KECINTERNATIONAL LIMITED

OPERATION & MAINTENANCE MANUAL

KEC

PREFACE

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

1) Preventive Maintenance
2) Break down Maintenance

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

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

This O&M manual consists of two parts: -

Part – I deals with Preventative Maintenance of Substation Equipment's and Protective Switchgears.

Part – II deals with Preventative Maintenance of Transmission Lines.

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

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

- This manual covers preventive and normal breakdown maintenance. The effort has been made to make the manual comprehensive and authentic. However, suggestion for further improvement are always welcome.

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

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

13. Target Availability for recovery of full transmission charges

1. AC System : 98%
2. HVDC bi-pole links and HVDC back-to-back stations : 95%

Notes:

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

25. Incentive

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

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

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

Appendix -2

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

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

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

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

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

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

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

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

2. In Appendix-2 of the Principal Regulations:

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

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

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

Important Provisions of Grid Code: -

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

3.5 Safety Standard

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

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

3.9.2 Fault Clearance Times

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

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

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

(2) Back-up protection shall be provided for required isolation/ protection in the event of failure of the primary protection systems provided to meet the above fault clearance time requirements. If a Generating unit is connected to the Transmission System directly, it shall be capable to withstanding the fault, until clearing of the fault by back-up protection on the Transmission System side.

4.1 Operating Policy

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

4.1.5 The control rooms of the National Load Dispatch Centre including Area Load Dispatch Centre, Power Plants, substations of 220 kV and above and any other control center of Transmission Licensees and Users shall be manned round-the-clock by qualified and adequately trained personnel.

4.2 System Security Aspects

4.2.2 No part of the Grid shall be deliberately isolated from the rest of the Grid, except (i) under an emergency and conditions in which such isolation would prevent a total grid collapse and/ or would enable early restoration of power supply, (ii) when serious damage to a costly equipment is imminent and such isolation would prevent it and (iii) when such isolation is specifically instructed by NLDC. Complete synchronization of Grid shall be restored as soon as the conditions again permit it. The restoration process shall be supervised by NLDC, as per operating procedures separately formulated.

4.2.13 Users and Transmission Licensees shall provide automatic under frequency and df/dt relay-based load shedding/ islanding schemes in their respective systems, wherever applicable, to arrest frequency decline that could result in a collapse/ disintegration of the State Grid, as per the plan separately finalized by the RPC and shall ensure its effective application to prevent cascade tripping of generating units in case of any contingency.

4.2.19 The State Constituents shall be sent information/ data including disturbance recorder/ sequential event recorder output etc……, to NLDC for purpose of analysis of any grid disturbance/ event. No State constituent shall block any data/information required by the NLDC for maintaining reliability and security of the grid and for analysis of an event.

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

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

5.4 Demarcation of responsibilities

5.4.12 The STU shall install special energy meters on all inter-connections between the State constituents and other identified points for recording of actual net MWh interchanges and MVArh drawls. The type of meters to be installed, metering scheme, metering capability, testing and calibration requirements and the scheme for collection and dissemination of metered data shall be as per Regulations for Installation and Operation of Meters issued by the Authority under section 54(2) (d) of the Act. All concerned entities (in whose premises the special energy meters are installed) shall fully co-operate with the STU/NLDC and extend the necessary assistance by taking weekly meter readings and transmitting them to the NLDC.

5.6 Reactive Power and Voltage Control

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

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PART – I
O&M OF EHV SUBSTATIONS

CHAPTER 1

PREVENTIVE MAINTENANCE PROCEDURES

1. INTRODUCTION

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

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

2. GENERAL INSTRUCTIONS FOR MAINTENANCE OF SWITCH YARD EQUIPMENT

(a) External Cleaning

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

(b) Rust Protection

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

(c) Lubrication

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

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

(d) Treatment of Contact Surfaces

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

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

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

(e) Moving Contact Surfaces

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

3. TRANSFORMERS AND REACTORS

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

I. General Supervision

(a) Dirt and Dust

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

(b) Rust and Treatment

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

(c) Check for any Signs of Mechanical Damage

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

(d) Check on all Joints for Signs of Leakage

All joints, both welded and gasket placed, must be checked for signs of oil leakage. If there is any doubt of a leak, the area must be cleaned of oil, using a suitable solvent (methyl alcohol) and sprayed with liquid chalk. This will promote the flow of the leak and give a good indication as to the exact location of the leak, if in fact there is one. If a leak is suspected on a gasket, the joint must be tightened until such time that it can be changed with a new gasket. If a leak is apparent at a welded joint once again clean the area and apply liquid chalk and allow to dry.

This will highlight the point exactly if in fact there is a leak. It must be properly repaired with welding procedures when convenient. Prior to leaving the leak, it must be highlighted with a marker, or something similar, so it is not lost when permanent repair takes place. Other areas commonly associated with oil leaks are drain plugs in radiators, valves in the oil management and cooling system and the gas and oil actuated relay.

(e) Check for Oil Level

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

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

(f) Check on the Surrounding Areas

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

II. Checks on Breathers

(a) Checks on Silica Gel Breather

In open breathing transformer, the breather plays active role in maintaining the transformer dry by admitting dry air when transformer breathes. In transformers having air cell or diaphragm, the breather ensures dry air inside the air cell or above the diaphragm. The silica gel inside the breather should become pink from bottom to top over a period of time. Any de-colorization at top or sides indicates leakage in container and need to be attended immediately. In order to prevent severe deterioration of the silica gel, it is recommended that it is replaced when half to two thirds of the silica gel has become saturated and turned pink in colour. Failure to do so will severely retard the drying efficiency of the breather. The silica gel can be reactivated by heating it to 130°C-140°C in a ventilated oven until it has achieved the bright blue colour. Check that the oil level is correct in the oil cup at the breather base and fill oil if the level is found low.

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

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

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

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

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

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

(b) Drycol Breather Check (If Available)

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

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

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

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

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

III Checks for Conservator

(a) Visual Check for Conservator Oil Level

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

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

(b) Leakage Test for Air Cell

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

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

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

Continue filling oil into the conservator until it is full and oil starts coming out of the Air Release Valve. Close the Air Release Valve after ensuring that all the air has come out from the oil portion below the diaphragm. Slowly drain the oil from the conservator until the oil level as indicated on the oil level gauge corresponds to the transfom1er oil temperature.

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

(c) Caution

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

IV. Check for Cubicle and Marshalling Kiosk and Valves

Marshalling Cubicle and Kiosk Check

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

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

V. Checks for Auxiliaries

(a) Cooling System

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

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

(b) Cooling System-Fans-Controls

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

(c) Calibration of OTI / WTI

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

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

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

(e) Gas Pressure Relay

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

(f) Buchholz Relays

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

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

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

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

(g) Bushings

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

VI. Operational Checks and Inspection / Maintenance of Tap Changer

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

(a) Precautions

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

(b) Tap Changer Hand Operation

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

(c) Maintaining Circuit

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

(d) Drive Motor

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

Set the motor overload to 10% above running current

(e) Out of Step Relay

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

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

(f) Tap Change Incomplete Alarm

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

(g) Remote Indication

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

(h) Tap Changer (Surge) Protective Relay

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

(i) Inspection and Maintenance of OLTCs

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

Following de-energization, close all valves between oil conservator, transformer tank and tap-changer head, then lower the oil level in the diverter switch oil compartment by draining of oil for internal inspection. Upon opening the OLTC compartment, the door gasket should be inspected for signs of deterioration. The compartment floor should be inspected for debris that might indicate abnormal wear and sliding surfaces should be inspected for signs of excessive wear. Finally, the tap selector compartment should be flushed with clean transformer oil and all carbonization, which may have been deposited, should be removed. Min BDV should be 50 kV and moisture content should be less than 20 PPM.

Dissolved Gas Analysis (DGA)

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

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

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

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

Individual Fault Gases Acceptable Limits

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

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

Transformer Type	Fault Gases (in µ1/1)						
	H_2	CH_4	C_2H_6	C_2H_4	C_2H_2	CO	CO_2
No OLTC	60-150	40-110	50-90	60-280	3-50	540-900	5100-13000
Communicating OLTC	75-150	35-130	50-70	110-250	80-270	400-850	5300-12000

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

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

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

Total Dissolved Combustible Gas (TDCG) Limits

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

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

Evaluation of Gases

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

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

Faults Associated with Different Gases

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

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

4. CIRCUIT BREAKERS

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

(a) Interrupting Chamber

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

(b) Operating Mechanisms

Normally circuit breakers have pneumatic, hydraulic and spring operating mechanisms. As operating force is required for closing and tripping of circuit breakers, there can be combination of these mechanisms in one circuit breaker. Since operating mechanisms have a number of moving parts, they need more maintenance such as greasing, lubrication, cleaning, setting of limit switches, etc. Compressors/ oil pumps/ spring charging motors also require maintenance. Other maintenance on particular operating mechanism such as air compressor maintenance, nitrogen priming pressure checking in hydraulic mechanism, checking of over travel, checking of gaps in operating plunger of close/ trip coils etc. are to be carried out as the case may be and as specified by the manufacturers.

(c) SF_6 Gas

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

(d) Emptying and Re-filling of Gas

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

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

(e) Evacuation of SF6 Gas Circuit Breakers

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

5. PREVENTIVE MAINTENANCE OF CURRENT TRANSFORMERS

(a) Visual Inspection

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

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

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

(b) Maintenance of Gaskets

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

(c) Secondary Terminals Connections

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

(d) Primary Terminals

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

6. CAPACITANCE VOLTAGE TRANSFORMERS/ POTENTIAL TRANSFORMERS/ CAPACITOR COUPLING

(a) Visual Inspection

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

(b) Electro-Magnetic Unit

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

(c) Secondary Voltage

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

(d) Other Maintenance

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

7. DISCONNECTORS/ISOLATORS

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

The alignment of Disconnectors is very important for smooth operation. The limit switches, the healthiness of auxiliary contacts needs to be checked periodical1y. The main contacts are to be inspected and made smooth if any pitting marks seen. The corona shields are to be kept smooth and shining and checked for tightness of fitting. Damaged corona rings should be replaced. All moving parts are to be lubricated for smooth operation. The gear mechanism and motor normal1y do not require any maintenance and manufacturer's recommendation should be referred for maintenance of gears.

Earth Switches

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

8. LIGHTING ARRESTER/SURGE ARRESTERS

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

9. BATTERY AND BATTERY CHARGERS

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

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

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

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

(a) Battery Chargers

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

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

(b) BATTERY CAPACITY TESTING

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

(c) INITIAL REQUIREMENTS

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

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

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

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

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

(d) Record the battery terminal float voltage

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

CHAPTER 2

MAIN AND AUXILIARY SUBSTATION EQUIPMENT

GENERAL TECHNICAL REQUIREMENTS

1. INTRODUCTION

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

2. CIRCUIT BREAKERS

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

Table- 1

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

(a) Rated Operating Sequence (Duty Cycle)

The operating sequence denotes the sequence of Opening and Closing operation which the breaker can perform. The, operating mechanism experiences severe mechanical stresses during the auto re-closure duty.

Table 2

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

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

72.5 KV	60 ms to 100 ms
145 KV	60 ms to 100 ms
245 KV	Not exceeding 80 ms
420 KV	Not exceeding 40 ms
800 KV	Not exceeding 40 ms

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

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

(c) Operating Mechanism

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

(a) Pneumatically operated mechanism
(b) Spring operated mechanism
(c) Hydraulically operated mechanism

3. DISCONNECT SWITCHES/ISOLATORS AND EARTHING SWITCHES

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

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

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

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

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

4. INSTRUMENT TRANSFORMERS

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

Current transformer may be either of the bushing type or wound type. The bushing types are normally accommodated within the turret of main transformer and the wound types are invariably separately mounted. The location of the current transformer with respect to associated circuit breaker has an important bearing upon the protection scheme as well as layout of substation.

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

Typical ratings for instrument transformers normally used are given below:

(a) Current Transformer

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

(b) Voltage Transformers

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

(c) Capacitor Voltage Transformer

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

5. TRANSFORMERS

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

33 kV Power Transformers

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

Vector Group: Dyn11

66 kV Power Transformers

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

Vector Group: YNyn0

145 kV Power Transformers

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

Vector Group: YNyn0 or YNdl1

245 kV Power Transformers

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

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

Vector Group: YNaodl1

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

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

Vector Group: YN0d11

Auto Transformers (800 kV voltage level)

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

Vector Group: YN0dll

6. PROTECTION AGAINST LIGHTNING

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

Typical technical parameters adopted for surge arrestors are as follows:

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

7. INSULATORS

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

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

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

The following types of insulators are normally used:

(A) Support Insulators:

(i) Cap and pin type
(ii) Solid core type
(iii) Polyclone type

(B) Strain Insulators:

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

8. PROTECTION

(A) Line Protection

(i) *400 kV Lines*

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

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

(ii) 220 k V Lines

There should be at least one carrier aided non-switched three zone distance protection scheme. In addition to this another non-switched/switched distance scheme or directional over current and earth fault relays should be provided as back up. Main protection should be suitable for single and three phase tripping. Additionally, auto-reclose relay suitable for I ph/3 ph (with dead line charging and synchro check facility) re-closure shall be provided.

In case of both line protections being Distance Protections, IDMT type E/F relay shall also be provided additionally.

(B) Bus bar Protection

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

(C) Transformer Protection

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

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

(v) Protection and monitors built in to Transformer (Buchholz relay, Winding and Oil Temperature Indicators, Oil Level Indicator, OLTC Oil Surge Relay and Pressure Relief Device)

(vi) Protection for tertiary winding
(vii) Overload alarm
(viii) Circulating current Differential Protection (Inter-turn phase fault)

(D) Local Breaker Back-up Protection

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

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

9. CLEARANCES

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

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

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

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

10. Earthing

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

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

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

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

All substations should have provision for earthing the following:

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

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

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

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

Switchyard areas are usually covered with about 10 cm of gravel or crushed rock which increases the safety of personnel against shocks, prevents the spread of oil splashes and aids in weed control. This entails the provision of service roads for movement of vehicles required for carrying the equipment from the switchyard to service bay and back.
Bare stranded copper conductor or copper strip found extensive application in the construction of earth mat in the past. However, account of high cost of copper and the need to economies in the use of copper, current practice in the country is to use mild steel conductor for earth mat.

11. Fire Fighting System

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

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

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

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

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

(i) Fire Prevention

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

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

(ii) Fire Detection and Annunciation

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

Fire detectors of the following type are usually used:

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

(iii) Fire Extinguishing

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

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

(a) Hydrant System

This type of Fire Protection System is provided for Buildings.

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

(b) High Velocity Water (HVW) Spray System

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

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

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

(c) Portable Fire Extinguishers

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

The following types of portable fire extinguishers are normally used.

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

Fire Buckets

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

Water Supplies

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

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

Instrumentation and Control

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

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

Filtration/Hot Oil Circulation

- Connect bottom filter valve of tank to inlet point of filter machine.
- Connect top filter valve of tank to outlet of vacuum filter machine and start oil circulation
- The filter outlet temperature should be limited to 60 ~ 70^0 C.
- Continue filtration for 4 cycles whole oil should be circulated 4 times.

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

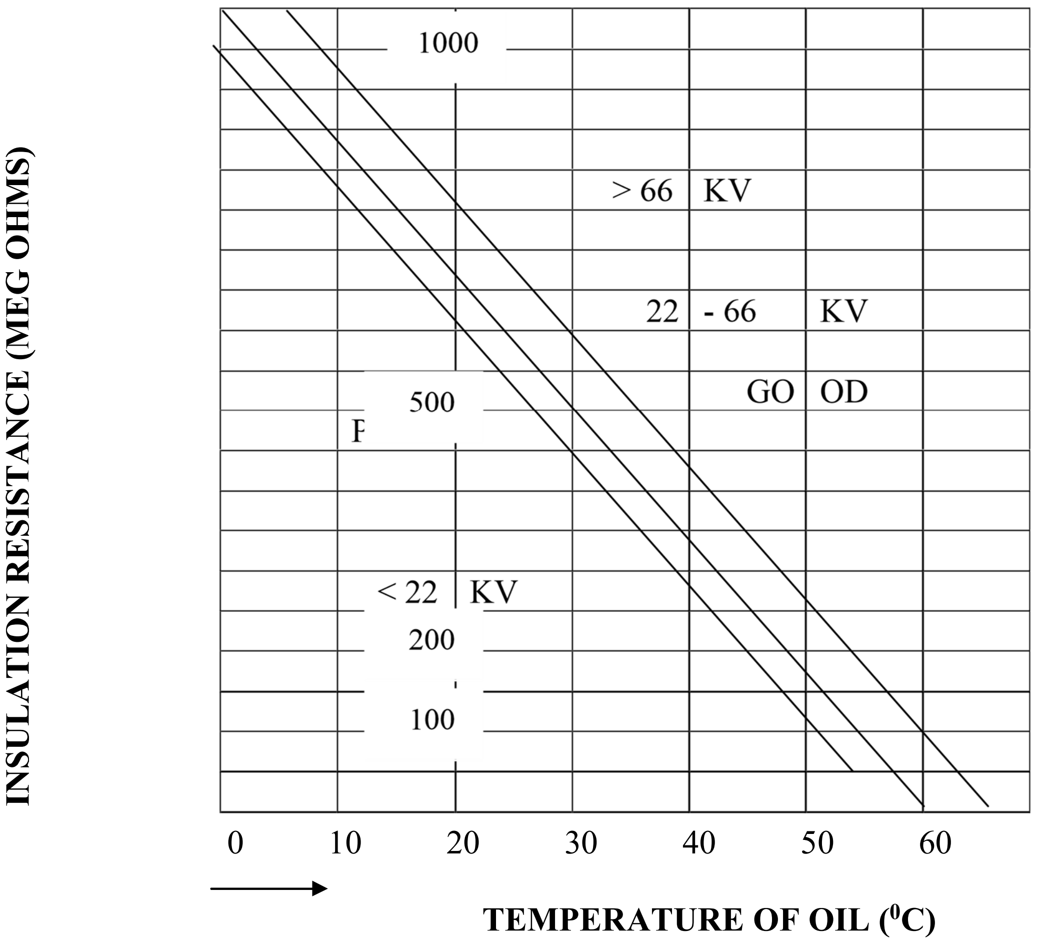
- Oil drawn from transformer is passed through a filter press before being admitted to the vacuum chamber to remove impurities.

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

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

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

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



Variation of Insulation Resistance with Temperature

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

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

Acid Content of Insulating Oil (By neutralization)

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

Resistivity of Insulating Oil

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

Water Content

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

Dielectric Dissipation Factor

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

CHAPTER 3

MAINTENANCE SCHEDULES FOR EHV S/S EQUIPEMENTS

Maintenance schedules for various equipment's of EHV Substation are given below:

A. TRANSFORMERS AND REACTORS

(i) Without Shut Down Activities

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

(ii) Shut Down Activities

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

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

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

B. CIRCUIT BREAKERS

(i) Breaker Operation Checks

1	CB operating timings (Main, PIR, Aux.)	2Y
2	Static contact resistance measurement	2Y
3	Dynamic contact resistance (DCRM), contact travel, contact speed, contact wipe, arcing contact length (Above 400 KV)	2Y
4	Checking of pole discrepancy relay	Y
5	Functional checks, duty cycle operation including rapid re-closing	Y
6	Checking of all operation lockouts including SF_6 density monitor	Y
7	Checking of all interlocks	Y
8	Checking of pressure settings	Y
9	Cleaning of breaker interrupter, support insulators and grading capacitors	Y

(ii) Measurement/Testing

1	Checking of close/trip coil currents	Y
2	Checking of healthiness of operation counter	Y

(iii) Control cabinet

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

(iv) SF_6 Circuit Breakers

1	SF6 gas leakage test	SOS
2	Dew point measurement of SF6 gas	3Y
3	Checking tightness of foundation bolts	Y

(v) Air Blast Circuit Breakers

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

(vi) Minimum Oil Circuit Breakers

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

(vii) Vacuum Circuit Breakers

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

(viii) Hydraulic Operating Mechanism

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

(ix) Pneumatic Operating Mechanism

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

(x) Spring Operated Mechanism

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

C. CURRENT TRANSFORMERS

1	Checking of bellow expansion	M
2	Visual inspection of CT for oil leakage and crack in insulator, etc.	M
3	Checking of oil leakage in terminal box	Y
4	Checking of primary connection strips, if provided externally	Y
5	Measurement of Tan δ and capacitance	2Y*
6	I R measurement	2Y
7	Checking of primary connection strips, if provided internally	SOS
8	Measurement of CT secondary resistance	SOS
9	Magnetization characteristics	SOS
10	CT ratio test	SOS

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

(i) Marshalling Box

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

D. POTENTIAL TRANSFORMERS/CAPACITANCE VOLTAGE TRANSFORMERS

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

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

E. DISCONNECTORS/ISOLATORS AND EARTH SWITCHES

(i) Main Contacts

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

(ii) Operating Mechanism

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

(iii) Earth Switch

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

F. SURGE ARRESTERS

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

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

1	Cleaning of insulators	Y
2	Checking of insulators for cracks	Y
3	Checking of all conductor joints, terminal connectors/clamps	Y
4	Checking of earthing connection of all structures	Y
5	Removal of hot spots	SOS
5	Repainting, rust removal of all structures, equipment's, etc.	SOS
6	Checking of switchyard lighting	SOS

H. PROTECTION SYSTEMS

1	Checking of voltage (in service) for relays	Y
2	Checking of DC logic circuits for trip and annunciations including timers by simulation	Y
3	Calibration of panel meters (Indicating/recording instruments along with the transducers)	SOS

(i) Distance Protection

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

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

(iii) Common Tests for Distance and Unit Protections

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

(iii) Bus Bar Protection

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

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

(iv) Differential Relays

1	Pick up current at the fixed/selected setting	Y
2	Operation of high set element/instantaneous unit at the fixed/selected setting	Y
3	Operation of the relay at the selected restraint bias setting.	Y
4	Checking of 2nd harmonic current restraint feature	Y
5	Operation of alarm and trip contacts.	Y
6	Through current stability checks on the existing load.	Y
7	Transformer differential protection.	Y
8	Restricted earth fault	Y
9	Auxiliary relays (Buchholz, PRV, etc.)	Y

(v) Under Voltage Relay

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

(vi) Over Voltage Relay

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

(vii) Neutral Displacement Relay

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

(viii) Over current And Earth Fault Relay

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

(ix) Under Frequency Relay

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

(x) Over Fluxing Relay

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

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

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

(xii) Fuse Failure Relays

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

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

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

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

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

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

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

I. PLCC SYSTEM

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

J. TELEPHONE EXCHANGE

1	Maintenance of EPAX as per recommendations of the manufacturers	SOS

K. AIR CONDITIONING PLANT

(i) Compressors

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

(ii) Condenser Unit

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

(iii) Water Treatment Plant

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

(iv) Cooling Towers

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

(v) Electrical Motors

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

(vi) LT Panels

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

(vii) Air Handling Units

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

L. BATTERIES AND DC DISTRIBUTION SYSTEM

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

M. FIRE PROTECTIONS SYSTEM

(i) Fire Alarm System

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

(ii) Diesel Engine

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

(iii) Jockey Pump

1	Check leakage and lubrication	M
2	Pump Overhauling	SOS

(iv) V-Belt Drive

1	Checking of belt tightness	QY

(v) Pumps

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

N. DIESEL GENERALTOR SET

(i) Lubricating System

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

(ii) Cooling System

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

(iii) Air Intake System

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

(iv) Fuel System

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

(v) Main Generator

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

(vi) Exhaust

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

(vii) General

1	Battery voltage and specific gravity measurement	M

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

(i) LT Panels

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

(ii) LT Switch Gears

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

(iii) LT Transformers

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

SUBSTATION AUTOMATION

Open Systems

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

An open system is a computer system that embodies supplier independent standards so that software may be applied on many different platforms and can interoperate with other application on local and remote systems. An open system is an evolutionary means for a substation control system that is based on the use of nonproprietary, 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 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 can interchange and share information. The benefits of open systems include longer expected system life, investment protection, upgradeability and expandability and readily available third-party components.

Levels of Integration and Automation

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

Since substation integration and automation technology is fairly new, there are no industry standard definitions, except for the definition of an IED. The industry definition of an IED is given below as well as definitions for substation integration and substation automation.

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

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

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

Architecture Functional Data Paths

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

- 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 nonoperational and remote access data paths. The latter two data paths must be done outside of the conventional RTU.

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

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

Substation Automation Training Simulator

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

Protocol Fundamentals

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

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

Protocol Considerations

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

Utility Communication Architecture

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

IEC 61850

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

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

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

Annexure-A

FORMAT OF RECORD TO BE MAINTAINED AT EHV SUBSTATIONS

B. FORMAT OF RECORD TO BE MAINTANED AT EHV SUBSTATION

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

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

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

TRANSFORMERS & REACTORS-MONTHLY MAINTENANCE RECORD

Monthly Maintenance-Without Shutdown Activity

MONTH…………………..

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

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

TRANSFORMERS & REACTORS - YEARLY MAINTENANCE RECORD

(VI) ALARM/TRIP TEST DATE…………

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

(VII) MARSHALING BOX – MAINTENANCE DATE………………

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

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

(III) TAN δ MEASUREMENT FOR BUSHINGS

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

NO.	Bushings	Capacitance		Tan				Remarks
		Pre-commissioning * Values	Measured Value	Pre-commissioning* Values		Measured Value		Measurement to be taken after cleaning
	Transformer Bushings 400 KV	C1	C1	Tan 1	Tan 2	Tan 1	Tan 2	TAN AT 20 DEG C= 0.007 (MAX)
	R ø							
	Y ø							Rate of rise of Tan per year =0.001 Max.
	B ø							Rate of rise of Capacitance value per year =+/- 1%Max.
	220 KV BUSHING							
	R ø							Note: For Measurement of C1 values of the Bushings, connection will be between HV and Test Tap and measurements in UST mode at 10.0 kV.
	Y ø							
	B ø							

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

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

CIRCUIT BREAKER – MONTHLY MAINTENANCE RECORD

Dt. Of Commissioning……. MAKE…… RATING……. SL.NO……….. Bay No.: ……….

(A) MONTHLY MAINTENANCE – ACTIVITY

ACTIVITY	OBSERVATION & REMARK
a) SF6 Gas Leakage in Champers	
b) Gas pressure check in Gauge	
c) Thermostat set value in MB	

Signature of Maintenance Engineer………………………………

CURRENT TRANSFORMER – MAINTENANCE RECORD

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

(A) MONTHLY MAINTENANCE –W/SD Activity

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

Checking of bellow for expansion …………………………………………………….

MARSHALLING / SECONDARY TERMINAL BOX

Check for any oil leakage from Secondary Terminal BOX …………………………

Checking of healthiness of gaskets ……………………………………………………

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

CURRENT TRANSFORMER – YEARLY MAINTENANCE RECORD

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

(i) MARSHALLING BOX

(I) Cleaning of MB…………………………….

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

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

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

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

CAPACITOR VOLTAGE TRANSFORMER – MAINTENANCE RECORD

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

A. MONTHLY MAINTENANCE –W/SD

(i) Checking of Oil Leaks

B. 3 MONTHLY MAINTENANCE

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

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

C. YEARLY MAINTENANCE

- ❖ Visual Checking of Earthing of HF Point – (IN CASE IT IS NOT USED FOR PLCC)
- ❖ Checking of any breakage of cracks in HF bushing.
- ❖ Cleaning of CVT Capacitor Stacks and tightness of terminal connections.

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

- ❖ Checking of Neutral Earthing in CVT MB and Tightness of All connections
- ❖ Cleaning of Marshalling Box & Junction Box
- ❖ Checking of Space heater & illumination
- ❖ Checking healthiness of all gaskets

DISCONNECTING SWITCHES/ISOLAORS AND EARTH SWITCHES – MAINTENANCE RECORD

Dt. Of Commissioning …………… MAKE …………….

RATING/ Type……………. SI. No………… Bay No.: …………….

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

(i) OPERATING MECHANISM

(a) Maintenance of linkages including transmission gears-

(b) Maintenance of Stopper bolts-

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

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

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

(f) Checking & Tightening of all the mounting bolts

(ii) MAIN CONTACTS

(a) Cleaning and Lubrication of Main Contacts

(b) Alignment

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

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

(e) Checking of interlocks

(iii) MARSHALLING BOXES OF ISOLATORS AND EARTH SWITCHES

(a) Checking of space heater & illumination.

(b) Checking of healthiness of Rubber Gaskets.

(c) Visual Check of auxiliary contacts.

(d) Cleaning and tightness of all terminations

(iv) EARTH SWITCH

(a) Checking and Alignment of Earthing Blades

(b) Cleaning of Contacts

(c) Operation of Earth Switch

(d) Checking of Aluminum/Copper flexible conductor:

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

SURGE ARRESTER – MAINTENANCE RECORD

Dt. Of Commissioning …………… MAKE …………….

RATING/ Type……………. SI. No………… Bay No.: …………….

(A) YEARLY MAINTENANCE

(a) Checking of Leakage by Current Analyzer (mA) after cleaning the porcelain surface.

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

(b) Testing by Surge Monitor kit - Counter and meter tests
(c) Cleaning of LA Insulators

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

BUSBAR AND BUS POST INSULATOR – MAINTENANCE RECORD

YEARLY MAINTENANCE OF BUS BAR & BPI

SL.NO.	ACTIVITY	SCHEDULED DATE/ACTUAL DONE ON DATE	MEASURED VALUE	REMARKS
1.	Measurement of station earth resistance			
2.	Cleaning of Insulators		Done/Not Done	
3.	Checking of Insulators for cracks		Done/Not Done	

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

YEARLY MAINTENANCE FORMAT FOR SUB-STATION ILLUMINATION SYSTEM

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

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

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

MONTHLY MAINTENANCE FORMAT FOR SUB-STATION AIR CONDITIONG SYSTEM

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

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

Signature :
Name :
Designation :
Date :

Signature :
Name :
Designation :
Date :

MAINTENANCE FORMATE FOR BATTERY SETS

SUB-STATIO :
DATE OF INSPECTION :
BATTERY SET :
VOLTAGE :
MONTH :
BATTERY VOLTAGE : -------------VOLT

(A) MONTHLY MAINTENANCE FORMAT – Bank - A

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

The cell voltage should be less than 2.16 and Specific Gravity 1150+/-10 at 27 deg C

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

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

Signature : Signature :

Name : Name :

YEARLY MAINTENANCE FORMATE FOR SUB-STATION FOR FIRE ALARAM SYSTEM

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

PTW NO : **DATE :**

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

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

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

MONTHLY MAINTENANCE FORMAT FOR SUB-STATION DG SET

DG SET BI : DATE OF MAINTENANCE : MTC.DONE BY :

DG SET CAPACITY : PTW NO/DATE : RUNNING HOURS OF DG SET:

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

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

PLCC EQUIPMENT MAINTENANCE RECORD

Dt. Of commissioning………… Make/ Modern………… Cab. SI. No…………… Name of Line Direction…………

YEARLY MAINTENANCE – S/D ACTIVITY

SR.NO.	MAINTENANCE	TEST POINTS (T.P) WHERE MESUREMENTS TO BE DONE	SPEECH TX…. Rx….	PROTECTION-1 TX…. Rx….	PROTECTION-2 TX…. Rx….
1.	POWER SUPPLY MEASUREMENTS				
2.	INPUT VOLTAGES				
3.	STABILISED DC VOLTAGES				
4.	TRANSMITTER CHECKS				
5.	FM OSCILLATOR-Frequency measurement				
6.	AM OSCILLATOR- Time measurement				
7.	OUTPUR LEVEL MEASUREMENT				
8.	RECEIVER CHECKS				
9.	Receiver level FM				
10.	Receiver level AM				
11.	ALARM CHECKS				
12.	TRANSMISSION OF PROTN. CODE CODE I CODE II				
13.	RECEIPT OF PROTN. CODE CODE I CODE II				
14.	LOOP TEST/REFLEX TEST				

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

Sign. Testing Engr…………… Sign. Station In-charge……………….

PREVENTIVE MAINTENANCE RECORD FOR PROTECTION SYSTEM

MONTHLY PREVENTIVE MAINTENANCE RECORD – GENERAL

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

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

Annexure-B ESSENTIAL REGISTERS TO BE MAINTAINED AT EACH SUBSTATION

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

INSTRUCTIONS FOR MAINTENANCE OF ESSENTIAL REGISTERS:

1. INDEX REGISTER:

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

2. PLANT HISTORY REGISTER:

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

3. OPERATION AND MAINTENANCE MANUALS

4. SHIFT ARRANGEMENT:

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

5. ATTENDANCE REGISTER:

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

6. TESTING REGISTER:

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

7. DEFECT REGISTER:

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

8. DAILY ENERGY ACCOUNT REGISTER:

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

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

9. SHUT-DOWN/WORK PERMITS FORM REGISTER:

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

10. TRIPPING REGISTER (PRIMARY SYSTEM):

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

11. STOPPAGE REGISTER:

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

12. AUTHORISATION REGISTER:

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

13. INSTRUCTION REGISTER:

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

14. INSPECTION REGISTER:

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

15. ROSTERING PROGRAMME REGISTER:

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

16. MESSAGE REGISTER:

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

17. MAXIMUM/MINIMUM LOAD REGISTER:

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

18. CARRIER FAULT REGISTER:

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

19. COMPRESSOR READING REGISTER:

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

20. LA's SURGE COUNTER READING REGISTER:

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

21. DAILY LOG SHEET – As per Substation requirement