency of inspection /Maintenance	Remarks
1		2		3	4
1	Capacitor unit	a	Check of leakage of impregnate form terminals / lid , welded seams	Monthly	If necessary, the capacitor unit may be checked by testing the IR values and charging current (should be within acceptable limits). Repairs may be carried out; if possible, otherwise it is removed from the circuit to avoid damage to other healthy units in the proximity.
		b	Check for cracks or bulging of the relay of capacitor units.	Weekly	
		c	Terminal bushings I Examine for cracks and other damages II Remove all dirt, paint and other deposits	Monthly	
		d	Check for general cleanliness		Capacitor units should be properly cleaned as and when the surface condition deteriorates and warrants repainting.
		e	Repaint capacitor units and supporting structures.	As and when necessary	
		f	Check IR values of the capacitor units		The insulation resistance of the capacitor units between bushing to earth shall be checked half yearly with a megger of not less than 500 volts (preferably 2500 V) output. The other bushings should be shorted during test. The readings are compared with those taken at the time of commissioning and on the previous occasions. For capacitor designed and

				manufactured as per ISS the insulating resistance so determined shall not be less than 50 M.ohms. In case the value measured is less than 50 M. ohms, the unit should not be put in service. For the capacitors manufactured according to other specifications, the minimum insulation resistance should be as specified in the supplier's technical literature.
		Check charging current	Half yearly	The current drawn by the unit at specified voltage giving LT supply is measured with the help of ammeter and volt meter (or AVO meter) and compared with the design current (rated current of unit) in similar condition. Lower current indicates partial failure. The capacitance of the units be checked with the help of capacitance meter wherever available instead of nothing the charging currents.
2	Capacitor fuse (if external fuses are provided).	Check for continuity and tightness	Weekly	In case of capacitor units protected through external fuses, it should be ensured that the fuses are of proper design and rating and are properly fitted. They should be fitted in such a way as not to cause unnecessary tension at the joint, where the terminal bushing is fitted at the top of the container. Ensure for the availability of spare fuses of correct ratings.
3	Capacitor bank, bus bar connections	Post-insulation used for bus for support. Estimate for cracks and other damages.	Monthly	

	and rack.	Remove all dirt, and other deposits.		
		b) The bus bar should be checked for tight connections, deformation and clearances. The bus bar should not be allowed to get rusty.		
		c) The racks should be checked for corrosion and dirt.		
		d) Causes for developing hot spots in the system on account of loose jointing improper sizes of equipments are checked up and remedial measures taken.		Tighten up all screws and nuts especially electrical connections so that there are no loose contacts. Tighten the bushing terminal nuts just sufficient to make good electrical contacts. Avoid over tightening as it may result in rotation of bushing rod and in leakages from the soldered bushings due to excessive stress on the soldered joints
		e) earthing of the capacitor bank. Check	Monthly	Adequate earthing of capacitor units/ rack should be ensured. Capacitor unit case should be properly screwed with the supporting channel making good electrical contacts. It should be ensures that neutral of star connected capacitor bank is not earthed.
		f) Check IR value of the capacitor bank bus.	Half yearly.	
4	Voltage transformer (RVT)	a) Check terminal connections for tightness	Monthly	
		b) Check oil level	Monthly	
		c)Check dielectric strength of oil.	Half yearly.	
		d) Check RVT fuses for their healthiness	Monthly	
		e) Check IR Value	Half yearly.	Sudden drop in IR value needs to be investigated.

		f) Voltage across open delta winding of RVT at the C&R panel	Monthly	Voltage across open delta winding of RVT should be checked monthly. Normally it should be the same as was recorded during first commissioning. However, if there has been an increase, it will mean some unbalance is there although the limit has not reached to trip the breaker. The reasons of unbalance should be investigated and remedial measures taken accordingly.
5	<i>Series reactor</i>	<i>Where the series reactor are installed with the capacitor banks, their inspection and maintenance be done as per prevalent practice for that of the transformer according to the 'MSE Manual' of Punjab State Electricity Board.</i>	<i>As per MSE manual</i>	

Note: The work on the capacitor bank should be done after switching 'OFF' the capacitor bank fully discharging to a safe value with the insulating earthing rod (wait for 5 minutes before handling) and after providing temporary earth which is left intact till the work is finished. Ensure that no hardware or tools are left inside the assembly.

GAS INSULATED SWITCHGEAR-SUBSTATION

1.2 INTRODUCTION

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

The land area required for a GIS substation is in the order of 10% to 20% of that for an AIS substation considering the switchgear bay. The saving in overall land area depends very much on the specific voltage level and the connection to transformers, reactors and incoming and outgoing lines. If the substation is connected to over headlines, 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 is also 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.

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

When ever 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/de-gassed 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.

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 IEC62271-203/2003 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 the insulation properties. Further the quality and dew-point of S_f6 gas should also be monitored as the property of SF₆ is related to its insulation quality.

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.

(a) UHF Partial Discharge Measurement

The partial discharge signals in the range 1000MHz to 2GHz 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.

(b) Acoustic Partial Discharge Measurement

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

Acoustic signals can be picked up by means of externally mounted sensors. The location of the defect can be found by searching for the acoustic signal with highest amplitude or time travel measurements with tow sensors. Bouncing particles producing discharges in the 5pC

range can be detected with a high signal to noise ratio. Sensitivity decreases with distance because the acoustic signals are absorbed and attenuated as they propagate in the GIS. Acoustic measurement is immune to electromagnetic noise in the substation. The acoustic sensitivity to bounding particles is much higher than the sensitivity of any other method. PD measurement in a GIS installation is recommended once in 5 years.

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

SUB-STATION AUTOMATION

Open Systems

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

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

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

Levels of Integration and Automation

Substation integration and automation can be broken down in to five levels. The lowest level is the power system equipment, such as power transformers and circuit breakers. The middle 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 device 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.

Sub station 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 4s. 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 (wave forms 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). An other challenge is whether the data is pushed from the substation in to 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 these 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 hard wired 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 hard wired 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 two 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 device 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, UCA2MMS).

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 (EPRI's) UCA.

IEC61850

The UCA2 substation automation work has been brought to IEC Technical Committee (TC) 57 Working Groups (WGs) 10, 11, and 12, who are developing IEC61850, the single worldwide standard for substation automation communications. IEC61850 is based on UCA2 and European experience and provides additional functions such as substation configuration language and a digital interface to non conventional current and potential transformers.

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

Acronyms and Abbreviations	
DNP	Distributed Network Protocol
ECM	Equipment Condition Monitoring
EPRI	Electric Power Research Institute
GOMSFE	Generic Object Models for Substation and Feeder Equipment
GPS	Global Positioning System
ICCP	Inter-Control Centre Communications protocol
IEC	International Electrotechnical 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	Mega bits 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