NATIONAL TRANSMISSION AND DESPATCH COMPANY LTD

STANDARD OPERATING PROCEDURES (SOP)
FOR
GRID SYSTEM OPERATION AND MAINTENANCE

1) GRID STATION EQUIPMENT
2) PROTECTION AND INSTRUMENTATION
3) TRANSMISSION LINES

TECHNICAL SERVICES GROUP (TSG) LAHORE

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1. INTRODUCTION

To keep the electrical power system in safe, stable and reliable operating condition, it is necessary that the system should be operated and maintained properly to retain its each component in or restore it to a state in which it can perform a required function.
Maintenance has become nowadays an important factor due to many reasons. Economic and legal considerations are among the most significant, for example extending the service life, reducing life cycle costs, reducing downtimes, safety aspects and environmental protection regulations. In addition to the purchase costs, the profitability of switchgear and control-gear in both the high and low voltage systems depends above all on the calculated operating costs for the entire service life. Therefore, to meet with the current requirements of up-gradations in the electro-technical technologies, emerging modern trends of operation and maintenance, technical standards/specifications and safety awareness this new edition of Standard Operating Procedure (SOP) has been compiled.

This booklet of SOP covers all the operation and maintenance requirements of grid system of GSO departments of NTDC and DISCOS in all the three main fields of grid system:

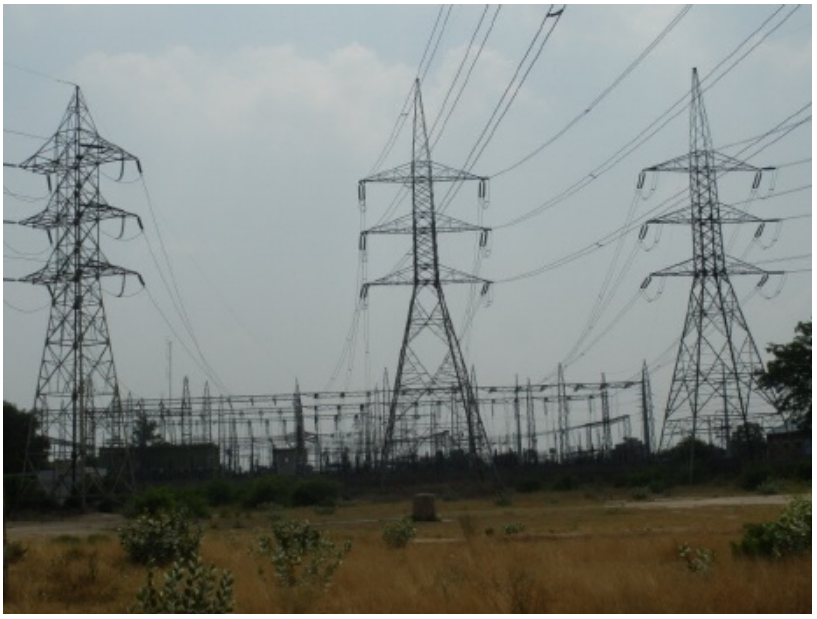
- Grid Station Equipment,

- Protection and Instrumentation,

- Transmission Lines.

A view of 220kV switchyard of 220kV G/S NTDC NKLP Lahore

A view of protection relay room at 220kV G/S NKLP Lahore



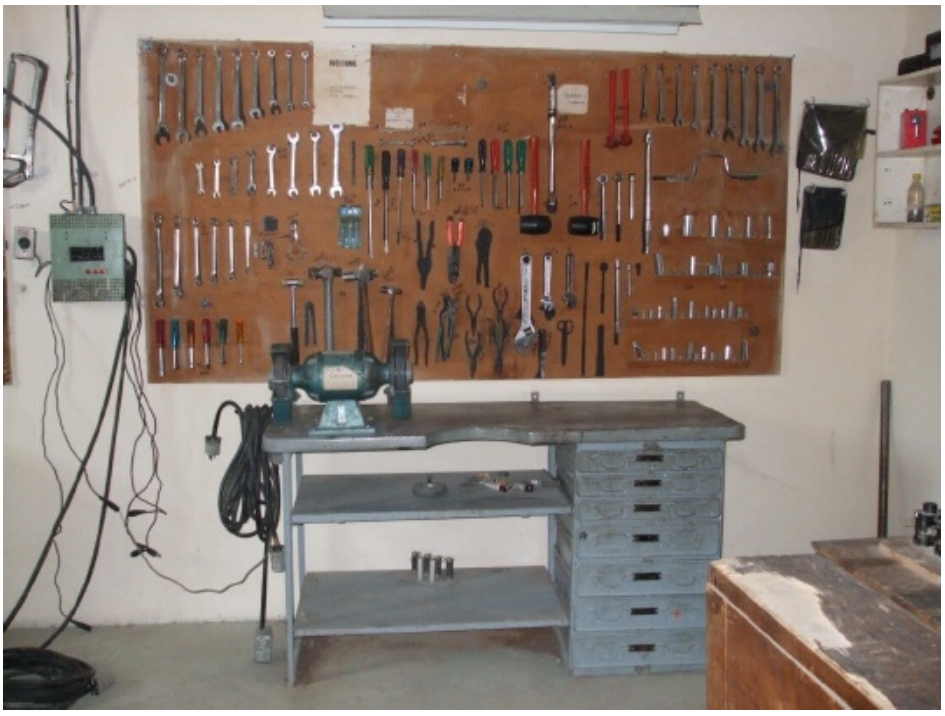
A view of 220kV transmission lines entering 220kV G/S NKLP Lahore

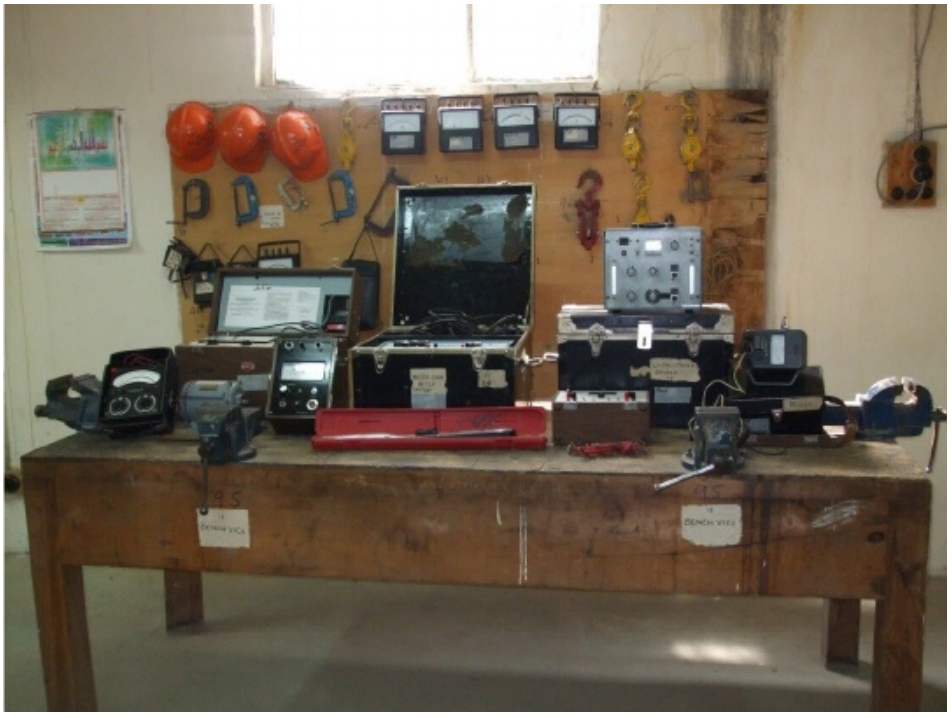
The scope of operation and maintenance work relevant to the above mentioned main fields including the other allied works have been described in terms of implementation frequency and schedules, work activities, testing, etc. In simple words this SOP describes that what to do and when to do but for how to do, the work procedures have been described in skill enhancement training course books of TSG training program. The relevant reference data for comparison and interpretation of different operating conditions and test results has also been included in the booklet.

Safety and health of the workers has a paramount importance in implementation of the SOP. Lack of Safety awareness, Un-safe acts and Un-safe working conditions, etc. always result into accidents and damages either to the workers or the equipment. It is essential that while on work each worker must follow the safe working methods and procedures as the life or loss he saved could very well be his own. The safety instructions as per Power Safety Codes of NTDC and DISCOs shall be followed by the each individual employee while on work at the company premises.

The contents herein the booklet are in-line with the WAPDA/PEPCO technical specifications, NTDC Grid Code, IEC standards and the recommendations of the manufacturers dealing with the grid system equipment and other hardware. However, deviation to these instructions and guidelines is permissible if the more effective alternatives are implemented.

2. MAINTENANCE OF GRID SYSTEM





2.1 GENERAL

The word “maintenance” in encountered frequently, though it is used with different meanings. Its overall concept includes inspections, scheduled maintenance, non-scheduled maintenance and corrective measures. As per IEC standard, maintenance is the combination of all technical and administrative actions, including supervision actions, intended to retain an item in, or restore it to, a state in which it can perform a required function. The proper maintenance also ensures correct operation of grid station equipment permanently over its design life, even longer if it is justified economically and technically. Generally the maintenance work is categorized as scheduled maintenance and non-scheduled maintenance.

2.2 SCHEDULED MAINTENANCE

The preventive maintenance carried out in accordance with an established time schedule. Scheduled maintenance covers all measures aimed at retaining the design state of the technical equipment belonging to a system and may take place as and when required or in regular/fixed interval of time. Scheduled maintenance includes such activities as cleaning and washing, conservation, lubrication and where necessary amending or replacing parts subject to wear and tear. Scheduled maintenance also involves preparation of maintenance schedules, carrying out the specified work and dealing with feedback relating to this work.

2.3 NON-SCHEDULED MAINTENANCE

Non-scheduled or corrective or emergency maintenance is often not in accordance with an established time schedule and usually needs as result of malfunction or unexpected defect. Non-scheduled maintenance covers all measures aimed at restoring the designed state of the technical equipment belonging to a system. Repair work and part replacement are typical types of corrective maintenance. It also involves planning, handling requests for performing/checking and evaluating the necessary measures (functional tests etc.). It is worth mentioning that an effective preventive maintenance program always minimizes emergency maintenance breakdowns and damages of grid station equipment.

2.4 PREVENTIVE MAINTENANCE PROGRAM

The responsibility of carrying out maintenance work always lies with the owner of the equipment, e.g. NTDC/DISCOs. The company is under an obligation to observe all the valid safety rules, technical rules/procedures and specifications. The specifications of maintenance work must be based on certain requirements, standards, specifications and the guidelines supplied by the manufacturer, local experience, etc.

2.4.1 MAINTENANCE INTERVALS

Generally following are the three main criteria which determine the time period or intervals to carry out the preventive maintenance on grid system equipment:

- The recommended time and service period,
- The number of mechanical operations,
- The number of short circuit current disconnections or the total number of breaking currents.

It is a universal practice that most of the maintenance work is carried out on the criteria of recommended time periods of service life of the equipment (daily, weekly, monthly, quarterly, annually, 5 to 10 yearly, 20 yearly, etc.). The time period are specified on the bases of the recommendations of the manufacturers and the local experiences. The local experiences include administrative rules & regulations, service conditions, the available resources, other influencing factors, etc. Maintenance, on the criteria of numbers of mechanical operations or electrical switching operations, is carried out rarely. Whether, visual inspections or scheduled or non-scheduled maintenance all contribute to a preventive maintenance program.

2.5 INSPECTION

Visual inspection/investigation of the principal features of the switchgear & control-gear and other equipment in service belonging to a system is carried out, without dismantling, to evaluate the actual status. This investigation is generally directed toward pressures (air, gases) and / or levels of fluids (insulating oil, lubricating oil, hydraulic oil), tightness, position of relays, pollution of insulating parts, but actions such as lubricating, cleaning, washing etc. which can be carried out with the switchgear and control-gear in service are also included. Inspections are also described as walk around visual inspection from ground level keeping in view the safe limits of approaches. Shutdown of the equipment is not involved normally. On the bases of inspection data, short-term and long-term work program for carrying out preventive maintenance are prepared to meet with the best possible level of operational availability and reliability of the grids system.

2.6 GENERAL TERMS USED IN MAINTENANCE WORK

Overhaul

Work done with the objective of repairing or replacing parts which are found to be out of tolerance by inspection, tests, examination, or as required by manufacturer's maintenance manual, in order to restore the component and / or the switchgear and control-gear to an acceptable condition. Overhauling can be categorized as minor

overhauling and major overhauling depending upon the specific instructions of the manufacturer and / or local experience and policy of the company.

Minor Overhaul
Minor overhauling of the equipment is a sort of detailed/expanded visual inspection for which shutdown is normally involved. Routine functional tests are performed to assess the operational condition and reliability of the equipment. Dismantling of the equipment is normally not involved, hence no need of spare parts. The time period of one to two years of service life is considered as normal frequency for minor overhauling.

Major Overhaul
Major overhauling of the equipment involves dismantling into sub-assemblies and detailed examination of the component parts and measurements of the wear tear effects. Replacement of certain parts is essential such as tightness system gaskets, O-rings etc. The time period of five to twenty years of service life is considered as normal frequency for major overhauling. Shutdown of the equipment is an essential requirement.

Diagnostic Tests
These tests are comparative tests of the characteristic parameters of switchgear & control-gear and other equipment to verify that they perform their functions, by measuring one or more of these parameters.
Note. The test results from diagnostic tests can lead to the decision to carry out overhaul.

Down Time
This is the time interval during which an item is in a down state (not functioning).

Examination
Inspection with the addition of partial dismantling, as required, supplemented by means such as measurements and non-destructive tests in order to reliably evaluate the condition of the switchgear and control-gear.

Defect
An imperfection in the state of an item (or inherent weakness) which can result in one or more failures of the item itself, or of another item under the specific service or environmental or maintenance conditions, for a stated period of time.

Failure
The termination of the ability of an item to perform a required function is called failure.

Note. 1 After "failure" the item has a fault.

Note. 2 "Failure" is an event, as distinguished from "fault", which is a state.

Note. 3 This concept of "failure" as defined does not apply to items consisting of software only.

Minor Failure (of switchgear & control-gear and other equipment)
Any failure of a constructional element or a sub assembly which does not cause a major failure is referred as minor failure.

Major Failure (of switchgear & control-gear and other equipment)
Failure of switchgear & control-gear and other equipment which causes the blockage of one or more of its fundamental functions is referred as major failure. A major failure will result in an immediate change in the system operating conditions, e.g. the backup protective equipment will be required to remove the fault, or will result in mandatory removal from service within 30 minutes for unscheduled maintenance.

Disruptive Discharge
Phenomenon associated with the failure of insulation under electric stress, in which the discharge completely bridges the insulation under test, reducing the voltage between the electrodes to zero or nearly to zero.

Note.1 This term applies to "discharges" in solid, liquid and gaseous dielectrics and to combinations of these.

Note. 2 A "disruptive discharge" in a solid dielectric produces permanent loss of dielectric strength (non-self-restoring insulation); in a liquid or gaseous dielectric, the loss may be only temporary (self-restoring insulation).

Spark-over
A disruptive discharge which occurs in a gaseous or liquid dielectric is referred as spark over.

Flashover
A disruptive discharge which occurs over the surface of a solid dielectric in a gaseous or liquid medium is referred as flashover.

Puncture
A disruptive discharge which occurs through a solid dielectric is referred as puncture.

Partial Discharge (PD)
Localized electrical discharge that only partially bridges the insulation between conductors and which can or cannot occur adjacent to a conductor.

Note. 1 'Partial discharge' is in general a consequence of local electrical stress concentrations in the insulation or on the surface of the insulation. Generally, such discharges appear as pulses having duration of much less than one μs. More continuous forms can, however, occurs, such as the so-called pulse-less discharges in gaseous dielectric.

Note. 2 'Corona' is a form of partial discharge that occurs in gaseous medium around conductors which are remote from solid or liquid insulations. "Corona" should be used as a general term for all forms of PD.

Corona
Corona discharge is defined as a luminous discharge due to ionization of air surrounding a conductor caused by a voltage gradient exceeding a certain value. The ionization takes place in a zone which is a very thin circumferential layer (not more than 2 cm) surrounding the conductor surface. Corona discharge forms at the surface of transmission line conductor when the electric field intensity on the conductor surface exceeds the breakdown strength of air. If the voltage is high, the surface stress may reach a value at which the air breakdowns and become a conductor. The conducting layer of air forms part of conductor and the radius of the conductor increases due to which the surface stress decreases. If the spacing between conductors is small, the corona discharge may bridge the conductors and cause flash over. The corona discharge is accompanied by the "faint glow" and a hissing noise.

External Insulation
The distances in air and the surfaces in contact with open air of solid insulation of equipment, which are subject to dielectric stresses and to the effects of atmospheric

and other external conditions such as pollution, humidity, vermin, etc. is referred as external insulation.

Internal Insulation
The internal solid, liquid or gaseous parts of the insulation of equipment, which are protected from the effects of atmospheric and other external conditions is referred as internal insulation.

Self-restoring Insulation
Insulation which completely recovers its insulating properties after a disruptive discharge is referred as self-restoring insulation.

Non Self-restoring Insulation
Insulation which loses its insulating properties or does not recover them completely after a disruptive discharge is referred as non-self-restoring insulation.

Degree of Protection (IP Code)
A coding system to indicate the degrees of protection provided by an enclosure against access to hazardous parts, ingress of solid foreign objects, ingress of water and to give additional information in connection with such protection. The classification of degree of protections is identified by a symbol comprising two letters IP (International Protection) which always remain the same and two digits indicating the degree of protection e.g. IP-44 (Reference IEC 60529, VDE 0470 Part-1 and EN 60529).

3. JOB PLANNING

Jobs are executed more efficiently and effectively when they are planned well and all concerned know what is expected. The following steps and guidelines should be considered for planning the routine maintenance jobs. The emergency maintenance jobs (such as trouble shooting, repairing, etc.) are non-scheduled, however, the procedure/steps followed in planning a scheduled work and the experience gained thereof is equally applicable in handling emergencies. Special attention should be given to the safety requirements.

1) Follow the approved work program.
2) Arrange the maintenance procedures.
3) Arrange equipment manual and drawings.
4) Arrange previous maintenance records.
5) Arrange the spare parts required.
6) Arrange T & P and test equipment needed.
7) Estimate and arrange to meet the expenditure involved.
8) Estimate the number of man hours and the length of time required to complete the job.
9) Arrange to get co-ordination of the other work groups (such as Grid maintenance, P&I, T/L, etc.) if needed.
10) Arrange shut down of the equipment to be worked on if needed (refer procedure for PTW).
11) Inspect job site to look for:

11.1) Hazards.
11.2) What equipment are to be de-energized to get safe working clearances?
11.3) Isolation points & grounding facilities
11.4) What types of aerial devices (i.e. scaffold, bucket truck, ladders, cranes, etc.) are required?
11.5) Is there enough room/space for aerial devices and the ground condition permit them to be fix/move.
11.6) Approach roads condition.
11.7) Other information of job site which you think necessary for execution of the job.

12) Conduct a tailboard conference or meeting with the crew members so that each member of the crew may know and understand his job and responsibility.

3.1 DESCRIPTION OF THE STEPS INVOLVED IN JOB PLANNING

1) Follow work program.

Each grids maintenance crew must have an approved work program involving each equipment to be maintained by the crew in his work jurisdiction. See your work program for the job to do.

2) Arrange maintenance procedures.

Each grid maintenance crew is supposed to have an approved package of maintenance procedures regarding every type of maintenance work to be done, for example regular maintenance, minor overhauling and major overhauling procedures. Such a set of maintenance procedures should also be available at central places in GSO organization. Check your package of such procedures and make sure that you have procedure to do the job, otherwise arrange to get the same.

3) Arrange equipment manual and drawings.

Manufacturer's manual of each type of equipment and a set of drawings (schematic control diagram, A.C. and D.C schematic diagrams and wiring diagrams of each equipment and grid station in the, jurisdiction of a grid maintenance crew) must be available with the crew or at central places in GSO organization where they can be easily available to the crew. Check your package and make sure that you have the manual and drawings for the job to do, otherwise arrange to get the same.

4) Arrange previous maintenance record.

Each grid maintenance crew must be available with the previous maintenance record of each equipment involved in their maintenance programme. This record is actually the history of the equipment from where one can see the nature of maintenance work done, such as type of faults, how they were rectified or any fault/discrepancy still exists, test results etc. Get the previous maintenance record if available. Also look at the last station inspection report to determine if there was a problem reported. In future you will open a file on the concerned maintenance record. These maintenance record files should be available in the control room at each grid station in the custody of shift incharge, but not in the custody of grid station incharge.

5) Arrange for the spare parts required.

Enough quantity of spares (such as equipment component parts, insulating oil, SF6 gas etc.) needed in regular maintenance, minor and major overhauling of the grid equipment must always be available in stock of local/C-type/A-type stores or warehouses of GSO organization. You will pay special attention regarding availability

of spares and submit demands to the higher well in time so that work program may not suffer due to non-availability of spares. Get the spares required.

6) Arrange for T&P and test equipment needed.
Each grid maintenance crew is supposed to have a complete package of routine used T&P and basic test equipment (Refer standard T&P list attached), otherwise arrange to have the same. The type and quantity of T&P is determined by breaking the job into a number of tasks and the T & P required for each task. Each crew may not have all the test instruments and special tools due to being costly, so one or two sets of these test equipment and special tools can be arranged at circle level and be used by all the crews in that circle with mutual co-ordination. A guideline for this mutual co-ordination is that work programs for crews in a circle should be prepared in such a way that their work activities timings not overlap each other. You will get the test equipment and special tools required for the job well before.

7) Estimate and arrange to meet the expenditures involved.
Following the NTDC financial rules and procedures, the crew in-charge should submit his budget demands and get the required budget allocated for the financial year. The crew may needs budget for overtime work payments, repair of vehicles, purchase of cleaning and lubricating hard wares, medical bills, other petty purchase and repairs etc. You will estimate and get the money required to meet the expenditures with the job well before.

8) Estimate number of man-hours and the length of time required to complete the job.
Keeping in view the nature of job to be done you will estimate the men required for the job and for how much hours they will need to complete the job. This is done by breaking the job into a number of tasks. Hence, you will estimate the total time required for the job and the same will be the equipment shut down time if shut down is required.

9) Arrange to get co-ordination of the other work groups (P&I, T/L, etc.) if needed.
To minimize the shut down on an equipment, inform other work groups (P&I, T/L etc.) if they have to do some job on the same equipment. For example, P&I staff can test the protection of a transformer when you have arranged its outage for minor/major maintenance. Another example, that you are going to perform annual maintenance on station battery ask P&I staff to verify and adjust settings of battery charger.

10) Arrange shut down of the equipment to be worked on if needed. (refer to PTW procedure).

If shut down of the equipment to be worked on is required, you have calculated the duration of shut down (refer step-8), apply to the NPCC/RCC for shut down 72-hours before the shutdown start time.

11) Inspect job site to look for:

11.1) Hazards: Hazard/accident is a result of unwanted energy flow. Look for the energy forms involved in the work, such as body mechanics, chemical energy, electrical energy, heat energy, light energy, mechanical energy, noise, pressurized fluids (gases and liquids) etc. Look for the hazards due to fall, travel and contact.

11.2) Is there any chance of back feeding. What equipment are to be de-energized to get safe working clearances?

11.3) Isolation points and grounding facilities.

11.4) What types of aerial devices (scaffold, bucket truck, ladders, etc.) and crane are required?

11.5) Is there enough room/space for aerial devices and ground condition permits to be use/fixe/move them?

11.6) Condition of the approach roads be kept in mind.

11.7) Other information about job site, which you think necessary for execution of the job.

12) Conduct a tailboard conference. You being in-charge of the crew will conduct a conference/meeting with the crew members the day before commencing the work. For emergency jobs it is also necessary to conduct a tailboard conference before commencing the work for the following purposes:

12.1) To tell them what is the job to do,

12.2) To discuss the hazards identified at the site,

12.3) To assign the job/responsibility to each member,

12.4) To decide any changes to work methods,

12.5) To finalize the work plan,

12.6) To ensure each person knows what to do,

12.7) To develop a safety program for the job to be done. Some of the key points for a safety program are;

12.7.1) Recognize the five basic safety principles as given below:

- Identify the hazards

- Eliminate the hazards wherever practical

- Control the hazards, when they cannot be eliminated

- Minimize the severity of injuries when a hazard is out of control

- Minimize severity of an injury after it has occurred

12.7.2) Consider safe limits of approach,

12.7.3) Use barriers and warning signs,

12.7.4) Use fall arrest and travel restrict systems.

4. JOB SAFETY AWARENESS AND SAFETY CODE

You will get safety awareness and follow the prescribed safety rules and guidelines while on work for your own safety, of fellow workers and of the company's property. It is the responsibility of the man-in-charge and of each crew member to constantly be on the lookout for safety hazards and to take definite steps to eliminate or control all identified hazards.

Prior to undertaking any of the maintenance procedures, proper work protection shall be established as necessary in accordance with the PTW and the Company's Safety Code. All work activities shall comply with applicable safety rules and regulations. In addition to the above, a safety hazard identification exercise shall be undertaken.

In a work place hazards are always expected to the workers and/or the equipment. The **unsafe acts** and **unsafe conditions** increase the chances of accidents whether fatal or non-fatal. Flow of unwanted energy also presents accidents. Safety can be achieved only through intelligence, cooperation and an understanding of and adherence to safety measures.

4.1 BASIC SAFETY GUIDE LINES

Personal safety is a primary feature of our daily work, whether at home or office or field so all the employees of the company, mainly the un-trained and having multi-nature jobs, must become familiar with these basic safety guide lines.

General Principles: Accident prevention can be accomplished only through possessing and applying safety know-how and wholehearted cooperation of all members of the organization. Learn and understand the following five basic principles in job safety to deal with the hazards:

a) IDENTIFY the Hazards.
b) ELIMINATE the hazards wherever practical.
c) CONTROL the hazards when they cannot be eliminated.
d) PROTECT against injuries in case a hazard gets out of control.
e) MINIMIZE the severity of an injury, if an accident occurs.

- Neither management and supervision, nor the Safety Code can prevent accident without the help of each employee.

- Unsafe workers are a danger to themselves, their fellow workers, the public property

and the equipment with which they work. Due care and attention to all safety rules and devices is essential not only to prevent injury to the workers but also to protect equipment.

- Capable and mentally alert employees will avoid accidents by learning all they can about their work, using proper safeguards and protective equipment and avoiding shortcuts and make shift work methods.

- Good operation is safe operation. This is true for both employees and equipment. A job done safely is job done efficiently.

Accidents do not "just happen". Accidents are the natural result of unsafe condition or unsafe acts, usually a combination of both. Machinery and equipment generally are manufactured to perform safely within limits of design. In fact, statistics show that more than 90% of accidents are due to the human element, such as failure to use safety devices and observe safety rules and procedures.

UNSAFE CONDITIONS: Some examples of unsafe conditions which may cause accidents are:

Improper Guarding such as unshielded moving parts of machine, in-barricaded floor openings and excavation, unenclosed high voltage equipment, lack of protective equipment and insufficient warning signs etc.

Defective Material or equipment such as mushroomed-head chisels, split handles, deteriorated poles, poorly manufactured or weak equipment.

Hazardous Arrangements such as those due to poor housekeeping at work locations, unsafe planning or inadequate working space.

Insufficient Light unsuitable location producing glare or objectionable shadows.

Improper Ventilation such as insufficient change of air or presence of harmful vapor, dust or gas.

Unsafe Clothing that fits loosely and can become entangled in wires and machinery, and failure to use goggles, proper shoes and insulated gloves or sleeves.

Unsafe Design and Construction due to deviations from standard design and specifications and poor workmanship.

UNSAFE ACTS: Some examples of unsafe acts which may cause accidents are:

Operating Without Authority or Warning such as closing switches without authority, operating hoists and trucks without warning, failure to place warning signs or signal man where needed, failure to block equipment against unexpected movement, failure to observe work clearance procedures.

Operating or Working at Unsafe Speed such as driving too fast, throwing material or tools to another worker, jumping from vehicles or platforms or running.

Making Safety Devices Inoperative such as removing guards from machines, using oversize fuses, blocking safety valves, bypassing interlocks and isolating fire protection etc.

Use of Unsafe Equipment or Improper Use of Equipment such as using dull cutting tools, mushroom-head chisels, pipe extension on wrenches not designed for them, or the wrong tool for the job, or using hands instead of hand tools.

Unsafe Loading such as overloading cranes and winches, carrying too heavy load.

Placing or Leaving Objects where they are likely to fall.

Mixing Improper Packing or combining chemicals to form a dangerous mixture.

Taking Unsafe Position or Posture such as working on live conductors from above instead of below, walking under suspended loads or too close to openings, lifting while in awkward position, entering areas where there are dangerous gases or fumes, passing on curves of hills, riding on running boards or other unsafe places on vehicles.

Working on Equipment without Taking Proper Precautions such as installing and removing temporary earth, cleaning, oiling or adjusting moving machinery, and working on or near live electrical equipment.

Distracting, Teasing or Startling such as practical joking, horseplay, quarrelling or annoying.

Failure to Use Safe Clothing or Protective Equipment such as failure to use insulated gloves, hardhat or goggles or other personal protective equipment (PPE).

5. MAINTENANCE SCHEDULE AND CHECKS; GRID STATION EQUIPMENT

Preventive maintenance is a cycle of planned inspections, work activities and tests to be implemented to get and ensure safe and reliable performance of equipment and infrastructure components of the grid system. The maintenance cycle or frequency of implementation is given in terms of time-periods, which can be modified due to environmental conditions and constraints of the man-hours and quantity of the equipment under the jurisdiction of the work crew.

The check sheets given hereunder describe only the maintenance schedules and checks/tests in terms of what to do and when to do. For the aspect of how to do, one should consult relevant manufacturer's instruction manual, TSG training course books and/or TSG technical experts. In addition to the inspection and maintenance activities given in this SOP, manufacturer's recommended instructions are also applicable.

The symbols used for time-periods for inspection and maintenance/frequency of implementation are as under:

D stands for daily,
W stands for weekly,
M stands for monthly,
Y stands for yearly.

1. MAINTENANCE OF POWER TRANSFORMERS

250MVA, 220/132KV Auto Transformer at 220kV G/S NKLP Lahore

SOP CHECK SHEET: MAINTENANCE SCHEDULE AND CHECKS/TESTS OF POWER TRANSFORMERS					
Description of Inspection and Maintenance Work	**Specified Time Period**				**Remarks/Criteria/Standard/Safety Precautions**
	D/W	**M3-6**	**Y1**	**Y5-10**	
1. Visual inspection (A walk around visual inspection from ground level and keeping in view the safe limits of approach to live and moving parts to check apparent condition, abnormal noise, rust on body of the equipment and component parts, etc.)	Yes	-	-	-	Wear PPE and carry basic tools, multi-meter, clip-on-ammeter, etc. Make entries of the observations in check sheets/note book.
2. Oil level: Conservator Tank Main	Yes	-	-	-	Should be OK as per indicator. The indicator should be kept clean and visible. Should be no oil leakages
3. Oil level: Conservator Tank OLTC	Yes	-	-	-	Should be OK as per indicator. The indicator should be kept clean and visible. Should be no oil leakages
4. Oil level: Bushings	Yes				Should be OK as per indicator. The indicator should be kept clean and visible. Should be no oil leakages
5. De-railing locking devices	Yes	-	-	-	Should be intact as per design
6.Cooling System (AF): Fans	Yes	-	-	-	Should be as per transformer construction design and operative. Check for proper speed, correct direction and noisy bearings.
7. Cooling System(OF): Oil Circulation Pumps	Yes	-	-	-	Should be as per transformer construction design and operative. Check for correct direction and noisy bearings.
8. Oil Temperature Gauges	Yes	-	-	-	Should be healthy and accurate
9. Oil Temperature Indicators	Yes	-	-	-	Should be OK at local/remote
10. Winding Temperature Gauges	Yes	-	-	-	Should be healthy and accurate
11. Winding Temperature Indicators	Yes	-	-	-	Should be OK at local/remote
12. Ground Connections of Neutral Terminal	Yes	-	-	-	Measure neutral current with clip-on-ammeter to ensure healthy connection between terminal and the earth mesh. Transformer neutral is grounded at two points i.e. with earth mesh and with separate earth electrode.
13. Ground Connections of Body Tank	Yes	-	-	-	Should be proper and tight. Measure leakage current with clip-on-

					ammeter to ensure healthy connection between the body tank and earth mesh. Transformer body tank has two grounding points.
14. Ground Connections of Tertiary Winding Terminal as applicable (see note at the end)	Yes	-	-	-	Measure neutral current with clip-on-ammeter to ensure healthy connection between the terminal and earth mesh.
15. Silica-gel Breather of Main Conservator Tank	Yes	-	-	-	Bubbling in the oil indicates healthy breathing. The colour of silica-gel should be BLUE and oil in glass pot clean. If 1/3 volume of the silica-gel has changed colour into PINK then recondition or replace the whole silica-gel
16. Silica-gel Breather of OLTC Conservator Tank	Yes	-	-	-	Bubbling in the oil indicates healthy breathing. The colour of silica-gel should be BLUE colour and oil in glass pot clean. If 1/3 volume of the silica-gel has changed colour into PINK then recondition or replace the whole silica-gel
17. Oil Leakages all around the transformer	Yes	-	-	-	Should be no oil leakages
18. Bushing Condition (HV, LV, Neutral, Tertiary, etc.)	Yes	-	-	-	Should be neat and clean, no damages and no oil leaks
19. Bushing Terminal Connections (HV, LV ,Neutral, Tertiary, etc.)	Yes*	-	Yes	-	Dismantle connections, clean properly, apply corrosion inhibitor and fix/tight with recommended torque. Should be no hotspot/s (* check during night patrolling/thermovision survey). While handling bushing terminal connections, take care of oil sealing system, arcing horns (if provided), the spacing between electrodes should be as per recommendations and/or in accordance with 1cm per kV of the rated phase-to-ground voltage. In 500/220kV transformers, tertiary winding terminals are enclosed in separate cubicle, give special attention to water proofing and vermin proofing of the cubicle.
20. Radiator Tubes Fixture	Yes	-	-	-	Should be secured with proper

					clamping/supports
21.Radiator Tubes Valves	-	-	Yes	-	The valves should always be kept opened, operative and no oil leaks (the temperature of radiator tubes should be observed by touching the tubes and feeling the degree of hotness by comparison with each other tube
22. Pressure Relief Devices (PRD)/Auto Reset Relief Vent	-	-	Yes	-	Should be intact, no damages, and healthy micro switch and wiring terminal connections
23. Buchholz Relay	-	-	Yes	-	Should be operative, no damages, arrow mark points toward conservator tank, 0.5º to 1º ascending level towards conservator tank, gas sampling valve operative (in some models a separate device for gas collection is provided near ground level of the transformer tank) , no oil leaks, cover packing healthy, neat & clean, proper glands at wiring cable entrance and moisture proofing, wiring terminals tight, velocity setting (65/100/150 cm per second, factory setting is normally at 100 cm/s), etc.
Control Cubicle					
24. Doors, Door locks, Door packing, Door stops, Light, Cleaning, Ground connections, Proper glands at wiring cable entrance, Wiring cable numbering, Vermin proofing, etc.	Yes	-	-	-	Should be OK and no defect/damage
25. Space heaters & Thermostat setting	-	Yes	-	-	Should be intact and operative
26. Wiring and Terminal Blocks	-	-	Yes	-	Should be tight and secured
27. Control Switches and Accessories	-	Yes	-	-	Should be as per design, healthy and secured
On Load Tap Changers (OLTC)					
28. Motor drive unit cubicle: Doors, Door locks, Door stops, Door packing, Light, Cleaning, Proper glands at wiring cable entrance, Wiring	Yes	-	-	-	Should be OK and no defect/damage

cable numbering, Vermin proofing, Ground connections, etc.					
29. Tap Position Indication (Local/Remote)	Yes	-	-	-	Should be OK and no defect
30. Motor drive unit cubicle: Wiring and Terminal Blocks	-	-	Yes	-	Should be tight and secured
31. Motor drive unit cubicle: Space heaters & Thermostat setting	Yes	-	-	-	Should be intact and operative
32. Motor drive unit cubicle: Controls and Accessories	Yes	-	-	-	Should be OK and no defect/damage
33. Motor drive unit cubicle: Operation Counter Reading	Yes	-	-	-	Should be healthy functioning. Record reading for over hauling reference
34. Motor drive unit cubicle: Step-by-Step Function	-	-	Yes	-	Should be healthy functioning
35. Motor drive unit cubicle: Extreme Electrical Limits Stop Function (on both raise/lower ends)	-	-	Yes	-	Should be healthy functioning
36.Motor drive unit cubicle: Extreme Mechanical Limits Stop Function (on both raise/lower ends)	-	-	Yes	-	Should be healthy functioning
39.Motor drive unit cubicle: Safety Switch Function	-	-	Yes	-	Should be healthy functioning
40. Motor drive unit cubicle: Emergency Stop Function	-	-	Yes	-	Should be healthy functioning
41. Motor drive unit cubicle: Gearbox Lubrication Oil Level and Condition	-	-	Yes	-	Should be OK as per indicator. Replace oil as applicable and with recommended type of oil. The indicator should be kept clean and visible
42. Motor drive unit cubicle: Motor Drive Belt Tension and Condition	-	-	Yes	-	Should be OK as per original design
43. Bevel Gearboxes Greasing	-	-	-	Yes	Apply grease. Ensure for intact water proofing of the box
44. Auto Voltage Regulator (AVR) (if applicable)	-	-	Yes	-	Verify settings
45. Inspection and Overhauling of OILTAP OLTC. Inspection and Overhauling of OLTC Diverter Switches	-	-	-	Yes	As per specifications (overhauling of OLTC is due after 4-5 years or after specified number of operations, whichever comes first).

(cleaning, checking contacts, measurement of transition resistors value, replacements as applicable, etc.)					
46. Simultaneous Operation of Diverter Switches if more than one units are provided	-	-	-	Yes	All the Diverter Switches must operate within half-cycle of hand cranking
47. Rotation Lack Balancing	-	-	-	Yes	Should be equal rotations for Raise and Lower operation after switching action in the diverter switch
48. Diverter Switch Compartment Protective Relay (RS2001 or other models)	-	-	Yes	-	Should be operative, no damages, arrow mark points toward conservator tank, 0.5° to 1° ascending level towards conservator tank, no oil leaks, cover packing healthy, proper glands at wiring cable entrance and moisture proofing, neat & clean, wiring terminals tight, etc.
49. OLTC Test Operations (Raise and Lower)	-	-	Yes	-	Should be OK from Local/Remote and/or Auto
50. Inspection and Overhauling of VACUTAP OLTC. Inspection and Overhauling of OLTC Diverter Switches (cleaning, checking of vacuum interrupters, measurement of transition resistors value, replacements as applicable, etc.)	-	-	-	Yes	VACUTAP OLTC Make: MR and Type; VV has been provided in 132/11kV Power Transformers and type VR in 220/132kV Auto Transformers. Inspection/overhauling has been recommended after 300,000 operation as per technical specifications.
51. Simultaneous Operation of Diverter Switches if more than one units are provided	-	-	-	Yes	All the Diverter Switches must operate within half-cycle of hand cranking
52. Rotation Lack Balancing	-	-	-	Yes	Should be equal rotations for Raise and Lower operation
53. Diverter Switch Compartment Protective Relay (RS2001 or other models)	-	-	Yes	-	Should be operative, no damages, arrow mark points toward conservator tank, 0.5° to 1° ascending level towards conservator tank, no oil leaks, cover packing healthy, proper glands at wiring cable entrance and moisture proofing, neat & clean, wiring terminals tight, etc.
54. OLTC Test Operations	-	-	Yes	-	Should be OK from Local, Remote

(Raise and Lower)					and/or Auto
OFF LOAD TAP CHANGER (if applicable)					
55. Off Load Tap Changer Test Operation	-	-	Yes	-	Should be OK from Local
Tests					
56. DES test of Oil of main tank and OLTC compartments	-	-	Yes	-	DES value should be >30kV, 40kV, 50kV at 2.5 mm gap for 66kV, 132kV, 220kV/ 500kV respectively
57. Chemical Analysis of Oil	-	-	-	Yes	Should be as per test laboratory specifications
58. Tangent Delta (Tan δ) test of Oil	-	-	-	Yes	Should be as per test laboratory specifications
59. Dissolved Gases Analysis (DGA) of oil	-	-	Yes	-	Should be as per test laboratory specifications
60. Insulation Resistance test (Megger test) of Windings	-	-	Yes	-	Should be as per commissioning test results and/or specifications after correction of test results at 20 °C
61. Insulation Resistance test (Megger test) of Core and/or Clamping	-	-	Yes	-	Should be as per commissioning test results and/or specifications after correction of test results at 20 °C
62. Insulation Resistance test of tertiary bus bar of single-phase bank connection transformers	-	-	Yes	-	Should be as per commissioning test results and/or specifications after correction of test results at 20 °C
63. Capacitance and Dissipation Factor test (C&DF test) of windings and bushings	-	-	Yes	-	Should be as per commissioning test results and/or specifications after correction of %DF test results at 20 °C
64. Transformer Turn Ratio test (TTR test)	-	-	Yes	-	Should be as per commissioning test results and/or specification (tolerance: ± 0.5% between calculated and measured values)
65. Short circuit test (special test)	-	-	Yes	-	Should be as per commissioning test results and balanced current values. In the short circuited "Y" winding, check for abnormal current value in neutral lead during OLTC operation which indicates damage to transition resistors of OLTC. The applied 3-phase voltage should also be balanced
66. Open circuit test (special test)	-	-	Yes	-	Should be as per commissioning test results and balanced voltage ratio. This test is also a substitute of TTR test. The applied 3-phase voltage should also be balanced

67. Winding Resistance test	-	-	Yes	-	Should be as per commissioning test results and/or specifications after correction of test results at 75 °C(*)
68. Sweep Frequency Response Analysis (SFRA)	-	-	-	Yes	Should be as per commissioning test results and /or factory test results
69. Buchholz Relay functional tests; Alarm and Trip, Indications and Alarm	-	-	Yes	-	Should be OK and intact
70. OLTC Protective Relay functional tests; Trip and Reset, Indications (local mechanical and remote) and Alarm	-	-	Yes	-	Should be OK and intact
71. Oil temperature; Alarm and Trip test, Indications and Alarm	-	-	Yes	-	Should be OK and intact
72. Winding temperature; Alarm and Trip test, Indications and Alarm	-	-	Yes	-	Should be OK and intact
73. Pressure Relief Device (PRD); Trip test, Indications (local, mechanical and remote) and Alarm	-	-	Yes	-	Should be OK and intact

Note. TERTIARY WINDING (Transformers with more than two windings)
When a power transformer or auto transformer is "Y" connected both on high voltage and low voltage, triple frequency component (3^{rd} harmonic) of the magnetizing current is suppressed and a corresponding voltage is induced in both windings. This voltage is usually negligible in three-phase core-type transformers, but in single-phase units it can be dangerous. To allow triple frequency current to flow and thus eliminate this over-voltage, a third or tertiary winding is usually provided. This winding must be connected in delta, whether or not it is to be used as a source of power.

In the event of failure of one phase of three-phase core-type transformer, it cannot be operated with two phases in open-delta, unless the entire damaged phase is removed from the core, or unless every damaged turn is open-circuited and the series connection between the other coils of the damaged phase broken in three or four places.

Three-phase transformers are usually arranged for simultaneous loading on all three windings. In many transformers, it is permissible to take full-load current from both the secondary and tertiary windings, provided the power-factor between these loads is such that only full-load current is drawn from the primary. There are other cases where the transformer has not been designed to dissipate the losses due to full-load current in all three windings without over-heating. These windings should be loaded in accordance with nameplate specifications.

Protection of floating windings

Windings which are not connected to a transmission system or load may be termed “floating” windings. Under unfavourable conditions, such as lightning, and arcing grounds, these windings may assume abnormally high electrostatic charges. It is desirable to guard against such charges by grounding the neutral if “Y” connected, or one corner of the delta, if delta connected.
If it is not possible to do this, provide suitable lightning arresters, or connect the circuit (or at least one lead) to a load or network having large capacitance to ground.
REFERENCE: Instructional manual of Canadian General Electric (CGE) Guelph, Ontario Canada make 450 MVA (3x150), 500/220/11kV auto transformers, year of manufacturing 1976 at 500 kV G/S Gatti, Faisalabad).

Note. CORRECTION OF INSULATION RESISTANCE TEST RESULTS AT STANDARD TEMP ERATURE 20 °C

Because most of the insulation materials have a negative temperature co-efficient i.e. , the resistance decreases with increase in temperature, so the IR value should be corrected to a standard temperature of 20 °C.

Roughly IR value decreases to ½ of its value for every 10 °C rise in the temperature above 20 °C. So for correction at 20 °C, for every 10 °C rise in the temperature above 20 °C, increase the measured value to 2 times. Formula for accurate temperature correction calculations;

IR 20 = IRt x 2^(t – 20) /10

where IR 20 is the corrected value at 20°C, t is the temperature of insulation mass and IRt is the measured insulation resistance value at temperature t °C.

IR value is usually in mega ohms (M Ω).

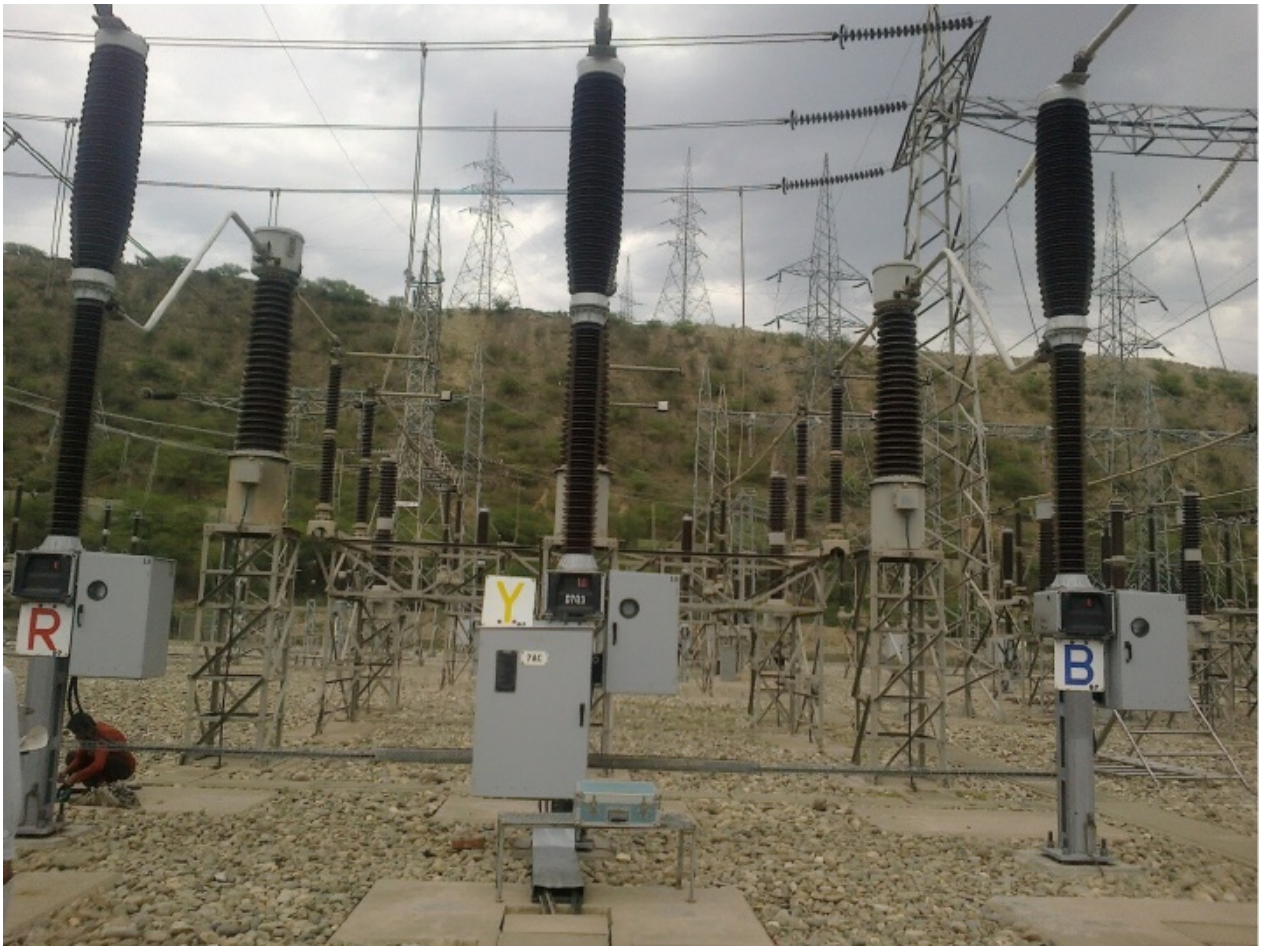
Note. CORRECTION OF WINDING RESISTANCE TEST RESULTS AT STANDARD TEMPERATURE 75 °C

The measured of winding resistance value should be corrected to a standard temperature of 75 °C.

R 75 = Rt (235 + 75) / (235 + t) Ω

where R 75 is the corrected value at 75°C, t is the winding temperature and Rt is the measured winding resistance value at temperature t °C.

2. MAINTENANCE OF CIRCUIT BREAKERS



220kV SF6 Gas Circuit Breaker make; SIEMENS at Mangla Power House

SOP CHECK SHEET: MAINTENANCE SCHEDULE AND CHECKS/TESTS OF HV CIRCUIT BREAKERS					
Description of Inspection and Maintenance Work	**Specified Time Period**				**Remarks/Criteria/Standard / Safety Precautions**
	D/W	**M3-6**	**Y1**	**Y5/10**	
1. Visual inspection (A walk around visual inspection from ground level and keeping in view the safe limits of approach to live and moving parts to check apparent condition, abnormal noise, rust on body of the equipment and component parts, position of opening and closing indicators, etc.)	Yes	-	-	-	Wear PPE and carry basic tools, multi-meter, clip-on-ammeter, etc. Make entries of the observations in check sheets/note book.
2. SF6 Gas Pressure (GCB)	Yes	-	-	-	Should be OK as per rated pressure/indicator and corrected at temperature 20 °C (*). The indicator should be kept clean and visible. Should be no gas leakages *(+0.025 bar for every 1°C)
3. Oil Level (OCB)	Yes	-	-	-	Should be OK as per indicator. The indicator should be kept clean and visible. Should be no oil leakages
4. Air Pressure (ABCB)	Yes				Should be OK as per rated pressure/indicator. The indicator should be kept clean and visible. Should be no oil leakages
5. Steel Structure Ground Connections	Yes	-	-	-	Should be OK as per design
6. HV Terminal Connections	-	-	Yes	-	Dismantle connections, clean

					properly, apply corrosion inhibitor and fix/tight with recommended torque. Should be no hotspot/s (check during night patrolling/thermovision survey)
7. Porcelain Bushing Condition	Yes	-	-	-	Should be clean and no damage
8. Supporting Structure Nut/Bolts/Level	-	Yes	-	-	Should be OK as per design, and tight and secured
Control Cubicle					
9. Cubicle Doors, Door locks, Door packing, Door stops, Light, Cleaning, Proper glands at wiring cable entrance, Wiring cable numbering, Vermin proofing, Ground connections, etc.	Yes	-	-	-	Should be OK and no defect/damage
10. Control switches, Key switches, Indications, Accessories, etc.	Yes	-	-	-	Should be OK and no defect/damage
11. Space heaters & Thermostat setting	Yes	-	-	-	Should be intact and operative
12. Wiring and Terminal Blocks	-	-	Yes	-	Should be tight and secured
13. Operation Counter	Yes	-	-	-	Should be intact and operative
Motor Spring Operating Mechanism					
14. Cubicle Doors, Door locks, Door packing, Door stops, Light, Cleaning, Proper glands at wiring cable entrance, Wiring cable numbering, Vermin proofing, Ground connections, etc.	Yes	-	-	-	Should be OK and no defect/damage
15. Control switches, Key switches, Indications, Accessories, etc.	Yes	-	-	-	Should be OK and no defect/damage
16. Space heaters & Thermostat setting	Yes	-	-	-	Should be intact and operative
17. Wiring and Terminal Blocks	-	-	Yes	-	Should be tight and secured
18. Operation Counter	Yes	-	-	-	Should be intact and operative
19. Cleaning	Yes	-	-	-	Should be OK neat and clean
20. Closing Spring Motor Charging Time	-	-	Yes	-	Should be OK as recommended (usually < 15sec)
21. Lubrication of moving/sliding/rolling parts	-	-	Yes	-	Should be OK as per recommendations

22. Closing Dash Pot Oil Level	-	-	Yes	-	Should be OK as per design
23. Opening Dash Pot Oil Level	-	-	Yes	-	Should be OK as per design
24. Manual Charging of Closing Spring	-	-	Yes	-	Should be OK as per design
25. Supporting Structure Nut/Bolts/Level	-	Yes	-	-	Should be OK as per design, tight and secured
26. CB Close/Open or ON/OFF Indication (electrical/mechanical indicators)					Should be in accordance with the actual position of CB and OK as per design
Hydraulic Oil Pressure Operating Mechanism					
27. Cubicle Doors, Door locks, Door packing, Door stops, Light, Cleaning, proper glands at wiring cable entrance, Wiring cable numbering, Vermin proofing, Ground connections, etc.	Yes	-	-	-	Should be OK and no defect/damage
28. Control switches, Key switches, Indications, Accessories, etc.	Yes	-	-	-	Should be OK and no defect/damage
29. Space heaters & Thermostat setting	Yes	-	-	-	Should be intact and operative
30. Wiring and Terminal Blocks	-	-	Yes	-	Should be tight and secured
31. Operation Counter	Yes	-	-	-	Should be intact and operative
32. Hydraulic Oil Level	Yes	-	-	-	Should be OK as per design
33. Hydraulic Oil Replacement	-	-	-	Yes	Should be replaced as per recommendations
34. Hydraulic Oil Pressure	Yes	-	-	-	Should be OK as per design
35. Hydraulic Oil Leakages	Yes	-	-	-	Should be no leakages
36. N_2 Gas Pressure	-	-	Yes	-	Should be OK as per design
37. Hydraulic Oil: Low Pressure Alarm and Lockout Check	-	-	Yes	-	Should be OK as per design and remote indications
38. Hydraulic Oil Filter Check	-	-	Yes	-	Should be OK as per design, clean or replace the filter as per recommendations
39. Hydraulic Oil Pressure Safety Valve Function Check	-	-	Yes	-	Should be OK as per recommendations
40. Hydraulic Oil Pump: Cut IN/OUT Pressure Value Check	-	-	Yes	-	Should be OK as per recommendations
41. Hydraulic Oil Pump and Accessories Mounting Structure Nut/Bolts/Level	Yes	-	-	-	Should be OK as per design, Tight and secure
Pneumatic Operating Mechanism					
42. Cubicle Doors, Door locks, Door packing, Door stops, Light, Cleaning, proper glands at wiring	Yes	-	-	-	Should be OK and no defect/damage

cable entrance, Wiring cable numbering, Vermin proofing, Ground connection, etc.					
43. Control switches, Key switches, Indications, Accessories, etc.	Yes	-	-	-	Should be OK and no defect/damage
44. Space heaters & Thermostat	Yes	-	-	-	Should be intact and operative
45. Wiring and Terminal Blocks	-	Yes	-	-	Should be tight and secured
46. Operation Counter	Yes	-	-	-	Should be intact and operative
47. Rated Air Pressure	Yes	-	-	-	Should be OK as per design
48. Rated Air Pressure: Low Pressure Alarm and Lockout Check	-	-	Yes	-	Should be OK as per design and remote indications
49. Air Compressor: Air Intake Filter Check	-	Yes	-	-	Should be OK as per design, clean or replace filter as per recommendations
50. Air Compressor: Lubrication Oil Level and Condition Check	-	Yes	-	-	Should be OK as per design, replace oil as recommended
51. Air Compressor: Operation Hours Counter Check	Yes	-	-	-	Should be intact and operative
52. Air Pressure: Safety Valve Function Check	-	-	Yes		Should be OK as per recommendations
53. Air Compressor and Accessories Mounting Structure Nut/Bolts/Level	-	Yes	-	-	Should be OK as per design, and tight and secured
Tests					
54. Test Operation: ON/OFF Local/Remote/Auto	-	-	Yes	-	Should be intact and operative along with remote indications
55. CB Position Mechanical Indication (ON/OFF)	Yes	-	-	-	Should be correct as per actual position
56. Oil DES Test (OCB)	-	-	Yes	-	DES value should be >40 KV at 2.5 mm gap, Replace oil after 10 tripping
57. SF6 Gas Purity Test (GCB)	-	-	Yes	-	Purity should be > 97 %
58. SF6 Dew Point/Moisture Contents Test (GCB)	-	-	Yes	-	Dew point should be >-15°C or Moisture contents should be < 50 PPm
59. Contact Resistance Test	-	-	Yes	-	Should be OK as recommended
60. Close/Open Time Test	-	-	Yes	-	Should be OK as recommended. The permissible differences between timings of 3-poles

					and between timings of breaks within 1-pole are: Closing time: 5ms (1/4 cycle) Opening time: 3.33ms (1/6 cycle) Within breaks of 1-pole: 2.5ms (1/8 cycle)
61. Anti-Pumping Feature Check	-	-	Yes	-	Should be OK and intact
62. Pole Discrepancy Control Feature Check (applicable in single-pole operated CBs)	-	-	Yes	-	Should be OK and intact, remote indication
63. Minimum Voltage Close/Open Test	-	-	Yes	-	The CB should open at 50-75% voltage of rated value and close at 80% voltage of rated value
64. SF6 Gas: Low Pressure Alarm and Lockout Check	-	-	Yes	-	Should be OK as per design and remote indications

3. MAINTENANCE OF ISOLATORS/DISCONNECT SWITCHES

220kV Isolator/Disconnect switch at 500 kV G/S NTDC Sheikhupura

SOP CHECK SHEET: MAINTENANCE SCHEDULE AND CHECKS/TESTS OF ISOLATORS/DISCONNECT SWITCHES (BUS BAR AND LINE)					
Description of Inspection and Maintenance Work	**Specified Time Period**				**Remarks/Criteria/Standard / Safety Precautions**
	D/W	**M3-6**	**Y1**	**Y5/10**	
1. Visual inspection (A walk around visual inspection from ground level and keeping in view the safe limits of approach to live and moving parts to check apparent condition, abnormal noise, rust on body of the equipment and component parts, position of opening and closing indicators, etc.)	Yes	-	-	-	Wear PPE and carry basic tools, multi-meter, clip-on-ammeter, etc. Make entries of the observations in check sheets/note book.
Isolator					
2. Contact Alignment (Close/Open)	Yes	-	-	-	Should be OK either fully Closed or Opened
3. Contact Grip/Pressure (Close Position)	Yes	-	-	-	Should be OK as per contact fingers design
4.Mechanical Stops	Yes	-	-	-	Should be OK as per design
5. Steel Structure Ground Connections	Yes	-	-	-	Should be OK as per design
6. Inter Phases Mechanical Linkages	Yes	-	-	-	Should be intact and no damages
7. HV terminal/connector bearing condition & lubrication	-	-	Yes	-	Should be OK as per design

8. HV Terminal Connections	Yes	-	-	-	Should be OK as per design and no hotspot/s (check during night patrolling / thermovision survey)
9. Porcelain Insulator Condition	Yes	-	-	-	Should be Clean and no damage
10. Porcelain Insulator base bearing condition & lubrication	-	-	Yes	-	Should be OK as per design
10. Supporting Structure Nut/Bolts/Level	Yes	-	-	-	Should be OK as per design and tight and secured
Earth Switch (For Line Isolator)					
11. Earth Blade/Contact Alignment (Close/Open)	Yes	-	-	-	Should be OK either fully Closed or Opened
12. Contact Grip/Pressure (Close Position)	Yes	-	-	-	Should be OK as per contact fingers design
13. Mechanical Stops	Yes	-	-	-	Should be OK as per design
14. Ground Connections	Yes	-	-	-	Should be OK as per design
15. Inter Phases Mechanical Linkages	Yes	-	-	-	Should be intact and no damages
Control Cubicle					
16. Cubicle Doors, Door locks, Door packing, Door stops, Light, Cleaning, proper glands at wiring cable entrance, Wiring cable numbering, Vermin proofing, Ground connections, etc.	Yes	-	-	-	Should be OK and no defect/damage
17. Control switches, Key switches, Indications, Accessories, etc.	Yes	-	-	-	Should be OK and no defect/damage
18. Space heaters & Thermostat setting	Yes	-	-	-	Should be intact and operative
19. Wiring and Terminal Blocks	-	-	Yes	-	Should be tight and secured
20. Operation Counter	Yes	-	-	-	Should be intact and operative
Operating Mechanism of Isolator					
21. Cubicle Doors, Door locks, Door packing, Door stops, Light, Cleaning, proper glands at wiring cable entrance, Wiring cable numbering, Vermin proofing, Ground connections, etc.	Yes	-	-	-	Should be OK and no defect/damage
22. Control switches, Key switches, Indications, Accessories, etc.	Yes	-	-	-	Should be OK and no defect/damage

23. Space heaters & Thermostat setting	Yes	-	-	-	Should be intact and operative
24. Wiring and Terminal Blocks	-	-	Yes	-	Should be tight and secured
25. Operation Counter	Yes	-	-	-	Should be intact and operative
26. Cleaning	Yes	-	-	-	Should be OK neat and clean
27. Lubrication of moving/sliding/rolling parts	-	-	Yes	-	Should be OK as per recommendations
28. Manual Operation: Close/Open	-	-	Yes	-	Should be intact and operative
29. Supporting Structure Nut/Bolts/Level	-	Yes	-	-	Should be OK as per design, tight and secured
30.Ground Potential Gradient Control Mat Condition and Grounding	Yes				Should be OK as per design, tight and secured
Operating Mechanism of Earth Switch					
31. Cubicle Doors, Door locks, Door packing, Door stops, Light, Cleaning, proper glands at wiring cable entrance, Wiring cable numbering, Vermin proofing, Ground connections, etc.	Yes	-	-	-	Should be OK and no defect/damage
32. Control switches, Key switches, Indications, Accessories, etc.	Yes	-	-	-	Should be OK and no defect/damage
33. Space heaters & Thermostat setting	Yes	-	-	-	Should be intact and operative
34. Wiring and Terminal Blocks	-	-	Yes	-	Should be tight and secured
35. Operation Counter	Yes	-	-	-	Should be intact and operative
35. Cleaning	Yes	-	-	-	Should be OK neat and clean
36. Lubrication of moving/sliding/rolling parts	-	-	Yes	-	Should be OK as per recommendations
38. Manual Operation: Close/Open	-	-	Yes	-	Should be intact and operative
39. Supporting Structure Nut/Bolts/Level	-	Yes	-	-	Should be OK as per design, tight and secured
40.Ground Potential Gradient Control Mat Condition and Grounding	Yes				Should be OK as per design, tight and secured
Tests					
41. Test Operation: ON/OFF Local/Remote (Check Scheme for Earth Switch Test Operation)	-	-	Yes	-	Should be intact and operative along with remote semaphore indications

42. Contact Resistance Test	-	-	Yes	-	Should be OK as recommended
43. Mechanical Inter Locking	-	-	Yes	-	Should be OK as per design
44. Electrical Inter Locking With CB	-	-	Yes	-	Should be OK as per scheme
45. Inter Locking Between Isolator and Earth Switch	-	-	Yes	-	Should be OK as per scheme

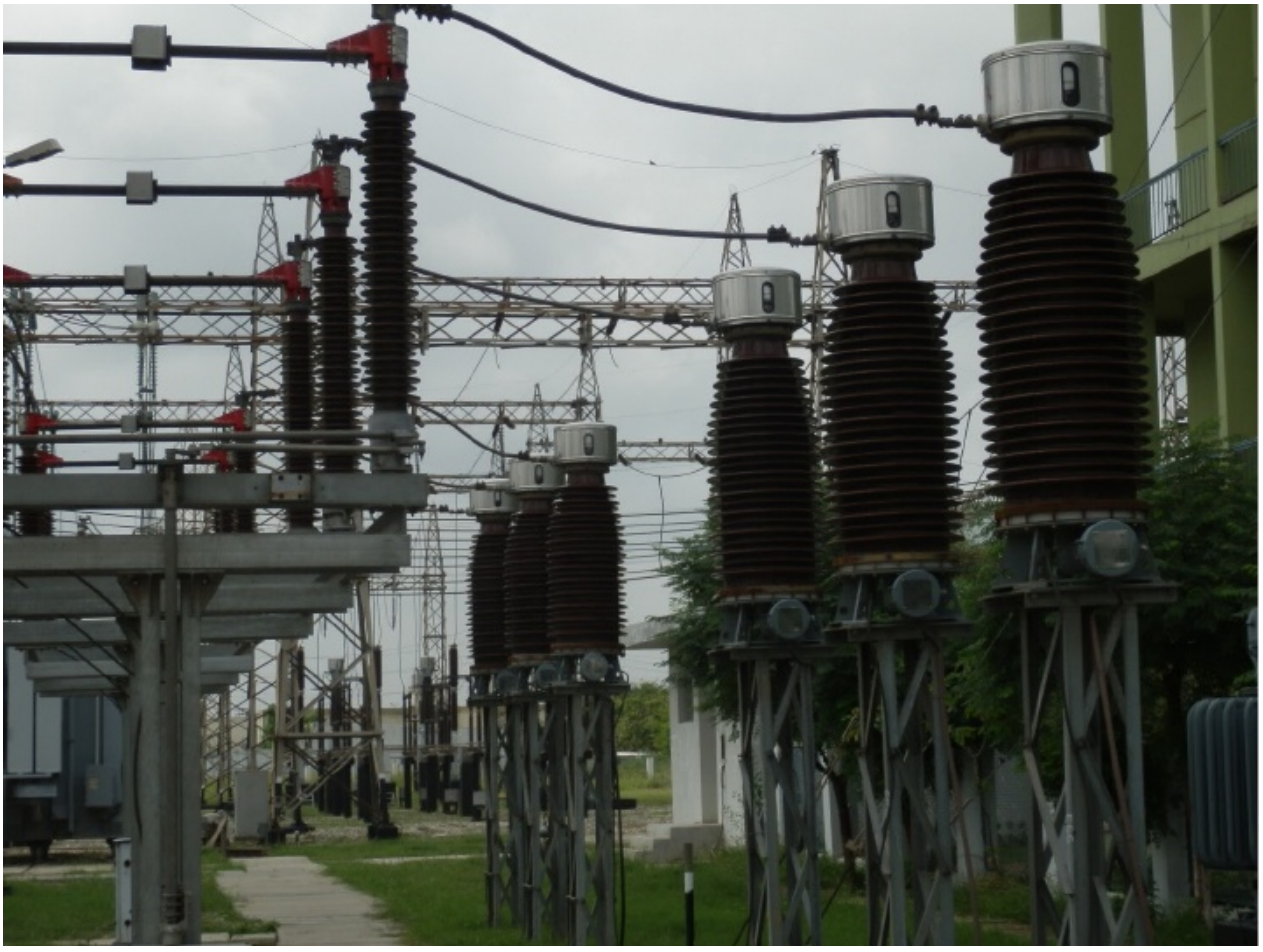
4. MAINTENANE OF CURRENT TRANSFORMERS (CT)

220kV Current Transformer at 550kV G/S NTDC Sheikhupura

SOP CHECK SHEET: MAINTENANCE SCHEDULE AND CHECKS/TESTS OF CURRENT TRANSFORMERS (CT)					
Description of inspection and maintenance work	**Specified Time Period**				**Remarks/Criteria/Standard/Safety Precautions**
	D/W	**M3-6**	**Y1**	**Y5/10**	
1. Visual inspection (A walk around visual inspection from ground level and keeping in view the safe limits of approach to live and moving parts to check apparent condition, abnormal noise, rust on body of the equipment and component parts, etc.)	Yes	-	-	-	Wear PPE and carry basic tools, multi-meter, clip-on-ammeter, etc. Make entries of the observations in check sheets/note book.
2. Oil Level	Yes	-	-	-	Should be OK as per indicator. The indicator should be kept clean and visible. Should be no oil leakages
3. HV Terminal Connections (P1&P2)	Yes	-	-	-	Should be OK as per design and no hotspot/s (check during night patrolling/thermovision survey)
4. Porcelain Bushing Condition	Yes	-	-	-	Should be clean and no damage
5. Supporting Structure Nut/Bolts/Level	-	Yes	-	-	Should be OK as per design, tight and secured
6. Ground Connections	Yes	-	-	-	Should be OK as per design
7.Secondary Terminal Box: Cover, Cover locks, Cover packing, Cleaning, Proper glands at wiring cable entrance, Wiring cable numbering, Vermin proofing, Ground connections, etc.	Yes	-	-	-	Should be OK and no damage/no defect, water proofing & vermin proofing intact
8. Secondary Terminal Connections	-	-	Yes	-	Should be tight and secured
Tests					
9. DES test of Oil (special test)	-	-	-	Yes	DES value should be >30kV, 40kV, 50kV at 2.5 mm gap for 66kV, 132kV, 220kV/ 500kV respectively
10. Chemical Analysis of Oil (special test)	-	-	-	Yes	Should be as per test laboratory specifications
11. Tangent Delta (Tan δ) test of Oil (special test)	-	-	-	Yes	Should be as per test laboratory specifications

12. Dissolved Gases Analysis (DGA) of oil (special test)	-	-	-	Yes	Should be as per test laboratory specification
13. Insulation Resistance test (Megger test) of Windings	-	-	Yes	-	Should be as per commissioning test results and/or specifications after correction of test results at 20 °C
14. Capacitance and Dissipation Factor test (C&DF test) of windings	-	-	Yes	-	Should be as per commissioning test results and/or specifications after correction of %DF results at 20 °C
15. Magnetizing or Exciting Current/Knee-Point Voltage Test (special test)	-	-	-	Yes	Should be as per commissioning test results and /or specification
16. Current Ratio and Accuracy Test (special test)	-	-	-	Yes	As per selected primary/secondary current ratio and /or specifications. Accuracy test results should be in accordance with the relevant Metering/ Protection core specifications.
17. Nitrogen (N2) Gas Pressure Check (if applicable)	-	-	-	Yes	Should be OK as per design
Marshaling Kiosk/Cubicle					
18. Doors, Door locks, Door packing, Door stops, Light, Cleaning, Proper glands at wiring cable entrance, Wiring cable numbering, Vermin proofing, Ground connections, etc.	Yes	-	-	-	Should be OK and no defect/damage
19. Space heaters & Thermostat setting	Yes	-	-	-	Should be intact and operative
20. Wiring and Terminal Blocks	-	-	Yes	-	Should be tight and secured

5. MAINTENANCE OF POTENTIAL TRANSFORMERS (PT)

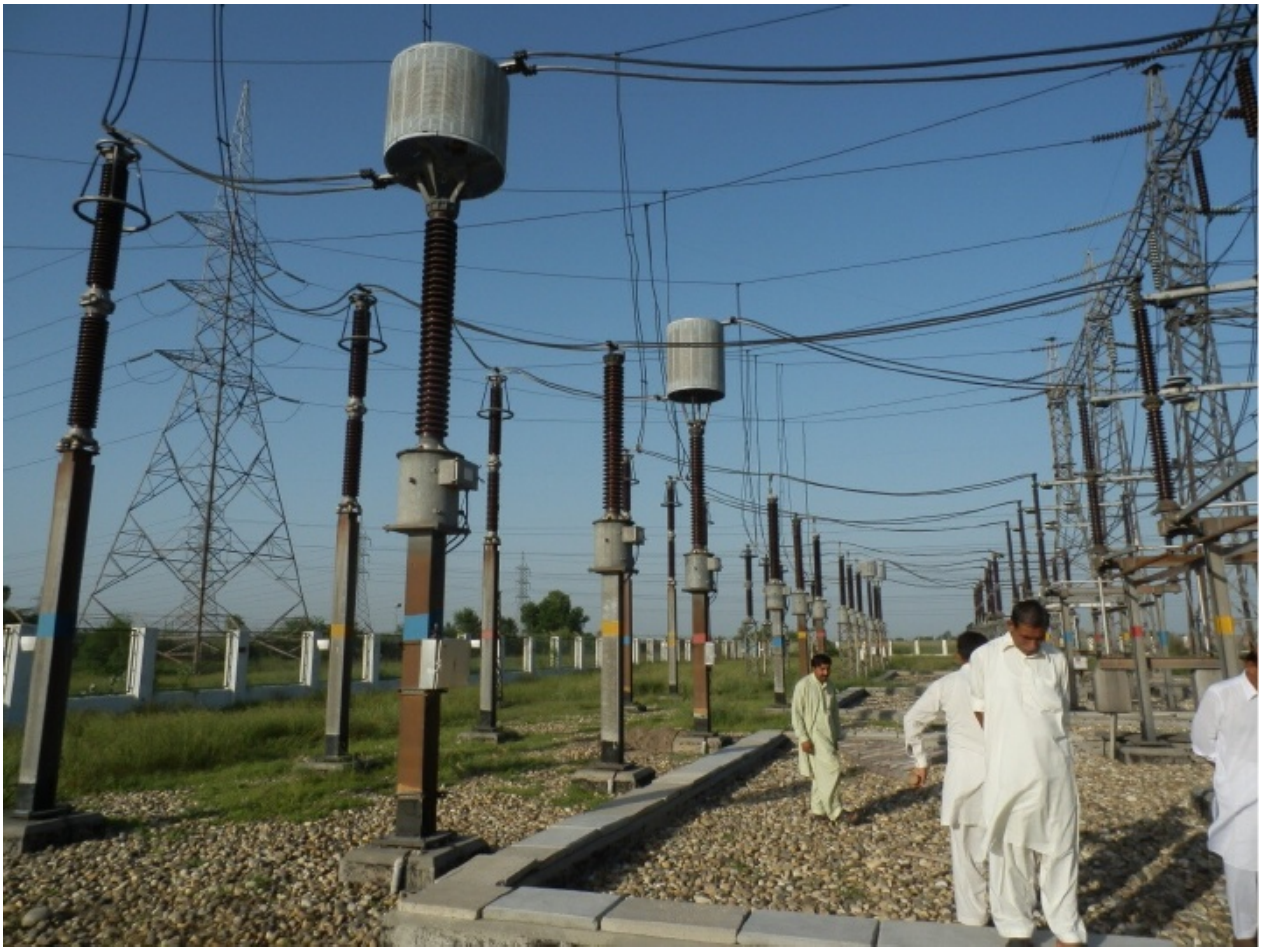


132 kV Potential Transformers (Bus bar PT) at 220kV G/S NTDC NKLP Lahore

SOP CHECK SHEET: MAINTENANCE SCHEDULE AND CHECKS/TESTS OF POTENTIAL TRANSFORMERS (PT)					
Description of Inspection and Maintenance Work	**Specified Time Period**				**Remarks/Criteria/Standard/Safety Precautions**
	D/W	**M3/M6**	**Y1**	**Y5/10**	
1. Visual inspection (A walk around visual inspection from ground level and keeping in view the safe limits of approach to live and moving parts to check apparent condition, abnormal noise, rust on body of the equipment and component parts, etc.)	Yes	-	-	-	Wear PPE and carry basic tools, multi-meter, clip-on-ammeter, etc. Make entries of the observations in check sheets/note book.
2. Oil Level	Yes	-	-	-	Should be OK as per indicator. The indicator should be kept clean and visible. Should be no oil leakages
3. HV Terminal Connections (Line)	Yes	-	-	-	Should be OK as per design and no hotspot/s (check during night patrolling/thermovision survey)
4. Porcelain Bushing Condition	Yes	-	-	-	Should be clean and no damage
5. Supporting Structure Nut/Bolts/Level	-	Yes	-	-	Should be OK as per design, tight and secured
6. Ground Connections	Yes	-	-	-	Should be OK as per design
7. Secondary Terminal Box: Cover, Cover locks, Cover packing, Cleaning, Proper glands at wiring cable entrance, Wiring cable numbering, Vermin proofing, Ground connections, etc.	Yes	-	-	-	Should be OK and no damage no defect, water proofing & vermin proofing intact
8. Secondary Terminal Connections	-	-	Yes	-	Should be tight and secured
Tests					
9. DES test of Oil (special test)	-	-	-	Yes	DES value should be >30kV, 40kV, 50kV at 2.5 mm gap for 66kV, 132kV, 220kV/ 500kV respectively
10. Chemical Analysis of Oil (special test)	-	-	-	Yes	Should be as per test laboratory specifications
11. Tangent Delta (Tan δ) test of Oil (special test)	-	-	-	Yes	Should be as per test laboratory specifications
12. Dissolved Gases Analysis (DGA) of Oil	-	-	-	Yes	Should be as per test laboratory specification

(special test)					
13. Insulation Resistance test (Megger test) of Windings	-	-	Yes	-	As per commissioning test results and/or specifications after correction of test results at 20 °C
14. Voltage Ratio and Accuracy Test (special test)	-	-	-	Yes	Should be as per specifications
Marshaling Kiosk/Cubicle					
15. Doors, Door locks, Door packing, Door stops, Light, Cleaning, Proper glands at wiring cable entrance, Wiring cable numbering, Vermin proofing, Ground connections, etc.	Yes	-	-	-	Should be OK and no defect/damage
16. Space heaters & Thermostat setting	Yes	-	-	-	Should be intact and operative
17. Wiring and Terminal Blocks	-	-	Yes	-	Should be tight and secured

6. MAINTENANCE OF CAPACITOR VOLTAGE TRANDFORMERS (CVT)



220KV Capacitor Voltage Transformer (Make: HAEFELY) at 220kv G/S NTDC Summandri Road Faisalabad

SOP CHECK SHEET: MAINTENANCE SCHEDULE AND CHECKS/TESTS OF CAPACITOR VOLTAGE TRANSFORMERS (CVT)					
Description of Inspection and Maintenance Work	**Specified Time Period**				**Remarks/Criteria/Standard/Safety Precautions**
	D/W	**M3/M6**	**Y1**	**Y5/10**	
1. Visual inspection (A walk around visual inspection from ground level and keeping in view the safe limits of approach to live and moving parts to check apparent condition, abnormal noise, rust on body of the equipment and component parts, etc.)	Yes	-	-	-	Wear PPE and carry basic tools, multi-meter, clip-on-ammeter, etc. Make entries of the observations in check sheets/note book.
2. Oil Level of Capacitors	Yes	-	-	-	Should be OK as per indicator if applicable. The indicator should be kept clean and visible. Should be no oil leakages
3. Oil Level of VT	Yes	-	-	-	Should be OK as per indicator. The indicator should be kept clean and visible. Should be no oil leakages
4. HV Terminal Connections (Line)	Yes	-	-	-	Should be OK as per design and no hotspot/s (check during night patrolling/thermovision survey)
5. Porcelain Bushing Condition	Yes	-	-	-	Should be clean and no damage
6. Supporting Structure Nut/Bolts/Level	-	-	Yes	-	Should be OK as per design, tight and secured
7. Ground Connections	Yes	-	-	-	Should be OK as per design. Take care of PLC connections if applicable
8. Secondary Terminal Box: Cover, Cover locks, Cover packing, Cleaning, Proper glands at wiring cable entrance, Wiring cable numbering, Vermin proofing, Ground connections, etc.	Yes	-	-	-	Should be OK and no damage/no defect, water proofing & vermin proofing intact
9. Secondary Terminal Connections	-	-	Yes	-	Should be tight and secured
Tests					
10. DES test of Oil in VT (special test)	-	-	-	Yes	DES value should be >30kV, 40kV, 50kV at 2.5 mm gap for 66kV, 132kV, 220kV/ 500kV respectively

11. Chemical Analysis of Oil (special test)	-	-	-	Yes	Should be as per laboratory specifications
12. Tangent Delta (Tan δ) test of Oil (special test)	-	-	-	Yes	As per laboratory specifications
13. Dissolved Gases Analysis (DGA) of oil (special test)	-	-	-	Yes	As per laboratory specifications
14. Insulation Resistance test (Megger test) of Windings	-	-	Yes	-	Should be as per commissioning test results and/or specifications after correction of test results at 20 °C
15. Capacitance and Dissipation Factor test (C&DF test)	-	-	Yes	-	As per commissioning test results and/or specifications after correction of %DF results at 20 °C
16. Voltage Ratio and Accuracy Test	-	-	-	Yes	Should be as per specifications
Marshaling Kiosk/Cubicle					
17. Doors, Door locks, Door packing, Door stops, Light, Cleaning, Proper glands at wiring cable entrance, Wiring cable numbering, Vermin proofing, Ground connections, etc.	Yes	-	-	-	Should be OK and no defect/damage
18. Space heaters & Thermostat setting	Yes	-	-	-	Should be intact and operative
19. Wiring and Terminal Blocks	-	-	Yes	-	Should be tight and secured

7. MAINTENANCE OF SURGE ARRESTERS/LIGHTNING ARRESTERS

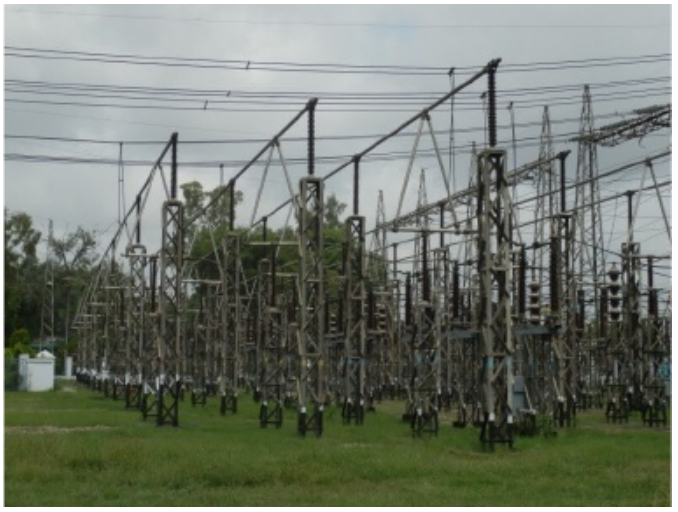
500 KV Surge Arresters at 500 kV G/S NTDC Sheikhupura

SOP CHECK SHEET: MAINTENANCE SCHEDULE AND CHECKS/TESTS OF SURGE ARRESTERS/LIGHTNING ARRESTERS					
Description of Inspection and Maintenance Work	**Specified Time Period**				**Remarks/Criteria/Standard/Safety Precautions**
	D/W	**M3/6**	**Y1**	**Y5-10**	
1. Visual inspection (A walk around visual inspection from ground level and keeping in view the safe limits of approach to live and moving parts to check apparent condition, abnormal noise, rust on body of the equipment and component parts, etc.)	Yes	-	-	-	Wear PPE and carry basic tools, multi-meter, clip-on-ammeter, etc. Make entries of the observations in check sheets/note book.
2. HV Terminal Connections (Line)	Yes	-	-	-	Should be OK as per design and no hotspot/s (check during night patrolling/thermovision survey)
3. Porcelain Bushing Condition	Yes	-	-	-	Should be clean and no damage
4. Corona Ring Condition	Yes	-	-	-	Should be intact and secured
5. Supporting Structure Nut/Bolts/Level	-	Yes	-	-	Should be OK as per design, tight and secured
6. Ground Connections (at L/A Base Plate, Operation Counter and Steel support Structure)	Yes	-	-	-	Should be OK as per design
7. Operation Counter Condition and Reading	Yes	-	-	-	Should be OK as per design and operative
8. Leakage Current Monitor (Optional and built in accessory in the operation counter), Proper glands at wiring cable entrance, Vermin proofing, Ground connections, etc.	Yes	-	-	-	Should be OK as per design and operative along with remote indications
9. Insulators between L/A Base Plate and Steel Support Structure	Yes	-	-	-	Should be intact and secured (an essential requirement for proper functioning of Operation Counter)
10. Insulation of Conductor between L/A Base Plate and Operation Counter	Yes	-	-	-	Should be intact and secure (an essential requirement for proper functioning of Operation Counter)
Tests					
11. Insulation Resistance test (Megger test)	-	-	Yes	-	As per commissioning test results and/or specifications after correction of test results at 20 °C

12. Capacitance and Dissipation Factor test (C&DF test) (special test)	-	-	Yes	-	As per commissioning test results and/or specifications after correction of %DF results at 20 °C
13. Leakage Current Monitoring Test	-	Yes	-	-	Should be as per specifications and /or < 200 µA
14. Operation Counter Function Test	-	-	-	Yes	Should be tested as per procedure in the instruction manual and/or as per conventional test procedure given in the TSG Grid Maintenance Training Book

8. MAINTENANCE OF BUS BARS

132 kV Flexible Conductor Overhead Bus bar at 220kV G/S NTDC Summandri Road Faisalabad



132 kV Tubular Pipe Overhead Bus bar at 220kV G/S NTDC NKLP Lahore

SOP CHECK SHEET: MAINTENANCE SCHEDULE AND CHECKS/TESTS OF HV OUT DOOR BUSBARS					
Description of Inspection and Maintenance Work	**Specified Time Period**				**Remarks/Criteria/Standard/Safety Precautions**
	D/W	**M3/6**	**Y1**	**Y5/10**	
1. Visual inspection (A walk around visual inspection from ground level and keeping in view the safe limits of approach to live and moving parts to check apparent condition, abnormal noise, rust on body of the equipment and component parts, etc.)	Yes	-	-	-	Wear PPE and carry basic tools, multi-meter, clip-on-ammeter, etc. Make entries of the observations in check sheets/note book. Telescope/binocular is also useful for inspection of overhead bus bars.
Flexible Stranded Conductor Bus Bar					
2. Bus Bar Conductor Name / Rating: ---------- / ---------- A					Should be OK as per design and rated capacity of G/S
3. Bus bar Conductor Condition (broken/damaged strands, etc)	Yes	-	-	-	Should be OK and no damage
4. Bus Bar Conductor Sag or abnormal side-tension	Yes	-	-	-	Should be OK and normal
5. Disc Insulators Condition (broken/chipped, etc), Pins, Clamps, Cotter-keys, etc.	Yes	-	-	-	Should be OK, clean and no damage
6. Equipment Connections (Risers & Droppers)	Yes	-	-	-	Should be OK and no damage, OK as design and no hotspot/s (check during night patrolling/thermovision survey)
Tubular Pipe/ Rigged Bus Bar					
7. Bus Bar Pipe Size & Rating ----------A					Should be OK as per design
8. Porcelain Support Insulators (broken/chipped, etc)	Yes	-	-		Should be OK, clean and no damage
9. Supporting Structure Nut/Bolts/Level	Yes	-	-	-	Should be OK as per design, tight and secured
10. Supporting Steel Structure Ground Connections	Yes	-	-	-	Should be OK as per design
11. Flexible Connectors & Slide Fittings	-	-	-	Yes	Should be OK as per design, intact and secured

12. Equipment Connections (Risers & Droppers)	Yes	-	-	-	Should be no damage, OK as per design and no hotspot/s (check during night patrolling/thermovision survey)