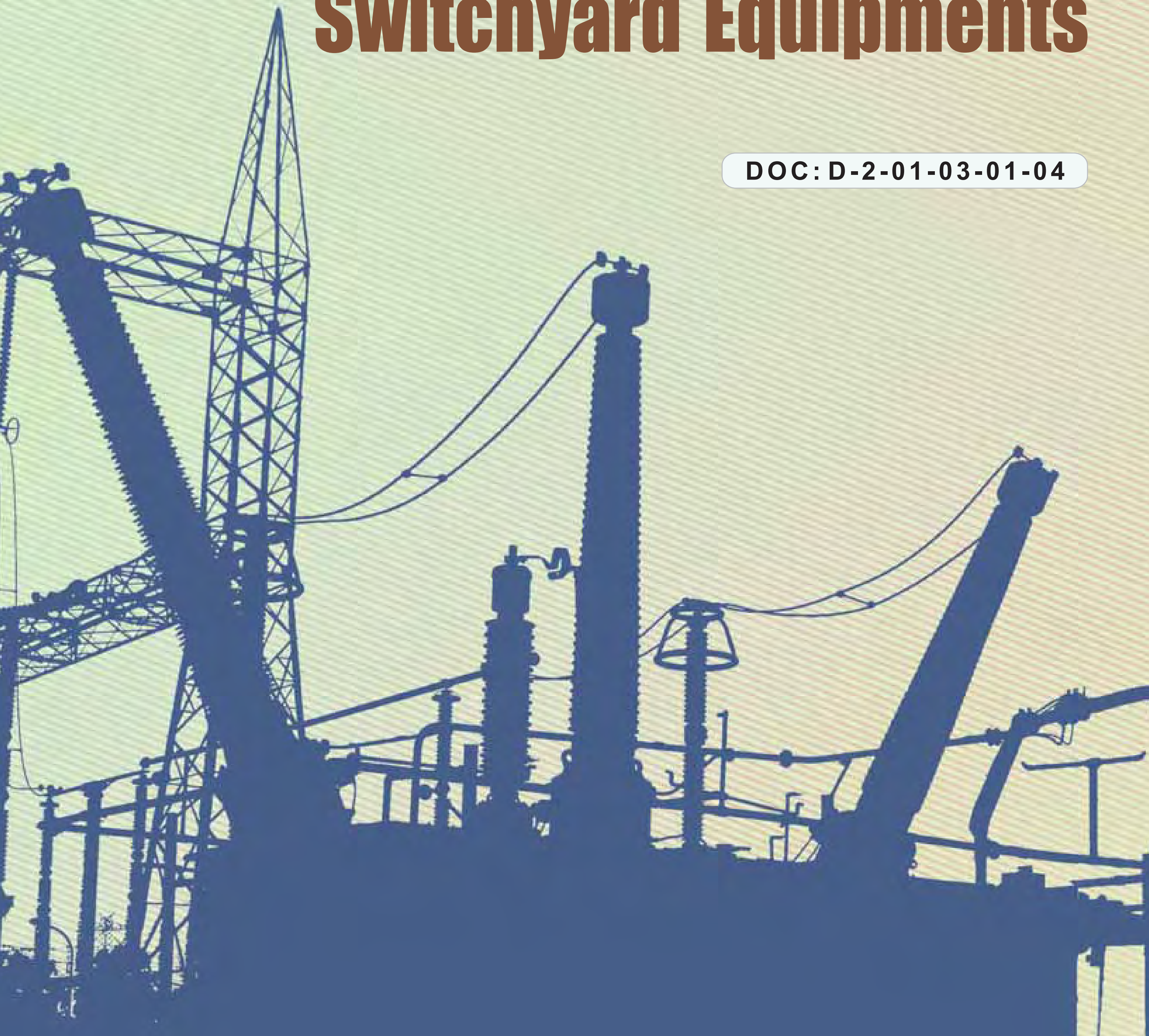
APRIL 2013

पावरग्रिड

Pre-Commissioning Procedures and Formats for Switchyard Equipments

DOC: D-2-01-03-01-04



CONTENTS

PRE-COMMISSIONING PROCEDURES FOR SWITCHYARD EQUIPMENTS

1.1 Purpose

This document is to provide guidance to POWERGRID personnel in carrying out Pre-commissioning checks along with formats for recording the test data and subsequently charging of Substation Bay equipments along with associated auxiliary equipments.

Pre-commissioning checks/ tests are the activities carried out to ascertain the correctness, completeness of installation and healthiness of the equipment before its charging. These checks/ tests are to be carried out by Contractor's representative in the presence of POWERGRID's authorized representative.

1.2 Commissioning Team

1.2.1 **Constitution of Commissioning team:** After completion of erection in all respects, a commissioning team may be constituted (as per procedures laid down in Works & Procurement Policy and Procedures -Clause C2.15.4.6 of WPPP Vol. II), to oversee/ coordinate with erection agency/ manufacturer of the equipment for the pre-commissioning tests and subsequently charging of the equipment. In case of Substation, Commissioning team may consist of following:

(i) I/C of Substation

(ii) O&M executive not below Manager

(iii) T&C executive not below Sr. Engineer

1.2.2 **Role of Commissioning team**: The Commissioning Team shall examine the following statutory and other clearances obtained by Execution Site prior to clearance for test charging of the equipment/transmission line at rated voltage:

Statutory Clearances:

a) Electrical Inspector's Clearance (provisional or final) for charging transmission line/bay equipment as per I.E. rules.

b) P.T.C.C. clearance.

c) Copy of notification informing public/administration regarding charging of the line.

d) Forest Clearance

Other Clearances:

a) Charging instruction from SEF Group of Corporate Engineering.

b) Relay setting details from Corporate Engineering.

(Clause C2.15.4.8 (v) of WPPP Vol-II)

1.2.3 **Responsibilities of Commissioning team** The responsibilities of the commissioning team are to go through statutory clearances and standing instructions before initial charging of new equipment, witness Pre-Commissioning tests after erection of individual equipment as per requirement of guidelines issued by Corporate OS or in line with manufacturer's recommendation and test charging, investigate failure of equipment during test charging, declare commencement of trial operation and evaluate guaranteed test results and recommend acceptance as may be provided in the contract, list out deviations/ exception/ incomplete work, for acceptance/ rejection (Clause C2.15.4.7 of WPPP Vol-II). Proper documentation also to be ensured by the Commissioning team based upon the observations for the above for future reference.

1.2.4 The Team shall also go through the factory test reports. If such tests have been repeated during pre-commissioning, the Team shall list out deviations, if any, in the results of pre-commissioning tests with respect to the factory tests.

(Clause C2.15.4.8 (vii) of WPPP Vol-II)

1.2.5 After all pre-commissioning checks and tests are found to be acceptable taking into account permissible deviation limits, the commissioning team, in consultation with regional O&M, shall give clearance for commissioning/ charging.

Please Note: In case of Transformers & Reactors, commissioning team shall forward the Pre-Commissioning report along with their recommendations to RHQ-OS and CC-OS for charging clearance and CC-OS shall give the final charging clearance after reviewing of the test results. In case of circuit breakers, operation timings and DCRM records to be sent to CC-OS for charging clearance.

1.3 Safety

All measures and precautions should be undertaken to prevent occurrence of unsafe acts. All the personnel involved should be thoroughly apprised about the safe procedures to be adopted while performing various activities including carrying out tests in the switchyard.
Adequate fire-fighting system as per procedures and their healthiness is to be ensured before charging.
Warning signs and Safety barriers should be positioned in conformity to IE rules as amended from time to time.

1.4 General Procedures during Pre-commissioning of Switchyard Equipment

All the equipment after erection/assembly at site, should be tested in order to check that it has not been damaged during transport, erection/assembly to such an extent that its future operation will be at risk. The significance of various tests with brief procedure has been elaborated in the subsequent sections of this document. Regarding the detailed testing methods / procedures for conducting various pre-commissioning tests refer to Doc. No. D-2-03-XX-01-01: Maintenance Procedures for Switchyard Equipments-Part 1: EHV Transformers & Reactors and Doc No. D-2-03-XX-01-01 –Part 2: Other Switchyard Equipments.

1.5 Documentation

The results of the test shall be documented on the test record formats as mentioned below, which are also part of this documentation:

Sl.No.	FORMAT NO.	EQUIPMENT
1.	No. CF/ICT/01/ R-4 DATED 01/04/2013	ICT
2.	No. CF/SR/02/ R-4 DATED 01/04/2013	SHUNT REACTOR
3.	No. CF/CB/03/ R-4 DATED 01/04/2013	CIRCUIT BREAKER
4.	No. CF/CT/04/ R-4 DATED 01/04/2013	CURRENT TRANSFORMER
5.	No. CF/CVT/05/ R-4 DATED 01/04/2013	CVT
6.	No. CF/BAY/06/ R-4 DATED 01/04/2013	BAY/FEEDER
7.	No. CF/ISO/07/ R-4 DATED 01/04/2013	ISOLATOR/GROUND SWITCH
8.	No. CF/SA/08/ R-4 DATED 01/04/2013	SURGE ARRESTOR
9.	No. CF/WT/09/ R-4 DATED 01/04/2013	WAVE TRAP
10.	No. CF/C&P/10/ R-4 DATED 01/04/2013	CONTROL & PROTECTION

These formats have all the tests recordings to be performed at site before energization/ charging. Switching and operational activities will be recorded in regular manner in the operator's log. Copies of this log, notes on special observations from inspections and other measurements will constitute the test records. The test records had to be signed by the responsible personnel from the OEM, the supplier, the erection agency and the POWERGRID representative. The test formats/records are to be distributed to Regional O&M office and Concerned Sub-Station library.

TRANSFORMER AND REACTOR

2.1 Following points to be checked after receipt of Transformer/Reactor at Site

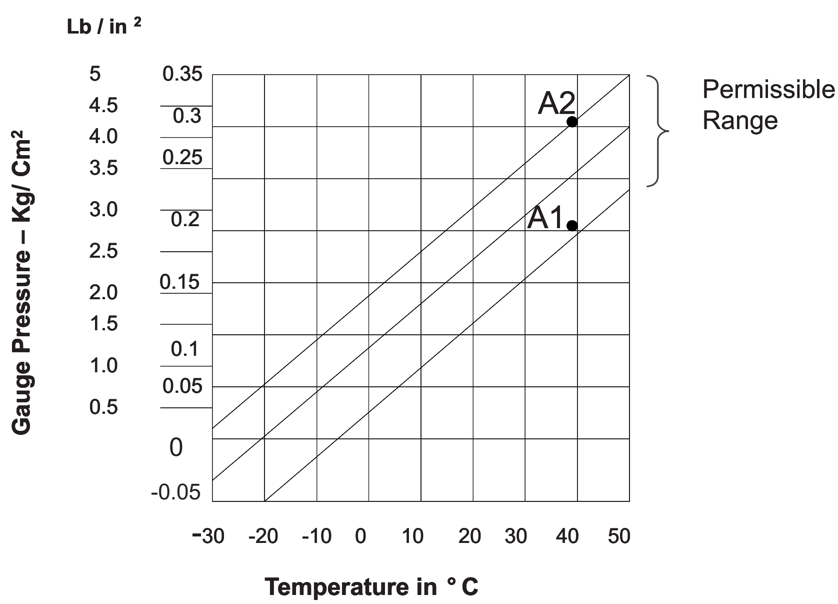
2.1.1 N_2 pressure and Dew point to be checked after receipt of Transformer at Site. It should be within permissible band (as per graph provided by manufacturer & given below in Fig-1)

2.1.2 Core Insulation Test shall be carried out to check insulation between Core (CC&CL) and Ground. (Not applicable for Air Core Reactors)

2.1.3 The data of impact recorder shall be analyzed jointly in association with the manufacturer. In case the impact recorder indicates shocks of $\geq$3g during shipment, further course of action for internal inspection shall be taken jointly with the manufacturer/ supplier. Impact Recorder should be detached from the Transformer/ Reactor preferably when the main unit has been placed on its foundation.

As present day impact recorders are of electronic type, analysis of impact recorder along with dew point and Core insulation tests to be performed on trailer itself. In case, the test results are not meeting permissible limits, same to be informed to OEM, CC-Engg. & CC-OS for further course of action.

Graph showing variation of Pressure v/s Temperature of gas for gas filled unit during Transport or storage



Example: For 40 °C Temperature (Depending upon the pressure of gas at the time of filling),
- minimum pressure of gas can be 0.185 Kg/ Cm^2 at point A1
- maximum pressure of gas can be 0.32 Kg/ Cm^2 at point A2

Fig. 1

2.1.4 Unpacking and inspection of all accessories to be carried out taking all precautions so that the tools used for opening do not cause damage to the contents. Proper storage of all accessories are to be ensured after unpacking. Fragile instruments like oil level gauge, temperature indicators, etc. are to be stored indoor. Any damaged or missing components should be reported to equipment manufacturer and insuring agency so that the same can be investigated or shortage made up as per the terms/ conditions of the contract.

2.1.5 Storage of the main unit and the accessories at site:

- If erection work can not start immediately due to some reasons, then accessories should be repacked into their own crates properly and packing list should be retained.
- All packing cases should be kept above ground by suitable supports so as to allow free air flow underneath. The storage space area should be such that it is accessible for inspection, water does not collect on or around the area and handling/transport would be easy. Proper drainage arrangement in storage areas to be ensured so that in no situation, any component gets submerged in water due to rain, flooding etc.
- It is preferable to store the main unit on its own location/foundation. If the foundation is not likely to be ready for more than three (3) months, then suitable action plan has to be taken from the manufacturer regarding proper storage of the Main Unit.
- If the transformer/ Reactor is to be stored up to three (3) months after arrival at site, it can be stored with N_2 filled condition. N_2 pressure to be monitored on daily basis so that chances of exposure of active part to atmosphere are avoided. In case of drop in N_2 pressure, dew point of N_2 has to be measured to check the dryness of the Transformer/ Reactor. If there is drop in dew point, fresh nitrogen need to be filled. Leaks are to be identified and rectified and Nitrogen to be filled to the required pressure.
- In case the transformer/ reactor is to be stored for more than 3 months, it needs to be stored in oil filled condition. Processed oil to be filled which complies the required specification and ppm $\leq$5ppm and BDV $\geq$70kV. In case of storage of transformer in oil-filled condition, the oil filled in the unit should be tested for BDV and moisture contents once in every three months. The oil sample should be taken from bottom valve. If BDV is less and moisture content is more than as given for service condition then oil should be filtered.

2.2 Insulating Oil

When oil is dispatched to site separately it is usually in sealed steel drums. In some of the cases, oil is supplied in tankers also. The oil to be used to filling and topping up must comply with oil specification given in POWERGRID Technical Specification for acceptance criteria. Oil Samples shall be taken from oil drums/ tanker received at site and sent to our nearest oil Lab for oil parameter testing (BDV > 50 kV, ppm<40, Resistivity > 150 x 10^{12} Ohm-cm & Tan delta < 0.0025 @ 90 °C). The later is important since dirty transportation vessels can significantly contaminate the oil. High dielectric losses cannot be removed by filter treatment, such lots have to be rejected. If the oil is supplied in railroad or trailer tanks, one or two samples are sufficient. If the oil is delivered in 200 litres drums, the following scheme for checking is recommended.

Number of drums delivered	No. of drums to be checked
2 to 5	2
6 to 20	3
21 to 50	4
51 to 10	7
101 to 200	10
201 to 400	15

In case any doubt arises, number of drums to be checked needs to be increased. However, before filling oil, each drum has to be physically checked for free moisture and appearance. A register needs to be maintained indicating the number of drums supplied in each lot as per LOA and number of drums of each lot used in filling a particular Transformer/ Reactor. The oil test results carried out as above should also be recorded.

The copy of test certificate of routine testing at oil refinery should be available at site for comparison of test results.

2.2.1 Samples from Oil Drum

Check the seals on the drums. The drum should first be allowed to stand with bung (lid) vertically upwards for at least 24 hours. The area around the bung should be cleaned & clean glass or brass tube long enough to reach to within 10mm of the lowermost part of the drum should be inserted, keeping the uppermost end of the tube sealed with the thumb while doing so. Remove the Thumb thereby allowing oil to enter the bottom of the tube. Reseal the tube and withdraw an oil sample. **The first two samples should be discarded**. Thereafter, the sample should be released into a suitable receptacle. Samples to be collected preferably in clean glass bottles. The bottles are to be rinsed with the same oil and to be without any air bubble.

2.3 Internal Inspection

Before starting erection, thorough internal inspection of Transformer/ Reactor is to be carried out by POWERGRID engineer along with manufacturer's representative.
Internal inspection should be preferred in dry and sunny weather and should be finished as quickly as possible to avoid ingress of moisture admitting dry air.
Prior to making any entry into the transformer tank, establish a foreign material exclusion programme to avoid the danger of any foreign objects falling into the transformer:

- Loose articles should be removed from the pockets of anyone working on the transformer cover.
- All jewellery, watches, pens, coins and knives should be removed from pockets.
- Protective clothing and clean shoe covers are recommended.
- Tools should be tied with clean cotton tape or cord securely fastened.
- Plated tools or tools with parts that may become detached should be avoided.
- An inventory of all parts taken into transformer should be recorded and checked before closing inspection cover to assure all items were removed.

If any object is dropped into the transformer and cannot be retrieved, the manufacturer should be notified.

The inspection should include:

- Removal of any shipping blocking or temporary support.
- Examination for indication of core shifting.
- Tests for unintentional core or core clamp grounds.
- Visual inspection of windings, leads, and connections including clamping, bracing, blocking, spacer alignment, phase barriers, oil boxes, and coil wraps.
- Inspection of DETC and in-tank LTCs including contact alignment and pressure.
- Inspection of current transformers, including supports and wiring harness.
- Checks for dirt, metal particles, moisture, or other foreign material.

In case of any abnormality noticed during internal inspection, same to be referred to manufacturer, CC-Engg. & CC-OS immediately before starting erection activities.
Detailed photographs of all visible parts/ components as per above are to be taken during internal inspection and to be attached with pre-commissioning report.

2.4 Precautions during erection

During erection, efforts to be made to minimize the exposure of active parts (core and coils) of transformer/ reactor. Moisture may condense on any surface cooler than the surrounding air. Excessive moisture in insulation or dielectric liquid lowers its dielectric strength and may cause a failure of Transformer/ Reactor.

Further, either dry air generator should be running all the time or dry air cylinders may be used to minimize ingress of moisture. The transformer should be sealed off after working hours. **Transformer/ reactor shall never be allowed to be opened without application of dry air.**

Remarks: As N2 is heavier than air, application of Vacuum to be ensured and thereafter dry air to be admitted before entering inside Transformer after shipment in N2 filled condition. Oxygen content should be between 19 % and 25 % prior to any entry. During inspection, dry air to be purged continuously.

It is practical to apply a slight overpressure overnight with dry air or N2 inside – less than 300 mbar (30 kPa or 0.3 atmospheres). Next day the pressure is checked and suspected leaks may be detected with leak detection instruments/ with soap water or with plastic bags tightened around valves (being inflated by leaking air)

For oil filled units whenever oil is drained out below the inspection covers, job will be treated as exposed. Other exposure activities are as below:

1) Bushing erections
2) Jumper connections of Bushings
3) Fixing bushing turrets
4) Core insulation checking (in case the checking point not accessible outside)
5) Buchholz relay pipe work fixing on cover
6) Gas release pipes/equalizer pipe fixing
7) Entering inside the tank for connections/inspection etc

For oil filled units depending upon the level up to which the oil is drained decides the exposure time. All such exposure time should be recorded in a log sheet to decide the oil processing (drying) and oil filling of transformer.

"GET THE TRANSFORMER UNDER OIL AS SOON AS POSSIBLE!" It is good practice to proceed with the erection in such a sequence that all fittings and auxiliaries with oil seals to the tank are assembled first. The oil filling will then be performed as easily as possible. The "active part" inside - core and coils - is then impregnated and protected. It has good time to soak properly, before the unit shall be energized, while remaining fittings are assembled on the unit, and commissioning checks carried out.

For transformers with a gas pressure of 2.5- 3 PSI, the acceptable limits of dew point shall be as under: (Courtesy: BHEL, Bhopal)

Temperature of Insulation in °F	Permissible dew point in °F	Temperature of Insulation in °C	Permissible dew point in °C
0	-78	-17.77	-61.11
5	-74	-15.0	-58.88
10	-70	-12.22	-56.66
15	-66	-9.44	-54.44
20	-62	-6.66	-52.22
25	-58	-3.33	-49.99
30	-53	-1.11	-47.22
35	-48	+1.66	-44.44
40	-44	+4.44	-42.22
45	-40	+7.44	-39.39
50	-35	+9.99	-37.22
55	-31	12.77	-34.99
60	-27	15.55	-32.77
65	-22	18.33	-29.99
70	-18	23.11	-27.77
75	-14	23.88	-25.55
80	-10	26.66	-23.33
85	-6	29.44	-21.11
90	-1	32.22	-18.33
95	+3	34.99	-16.11
100	+7	37.75	-13.88
110	+16	43.33	-8.88
120	+25	48.88	-3.88
130	+33	54.44	+0.55
140	+44	59.99	+5.55

TABLE 1- Variation of Dew Point of N2 Gas Filled in Transformer Tank w.r.t Temperature

2.5 Final tightness test with vacuum (i.e. leakage test or Vacuum Drop Test)

Before oil filling is started, a final check is made for the tightness of the transformer tank by applying vacuum. When vacuum is applied to a transformer without oil, a leakage test must be carried out to ensure that there are no leaks in the tank which would result in wet air being drawn into the transformer. The following procedure is to be adopted:

- Connect the vacuum gauge to a suitable valve of the tank. (Vacuum application and measurement should be performed only on top of the main tank) - A vacuum gauge of Mc Leod type or electronic type, with a reading range covering the interval - 1 kPa (1 - 10 mm mercury) to be used
- Connect the vacuum pump to another opening.
- Evacuate the transformer/ reactor tank until the pressure is below 50 mbar (5 kPa).
- Shut the vacuum valve and stop the pump.
- Wait for an hour and take a first vacuum reading – say P1
- Take a second reading 30 minutes later- say P2
- Note the volume of the tank (quantity of oil required according to the rating plate) and express as volume, V, in m^3
- Take the difference between P2 and P1, and multiply this with the oil quantity V. If the pressures are expressed in kPa, and the oil quantity in m^3, then the product shall be less than 3.6.

  (P2 – P1) x V < 3.6

  The transformer is then considered to be holding sufficient vacuum and is tight. Continue reading (at least 2 to 3) at successive 30 min intervals to confirm the result.
- If the leak test is successful, the pumping will be continued, until the pressure has come down to 0.13 kPa (1 Torr) or less. The vacuum shall then be held for the time given in Table-3 before the oil filling starts.
- If the specified vacuum cannot be reached, or if it does not hold, the leak in the transformer system shall be located and corrected.

In case the transformer is provided with an On Load Tap Changer (OLTC), while evacuating the main transformer tank, the diverter switch compartment may also be evacuated simultaneously so that no undue pressure is allowed on the tap changer chamber. While releasing vacuum, the tap changer chamber vacuum should also be released simultaneously. For this one pressure equalizer pipe should be connected between main tank and tap changer. Manufacturer's instruction manual should be referred to protect the air cell/diaphragm in the conservator during evacuation.

This vacuum must be maintained for the time specified as per the voltage class in Table-3 before and should also be maintained during the subsequent oil filling operations by continuous running of the vacuum pumps.

2.6 Oil Filling

Once the oil is tested from the drums and found meeting the requirements, the oil is transferred to oil storage tank for oil filtration before filling inside the transformer.

The drums or trailer tanks shall not be emptied to the last drop - a sump of an inch or so is left, to avoid possible solid dirt or water in the bottom.

Before being used, the tanks and hoses are visually inspected inside for cleanness. Any liquid residue from earlier use will be carefully removed, and the container flushed with a small quantity of new oil, which is then discarded.

After filtration, oil sample is tested for meeting POWERGRID specification for new oil.

Prior to filling in main tank at site and shall be tested for:

1. Break Down voltage (BDV)	:	70kV (min.)
2. Moisture content	:	5 ppm (max.)
3. Tan-delta at 90 °C	:	Less than 0.01
4. Interfacial tension	:	More than 0.035 N/m

For transformer dispatched with gas (N2) filled from the works, the filling of oil inside the tank is done under vacuum. Transformer of high voltage ratings and their tanks are designed to withstand full vacuum. Manufacturer's instructions should be followed regarding application of full vacuum during filling the oil in the tank.

When filling a transformer with oil it is preferable that the oil be pumped into the bottom of the tank through a filter press or other reliable oil drying and cleaning device should be interposed between the pump and the tank (please refer Fig-2).

The oil flow at the entry valve must be controlled to maintain a positive pressure above atmospheric and to limit the flow rate if necessary to 5000 litres / hour, or a rise in oil level in the tank not exceeding one meter / hour (as measured on the oil level indicator)

Continue oil filling until the level reaches approximately 200 mm above the ambient oil level indicated on the magnetic oil level gauge in the expansion vessel. Then, release the vacuum, with dry air of dew point -40deg C or better.

The diverter tank can now be topped up at atmospheric pressure. Reconnect oil outlet hose to valve on flange on tap changer diverter head. Reinstate breather and very slowly top up the diverter switch such that the correct level is reached in the diverter expansion vessel. In the event the expansion vessel is overfull drain oil from flange into a suitable container until the correct level is reached.

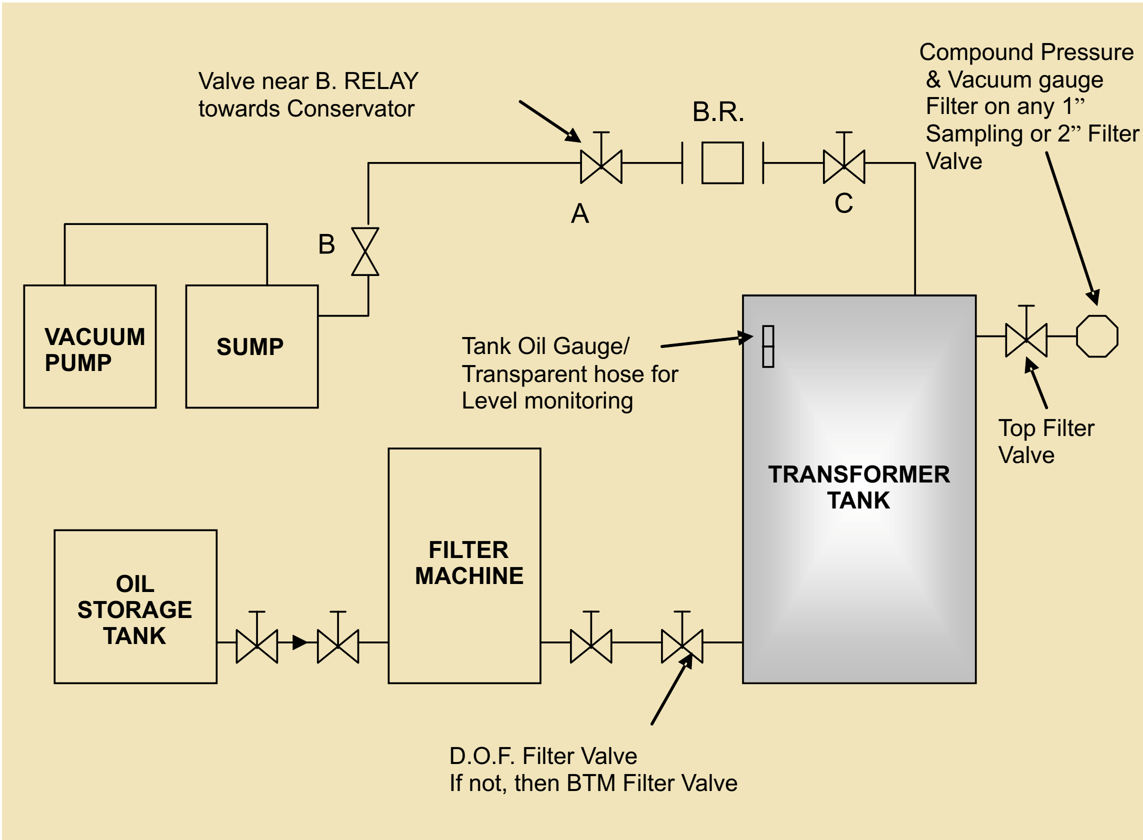


Figure-2 : Arrangement for Evacuation and Oil filling upto tank Oil gauge & Conservator

When the vacuum filling of the transformer and diverter tank is complete, the cooling system/ Radiator bank can be filled (WITHOUT VACUUM) at atmospheric pressure, via an oil processing plant. Oil must be admitted, very slowly, through the bottom cooler filter valve, with the cooler vented at the top and the top cooler filter valve unblanked and open to atmosphere. As the oil level reaches the top vent, then top valve to be closed and the processing plant can be shut down.

Note: Care must be taken not to pressurize the coolers/ radiators.

Upon completion, open the top cooler isolating valve in order to equalize the pressure in the cooler with the transformer tank. This will also allow contraction or expansion of the oil as the ambient temperature changes.

Before filling oil into the conservator, the air cell/ bellow to be inflated to 0.5 PSIG i.e. 0.035kg/cm2 max. by applying pressure (N2/Compressed dry air) so that it can take shape. After releasing pressure, breather pipe is to be fitted however it is recommended not to fit breather in position, instead a wire mesh guard over and flange of the pipe to prevent entry of any insect inside the pipe. This will ensure free air movement from the air cell to the atmosphere.

Use flow meter / indicator on outlet of filter machine and regulate the flow using the valve to limit oil filling rate to 2000 litres per hour (max.) in case filter capacity is more.

Oil to be pushed slowly into conservator through the transformer via valve No. 5 (valve 2,3 & 4 to remain open) till the oil comes out first through valve Nos. 2 & 3 (close these valves) and then through valve No. 4. Allow some oil to come out through valve No.4. Oil should come out freely into the atmosphere. This will ensure that air inside the conservator is expelled out and the space surrounding the air cell is full of oil. (Close valve No. 4). During all these operations valve No.1 shall be in closed position.

Excess oil from the conservator is to be drained by gravity only through valve No. 1 or through drain valve of the transformer via valve No. 5. Do not use filter machine for draining oil from the conservator. Also do not remove buchholz relay and its associated pipe work, fitted between the conservator and the transformer tank while draining oil.

Stop draining oil till indicator of magnetic oil level gauge reaches position-2 on the dial, which is corresponding to 30 °C reading on the oil temperature indicator. Fill the conservator according to the oil temperature and not the atmospheric temperature

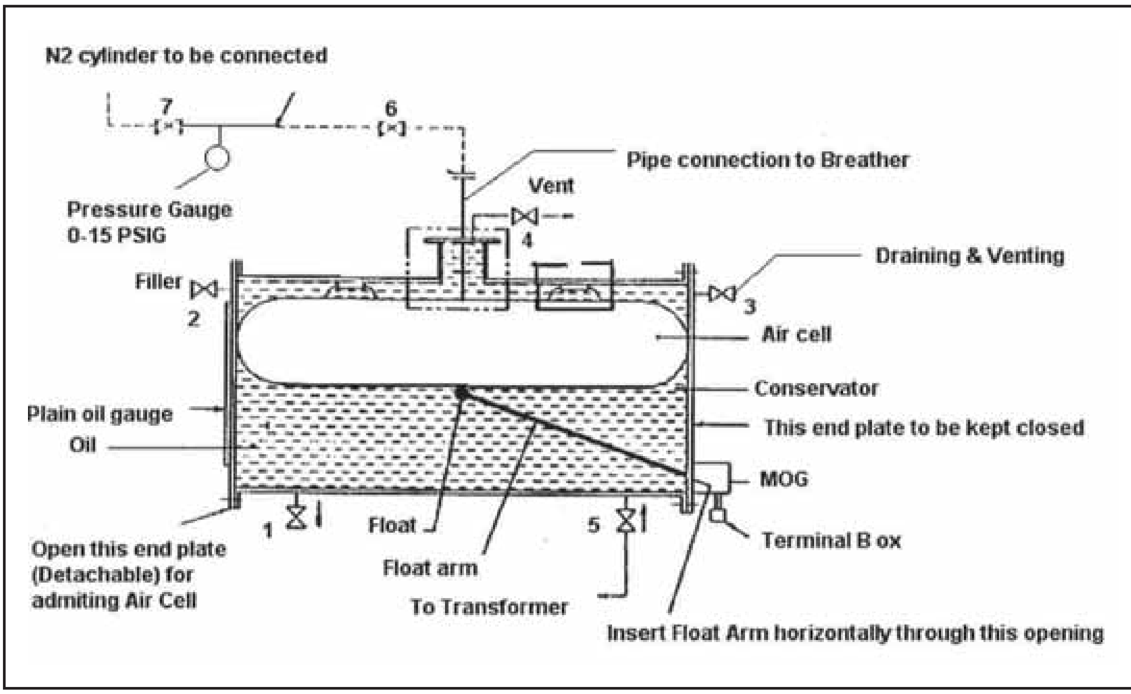


Figure-3 : General Arrangement For Oil Conservator

After Oil filling, Hot Oil Circulation has to be applied to all the Transformers/ Reactors except under the circumstances when active part of Transformer/ Reactor gets wet. Following conditions can be considered to define the Transformer/ Reactor wet:

1. **If Transformer/ Reactor received at site without positive N2 pressure.**
2. **If Dry air not used during exposure while doing erection activities**
3. **Overexposure of active part of Transformer/ Reactor during erection (Overexposure when exposure > 12 Hrs)**

Under above mentioned conditions, Manufacturer shall take necessary action for effective dry out of the Transformer/ Reactor. However general guidelines for dry out in such cases is given in section 2.8

2.7 HOT OIL CIRCULATION USING HIGH VACUUM OIL FILTER MACHINE

To ensure proper dryness and absorption of possible trapped gas bubbles, the oil in the tank is circulated through the vacuum filter and with circulation direction as shown in Fig.-4.

The circulation procedure for the main tank is as follows.

2.7.1 The Transformer/ Reactor is connected to the oil filter machine in a loop through the upper and lower filter valves. The direction of circulation shall be from the filter to the transformer at the top and from the transformer to the filter at the bottom. (Please note that at the initial oil filling time the direction is reverse to avoid air bubble formation).

2.7.2 The temperature of the oil from the filter to the Transformer should be around 60 ° C and in no case it should go beyond 70 ° C otherwise this may cause oxidation of oil.

2.7.3 The circulation shall proceed until a volume of oil has passed through the loop corresponding to 2 times the total oil volume in the tank. (At freezing ambient temperature the circulation time is increased, circulate 3 times the volume at temperature down to minus 20 ° C, increase to 4 times below that temperature).

The oil sample from the transformer tank, after filling in tank before commissioning should meet the following specifications (as per latest POWERGRID Revision) given in table-2 below.

Table-2

1.	Break Down voltage (BDV)	: 70 kV (min.)
2.	Moisture content	: 5 ppm (max.)
3.	Tan-delta at 90 °C	: 0.01 (max.)
4.	Total Gas Content	: < 1%
5.	Resistivity at 90 °C	: 6×10^{12} ohm-cm (min.)
6.	Interfacial tension	: 0.035 N/m (min.)
7.	*Oxidation Stability (Test method as per IEC 61125 method C, Test duration: 500 hour for inhibited oil)	
	a) Acidity	: 0.3 (mg KOH /g) (max.)
	b) Sludge	: 0.05 % (max.)
	c) Tan delta at 90 °C	: 0.05 (max.)

* For Sr. No. 7 separate oil sample shall be taken and test results shall be submitted within 45 days after commissioning for approval of Powergrid.

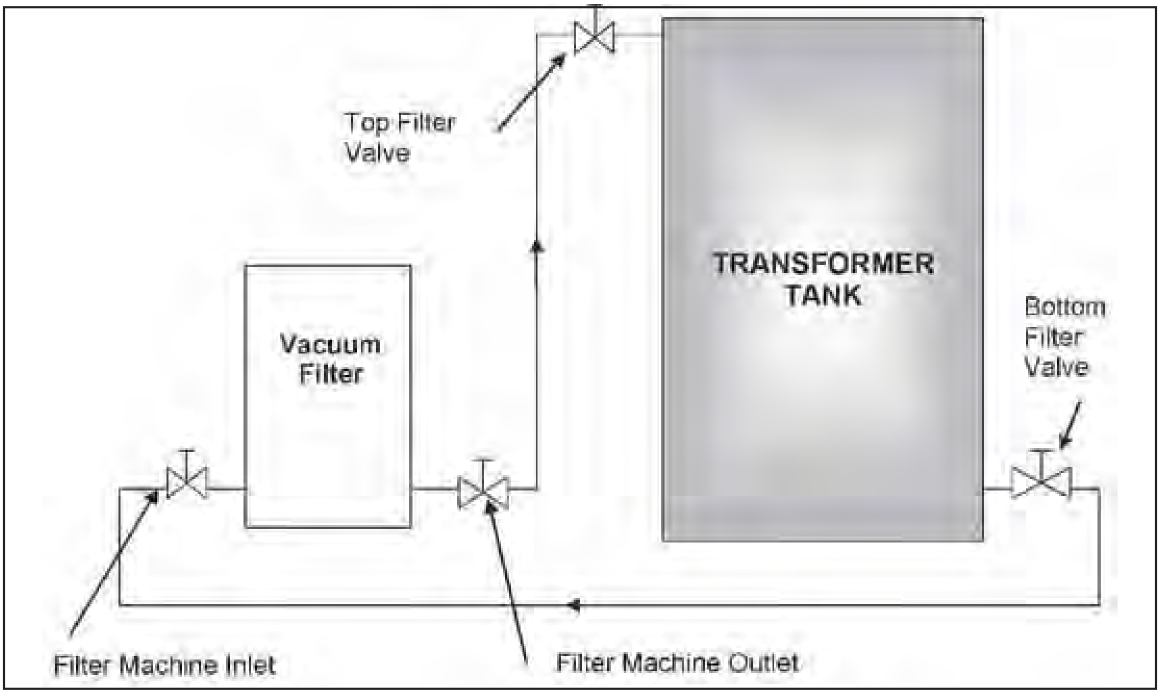


Figure-4: Arrangement for Hot Oil Circulation and Filtration

2.8 PROCEDURE FOR DRY OUT OF WET WINDING OF TRANSFORMER/REACTOR BY APPLICATION OF VACUUM, N2 FILLING AND HEATING

The drying of a new Transformer/ Reactor is required when the moisture gets absorbed by the solid insulation used in Transformers/ Reactors due to various reasons. The process of drying out a transformer requires care and good judgment. If the drying out process is carelessly or improperly performed, a great damage may result to the transformer insulation. In no case shall a transformer be left unattended during any part of the dry out period unless on-line dryout process is adopted which incorporates all necessary safety features. The transformer should be carefully watched throughout the dry-out process and all observations to be carefully recorded.

When the transformer is being dried out, it is necessary to ensure that fire fighting equipment is available near the transformer as a precaution as there are chances of fire as we are dealing with heat and inflammable oil.

2.8.1 Isolation Required

All the openings of transformer main tank like openings for coolers/radiators, conservator, OLTC etc. is to be properly isolated and totally blanked.

2.8.2 Procedure

a. Fill the main transformer/ reactor tank with Nitrogen (Use only Dry N2 gas as per IS: 1747 with less than 50 ppm moisture and 1% oxygen by volume) until it comes to a positive pressure of 0.15 $Kg/cm^{2.}$ It is kept for about 48 hrs. At the end of 48 hrs, dew point of N_2 at outlet is measured. If the dew point is not within acceptable limits as per Table-I, dry out method should be continued.

b. While N2 circulation is in progress, the heaters are to be installed around the transformer tank. The heaters are to be kept ON until we achieve a temperature of about 75–80 °C of the core & winding of transformer as measured by top oil temperature in the transformer.

c. After ascertaining that there is no leakage, pull out vacuum and keep the transformer/reactor under near absolute vacuum (1-5 torr) and keep under vacuum for about 96 hours running the vacuum pump continuously. The duration of vacuum can vary between 48 to 96 hrs depending upon the dew point being achieved. Keep vacuum machine ON and collect condensate for measurement. Observe the rate of condensate collection on hourly basis. Depending on the value of rate of condensate (less than 40 ml/hr for 24 hrs), continuation of further vacuum shall be decided.

d. Then the vacuum is broken with dry nitrogen. The dew point of nitrogen at the inlet is to be measured and should be of the order of - 50 °C or better. When the nitrogen comes to the positive pressure of 0.15 kg/cm^2, it is stopped and kept for 24 hours. Heating from outside is to be continued while N2 circulation is in progress. Then the nitrogen pressure is released and the outlet nitrogen dew point is measured. If the dew point is within acceptable limits as per Table-I then the dryness of transformer is achieved. If not again the transformer is taken for vacuum treatment and then nitrogen is admitted as mentioned above and tested. The cycle is to be continued till desired dew point as per Table-1 is achieved.

e. Periodicity of vacuum cycle may vary between 48-96 hrs. Initially two N2 cycles may be kept for 24 hrs. After that it may be kept for 48 hrs depending upon dew point being achieved.

After completion of drying process, oil filling and hot oil circulation is to be carried out before commissioning. Please ensure standing time as per table-3 given below before charging.

Note: If already known that the transformer is wet based on the tests or exposure time, then (a) above can be skipped to save time.

Transformer HV Rated Voltage (in kV)	**Application of Vacuum & holding for (before oil filling)*** (in Hours)	**STANDING TIME After Oil circulation and before energising** (in Hours)
Up to 145kV	12 HRS	12 HRS
145 kV and up to 420kV	24 HRS	48 HRS
Above 420 kV	48 HRS	120 HRS

*Without running the vacuum pump and leakage rate to be ≤40mbar-lit/sec

Table-3

After the expiry of this time, air release operation is to be carried out in Buchholz relays, turrets and other release points given by the manufacturers before charging.

For subsequent activities, proceed to format no. CF/ICT/01/ R-4 Dated 01/04/2013 for ICT & format No. CF/SR/02/ R-4 Dated 01/04/2013 for Reactor. Refer pre-commissioning test procedures given in next section for all required tests to be performed.

2.9 RELATION BETWEEN DIFFERENT UNITS (CONVERSION OF UNITS)

Pressure

1 bar = 10^5 Pa = 750 Torr = 14.5 psi = 1.02kg/cm^2

1 Torr = 1.33 mbar = 0.133 kPa

1 kPa(kilo-Pascal) = 10^3 Pa = 10 mbar = 7.501 Torr(mm of mercury)

1 MPa = 10^6 Pa

1 atmosphere=0.1 MPa=1.02kg/cm^2= 14.5 psi

Force

1 kp = 9.807 N

Weight

1 ton=1000 kg=2200 lbs

Temperature

$$°C = \frac{5}{9} * (°F - 32)$$

$$°F = \frac{9}{5} * (°C) + 32$$

Volume

1m^3= 1000 litres=260 US gallons=220 Imp gallons

1 litre =0.26 US Gallons

1 US Gallons = 3.78 litres

1 litre =0.22 Imp Gallons

Benchmarks

1-mm mercury (Torr) is about 1 millibar or 0.1 kPa

1 m^3 of oil weights 0.9 tons –say 1 ton

1000 US gallons of oil weights 3.5 tons

PRE- COMMISSIONING CHECKS/TESTS FOR TRANSFORMERS AND REACTORS

Once oil filling is completed, various pre-commissioning checks/ tests are performed to ensure the healthiness of the Transformer/ Reactor prior to its energization. Various electrical tests are to be performed and their significance is given below

Sr. No.	Name of Test/ Check point	Purpose of test/ check
3.1	Core insulation tests	Allows for investigating accidental grounds which results in circulating currents if there is more than one connection between the core and ground.
3.2	Earth pit resistance measurement	To check the resistance of earth pit provided for Transformer. In case, the resistance is more, proper treatment is to be given.
3.3	Insulation Resistance (IR) measurement	Test reveals the condition of insulation (i.e. degree of dryness of paper insulation), presence of any foreign contaminants in oil and also any gross defect inside the transformer (e.g. Failure to remove the temporary transportation bracket on the live portion of tap-changer part)
3.4	Capacitance and Tanδ measurement of bushings	Measurement of C1 & C2 Capacitance and Tanδ in UST mode. Changes in the normal capacitance of an insulator indicate abnormal conditions such as the presence of moisture layer, short -circuits or open circuits in the capacitance network.
3.5	Capacitance and Tan δ measurement of windings	Dissipation factor/Loss factor and capacitance measurement of winding is carried out to ascertain the general condition of the ground and inter-winding insulation
3.6	Turns ratio (Voltage ratio) measurement	To determine the turns ratio of transformers to identify any abnormality in tap changers/ shorted or open turns etc
3.7	Vector Group & Polarity	To determine the phase relationship and polarity of transformers
3.8	Magnetic Balance test	This test is conducted only in three phase transformers to check the imbalance in the magnetic circuit
3.9	Floating Neutral point measurement	This test is conducted to ascertain possibility of short circuit in a winding.
3.10	Measurement of Short Circuit Impedance	This test is used to detect winding movement that usually occurs due to heavy fault current or mechanical damage during transportation or installation since dispatch from the factory.

Sr. No.	Name of Test/ Check point	Purpose of test/ check
3.11	Exciting/Magnetising current measurement	To locate defect in magnetic core structure, shifting of windings, failures in turn to turn insulation or problems in tap changers. These conditions change the effective reluctance of the magnetic circuit thus affecting the current required to establish flux in the core
3.12	Operational checks on OLTCs	To ensure smooth & trouble free operation of OLTC during operation.
3.13	Tests/ Checks on Bushing Current Transformers (BCTs)	To ascertain the healthiness of bushing current transformer at the time of erection
3.14	Operational Checks on protection System	Operational checks on cooler bank (pumps & Fans), Breathers (Silicagel or Drycol), MOG, temperature gauges (WTI/OTI), gas actuated relays (Buchholz, PRD, SPR etc.) and simulation test of protection system
3.15	Stability of Differential, REF of Transformer/ Reactor	This test is performed to check the proper operation of Differential & REF protection of Transformer & Reactor by simulating actual conditions. Any problem in CT connection, wrong cabling, relay setting can be detected by this test.
3.16	Frequency Response Analysis (FRA) measurement	To assess the mechanical integrity of the transformer. Transformers while experiencing severity of short circuit current looses its mechanical property by way of deformation of the winding or core. During pre-commissioning this test is required to ascertain that Transformer active part has not suffered any severe impact/ jerk during transportation.
3.17	Winding resistance measurement	To check for any abnormalities due to loose connections, broken strands and high contact resistance in tap changers
3.18	Dissolved Gas Analysis (DGA) of oil sample	Oil sample for DGA to be drawn from transformer main tank before commissioning for having a base data and after 24 hrs. of charging subsequently to ensure no fault gas developed after first charging. DGA analysis helps the user to identify the reason for gas formation & materials involved and indicate urgency of corrective action to be taken

3.1 CORE INSULATION TEST

This test is recommended first after receiving the equipment at site and to be performed on trailer itself. Thereafter, before the unit is placed in service or following modifications to the transformer that could affect the integrity of its core insulation and at other times, when indicated by DGA (key gases being ethane and/or ethylene and possibly methane) or usually during a major inspection.

For core-insulation to ground test, remove the cover of the terminal block, Disconnect the closing link that connects the two terminals CL-G. Apply 1.0 kV direct voltage between CL and CC + G (core grounding strap). The tank shall be grounded during the test.

Acceptable Limit: The insulation value after 1min. should be minimum 10 M for new transformer at the time of commissioning. Core insulation resistance is generally more than 100 M for new assembled transformer when tested at factory.

3.2 Earth pit resistance measurement

Earth tester is used for measurement of Earth resistance. If earth resistance is more, proper treatment is to be given. For measurement of earth pit resistance, pit earthing connection should be disconnected from main grid. Thereafter, measurement is to be carried out by three point method.

Working of Earth Tester: - There is hand operated D.C.generator. While feeding current to spike, D.C. current is converted into A.C. current by the converter and A.C. current received from spike is again converted in D.C. current by the help of rectifier, while going to generator. A.C. current is fed to the spike driven in earth because there should not be electrolytic effect.

Measurement of Earth Resistance (Three point method):-

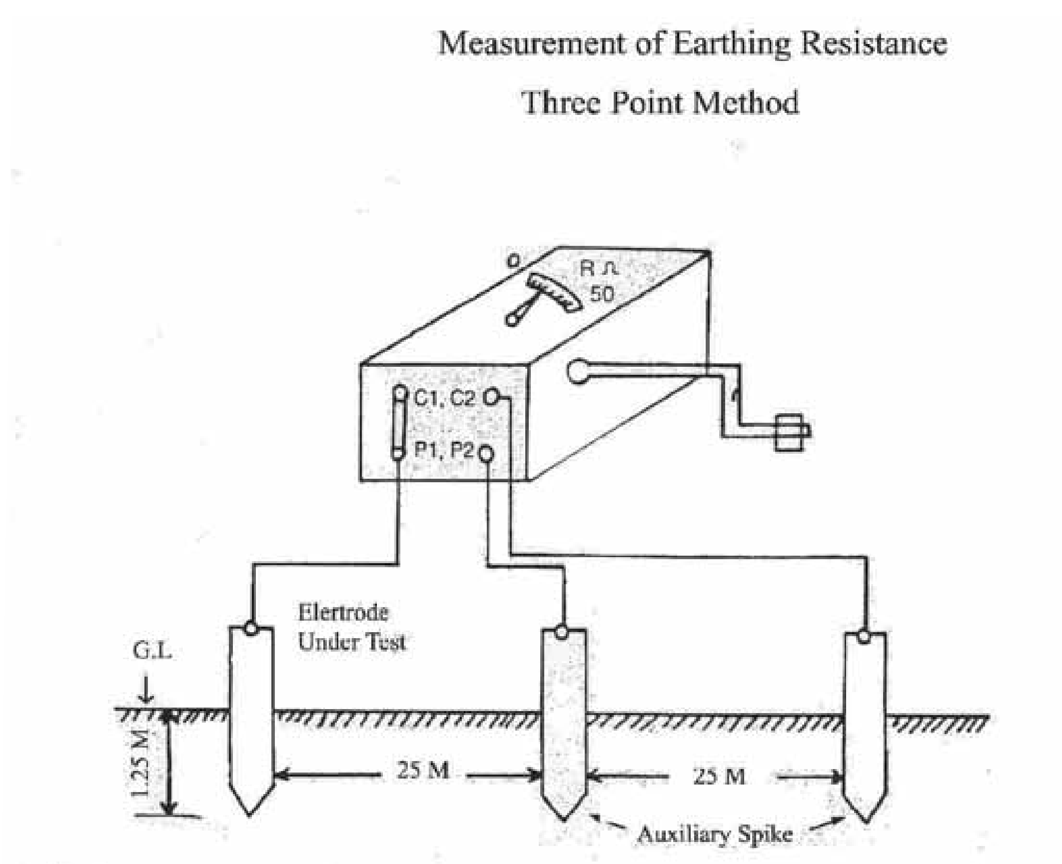


Figure-5

In this method, earth tester terminals C1 & P1 are shorted to each other and connected to the earth electrode (pipe) under test. Terminals P2 & C2 are connected to the two separate spikes driven in earth. These two spikes are kept in same line at the distance of 25 meters and 50 meters due to which there will not be mutual interference in the field of individual spikes. If we rotate generator handle with specific speed we get directly earth resistance on scale.

Acceptable Limit: Value of earth pit resistance should be less than or equal to 1Ω.

3.3 INSULATION RESISTANCE (IR) MEASUREMENT

IR measurements shall be taken between the windings collectively (i.e. with all the windings being connected together) and the earthed tank (earth) and between each winding and the tank, the rest of the windings being earthed. Before taking measurements the neutral should be disconnected from earth. Following table gives combinations of IR measurements for auto-transformer, three -winding transformer & Shunt Reactor

For Auto-transformer	For 3 winding transformer	For Shunt Reactor
HV + IV to LV	HV + IV to LV	HV to E
HV + IV to E	HV + LV to IV	
LV to E	HV + IV +LV to E	

Where HV-High voltage, IV-Intermediate voltage, LV-Low voltage/Tertiary voltage windings, E- Earth

Acceptable Limits: Unless otherwise recommended by the manufacturer, the following IR values as a thumb rule may be considered as the minimum satisfactory values at 30°C (one minute measurements) at the time of commissioning.

Rated Voltage class of winding	Minimum desired IR value at 1 minute (Meg ohm)
11kV	300 MΩ
33kV	400 MΩ
66kV & above	500 MΩ

Insulation resistance varies inversely with temperature and is generally corrected to a standard temperature (usually 20°C) using table (Source: BHEL instruction Manual) as given below:

Difference in temperatures (°C)	Correction Factor (k)
10	1.65
20	2.6
30	4.2
40	6.6
50	10.5

(The measured value to be multiplied by the factor k i.e $T_{20} = k*T_{measured}$)

The ratio of 60 second insulation resistance to 15 second insulation resistance value is called **dielectric absorption coefficient or Index (DAI).** For oil filled transformers with class A insulation, in reasonably dried condition the absorption coefficient at 30°C will be more than **1.3.**

The polarization index test is performed generally by taking mega ohm readings at 1min and 10min insulation resistance value. The **polarization index** is the ratio of the 10 min to the 1 min mega ohm readings.

PI= R_{10}/ R_1 (dimensionless), Where PI is Polarization Index and R is resistance

The following are guidelines for evaluating transformer insulation using polarization index values

Polarization Index	Insulation Condition
Less than 1	Dangerous
1.0-1.1	Poor
1.1-1.25	Questionable
1.25-2.0	Fair
2.0 – 4.0	Good
Above 4.0	Excellent

A PI of more than 1.25 and DAI of more than 1.3 are generally considered satisfactory for a transformer when the results of other low voltage tests are found in order. PI less than 1 calls for immediate corrective action. For bushings, an IR value of above 10,000 MΩ is considered satisfactory.

3.4 Capacitance and Tan δ measurement of Bushings

Dissipation Factor

Dissipation factor/loss factor (Tan delta) is defined as the ratio of resistive component (I_r) of current to that of capacitive current (I_c) flowing in an insulating material.

Power Factor

Power factor is the ratio of resistive current to that of total current. For very low value of resistive currents, values of dissipation factor and power factor are same (up to 2%).

UST

Test set connected for Ungrounded Specimen Test mode. This is used when specimen is isolated from earth e.g. Transformer bushing, CTs with test tap, CVTs and CB voltage grading capacitors. The test mode is often used to reduce the effect of stray capacitance losses to ground, and to reduce the effect of interference pickup from energized apparatus.

GST

Test set connected for grounded specimen test mode. This is used when specimen do not have two specific points (isolated from ground) for Tan delta measurement e.g. Transformer/ Reactor winding, CTs without test tap etc.

GSTg

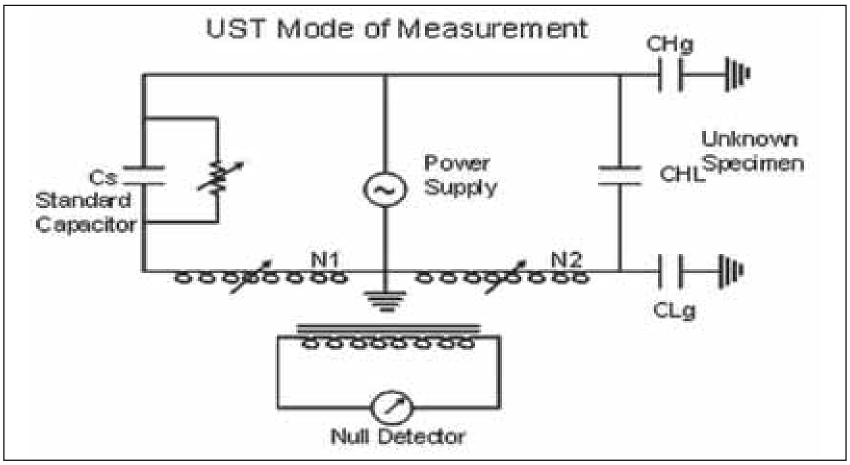
This test is used to separate the total values of a GST test into separate parts for better analysis. Often this test is used with GST test to confirm the test readings made using the UST mode

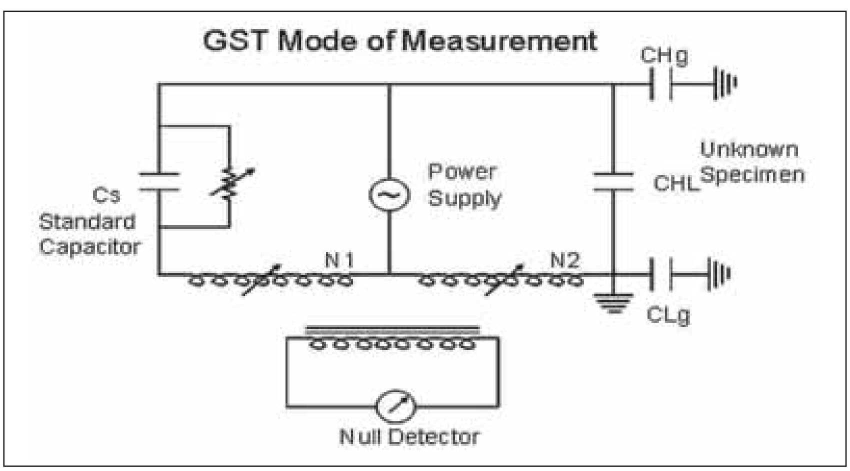
TEST EQUIPMENT
10 KV or 12 KV fully automatic Capacitance and Tan delta test kit to be used for accurate measurement and repeatability of test results.

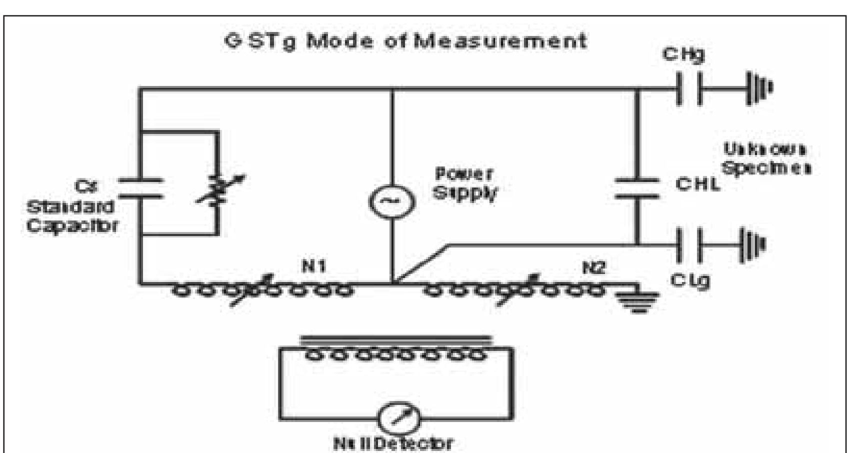
TESTING PROCEDURE

Typical arrangement for Tan δ measurement is given below:

Figure-6







PRECAUTIONS

a) There should be no joints in testing cables.

b) HV lead should be screened with double shield and shields should not have internal shorting otherwise tests in GST/GSTg modes, shall not be possible. Check the same by Insulation Tester(100V)

c) Test leads should not touch any live part.

d) Never connect the test set to energized equipment

e) The ground cable must be connected first and removed at last

f) High voltage plugs should be free from moisture during installation and operation.

g) Testing must be carried out by **experienced/ certified** personnel only.

h) After testing with high voltage (10 kV), test terminals must be grounded before being touched by any personnel.

➢ For 3-Ph auto-transformer, short together all 400kV, 220kV and Neutral (isolated from earth) Bushings. Also short all 33kV Bushings and earth the same.

Measurement of C1 Capacitance and Tanδ: Connect the crocodile clip of the HV cable to the top terminal of the shorted HV/IV bushings. Unscrew the test tap cover, Insert a pin in the hole of the central test tap stud by pressing the surrounding contact plug in case of 245 kV OIP Bushing and remove the earthing strip from the flange by unscrewing the screw (holding earth strip to the flange body) in case of 420 kV OIP Bushing. Connect the LV cable to the test tap (strip/central stud) of the bushing under test to the **C & TANδ KIT** through a screened cable and earth the flange body. Repeat the test for all Bushings by changing only LV lead connection of the kit to test tap of the Bushing which is to be tested

Measurement of C2 Capacitance and Tanδ : HV lead to be connected to the test tap of the bushing under test (if required additional crocodile type clip may be used) and LV of the kit to be connected to the ground. HV of the bushing is to be connected to the Guard terminal of the test kit. Test to be carried out in GSTg mode at 1.0kV.

➢ For measurement of 33kV Bushing Tan Delta, earth HV/IV Bushings (already shorted). Apply HV lead of the Test kit to shorted 33kV Bushings and connect LV lead of the test kit to Test tap of the Bushing under test.

➢ Measurements shall be made at similar conditions as that of a previous measurement. The oil-paper insulation combination of bushings exhibit fairly constant tan delta over a wide range of operating temperature. Hence, effort is to be made for testing at temperature near to previous test and correction factor need not be applied.

➢ Do not test a bushing (new or spare) while it is in its wood shipping crate, or while it is lying on wood. Wood is not as good an insulator as porcelain and will cause the readings to be inaccurate. Keep the test results as a baseline record to compare with future tests.

➢ It is to be ensured that C& Tan δ measurement of bushings and testing of turrets carried out before installation. This will prevent installation of bushings having C& Tan δ values beyond permissible limits.

- It is to be ensured that Test Tap points are earthed immediately after carrying out the measurements for that particular Bushing and earthing of test tap to be ensured by carrying out continuity test.

  Acceptable Limits: Bushing Tan δ should be less than 0.5% for all type of bushings.

3.5 CAPACITANCE AND TAN δ MEASUREMENT OF WINDINGS

The combination for C & tan δ measurement of winding is same as that of measurement of IR value. The summery of probable combination is given below.

Auto-Transformer (Two winding)	Test Mode	Shunt Reactor	Test Mode	3 winding Transformer	Test Mode
HV + IV to LV	UST	HV to E	GST	HV to LV1	UST
HV + IV to E	GSTg			HV to LV2	UST
LV to E	GSTg			LV1 to LV2	UST
				HV to Ground	GSTg
				LV1 to Ground	GSTg
				LV2 to Ground	GSTg

Table 4: Combination for C & tan δ measurement of winding for various transformers/ Shunt Reactor

- Ensure that test specimen is isolated from other equipments. **Removal of Jumpers from Bushings is Pre-Requisite for C & Tan δ Measurement of Windings.**
- **For ICTs (Auto-Transformers):** Shorting of all three phase Bushings (400kV&220kV) and neutral to be done. In case of single phase, 400kV, 220kV and neutral Bushings to be shorted Capacitance and Tan δ measurement of windings should be done in following combinations.

Test No.	Winding Combination	Test mode	Cap Symbol	Test lead Connection	Remarks
1.	HV-IV/LV	UST	C_{HL}	HV lead of test kit to HV/IV bushings of transformer LV lead of test kit to LV bushing of transformer	
2.	HV-IV/ LV+G	GST	$C_{HL}+C_{HG}$	-do-	
3.	HV-IV / LV with Guard	GST_g	C_{HG}	do–	LV to be Guarded
4	HV-IV/LV	UST	C_{HL}	LV lead of test kit to HV/IV bushings of transformer HV lead of test kit to LV bushing of transformer	
5	LV/ HV-IV +G	GST	$C_{HL}+C_{LG}$	-do-	
6.	LV/ HV-IV with Guard	GST_g	C_{LG}	-do-	HV to be Guarded

Table 5:.Winding combination for C & tan δ measurement for auto transformer

- Measurement inter-check can be done by calculating $\mathbf{C_1 = C_2 - C_3}$ **&** $\mathbf{C_4 = C_5 - C_6}$ **&** $\mathbf{DF_1 = C_2DF_2 - C_3DF_3 / C_2 - C_3 = C_4DF_4 - C_5DF_5 / C_4 - C_5}$ Where C stands for capacitance and DF for dissipation factor or tan δ and attached suffix (1…6) denotes the sr. no. of test in above table.

- For Reactors: All 400kV and neutral Bushings to be shorted. HV of the test kit to be connected to shorted Bushings and LV of the test kit to be connected to Earth connection. Measure the Capacitance and tan δ in GST mode. Neutral connection with earth/ NGR to be isolated before the test.

Acceptable Limit: Winding Tan δ should be less than 0.5% in all combinations.

3.6 TURNS RATIO (VOLTAGE RATIO) MEASUREMENT

Ratio measurements must be made on all taps to confirm the proper alignment and operation of the tap changers. The test should preferably be performed by automatic Transformer turns ratio (TTR) meter.

Open turns in the excited winding will be indicated by very low exciting current and no output voltage. Open turns in the output winding will be indicated by normal levels of exciting current, but no or very low levels of unstable output voltage. The turns-ratio test also detects high-resistance connections in the lead circuitry or high contact resistance in tap changers by higher excitation current and a difficulty in balancing the bridge.

Acceptable Limit: Results of the voltage ratio are absolute, and may be compared with the specified values measured during factory testing. The turns-ratio tolerance should be within 0.5 % of the nameplate specifications. For three phase Y connected winding this tolerance applies to phase to neutral voltage. If the phase-to-neutral voltage is not explicitly indicated in the nameplate, then the rated phase-to-neutral voltage should be calculated by dividing the phase-to-phase voltage by √3.

3.7 VECTOR GROUP AND POLARITY

Polarity and phase-relation tests are of interest primarily because of their bearing on paralleling or banking two or more transformers. Phase-relation tests are made to determine angular displacement and relative phase sequence. Phase-relation or vector group verification test is performed on a three phase transformer or on a bank of three single-phase transformers. The details of Additive and Subtractive polarity are given in IS: 2026-Part 1 and IEC 60076-1.

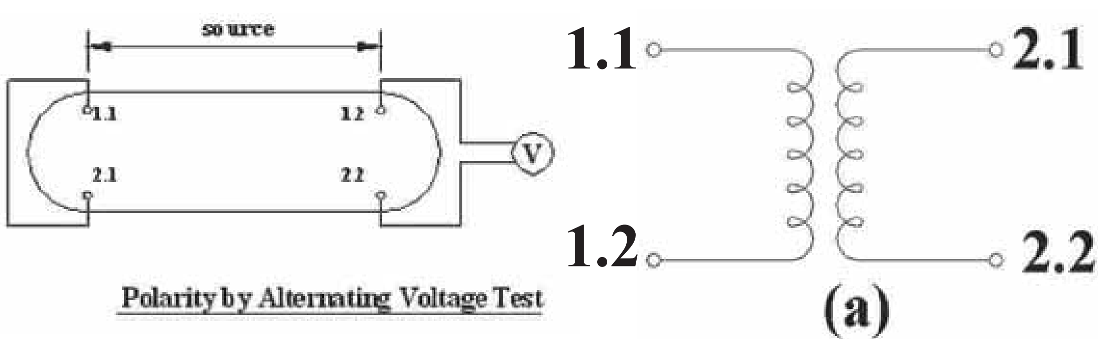


Figure-7

For a single-phase transformer having a ratio of transformation of 30 to 1 or less, the polarity test shall be done as follows. The line terminal of high voltage winding (1.1) shall be connected to the adjacent line terminal low-voltage winding (2.1) as shown in figure 7.

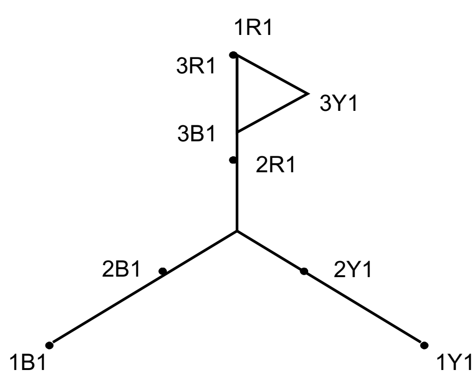
Any convenient value of alternating voltage shall be applied to the full high-voltage winding and readings shall be taken of the applied voltage and the voltage between the right-hand adjacent high-voltage and low-voltage leads.

When the later reading is greater than the former, the polarity is additive.

When the later reading is less than the former (indicating the approximate difference in voltage between that of the high-voltage and low-voltage windings), the polarity is subtractive. The test shall be conducted with 3 phase, 415V supply.

By the measured voltage data, it should be verified that the desired conditions of vector group and polarity are fulfilled

Example for Y D11



- Connect neutral point and LV phase with Earth
- Join 1R1 & 3R1 Terminals
- Apply 415 , 3-Ø supply to HV
- Ensure 2R1-N=2Y1-N=2B1-N=Constant
- If 3R1-N>3Y1-N>3B1-N, and 3Y1-1B1>3Y1-1Y1

Vector group Yna0d11 is confirmed and polarity verified.

Please Note: Most of the auto transformers in POWERGRID are of Yd11configuration.

3.8 MAGNETIC BALANCE TEST

This test is a low voltage test conducted at factory and site by applying single phase voltage between phase and neutral of a winding and measuring voltage induced in other two phases of the same winding. This test is carried out only in three phase units.

Keep the tap in nominal tap position. Disconnect transformer neutral from ground. Apply single phase 230 V across one phase of Highest Voltage (HV) winding terminal and neutral (call it v1) then measure voltage in other two HV terminals across neutral (call them v2 and v3 respectively). Repeat the test for each of the three phases. Repeat the above test for Intermediate Voltage (IV) winding also. The identical results confirm no damage due to transportation. The following points may be noted.

Transformer neutral should be disconnected from ground

(i) No winding terminal should be grounded, otherwise results would be erratic and confusing.

(ii) Zero voltage or very negligible voltage induced in any of the other two phases shall be investigated.

(iii) It is proposed that a set of readings should be taken for information and comparison later during service of the transformer.

Acceptable Limit: Also the applied voltage may be expressed as 100% voltage and the induced voltage may be expressed as percentage of the applied voltage. This will help in comparison of the two results when the applied voltages are different. **The voltage induced in the centre phase shall be 50 to 90% of the applied voltage. However, when the centre phase is excited then the voltage induced in the outer phases shall be 30 to 70% of the applied voltage.**

Zero voltage or very negligible voltage induced in the other two windings should be investigated.

3.9 FLOATING NEUTRAL POINT MEASUREMENT

This test is conducted by applying 3 phase 415 volt supply across HV windings or IV winding as the case may be after disconnecting the transformer neutral from the ground. For a healthy transformer, when 3 phase balance voltage is applied, the voltage between neutral and ground is zero or otherwise a negligible voltage will appear. But in case there is a short circuited winding, the voltage between the neutral and the ground is appreciable. This test will also help in detecting the gradual deterioration or development of fault in the winding during service.

Acceptable Limit For a healthy transformer the voltage between neutral and ground should be zero or negligible. **In case, significant voltage appears between neutral and ground, matter to be referred to the manufacturer.**

3.10 MEASUREMENT OF SHORT CIRCUIT IMPEDANCE

This test is used to detect winding movement that usually occurs due to heavy fault current or mechanical damage during transportation or installation since dispatch from the factory.

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

The measurement is performed in single phase mode. This test is performed for the combination of two windings. The one of the winding is short circuited and voltage is applied to other winding. The voltage and current reading are noted.

The test shall be conducted with variac of 0-280 V, 10 A, precision RMS voltmeter and ammeter. The conductors used for short-circuiting one of the transformer windings should have low impedance (less than 1m-ohm) and short length. The contacts should be clean and tight.

Acceptable Limit: The acceptable criteria should be the measured impedance voltage having agreement to within **3 percent of impedance specified in rating and diagram nameplate** of the transformer. Variation in impedance voltage of more than 3% should be considered significant and further investigated.

3.11 EXCITING/ MAGNETISING CURRENT MEASUREMENT

This test should be done before DC measurements of winding resistance as saturation of winding due to the application of DC voltage may alter the test results. If there is suspected residual magnetism in the winding, transformer under test may be demagnetized before commencement of magnetizing current test.

Three-phase transformers are tested by applying Single-phase 10 kV voltage to one phase (HV terminals) and keeping other winding open circuited and measuring the current at normal, minimum and max. tap positions.

Keep the tap position in normal position and keep HV and LV terminals open. Apply 1phase 10kV supply on IV terminals. Measure phase to phase voltage between the IV terminals and current on each of the IV windings.

Acceptable Limit: The set of reading for current measurement in each of the tap position should be equal. Unequal currents shall indicate possible short circuits in winding. Results between similar single-phase units should not vary more than 10 % .The test values on the outside legs should be within 15 % of each other, and values for the centre leg should not be more than either outside for a three-phase transformers. Results compared to previous tests made under the same conditions should not vary more than **25%. If the measured exciting current value is 50 times higher than the value measured during pre-commissioning checks, then there is likelihood of a fault in the winding which needs further analysis**. The identical results confirm no damage due to transportation. The availability of test data of normal condition and faulty condition results help us to analyze the problem in future.

3.12 OPERATIONAL CHECKS ON OLTC

Following checks should be carried out during pre-commissioning:

- Manual Operation: The tap changer has to be run manually by the hand crank through the total operating cycle. In each operating position, the position indicators of motor drive and tap changer (On TC head) show the same position.
- Motor drive for step by step tap changing operation: Push button to be kept pressed till the motor stops i.e. driving motor should be automatically switched off when the tap changer has performed one switching operation.

(Note: At the time of change over selector operation (i.e. 9b to 10 & vice-versa), higher torque is required. Tap changer end position should be checked that the same is not overrun to avoid any failure during operation. Same can be seen through the inspection glass in the tap changer head cover).

With the tap-changer fully assembled on the transformer the following sequence of operations shall be performed:

a. With the transformer un-energized, one complete cycles of operations (a cycle of operation goes from one end of the tapping range to the other, and back again). Check continuity of winding during this test. Ensure that the voltmeter needle does not deflect to zero. Specify where and how to connect the analog Voltmeter.

b. With the transformer un-energised, and with the auxiliary voltage reduced to 85% of its rated value, one complete cycle of operation.

c. With the transformer energized at rated voltage and frequency at no load, one complete cycle of operation.

The following additional check points/ guidelines for OLTC is recommended in consultation with OLTC manufacturer to ensure the absence of problems and proper operation:

a) Function of control switches

b) OLTC stopping on position

c) Fastener tightness

d) Signs of moisture such as rusting, oxidation or free standing water and leakages

e) Mechanical clearances as specified by manufacturer's instruction booklet

f) Operation and condition of tap selector, changeover selector and arcing transfer switches

g) Drive mechanism operation

h) Counter operation, Position indicator operation and its co-ordination with mechanism and tap selector positions

i) Limit switch operation

j) Mechanical block integrity

k) Proper operation of hand-crank and its interlock switch

l) Physical condition of tap selector

m) Freedom of movement of external shaft assembly

n) Extent of arc erosion on stationary and movable arcing contacts

o) Inspect barrier board for tracking and cracking

p) After filling with oil, manually crank throughout entire range

q) Oil BDV and Moisture content (PPM) to be measured and recorded (Min BDV should be 60 KV and Moisture content should be less than 10 PPM)

3.13 TESTS/ CHECKS ON BUSHING CURRENT TRANSFORMERS (BCTs)

Continuity, Polarity and secondary winding resistance tests of individual cores of Bushing CTs.

3.14 OPERATIONAL CHECKS ON PROTECTION SYSTEM

(For detailed procedure, please refer to DOC NO: D-2-03-XX-01-01 Maintenance Procedures for Switchyard Equipments Part1: EHV Transformers/ Reactors)

1) Operational Checks on Breathers (Conventional Silcagel or Drycol as supplied with the transformers).

2) Visual check of MOG of Main Conservator
3) Marshalling Box & Kiosk Checks
4) Valve Operational Checks
5) Checks on Cooling System
   i. Checks on cooling fans-rotation, speed & Control (Manual /temp /load) setting checks
   ii. Checks on Cooling pumps- rotation, vibration/noise, oil flow direction
6) Checks on temperature Gauges (OTI/WTI-Calibration and Cooler Control, alarm & trip setting tests)
7) Checks on gas actuated (SPRs/ PRDs/ Buchholz) relays –Operational checks by simulation as well as shorting the respective contacts as applicable
8) Checks on tightness of Terminal connectors - micro-ohm measurement of each connection
9) Checks on Transformer/ Reactor protection (differential, REF, Over-current & stability tests etc.)

3.15 STABILITY OF DIFFERENTIAL, REF OF TRANSFORMER/ REACTOR

This test is performed to check the correctness of CT polarity, CT secondary core connections, connections at relay terminals and operation of relay under fault conditions. Here the entire electrical protection scheme is checked.

3.15.1 REF STABILITY TEST FOR TRANSFORMER

1) After opening the Circuit Breaker and isolators at both side (H.V. and L.V. side) of transformer, use "Primary Test Tap (M point or PI1/PI2)" provided in the BUSHING TURRET CTs to bypass the Transformer with the help of Primary current injection leads. Now, after ensuring completion of all CT wiring & normal polarity, inject current with the help of Primary Injection kits in the relevant turret CTs of R phase & Neutral, subject to the maximum rating of Primary Test Tap.
2) Measure the spill current in REF relay which should be nearly zero.
3) Switch off Current Injection.
4) Reverse the polarity of R phase Bushing CT and again start Current Injection. Appreciable spill current will appear in REF relay.
5) Normalize the CT circuit which was reversed in step no. (4), after switching off Current injection.
6) Repeat the same procedure for Y and B phases and note down the results in formats.
7) Normalize the connections of CT.
8) This test has to be performed from both HV side & LV side w.r.t. Neutral.

However, if Primary Test Tap is not available in the Turret CTs, adopt following procedure:

1) After opening the Circuit Breakers and Isolators at both side (H.V. and L.V. side) of transformer apply 440V three phase voltage at three phase bushing of H.V. side with the help of three phase variac.
2) Earth the R phase of the LV side (through isolator earth switch or discharge rod).
3) Measure the spill voltage (in mV)/ spill current (in mA) at REF relay which should be nearly zero.
4) Switch off 440V supply.
5) Reverse the polarity of R phase Bushing CT and again switch on 440V supply. Appreciable spill voltage/ current will appear in REF relay.
6) Normalize the CT circuit which was reversed in step no. (5), after switching off 440V supply.
7) Repeat the same procedure for Y and B phases and note down the results in formats.
8) Normalize the connections of CT and remove feeding of three phase supply.

3.15.2 REF STABILITY TEST FOR REACTOR

1) After opening the Circuit Breaker and Isolators of Reactor, use "Primary Test Tap (M point or PI1/PI2)" provided in the BUSHING TURRET CTs to bypass the Reactor with the help of Primary current injection leads. Now, after ensuring completion of all CT wiring & normal polarity, inject Current with the help of Primary Injection kits in the relevant Turret CTs of R phase of Reactor & earth side CT of NGR, subject to the maximum rating of Primary Test Tap.
2) Measure the spill current in REF relay which should be nearly zero.
3) Switch off Current Injection.
4) Reverse the polarity of R phase Bushing CT and again start Current Injection. Appreciable spill current will appear in REF relay.
5) Normalize the CT circuit which was reversed in step no. (4), after switching off Current injection.
6) Repeat the same procedure for Y and B phases and note down the results in formats.
7) Normalize the connections of CT.

However, if Primary Test Tap is not available in the Turret CTs, adopt following procedure:

1) After opening the C.B. and isolators of Reactor, remove the jumpers of three phase bushings. Reactor Neutral will remain connected to NGR, however Earth connection of NGR Bushing will be opened.
2) Apply 415 volts, phase to phase voltage across R phase bushing of Reactor & earth side Bushing of NGR, after ensuring completion of all CT wiring & normal polarity.
3) Measure the spill voltage (in mV)/ spill current (in mA) in REF relay which should be nearly zero.
4) Switch off 415V supply to Reactor / NGR Bushing.

5) Reverse the polarity of R phase bushing CT.
6) Switch on 415V supply to Reactor / NGR Bushing.
7) Appreciable spill voltage/ current will appear in REF relay.
8) Now normalize the polarity of the Bushing CT which was reversed in step (5).
9) Repeat the same procedure for Y and B phase and note down the results in formats.
10) After completing the test for all three phases normalize the reactor CT connection and jumpers & Earth connection of NGR Bushing.

3.16 FREQUENCY RESPONSE ANALYSIS (FRA) MEASUREMENT

Frequency Response Analysis (FRA) is conducted to assess the mechanical integrity of the transformer which may get disturbed due to transportation shocks. FRA signatures will be taken after assembly and oil filling and compared with factory testing to ensure the healthiness of core /coil assembly during transportation. These signatures will be the benchmark for future reference. The FRA signatures should be analyzed in conjunction with Impact Recorder readings. Report of Impact recorder readings is to be obtained from manufacturer.

It is recommended to follow the standard procedure for the SFRA measurement as per the Table-7. It should be done on maximum, normal and minimum tap of the transformer.

Combination of tests for Auto Transformer

Test Type	Test	3 Φ	1 Φ
Series Winding (OC) All Other Terminals Floating	Test 1	H1-X1	H1-X1
	Test 2	H2-X2	
	Test 3	H3-X3	
Common Winding (OC) All Other Terminals Floating	Test 4	X1-H0X0	X1-H0X0
	Test 5	X2-H0X0	
	Test 6	X3-H0X0	
Tertiary Winding (OC) All Other Terminals Floating	Test 7	Y1-Y3	Y1-Y2 (Y1-Y0)
	Test 8	Y2-Y1	
	Test 9	Y3-Y2	
Short Circuit (SC) High (H) to Low (L) Short (X1-X2-X3)	Test 10	H1-H0X0	H1-H0X0 Short (X1-H0X0)
	Test 11	H2-H0X0	
	Test 12	H3-H0X0	
Short Circuit (SC) High (H) to Tertiary (Y) Short (Y1-Y2-Y3)	Test 13	H1-H0X0	H1-H0X0 Short (Y1-Y2)
	Test 14	H2-H0X0	
	Test 15	H3-H0X0	
Short Circuit (SC) Low (L) to Tertiary (Y) Short (Y1-Y2-Y3)	Test 16	X1-H0X0	X1-H0X0 Short (Y1-Y2)
	Test 17	X2-H0X0	
	Test 18	X3-H0X0	

Table-7: Various combinations for FRA measurement in Auto Transformer

Combination of tests for Shunt Reactor

In case of Shunt Reactor, FRA to be done in following combinations:

- **H1-H0**
- **H2-H0**
- **H3-H0**

3.17 WINDING RESISTANCE MEASUREMENT

Preferably to be carried out using Automatic kit, in case of non availability V/I method can be adopted.

To reduce the high inductive effect, it is advisable to use a sufficiently high current to saturate the core. This will reduce the time required to get a stabilized reading. It is essential that temperatures of the windings are accurately measured. Care shall be taken that self inductive effects are minimized. Care also must be taken to ensure that direct current circulating in the windings has settled down before the measurement is done. In some cases this may take several minutes depending upon the winding inductance.

The winding resistance shall be preferably done when the difference in the top and bottom temperature of the winding (temperature of oil in steady-state condition) is equal to or less than 5 °C.

The winding resistance should preferably be carried out last after completion of all other LV tests, as after this test core gets saturated and tests like magnetizing current, magnetic balance etc. carried out after winding test may be affected and indicate a misleading results, if the core is not de-magnetized before carrying out these tests.

For star connected auto-transformers the resistance of the HV side is measured between HV terminal and IV terminal, then between IV terminal and the neutral AT ALL TAPS. The tap changer should be changed from contact to contact so that contact resistance can also be checked. Measurement of winding resistance is to be carried out from tap position 1 to 17 and again from 17 to 9. While doing measurements in reverse order, 2 to 3 steps shall be enough.

During tap changing operation, continuity checks between HV to neutral to be carried out by analog multimeter while changing tap.
For delta connected windings, such as tertiary winding of auto-transformers, measurement shall be done between pairs of line terminals and resistance per winding shall be calculated as per the following formula:

Resistance per winding = 1.5 x Measured value

Take the winding temperature reading while doing the resistance measurement.

Calculate the resistance at 75°C as per the following formula

$\mathbf{R_{75} = R_t (235+75)/(235+t)}$, Where R_t = Resistance measured at winding temperature t

Acceptable Limit: The resistance value obtained should be compared with the factory test value. Results are compared to other phases in Star-connected transformers or between pairs of terminals on a Delta–connected winding to determine if a resistance is too high or low. Because field measurements make it unlikely that precise temperature measurements of the winding can be made, the expected deviation for this test in the field is not more than **5.0%** of the factory test value.

3.18 DISSOLVED GAS ANALYSIS (DGA) OF OIL SAMPLE

Dissolved Gas Analysis (DGA) is a powerful diagnostic tool to detect any incipient fault developing inside the oil-filled equipment. The oil sample is to be taken after oil filling (before commissioning) as a benchmark and there after 24hrs of charging, 7 days, 15 days, one month and three months after charging to monitor the gas build up if any. The oil samples are to be sent to the designated labs for DGA and first two samples for oil parameter testing also.

For detailed procedure for each test, please refer Transformer and Reactor Maintenance manual (Doc No. D-2-03-XX-01-01)-First Revision, Part B, C & D.

CHECK LIST FOR ENERGISATION OF TRANSFORMER/ REACTOR

4.1 PRELIMINARY CHECKS

1. Release air at the high points, like oil communicating bushings, buchholz petcock, tank cover and the cooling devices including headers, radiators, pumps, expansion joints etc. of the transformer. Air release should be resorted from low points to high points.

2. Check the whole assembly for tightness and rectify where necessary.

3. Check the general appearance and retouch the paint work if needed.

4. Check that the valves are in the correct position :
   - ➢ Tank: valves closed and blanked
   - ➢ Cooling circuit: valves open
   - ➢ Conservator connection:valves open
   - ➢ By-pass: valves open or closed as the case may be.
   - ➢ On-load tap changer:valves open
5. Check that the silica gel is completely filled in the breather and is blue and that there is oil in the breather cup (oil seal)
6. Ensure that CC & CL are properly grounded.
7. Check the oil level in the main conservator and the conservator of on-load tap changer, as per manufacturers recommendations
8. Check the bushings:
   - ➢ Oil level (bushings fitted with sight-glasses)
   - ➢ Adjustment of spark-gaps /arcing horn –gaps, if provided
   - ➢ Conformity of connection to the lines (no tensile stress on the terminal heads)
   - ➢ Bushing CT secondary terminals must be shorted and earthed, if not in use.
   - ➢ Neutral bushing effectively earthed
   - ➢ Tan delta cap should be tight and properly earthed.
9. Check the on-load tap changer:
   - ➢ Conformity of the positions between the tap changer control cubicle and the tap changer head

- Adjustment of the tap-changer control cubicle coupling
- Electric and mechanical limit switches and protective relays
- Step by step operation- local and remote electrical operation as well as manual operation and parallel operation, if any
- Signaling of positions

10. Check the quality of the oil:
    - Draw a sample from the bottom of the tank.
    - Carry out DGA and oil parameters test

11. Prior to energization at site, oil shall be tested for following properties & acceptance norms as per below generally in line with IS: 1866 / IEC 60422:

1.	Break Down voltage (BDV)	: 70 kV (min.)
2.	Moisture content	: 5 ppm (max.)
3.	Tan-delta at 90 °C	: 0.01 (max.)
4.	Total Gas Content	: < 1%
5.	Resistivity at 90 °C	: 6 X 10^{12} ohm-cm (min.)
6.	Interfacial tension	: 0.035 N/m (min.)
7.	*Oxidation Stability (Test method as per IEC 61125 method C, Test duration: 500 hour for inhibited oil)	
	a) Acidity	: 0.3 (mg KOH /g) (max.)
	b) Sludge	: 0.05 % (max.)
	c) Tan delta at 90 °C	: 0.05 (max.)

· *For Sr. No. 7 separate oil sample shall be taken and test results shall be submitted within 45 days after commissioning for approval of POWERGRID

12 Check that equalizing link between OLTC tank and Main tank is removed

13 Extraneous materials like tools, earthing rods, pieces of clothes, waste etc. should be removed before energizing.

4.2 CHECKING OF AUXILIARY AND PROTECTIVE CIRCUITS

1. Ensure that the temperature indicators are calibrated.
2. Check the setting and working of the mercury switches of winding and oil temperature indicators

3. Ensure presence of oil in the thermometer pockets.
   - Follow the same procedure for the thermal replicas
4. Check the direction of installation of buchholz relay.
5. Check the operation of the buchholz relay and the surge protective relay of the tap-changer for:
   - Alarm and tripping
   - Protections and signals associated with these relays
6. Check the insulation of the auxiliary circuits with respect to ground by 2 kV insulation tester for 1 min. It should withstand the test.
7. Check the earthing of the tank and auxiliaries like cooler banks at two places.
8. Measure the supply voltages of the auxiliary circuits
9. Check the cooling system for the following:
   - Check the direction of installation of oil pumps
   - Check the direction of rotation of the pumps and fans
   - Check the working of the oil flow indicators
   - Check the setting of the thermal overload relays
   - Go through the starting up sequences, control and adjust, if necessary, the relay time delays
10. Check that there is sufficient protection on the electric circuit supplying the accessories and tightness of all electrical connections
11. Check the heating and lighting in the cubicles
12. Check the schemes of differential protection, over-current protection, restricted earth fault protection, over-fluxing protection etc. With implementation of settings as recommended by CC/Engg

After the inspection / tests are completed, the transformer may be energized from the incoming side on NO LOAD, 400kV or 220kV. The initial magnetizing current at the time of switching will be very high, depending upon the particular moment in the cycle. The transformer should be kept energised for twelve hours before taking on load. During this time, vibrations, abnormal cracking noise, etc. are to be observed.

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

DGA samples may be sent as per Standard practice (after 24 hrs of energizing, one week, 15 days, one month and three months after charging, thereafter as per normal frequency of 6 months). Loading data may be forwarded to CC/OS and manufacturer (if requested by them).

POST COMMISSIONING CHECKS/TESTS FOR TRANSFORMERS AND REACTORS

Sr. No.	Name of Test/ Check point	Purpose of test/ check
5.1	Thermovision Infra-red scanning (IR thermography)	A thermo vision Camera determines the temperature distribution on the surface of the tank as well as in the vicinity of the Jumper connection to the bushing. The information obtained is useful in predicting the temperature profile within the inner surface of tank and is likely to provide approximate details of heating mechanism.
5.2	On Line moisture measurement	To determine the moisture content in paper insulation by measuring % Relative Saturation/ Active Water. This test to be carried out once the Transformer/ Reactor is stabilized and operating at higher temperature (>60 deg C).
5.3	Vibration measurement of Oil-immersed Reactor	To measure the vibrations of core /coil assembly in the tank of the reactor. Movement of the core-coil assembly and shielding structure caused by the time–varying magnetic forces results in vibration of the tank and ancillary equipment. These vibrations have detrimental effects such as excessive stress on the core-coil assembly

5.1 THERMOVISION SCANNING (IR THERMOGRAPHY)

Once the transformer/ reactor is charged and loaded, Thermovision scanning is to be carried out to see any hotspots. Thermovision scanning of transformer to be done at least after 24 hrs. of loading and repeated after one week.

5.2 ON LINE MOISTURE MEASUREMENT

5.3 VIBRATION MEASUREMENT OF OIL-IMMERSED REACTOR

Movement of the core-coil assembly and shielding structure caused by the time –varying magnetic forces results in vibration of the tank and ancillary equipment. These vibrations have detrimental effects such as excessive stress on the core-coil assembly. The shunt reactor under test shall be completely assembled in normal operating condition with cooling equipments, gauges and accessories. The shunt reactor shall be energized at rated voltage and frequency. Three phase excitation for 3-ph units. The shunt reactor should be mounted on a level surface that will provide proper bearing for the base, in order to eliminate the generation of abnormal tank stresses.

The vibration of shunt reactor shall be measured by transducers, optical detectors or equivalent measuring devices. The measuring equipment should be accurate within +/- 10 % at 2^{nd} harmonic of the exciting frequency. The peak-to-peak amplitude shall be determined by direct measurement or calculated from acceleration or velocity measurement. The average amplitude of all local maximum points shall not exceed 60 μm (2.36 mils) peak to peak. The maximum amplitude within any individual reading shall not exceed 200 μm (7.87 mils) peak to peak.

PRE-COMMISSIONING CHECKS/TESTS FOR OTHER SWITCHYARD EQUIPMENTS

Once erection is completed, various pre-commissioning checks/ tests are performed to ensure the healthiness of the switchyard equipments prior to their energisation. Various major electrical tests to be performed and their significance are given below:

Sr. No.	Name of Test / Check point	Purpose of test/ check
6.1	Tan δ & Capacitance measurement of CT, each stack of CVT & total capacitance, CB voltage grading capacitor & each stack of Surge Arresters	The purpose of the dissipation factor measurement of high voltage insulation is to detect incipient weaknesses in HV insulation. The most important benefit to be gained from this measurement is to obtain a "benchmark reference reading" on costly and high voltage equipment when the equipment is new and insulation is clean, dry and free from impurities. Tan delta & Capacitance values shall be comparable with factory test results and in no case shall be more than 0.5 %.
6.2	**Checks/ Tests applicable for CTs**	
6.2.1	Polarity test for CT	To ascertain whether the polarity markings are correct or not as per drawing.
6.2.2	Magnetization characteristics of CT	To prove that the turns of CTs secondary windings are not short circuited and to check healthiness of CT cores. The magnetizing currents at KPV (Knee point voltage) shall be less than the specified value. The ratio of secondary and primary voltage shall also be measured.
6.2.3	Ratio test for CT	The ratio errors of the primary to the secondary currents should within specified ratio errors.
6.2.4	IR measurement of CT (Primary & Secondary windings)	Changes in the normal IR value of CT indicate abnormal conditions such as presence of moisture, dirt, dust, crack in insulator of CT and degradation of insulation.
6.2.5	DGA test of CT oil	This test shall be conducted after 30 days of commissioning. The purpose is to identify evolving faults in the CT and DGA values shall be comparable with factory values (if available)
6.3	**Checks/ Tests applicable for Circuit Breakers**	
6.3.1	Dew point measurement of SF6 gas	Dew point of SF6 gas is to measure moisture content in SF6 gas which shall indicate whether CB evacuation is done properly or not. This test shall be carried out preferably at rated pressure of SF6 gas.
6.3.2	Measurement of Circuit	To measure closing/ tripping/ CO timings. These timings

Sr. No.	Name of Test / Check point	Purpose of test/ check
	Breaker Operating Timings including PIR Timings	should be within permissible limits and shall be comparable with factory values. Pole discrepancies and Break to Break discrepancies shall be less than specified values.
6.3.3	DCRM Contact Travel Measurement / DC injected currents and trip/ close coil currents.	DCRM is the technique for measuring Contact Resistance during operation (Close/ Trip) of a circuit breaker with a delay Tco of 300ms. A DC current of at least 100 Amp is injected through the circuit breaker. The current and voltage drop are measured and resistance is calculated. The resistance and travel versus time data provides useful information on the condition of the circuit breaker contacts and is used as a diagnostic tool. DCRM test signatures shall be approved by Corporate OS.
6.3.4	Operational lockout checking for EHV Circuit Breakers	To ensure various lockout operation of CB by simulating the actual conditions at the specified pressure of oil/ air/ operating medium.
6.3.5	Measurement of static contact resistance	This test is conducted to evaluate healthiness of Main contacts. 100 Amp DC is injected and voltage drop is measured across each CB contact to compute contact resistance.
6.3.6	Checking the Anti-Pumping feature	By giving simultaneous close/ trip commands, CB hunting shall not take place by operation of Mechanical/ Electrical anti pumping feature.
6.3.7	Checking the Anti-Condensation Heaters	To check correct operation of Thermostat provided for anti condensation heaters.
6.3.8	Pole discrepancy relay testing	To test tripping of CB in case of pole discrepancy more than 2.5 seconds or specified value.
6.3.9	Checking the N2 priming pressure	This test is to check healthiness of N2 accumulators provided in Hydraulic drive mechanisms. N2 priming pressure shall be as per the rated pressure.
6.4	**Checks/ Tests applicable for CVTs**	
6.4.1	CVT polarity, Ratio test	This test is conducted in the same manner as for CT to determine correct CVT polarity, ratio and phasor group.
6.4.2	Insulation resistance measurement of Primary & secondary winding	Changes in the normal IR value of CVT indicate abnormal conditions such as presence of moisture, dirt, dust, crack in insulator of CVT and degradation of insulation.
6.5	**Checks/ Tests applicable for Isolators**	
6.5.1	MILLIVOLT Drop test	The voltage drop gives a measure of resistance of current carrying part and contacts by injecting minimum 100 A DC current.

Sr. No.	Name of Test / Check point	Purpose of test/ check
6.5.2	50 operation tests	To test operation of contacts etc with jumpers connected and contact resistance to be measured after 50 operations. There shall not be any change from the previous value.
6.6	**Checks/ Tests applicable for Surge Arrestors**	
6.6.1	Third Harmonic Resistive Current (THRC) for surge arrestors	To monitor healthiness of Surge arrestors by monitoring third harmonic resistive current from the leakage current. This test is to be conducted after charging of Las. The value of THRC shall be less than 30 μA.
6.6.2	IR measurement of each stack of LA	Changes in the normal IR value of LA indicate abnormal conditions such as presence of moisture, dirt, dust, crack in insulator of LA and degradation of insulation.
6.6.3	Checking of operation of LA counter	This test is done to check the healthiness of LA counter.
6.7	**Checks/ Tests for other areas/ equipments**	
6.7.1	Earth resistance measurement	To ensure value of earth resistance is below 1 ohm.
6.7.2	Secondary current injection test	Conducted for testing of protecting devices, circuit breakers, trip coils, motor overloads etc.
6.7.3	Contact Tightness check of Bay contacts by Primary injection method	Since complete bay contact resistance measurement is practically not possible because DC current may not be injected in CT primary, hence contact tightness check by primary injection method has been introduced to check overall contact tightness.
6.7.4	Stability check for Bus Bar	This test is performed to check the proper operation of Bus Bar protection by simulating actual conditions. Any problem in CT connection, wrong cabling, relay setting can be detected by this test.

6.1 TAN DELTA & CAPACITANCE MEASUREMENT OF CT, CVT, CB VOLTAGE GRADING CAPACITORS AND LA STACKS

To measure dissipation factor/loss factor (Tan delta) and Capacitance measurement of EHV class CTs, CVTs, CB Voltage Grading Capacitors & LA stacks by applying test voltages up to 10kV.

A) CURRENT TRANSFORMERS

CTs with test taps

1. Tan delta tap to be disconnected from ground.
2. High voltage lead from tan delta kit to be connected to primary(HV) Terminal and LV lead to be connected to the Tan delta test tap.
3. P1 and P2 to be shorted
4. Porcelain surface to be thoroughly cleaned.
5. Measurements have to be taken in UST mode with fully automatic test kit.
6. Standard procedure(as specified by kit supplier) for measuring capacitance and tan delta in charged switchyard/induced voltage conditions should be followed for measurement of capacitance and tan delta values.
7. It is to be ensured to connect the test tap to ground terminal after carrying out the test.

B) CB VOLTAGE GRADING CAPACITOR

1. Connect LV cable to the middle of the double interrupter.
2. Connect HV cable to the other end of the Grading capacitor to be tested.
3. The opposite end of the grading capacitor has to be grounded using earth switch.
4. Measurements have to be taken in UST Mode with fully automatic test kit.
5. Disconnect the HV cable and connect the same to the other grading capacitor and ground the previous grading capacitor. Now the second grading capacitor is ready for testing.
6. Standard procedure (as specified by kit supplier) for measuring capacitance and tan delta in charged switchyard/induced voltage conditions should be followed
7. Measurements are to be carried out at 10 kV/ 12 KV.

C) CAPACITOR VOLTAGE TRANSFORMERS

1. Testing procedure for Top and Middle Stacks:
   - (a) Apply 10 KV between flanges of Top/Middle stacks (whichever is being tested)
   - (b) Carry out measurements in UST mode at 10.0 KV
   - (c) While measuring Middle/ Bottom stacks, Top/ middle stacks to be shorted.

2. Testing procedure for Bottom Stack connected to EMU PT
   - (a) Connect HV of the test kit at the top flange of bottom stack. HF point to be grounded. Earth connection of the neutral of the PT to be opened/ isolated from ground.
   - (b) Top of CVT to be guarded. LV lead of the kit to be connected at the top of the CVT for guarding.

(c) Carry out measurements in GSTg mode at 10.0 KV
(d) Repeat the Test with neutral of PT connected to ground.
(e) In case Tan delta value is negative or erratic, only capacitance values are to be monitored.
(f) Measurement to be carried out using fully automatic kit.

3. Standard procedure (as specified by kit supplier) for measuring capacitance and tan delta in charged switchyard/ induced voltage conditions should be followed.

D) SURGE ARRESTERS

1. Testing procedure for Top, Middle and Bottom Stacks:
   (a) Apply 10 KV between flanges of Top/Middle/ Bottom stacks (whichever is being tested)
   (b) Carry out measurements in UST mode at 10.0 KV with fully automatic test kit.
   (c) While measuring Middle/ Bottom stacks, the stacks above the HV lead to be shorted.
2. Standard procedure (as specified by kit supplier) for measuring capacitance and tan delta in charged switchyard/ induced voltage conditions should be followed.
3. While doing measurement of bottom stack the earth connection to be removed.

6.2 CHECKS/ TESTS APPLICABLE FOR CTs

6.2.1 POLARITY TEST FOR CT

A centre zero voltmeter is connected across CT secondary. A 1.5 Volt battery is touched to primary of CT. The deflection of pointer should be similar in case of each CT core.

At any instant current entering the primary from P1 the current should leave secondary from the terminal marked S1. A setup shown in the Figure 9 can show whether the polarity markings are correct or not.

When the key is pressed, current enters the primary through terminal P1, the voltmeter connected as shown, should read positive. A general arrangement of polarity test setup is indicated in Fig. 10.

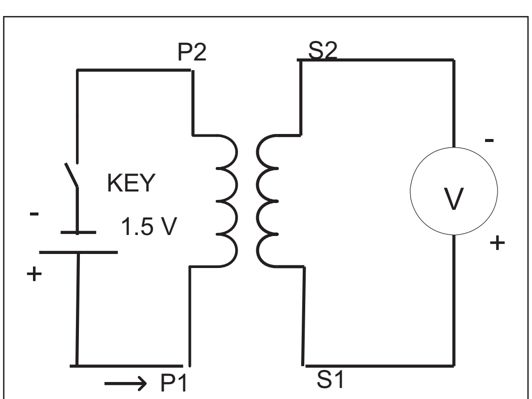


Figure - 9

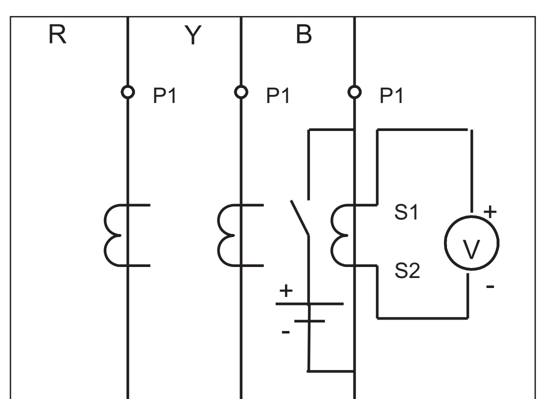


Figure - 10

6.2.2 MAGNETIZATION CHARACTERISTICS OF CTs

PRECAUTIONS

a) There should be no joints in testing leads/cables.

b) It should be ensured that whole testing equipment along with testing procedures are available at testing site. Testing must be carried out in presence of testing personnel only.

Test Equipment: Voltage source of 5 kV, Voltmeter of range 0 to 5 kV, Ammeter of range 0 to 500 Amps, testing leads/cables etc.

Test Procedure: Make connections as per diagram shown below (Fig- 11). After making proper connections, applied voltage is increased from zero to rated Knee Point Voltage in steps of 25%, 50%, 75% and 100%. Measure the current drawn by the CT secondary core at respective applied voltages and record the test results

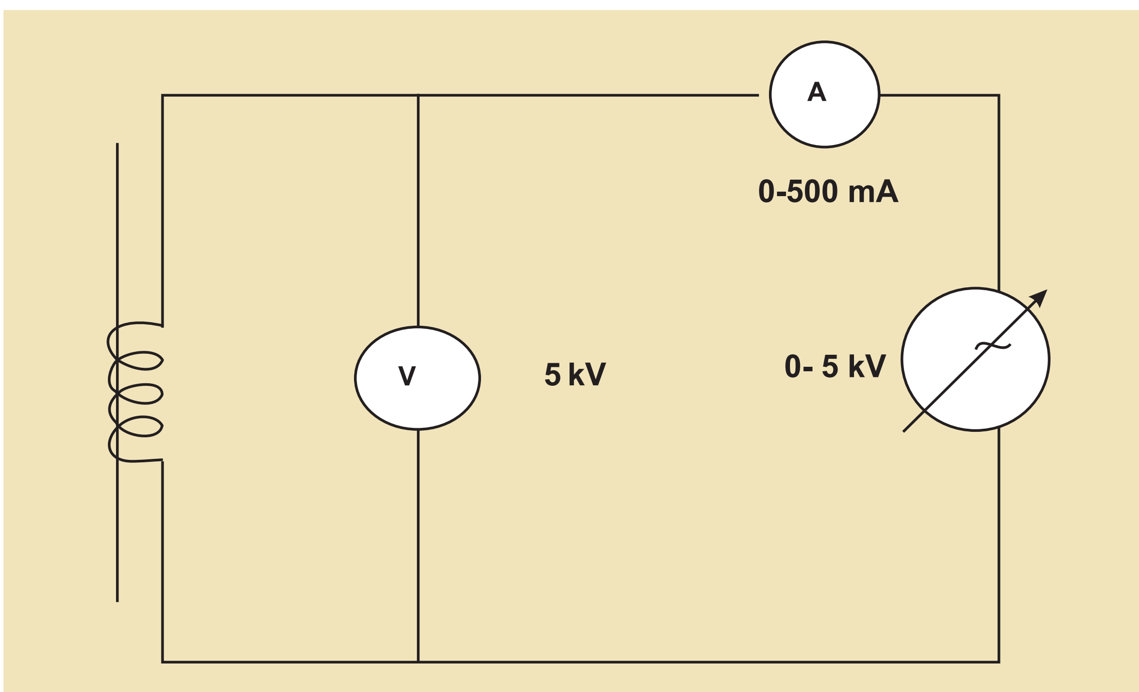


Figure - 11

Knee Point Voltage is normally defined as the voltage at which 10% increase in the applied voltage causes 30 to 50% increase in secondary current. The magnetization current at rated Knee Point Voltage should not be more than the specified/designed value. A curve can be drawn between applied voltage and magnetizing current. Typically, the curve drawn should be like the one given below in Fig.-12.

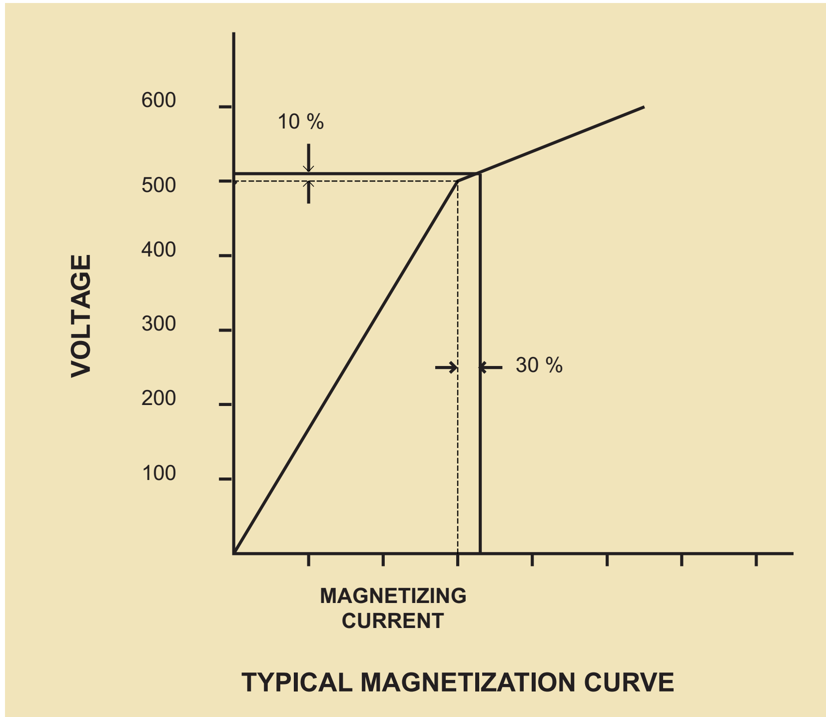


Figure - 12

From the curve it can be implied that up to rated KPV (Knee Point Voltage), the VI curve should be almost a straight line. However, if this line is not linear, this indicates that the magnetizing characteristics are not desirable. If the slop of the curve starts increasing, it indicates that magnetizing induction becomes low and total primary current is utilized in exciting the core alone. Consequently, out put of CT secondary disappears.

6.2.3 RATIO TEST FOR CURRENT TRANSFORMER

The ratio check has to be carried out as indicated in Fig-13 below.

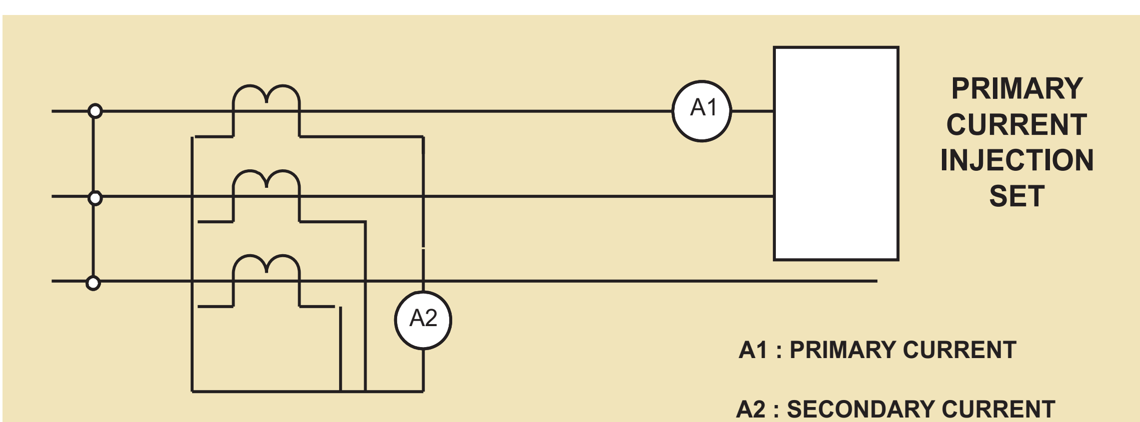


Figure - 13

It is customary to conduct this in conjunction with the primary injection test. Current is passed through the primary circuit with the secondary winding circuit to its normal circuit load. The ratio of the primary to the secondary currents should approximate closely to that stamped under CT identification plate.

Alternatively, ratio test is to be conducted as per the following method (Fig-14).

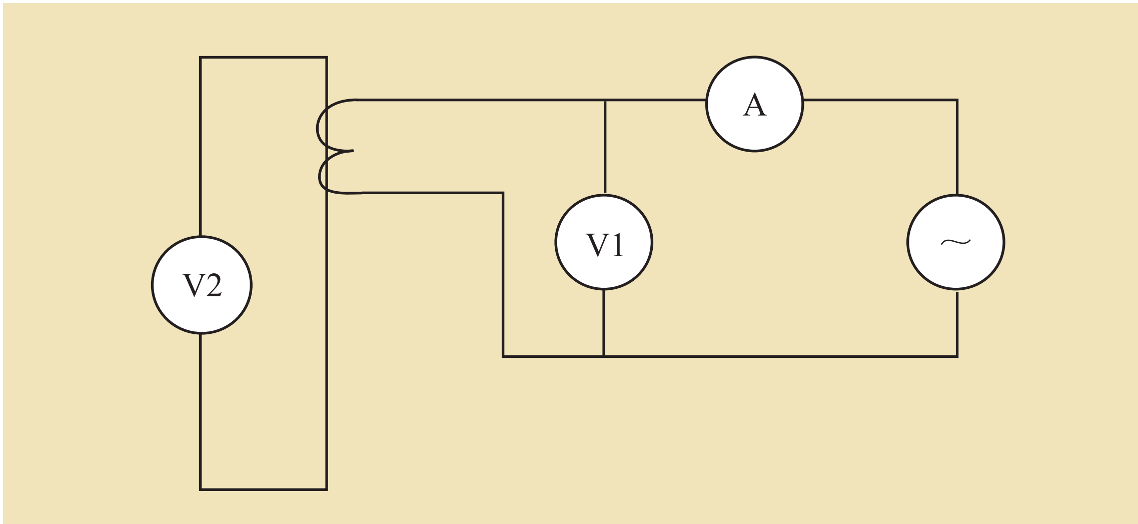


Figure - 14

Apply voltage from secondary of the CT and measure voltage in primary winding. Increase voltage in secondary up to rated KPV/ ISF and by recording Primary Voltage, compute ratio of V1/ V2. The ratio should match with the specified value.

6.2.4 INSULATION RESISTANCE MEASUREMENT OF CURRENT TRANSFORMER

PRECAUTIONS

a) There should be no joints in testing cables.

b) Test leads should not touch any live part.

c) Megger body should be earthed (if separate terminal is provided).

d) Surface/terminals should be cleaned.

e) IR measurement should be carried out preferably in dry and sunny weather.

f) Never connect the test set to energized equipment.

g) The ground terminal must be connected first and removed at last.

h) High voltage plugs should be free from moisture during installation and operation.

i) If oil traces are found on the surface of CT, the same should be cleaned by Methyl Alcohol only. Petrol or diesel should never be used.

j) It should be ensured that whole testing equipment along with testing procedures are available at testing site. Testing must be carried out in presence of testing engineer only.

k) After testing with high voltage, test terminals must be grounded before being touched by any personnel.

l) Test leads should be properly screened/ shielded.

Connect the Megger as per figure-15 given below. Connect the HV terminal to the Primary terminal of CT by using crocodile clip for firm grip

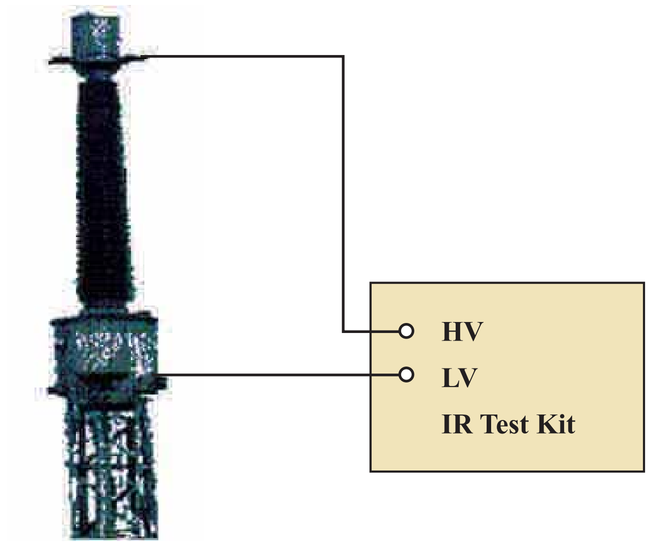


Figure-15 Typical Arrangement for IR measurement

Carry out the measurement as per standard procedure given by the kit supplier.

A test voltage as specified is applied as per the above connections and successive readings are taken. Values of IR should be recorded after 15 seconds, 60 seconds and 600 seconds. Ambient temperature and weather conditions are to be recorded.

6.2.5 DGA Test of CT Oil: Oil samples to be collected in 300ml bottles and to be sent to CIOTL Hyderabad for testing. Test results should be comparable to factory values. In case of any deviation, test results to be forwarded to CC-OS for approval.

6.3 CHECKS/ TESTS APPLICABLE FOR CIRCUIT BREAKERS

6.3.1 DEW POINT MEASUREMENT OF SF6 GAS FOR CIRCUIT BREAKER

Dew Point is the temperature at which moisture content in SF6 gas starts condensing.

Dew Point at rated pressure of CB: Dew Point when measured keeping regulating valve in service at the outlet of dew point kit to allow required flow rate of gas, is called at rated pressure of CB. Inlet valve is opened completely.

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

TESTING PROCEDURE

a) Make the connections to the kit from CB pole ensuring that regulating valve is fully closed at the time of connections of the Dew Point kit.

b) By regulating the flow rate of SF6 gas (0.2 liter/min to 0.5 liter/min - ref. IEC 60480), the value of dew point is observed till it becomes stable.

c) If the regulating valve is provided at outlet of the dew point kit then values as given in Doc. no. for rated pressures are to be monitored.

Dew Point of SF6 gas varies with pressure at which measurement is being carried out. This is due to the fact that Saturation Vapour Pressure decreases with increase in Pressure of the SF6 gas. Hence, dew point of SF6 gas at higher pressure is lower than dew point at atmospheric pressure Therefore, it is to be ensured that if measurement has been done at a pressure other than the atmospheric pressure, same is to be converted to the atmospheric pressure as given in the table below used at the time of commissioning for various CB manufacturers: Method for converting dew point at different gas pressures, is given/described in IEC-60480.

Sl. No.	Make of CB	Dew point at rated pressure	Dew point at Atmospheric Pressure (Limit)
1	BHEL	(-) 15° C	- 36° C
2	M & G	-	- 39° C
3	CGL	(-) 15° C	- 35° C
4	ABB	(-) 15° C	- 35° C
5	NGEF	(-) 15° C	- 36° C

6.3.2 MEASUREMENT OF CIRCUIT BREAKER OPERATING TIMINGS INCLUDING PRE INSERTION RESISTOR TIMINGS

PRECAUTIONS

a) There should not be any joint in testing cables.
b) Test leads should not touch any live part.
c) Never connect the test set to energised equipment.
d) The ground cable must be connected first and removed at last.
e) High voltage plugs should be free from moisture during installation and operation.
f) Circuit Breaker Analyser body should be earthed (if separate earth is provided).
g) It should be ensured that whole testing equipment along with testing procedures are available at testing site. Testing must be carried out in presence of testing personnel only.
h) Surface/terminals should be cleaned where the connections for testing are to be made.
i) Clean earth point with sand paper/wire brush where earth terminal is to be provided.
j) Ensure that all the poles trip simultaneously through single close/trip command.

TESTING PROCEDURE

a) Make connections as shown in the figure-16 below. It is to be ensured that R, Y, B phase marking cables are connected with the proper place in the CB analyser and colour codes are to be maintained for all the three poles of CB.
b) Make connections for recording operating timings of Auxiliary contacts.
c) Extend power supply to Circuit Breaker Analyzer.
d) Give closing command to closing coil of CB and note down the PIR and main contact closing time. Take the print out from the Analyzer.

e) Give tripping command to trip coil-I of CB & note down the main contact tripping time.

f) Give tripping command to trip coil-II of CB & note down the main contact closing time.

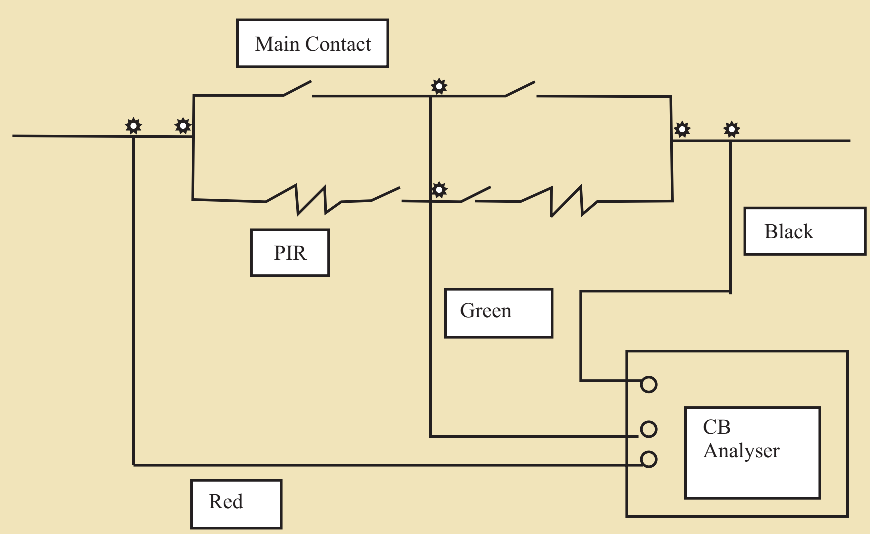
g) Note down the timings for `CO', and `OCO' by giving respective commands. CO command to be given without time delay but 300ms time delay to be given between O and CO operation in testing for OCO.

h) To find out opening time of PIR contacts, PIR assembly has to be electrically isolated from Main contacts and then PIR contacts are to be connected to separate digital channels of the Analyzer.

EVALUATION OF TEST RESULTS

A) CLOSING TIMINGS

Closing timings and Discrepancy in operating times of PIR and main contacts should not exceed the permissible limits as specified in the DOC NO: D-5-02-XX-01-03. In any case, main contacts should not close prior to closing of PIR contacts and PIR contacts should not open prior to closing of main contacts. In case, contact bouncing is observed in operating timings for PIR and main contacts, same should be rectified by tightening the cable connections.



Typical Arrangement for Operating Timings Measurement of CB

Figure - 16

B) TRIPPING TIMINGS

Trip time and pole discrepancy in operating timings should not exceed beyond permissible value given in Doc. No. D-5-02-XX-01-03. In case of ABB, NGEF and CGL make CBs, while tripping, PIR contacts should not open after opening of main contacts.

C) 'CO' TIMINGS

CO timings should be within permissible limits as specified by different manufacturers.
If operating timings of CB poles are not within limits, same may be corrected by:

1. Equalizing the SF6 gas pressure in all the poles
2. Adjusting plunger movement of trip/ close coils
3. Adjustment in operating mechanism
4. Changing of trip/ close coils (if required)

It is also important to measure timings of auxiliary contacts from the point of view of variations w.r.t. the main contacts.

6.3.3 DYNAMIC CONTACT RESISTANCE MEASUREMENT (DCRM) AND CONTACT TRAVEL MEASUREMENT OF EHV CIRCUIT BREAKERS

Test Equipment: 100 Amp. DCRM kit with CB operational analyzer with 10k Hz sampling frequency.

Isolation Required

a) CB should be in open position.

b) Isolator of both sides of CB should be in open position.

c) Earth switch of one side of CB should be in open position.

Precautions

a) There should be no joints in testing leads/cables.

b) It should be ensured that whole testing equipment along with testing procedures are available at testing site. Testing must be carried out in presence of testing personnel only.

c) Current leads should be connected such that voltage leads are not outside area of current flow.

Testing Procedure

1. Follow the standard procedure as given in instruction manual of DCRM kit.
2. The tightness of connections at CB flanges is most important to ensure error free measurement. CB during CO operation generates lot of vibrations and failure of connections during this period can dramatically change the dynamic signature of CB resistance.
3. DCRM signatures should be recorded for CO operation. Open command should be extended after 300 ms from the close command.
4. Clean portions of incoming and outgoing flanges of CB with polish paper to remove paint, oxidation etc, at points where Current clamps are mounted.
5. Select this point of connection, as close as possible to the end of porcelain insulator to ensure that minimum resistance is offered by flanges, bolts, terminal connectors etc.
6. It should be ensured that Travel Transducers are properly fitted.
7. Sampling frequency during measurement should be 10 KHz.
8. Resistance, travel, injected current and Trip/ Close coil currents are to be recorded.

The variations in the measured resistance versus time will be seen as a finger print for the breaker contacts and can be used as a bench mark for comparing with future measurements on the same breaker. This provides information on the condition of the breaker contacts, driving mechanism, operating levers etc.

Dynamic Contact Resistance Measurement for CB healthiness

By application of Dynamic Contact Resistance Measurement, condition of arcing contact, main contact, operating levers, driving mechanism can be predicted. If DCRM signature shows vide variations and also there is change in arcing contact insertion time, it indicates erosion of the arcing contacts to main contacts and subsequent failure.

Contact Travel Measurement

Transducers are attached to the operating rod or interrupting chamber in order to record the contact travel. When CB closes, contact travel is recorded. Contact bounces or any other abnormality is also clearly indicated by the Contact Travel Measurement.

If contact travel, contact speed and contact acceleration signature are compared with the original signatures, then it may indicate problems related with the operating mechanism, operating levers, main/ arcing contacts, alignments etc.

DCRM along with Contact Travel measurement is useful in monitoring length of Arcing contacts. Erosion of Arcing contacts may lead to commutation failures and current may get transferred to Main contacts. Due to heat of arc, main contacts may get damaged.

6.3.4 OPERATIONAL LOCKOUT CHECKING FOR EHV CIRCUIT BREAKERS

6.3.4.1 TESTING PROCEDURE:

A. SF6 GAS PRESSURE LOCKOUT

a) LOW PRESSURE ALARM

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

b) OPERATIONAL LOCKOUT:

Continue releasing SF_6 gas from isolated zone till the operational lockout Alarm Contacts are actuated which are detected by Multimeter. Note down the pressure and temperature at which the contacts get actuated. This is called operational lockout pressure.

B. PNEUMATIC OPERATING SYSTEM LOCKOUT

a) COMPRESSOR START/STOP SWITCH

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

b) CB AUTO RECLOSE LOCKOUT

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

c) CB CLOSING LOCKOUT

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

d) CB OPERATIONAL LOCKOUT

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

e) MECHANICAL CLOSING INTERLOCK (FOR ABB & BHEL CBs ONLY)

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

C. HYDRAULIC OPERATING SYSTEM LOCKOUT

a) Pump START/STOP

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

b) CB AUTO RECLOSE LOCKOUT

Close Isolation valve between hydraulic system and pressure switches. Release oil from the isolated zone to oil tank. Note down pressure at which A/R L/O contacts of pressure switch get actuated which are detected by Multimeter.

c) CB CLOSING LOCKOUT

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

d) CB OPERATIONAL LOCKOUT

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

D. OPERATING PRESSURE DROP TEST:

For Pneumatic/ Hydraulic operating system, operating pressure drop test to be performed during OCO operation of CB, keeping AC supply of Hydraulic pump/ Compressor in off condition. Hydraulic/ Pneumatic pressure drop should be within limits (as recommended by Manufacturer)

6.3.4.2 EVALUATION OF TEST RESULTS

A. SF6 GAS PRESSURE LOCKOUT

All the SF6 gas pressure switches settings should be checked and corrected with ambient temperature. Settings of SF6 gas pressure switches should be within ± 0.1 bar/ Kg/cm^2 of the set value (after taking into account the temperature correction factor).

B. AIR PRESSURE LOCKOUT

All the air pressure switches settings should be checked and corrected and should be within ± 0.3 bar/ Kg/cm^2 of the set value.

C. OIL PRESSURE LOCKOUT

All the oil pressure switches settings should be checked and corrected and should be within ± 0.3 bar/ Kg/cm^2 of the set value.

6.3.5 MEASUREMENT OF STATIC CONTACT RESISTANCE

The Static contact resistance of main circuit of each pole of a circuit breaker is of the order of a few tens of micro ohms. 100 A DC is injected and milli volt drop is measured across each CB contact to compute contact resistance. The values should be within specified limits.

6.3.6 CHECKING THE ANTI-PUMPING FEATURE

When the breaker is in open position and closing and opening commands are given simultaneously the breaker first closes and then opens, but does not reclose even though the closing command is maintained.

6.3.7 CHECKING THE ANTI-CONDENSATION HEATERS

Check the supervisory circuit of the anti-condensation heaters for correct functioning. With the heaters switched ON, measure their current output.

6.3.8 POLE DISCREPANCY RELAY TESTING

Pole Discrepancy is defined as the difference in closing & opening timings of different poles of CB.

A. WHEN CB IN OPEN POSITION

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

B. WHEN CB IN CLOSED POSITION

Tripping Command is extended to trip one pole, say R-Pole, of CB. Remaining Y and B- Poles of CB should automatically open after 2.5 seconds. Repeat the same test for remaining two poles of CB.

C. EVALUATION OF TEST RESULTS

Permissible value of pole discrepancy between two poles of CB is 3.33 msec. from system point of view and it should not be confused with the setting of pole discrepancy timer which is generally 1.0 or 2.5 sec. depending on Auto-reclose scheme.

6.3.9 CHECKING THE NITROGEN PRIMING PRESSURE

Close the pressure release valve. Shortly after the oil pump starts, the priming pressure (200 bar at 20 °C) in the accumulator can be read. The relationship between the pressure and temperature is indicated in Fig. 17.

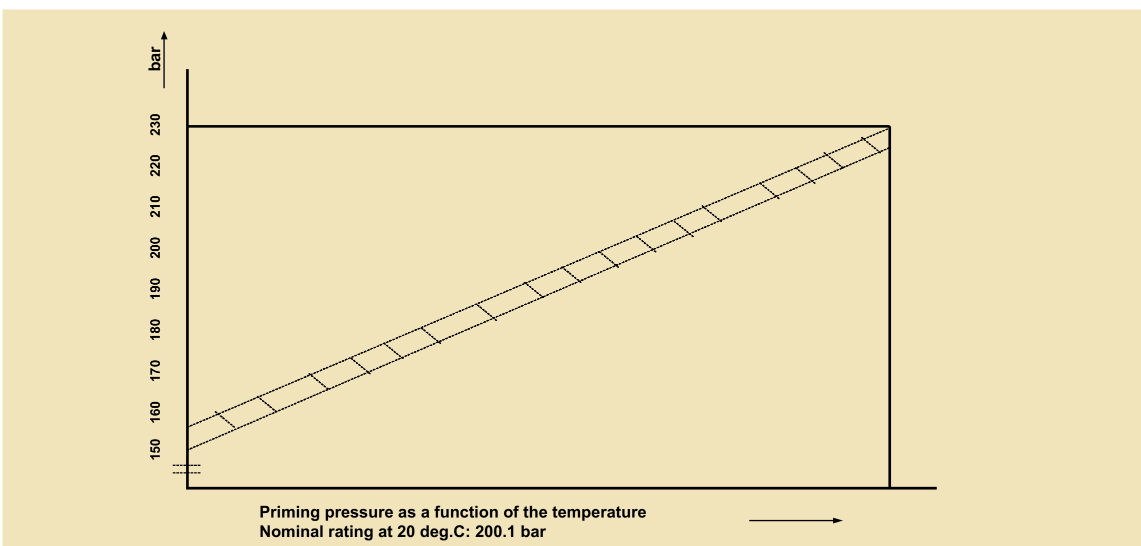


Figure - 17

6.4 CHECKS/ TESTS APPLICABLE FOR CVTs

6.4.1 CVT POLARITY, RATIO TEST

CVT polarity is checked in the same manner as for CT, taking care to ensure that the battery is connected to the primary winding. In case of star/star winding configuration care has to be taken to ensure that the primary and secondary neutral points are not connected together. It is necessary to verify that the phase rotation sequence of the 3 phase CVT is correct. The secondary voltage between phases and neutral are measured and then phase rotation meter is connected across the three phase terminal.

6.4.2 INSULATION RESISTANCE MEASUREMENT OF PRIMARY & SECONDARY WINDING

6.5 CHECKS/ TESTS APPLICABLE FOR ISOLATORS

6.5.1 MILLI VOLT DROP TESTS

The milli volt drop across the isolator is measured using DC current. The voltage drop gives a measure of resistance of current carrying part and contacts.

The DC current should be equal to or more than 100 A. The resistance of isolator should be measured at ambient air temperature. The temperature of specimen/environmental temperature should be recorded. The value of measured resistance should be converted to the value of temperature at which factory test results are taken. Temperature corrected value of resistance should be comparable to the factory value.

6.5.2 50 OPERATION TESTS

6.6 CHECKS/ TESTS APPLICABLE FOR SURGE ARRESTERS

6.6.1 MEASUREMENT OF THIRD HARMONIC RESISTIVE CURRENT FOR SURGE ARRESTERS

Testing Procedure

a. Make the connections as per the diagram given below (Fig.18)
b. The kit should be properly earthed.
c. Clamp On type CT should be placed above the surge monitor to pick up the total leakage current.
d. Carryout the measurements as per standard procedure supplied by the test kit manufacturer.
e. Note down the system voltage and ambient temperature along with the test current value.
f. Avoid measurement during monsoon.

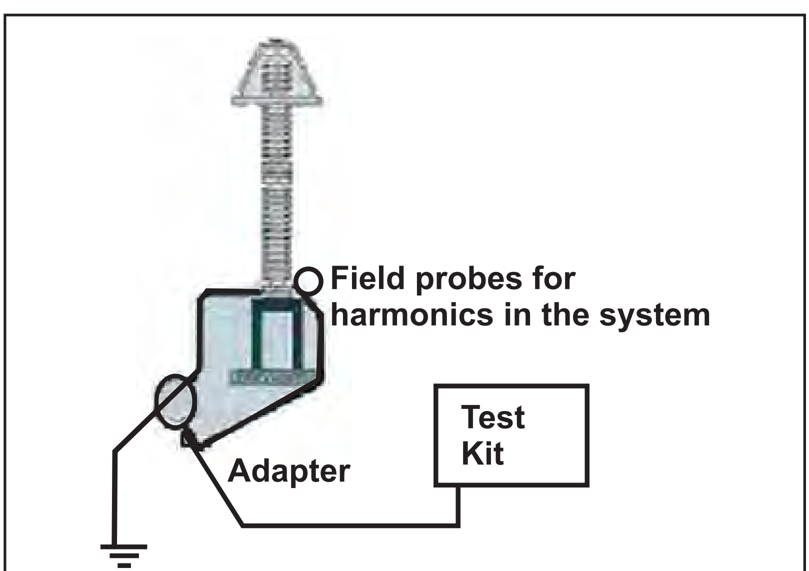


Figure- 18 Typical arrangement for THRCM Test

EVALUATION OF TEST RESULTS

A. ZnO Surge Arrester continuously conducts a small leakage current (Fig.19). The resistive component of this leakage current may increase with time due to different stresses causing ageing and finally cause arrester failure.

B. If Harmonics are present in the system voltage, it affects the value of measured third harmonic current. Compensating device provided to be used to nullify the effect. The value of Third Harmonic Resistive current shall be less than 30 μA

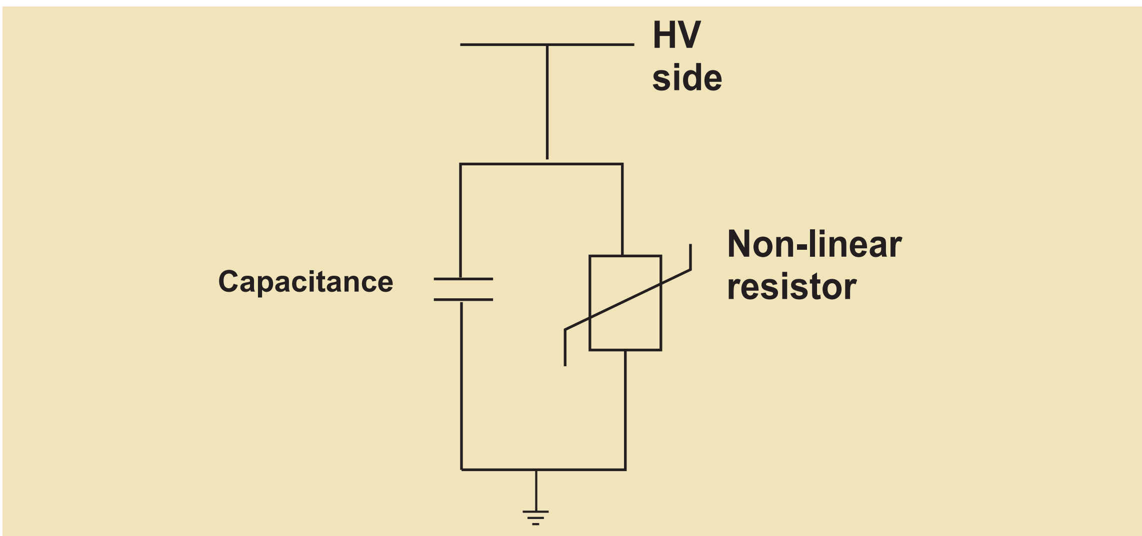


Figure-19 Arrester equivalent circuit

6.7 CHECKS/ TESTS FOR OTHER AREAS/ EQUIPMENTS

6.7.1 EARTH RESISTANCE MEASUREMENT

Normally Earth tester is used for measuring

(a) Soil resistivity

(b) Earth resistance

a. Prior to the testing of soil resistivity and earth resistance the operation manual of the testing instrument available at site may be referred for procedures to be adopted for measurement of soil resistivity and earth resistance.
A typical earth tester has 4 terminals. C1, P1, C2, P2 and 4 similar electrodes are driven in the ground at equal distances and connected to the instruments in the order of C1, P1 and P2, C2. Then the handle is rotated or button is pressed and the reading of the resistance is read on the scale of the instrument. If R is the resistance measured then

Specific Resistivity = $2\pi a R$

Where 'a' is the distance between the electrode

And R is the resistance in ohms measured on the earth tester.

b. In order to measure earth resistance of the electrode of the substation, it could be connected to C1 and the value of R could be read in the scale with the rotation of the handle of the Insulation tester. This will give the earth resistance. The value as far as possible should be around 1 ohm. To improve the value, water should be spread at the earth pit.

6.7.2 SECONDARY CURRENT INJECTION TEST SETS

The primary test is essential when commissioning and new installation as a test the whole protection system and will detect current transformers connected with incorrect polarity or relays that have been set in the wrong sequence in differential system. Secondary current injection sets are very useful for conducting these tests. The standard secondary current injection test equipment consists of a 1/5 A current injection set, separate wave form filter unit and a digital counter. The equipment is designed in a portable kit for on site testing of protecting devices, circuit breakers, trip coils, motor overloads, and similar apparatus. The filter unit should be used when testing saturating core type relays to ensure that the test current has a substantially sinusoidal waveform. The typical test setup is shown in fig. 20. Details of the testing will be elaborated in the relay testing.

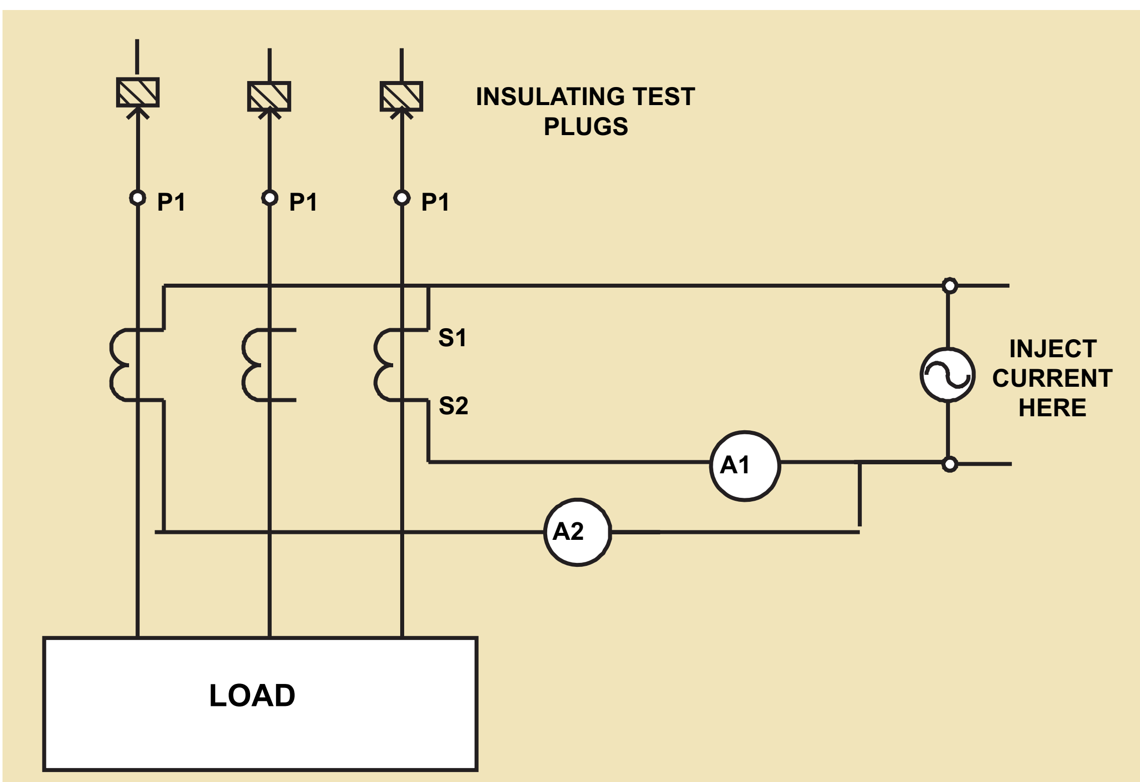


Figure - 20

6.7.3 CONTACT TIGHTNESS TEST OF BAY CONTACTS:

a. Isolate the Bay from Bus –Side and line side as shown in Fig.-21.

b. Ensure that all the secondary cores are connected or short if not in use.

c. Inject the Current at Point 1 (200A) from primary injection kit (w r t earth) and return current via earth point at 2 as shown in Fig.-21.

d. Check that we are able to inject current at point 1 and measure the current at point 2.

e. Injection of current is the indication of contact tightness.

f. Repeat the procedure for point 1 & 3

g. Repeat the procedure for point 1 & 4

Note: Above tests can be aborted if individual contact resistances are within satisfactory limit and physical phase checking is satisfactory.

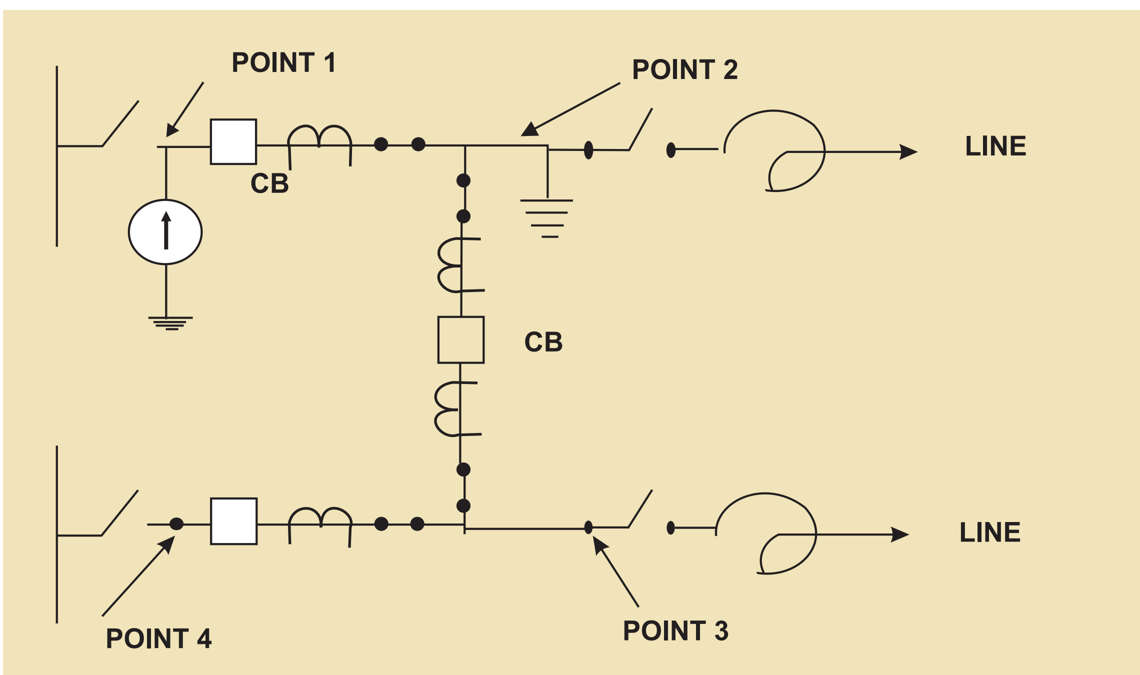


Figure-21 : Primary injection test to check contact tightness of Bay/ feeders

CHECKS/TESTS FOR BUS BAR PROTECTION

Types of bus bar protection
a) High impedance
b) Low impedance

7.1 High Impedance protection

The High-impedance protection scheme, is a good solution for single busbar arrangements, 1 ½ breaker systems or ring Busbars, provided that appropriate dedicated CT cores are available for this use alone.

Sensitive, stable and fast protection for single busbar arrangements and 1 ½ breaker systems.

Eg: RADHA (ABB), FAC 34 (EE), PBDCB (EE), PBLSB (EE)

7.1.1 Types of High impedance protection schemes

Two main protections with CT supervision feature

Main & check zone scheme

a) Two main protections

Generally used where direct measurement is possible without switching of the CT circuits

Trip command will be issued on operation of any one of the main protection.

b) Main & check zone scheme

Have highest degree of security in the form of check zone, generally used where CT switching is required through auxiliary contacts of isolator (like 220kV DMT scheme)

For a double busbar arrangement, two different high impedance units are required. In this case, the current must be switched between the two different measuring units by connecting auxiliary switches to the busbar isolator contacts.

In some cases the auxiliary switches did not operate correctly. This caused the busbar Protection to trip the busbar. For this reason, a safety precaution was introduced: An overall Check-Zone unit, fed from individual CT cores. This overall scheme does not include any switching of CT and therefore is more secure.

The TRIP command is only issued when both a discriminating and check-zone system Operates.

The relay coil will be designed as voltage measuring device consuming negligible current.

$V_f = I_f (Rct+2.Rl)$
$V_k=2V_f$

Paralleling CT current should be done at CT marshalling boxes.

7.1.2 CT requirements for High impedance protection system

- **Knee point voltage requirement of the CT will be high**
- CT core shall be dedicated to the High-impedance Busbar Protection Scheme (i.e. cannot be shared with other protection relays)
- CT Must have identical turns-ratio (CT Ratio) (Aux.CT for ratio corrections not acceptable)
- Shall have a low resistance of the secondary windings
- Shall have a minimum knee-point voltage of approx. 300-500V.
- Should have a low magnetising current (few milliamps)

7.1.3 Supervision of the CT circuits

Any interruption of CT currents up to the point of parallel connection can cause instability during external faults even though their degree of unbalance is with in the limits during normal operation. Hence supervision scheme for CT wire are required.

Supervision relay should be provided across each phase for each zone.

It will block the current passing through the differential relay by shorting the CT terminals

General setting of the CT supervision relay is 10% of the lowest circuit rating.

Calculation of typical settings for bus bar differential protection

CT ratio:	: 2000/1
CT resistance:	: 10 Ohms
Max. bus fault MVA	: 10000 MVA
Max. fault current	: $10000x10^6/1.732*400000 = 14434$ A
Fault current in secondary	: 7.217A
Voltage setting of the relay	: V_f or $V_S = I_f(R_{ct}+2R_L)$

Lead resistance of 1000m, 2.5sq.mm copper wire is 7.28 ohms

Assume 500m of lead length

Vs= 7.217* (10+2*7.28/2) =124.7V

Nearest available setting can be adopted for the relay

7.2 Low Impedance bus bar scheme

The most suitable protection scheme for Double and multiple busbar Systems (with or without transfer bus) with feeders being switched between sections of the busbar, which operates with full selectivity for all possible busbar configurations.

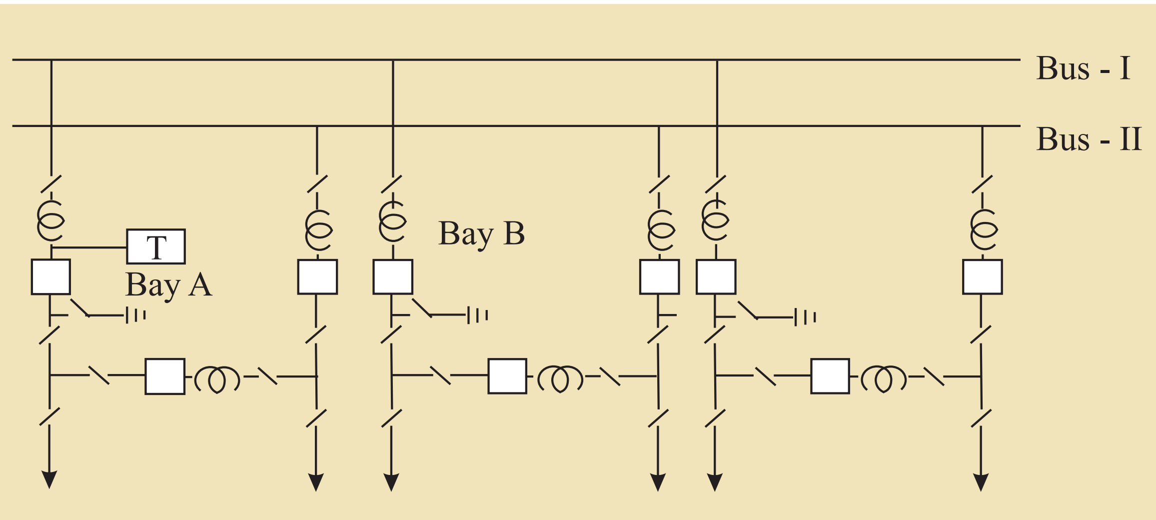
Free of any need for matched CT characteristic or ratios, low leakage reactance or resistance.

Other protective relays can be included in the same circuit.
Stable for infinite fault level.
Insensitive to CT saturation.

All the CT wiring will be routed to relay either directly or through aux. relay.

Eg: RADSS (ABB), MBCZ (EE)

7.3. Primary injection and bus bar differential stability test (New Substation)



1. Take one of the bays (A) as the reference

2. Select other bay (B) for testing the differential stability. Inhibit the tripping of the breaker in bay **B** from control room due to operation of distance or over current protection caused by primary current injection, if the earthing has been made after the breaker by using earth switch.

3. Earth the bus bar after CT using local earth or nearby earth switch on bay **B** to provide return path for the current.

4. Ensure bus bar is earthed only at bay **B**

5. Inject primary current using primary current injection test kit across one phase (e.g.R Phase) and ground; don't use other phase as return path for the current.

6. Measure the current at both CT marshalling boxes and voltage across differential relay terminals incase of high impedance differential protection.

7. Measure currents before and after aux. CTs and at relay terminals, incase of low impedance differential protection is being installed.

8. The measured spill voltage/current at relay terminals should not be more than 2%.

9. If the spill voltage/current is more (almost twice the CT secondary current) at the relay terminals, stop injecting the primary current and then reverse the secondary terminals of CT at bay **B.**

10. Start injecting primary current and measure the current at both CT marshalling boxes and at the relay terminals at control room and observe the spill current/ voltage magnitude less than 2%.

11. Stop injecting primary current and then create in-zone fault on primary side (by providing earthing between the two CTs) and start injecting primary current and Measures the current at both CT marshalling boxes and at the relay terminals at control room and observe the spill current/ voltage of considerable magnitude corresponding to the injected primary current. (a pictorial example is attached herewith at Annexure)

12. After ensuring the above stop injecting the current. The CT connection should be as per polarity thus proved.

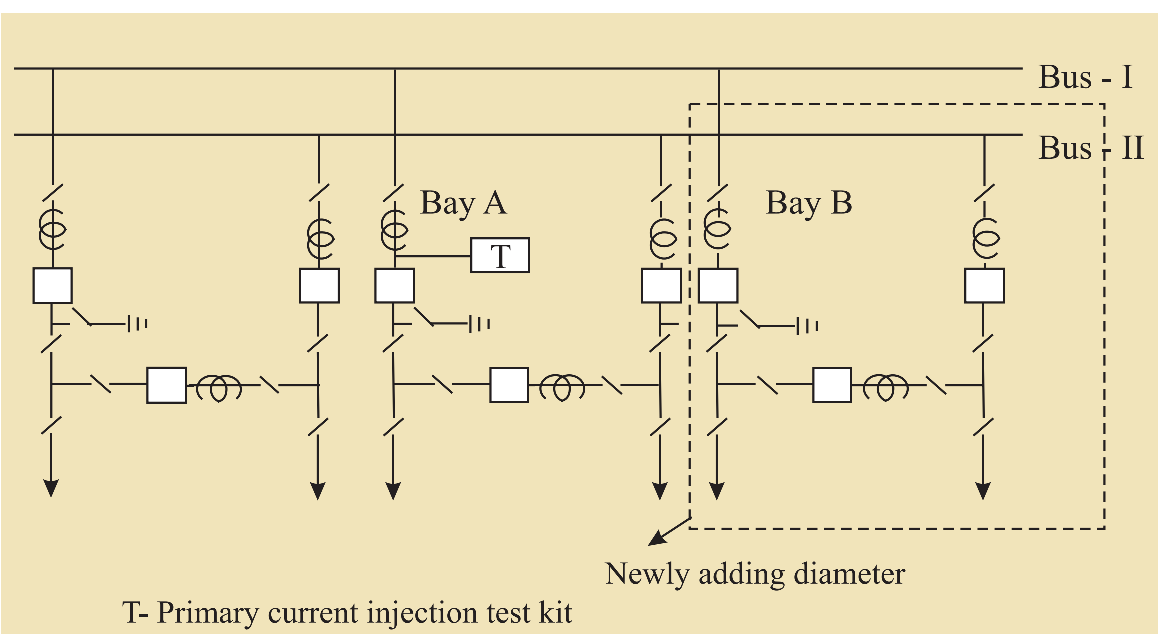
13. Repeat the test for other two phases.

14. Repeat the same procedure for other bays of the same bus bar by taking adjacent bus bar stability checked bay as the reference bay in order to inject max. possible current in the primary using primary injection test kit.

15. Repeat the above procedure for other bus bars also.

16. Above said procedure shall be carried out between Phase-Phase (R-Y &Y-B) by injecting in one phase and joining with other phase for using it as return path instead of earth return for one set of CTs (Two bays).

7.4. Primary injection and bus bar differential stability test (Bay Extension in the old substation):



1. Arrange the shutdown of the bus barunder test
2. Consider one of the existing bays (A) as the reference
3. Short the CT cores used for the other protections (like LBB, distance or differential or O/C or metering, etc), at CT MB itself, no CT core shall be in open condition.
4. Select one of new bays (B) for testing the differential stability and inhibit the tripping of the breaker from control room due to operation of distance or over current caused by primary current injection.
5. Earth the bus bar after CT using local earth or nearby earth switch on bay **B**.
6. Ensure bus bar is earthed only at bay **B**
7. Inject primary current using primary current injection testing kit across one phase (eg.R Phase) and ground; don't use other phase as return path for the current.
8. Measure the current at both CT marshalling boxes and voltage across differential relay terminals incase of high impedance differential protection.
9. Measure currents before and after aux. CTs and at relay terminals, incase of low impedance differential protection is being installed.
10. The measured spill voltage/current at relay terminals should not be more than 2%.
11. If the spill voltage/current is more (almost twice the CT secondary current) at the relay terminals, stop injecting the primary current and then reverse the secondary terminals of CT at bay **B.**
12. Start injecting primary current and measure the current at both CT marshalling boxes and at the relay terminals at control room and observe the spill current/voltage magnitude less than 2%.
13. Stop injecting primary current and then create in-zone fault on primary side (by providing earthing between the two CTs) and start injecting primary current and measure the current at both CT marshalling boxes and at the relay terminals at control room and observe the spill current/ voltage of considerable magnitude corresponding to the injected primary current. (a pictorial example is attached herewith at Annexure)
14. After ensuring the above stop injecting the current. The CT connection should be as per polarity thus proved.
15. Repeat the test for other two phases.
16. Repeat the same procedure for other bays of the same bus bar by taking adjacent bay (whose stability check completed) as the reference in order to inject max. possible current in the primary using primary injection test kit.
17. Repeat the above procedure for other bus bars also.
18. Restore the system to normal conditions.

7.5 Scheme Checking of bus bar protection & DC trip logic. (New substation & Bay extension)

7.5.1 Two Main protection philosophy

1. Test the relay by secondary injection.
2. Check the tripping of the corresponding breakers and non tripping of other bus breakers and tie breakers.
3. Check initiation of LBB relays of the breakers corresponding to particular bus.
4. Check blocking of the bus bar protection on operation of CT supervision relay.
5. Ensure that operation of CT supervision relay should not initiate bus bar tripping.
6. Check initiation of bus bar tripping by operation of corresponding breaker LBB relays.(Back Trip feature)
7. a. Check the direct tripping scheme on operation of bus bar protection (only if tie breaker is in open condition)

   b. Direct trip signal should not go on operation of Bus bar protection if the Tie CB is in close condition.
8. Test CT supervision relays and ensure for triggering control panel annunciation and event logger triggering as per approved scheme.
9. Check bus bar IN/OUT switch for correctness of wiring as per the drawing.

7.5.2 Main and Check zone philosophy

1. Test the both main and check zone relays by secondary injection.
2. Ensure bus bar should not initiate tripping for operation of either main or check zone alone.
3. For checking the tripping scheme, bypass the check zone contact.
4. Check the tripping of the corresponding breakers and non tripping of other bus breakers and tie breakers.
5. Check initiation of LBB relays of the breakers corresponding to particular bus.
6. Check blocking of the bus bar protection on operation of CT supervision relay.
7. Ensure operation of CT supervision relay should not initiate bus bar tripping.
8. Check initiation of bus bar tripping by operation of corresponding breaker LBB relays.(Back Trip feature)
9. a. Check the direct tripping scheme on operation of bus bar protection (only if tie breaker is in open condition)

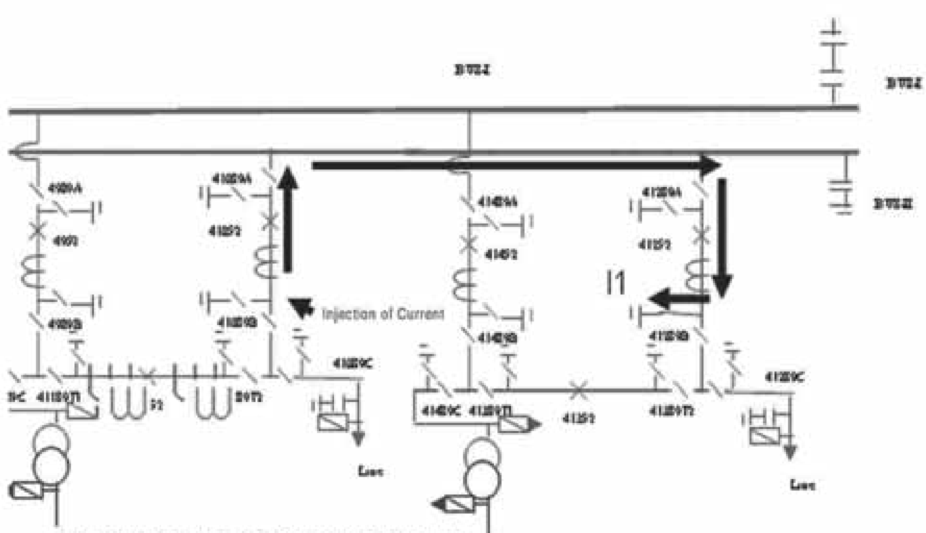
   b. Direct trip signal should not go on operation of Bus bar protection if the Tie CB is in close condition.
10. Test CT supervision relays and ensure for triggering control panel annunciation and event logger triggering as per approved scheme.
11. Check bus bar IN/OUT switch for correctness of wiring as per the drawing.
12. Repeat the above for check zone and CT supervision schemes.

7.6 AMP Testing of bus bar protection and scheme

1. Arrange bus bar shutdown for off line testing. Preferably the bus bar isolation should done through bus bar protection trip relay.
2. Insert the test block after shorting the incoming current terminals for on line testing.
3. Test the relays.
4. For off line testing:
   - i. Check tripping scheme of bus bar (2 main/ main and check scheme), in case of main and check scheme, operation of one relay should not initiate bus bar trip.
   - ii. Check initiation from LBB of corresponding bays of bus bar
   - iii. Check initiation of LBB of corresponding bays of bus bar
   - iv. Check annunciations and DR triggering as per the drawings
5. After completion of the above checks, normalise the connections and take bus bar into service.

CHECKING OF BUS BAR STABILITY

CONDITION 1- BUS –II EARTH SWITCH OPEN



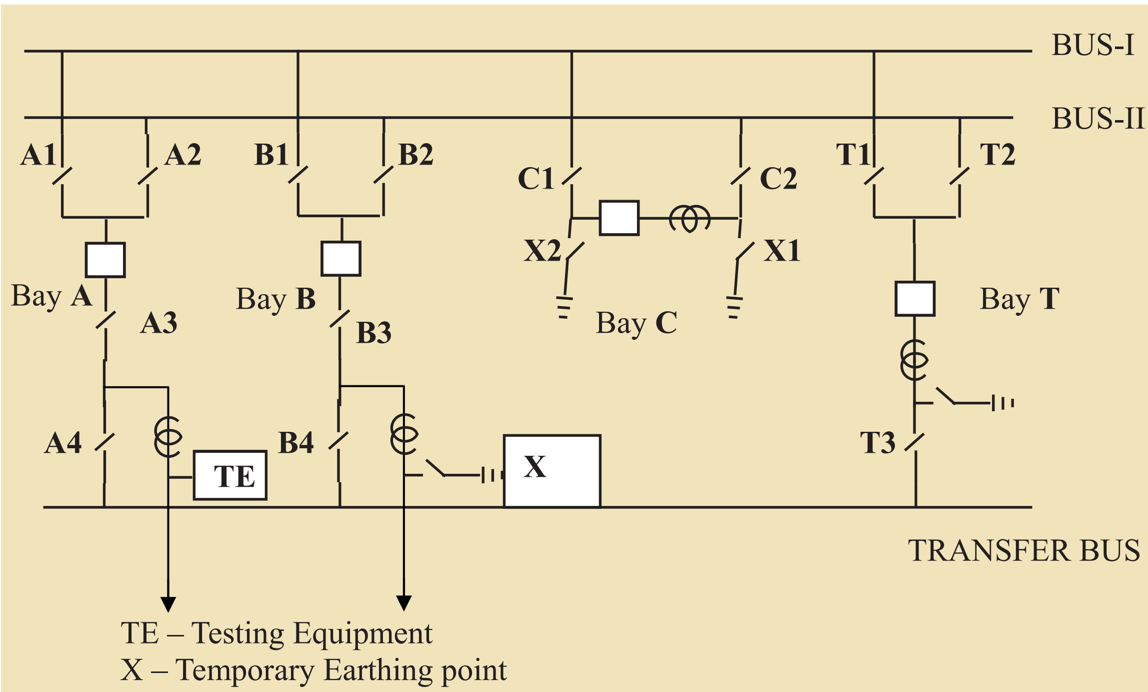
MEAUREMENT OF CURRENT

- Primary injected current = I 1(on single ph basis only)
- Secondary current for 410 CT for Ph & Neutral at
  - CT MB
- Secondary current for 412 CT for Ph & Neutral at
  - CT MB
- Relay diff current
  - As Summation of current is almost zero (Idiff= I1'-I1'),at relay current value should not more than spill

7.7 Double main transfer scheme (400kV/220kV):

For the double main transfer scheme, bus bar protection shall preferably be Main and check zone scheme because of dependency on CT switching between BUS-I & II bus bar protections.

7.7.1 Primary injection and bus bar differential stability test (New Substation):



1. Take one of the bays (**A**) as the reference
2. Select other bay (**B**) for testing the differential stability. Inhibit the tripping of the breakers in bay **A** and **B** from control room due to operation of distance or over current protection caused by primary current injection.
3. Earth the bus bar after CT at X using earth rods on bay **B**.
4. Preferably connect the primary injection testing kit to the CT terminal pad of reference bay (A) after opening the jumper from line side.
5. Ensure that bus or line connected to bay B shall not be earthed other than at X.
6. Close the isolators A1 in bay A, B1 in bay B and Ensure that corresponding CT switching relays operated for checking the bus bar differential stability of BUS-1.
7. Close isolator A3 and breaker in bay A and isolator B3 and breaker in bay B.
8. Measure the resistance of the CT cores (used for main and check zone) towards CT in the CT switching cubicle and it shall be equal to the sum of resistance of the CT core and lead resistance. If the resistance towards CT core is more, then check the CT circuit and corresponding CT switching relay.

9 Inject primary current using primary injection testing kit from bay **A**.

10. Measure the current at both CT marshalling boxes (both cores used for main and check zone) and relay terminals in the control room in case of low impedance protection or measure voltage across cores in CT MB and differential relay terminals incase of high impedance differential protection.

11. The measured spill voltage/current at relay terminals shall be very less compared to the primary current/corresponding voltage (around 2%).

12. If Spill current/voltage is more (almost twice the CT secondary current) at the relay terminals.

    a. Stop injecting the primary current and Check CT paralleling connections after the CT switching relay. If every thing is correct then reverse the secondary terminals of CT at bay **'B'.**

    b. Start injecting primary current and Measures the current/voltage at both CT marshalling boxes and relay terminals at control room and observe the spill current/ voltage magnitude shall be very less compared to the set value (around 2%).

13. Stop injecting primary current and then create in-zone fault in primary side (by providing earthing between two CTs).

14. Start injecting primary current and Measures the current at both CT marshalling boxes (both cores used for main and check zone) and at the relay terminals at control room and observe the spill current/ voltage of considerable magnitude corresponding to the injected primary current.

15. After ensuring the above stop injecting the current and normalize the system.

16. Open isolators A1 on bay A& isolator B1 on bay B and ensure that corresponding CT switching relay got resetted.

17. Close isolators A2 in bay A, B2 in bay B for connecting the feeder to bus-2 and ensure the operation of corresponding CT switching relay for checking the bus bar differential stability of BUS-2.

18. Repeat the above sequence from 9 to 16

19. Open isolators A2 on bay A& isolator B2 on bay B and ensure that corresponding CT switching relays got resetted.

20. Repeat the test for other two phases.

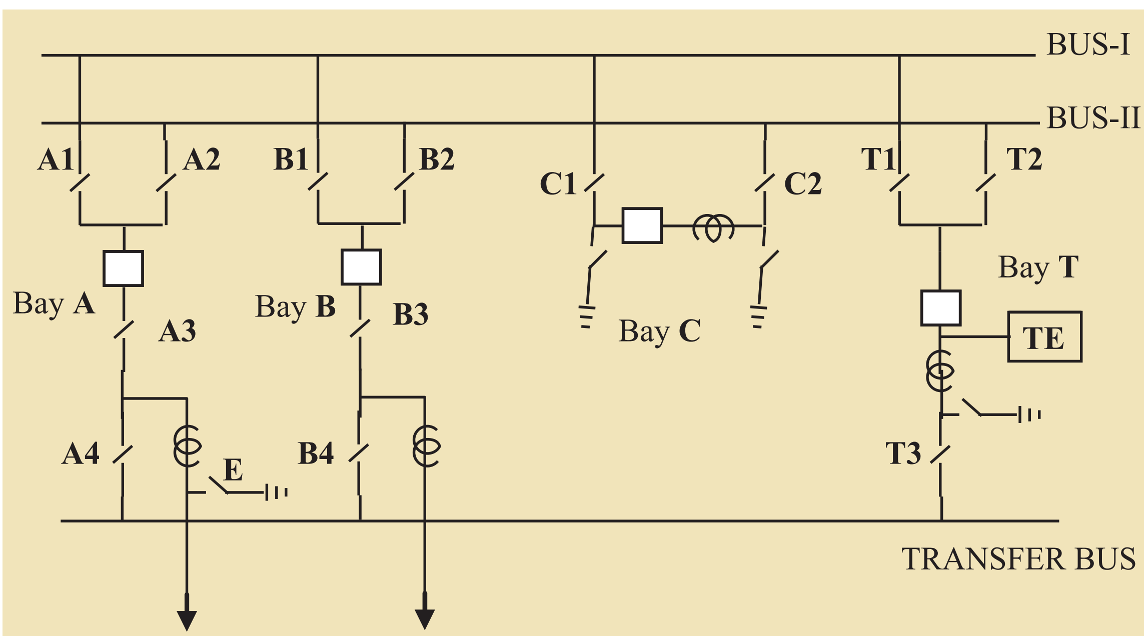
21. Above said procedure shall be carried out between Phase-Phase (R-Y &Y-B) by injecting in one phase and joining with other phase for using it as return path instead of earth return for one set of CTs (Two bays).

22. Repeat the same procedure for other bays including transfer bus coupler bay w.r.t Bus-I & II.

7.7.2 Checking of differential protection stability w.r.t bus coupler:

1. Take one of the bay A as the reference bay
2. Close isolator A1 in bay A to check differential stability of the bus coupler w.r.t Bus-1.
3. Close isolator C1 and breaker in bus coupler bay C and earth at X1 in bay C.
4. Adopt the same procedure as explained above for stability testing of normal bays.
5. Open breaker & isolators A1 in bay **A** and Open breaker & isolator C1 on bay C,
6. Close isolator A2 & breaker in bay **A** and isolator C2 & breaker on bay C to check differential stability of bus coupler CT w.r.t Bus - 2.
7. Earth bay C at X2.
8. Adopt the same procedure as explained above for stability testing of normal bays.
9. Open the breaker and isolator in bay A & bay C and open earthing on bay C and normalize the system.

7.7.3 Checking of differential protection stability w.r.t Transfer bus:



1. Before carrying out this test, ensure that differential protection stability with respect to Bus –I & Bus-II has been carried out on all bays including transfer bus coupler bay.
2. For checking the differential protection stability w.r.t to transfer bus, take one of the bays as reference bay and inject current from transfer bus coupler bay CT.
3. Close isolator T3 and breaker in transfer bus coupler bay T.
4. Close isolator A4 to check stability w.r.t transfer bus and ensure the operation corresponding CT switching relay.
5. Keep the normal/transfer switch of bay A in transfer mode.

6. Measure the resistance of the CT cores towards CT in the CT switching cubicle and it shall be equal to the resistance of the CT core and lead resistance. If the resistance towards CT core is more, then check the CT circuit and corresponding CT switching relay.

7. Inject primary current using primary injection testing kit from bay T.

8. Measure the current at both CT marshalling boxes and relay terminals in the control room in case of low impedance protection or measure voltage across cores in CT MB and differential relay terminals incase of high impedance differential protection.

9. The measured spill voltage/current at relay terminals shall be very less compared to the primary current/corresponding voltage (around 2%).

10. If Spill current/voltage is more (almost twice the CT secondary current) at the relay terminals.

    a. Stop injecting the primary current and Check CT paralleling connections after the CT switching relay. If every thing is correct then reverse the secondary terminals of CT at bay **'T' only while testing first bay.**

    b. Start injecting primary current and Measures the current/voltage at both CT marshalling boxes and relay terminals at control room and observe the spill current/ voltage magnitude shall be very less compared to the set value (around 2%).

11. Stop injecting primary current and then create in-zone fault in primary side (by providing earthing between two CTs)

12. Start injecting primary current and Measures the current at both CT marshalling boxes and at the relay terminals at control room and observe the spill current/ voltage of considerable magnitude corresponding to the injected primary current.

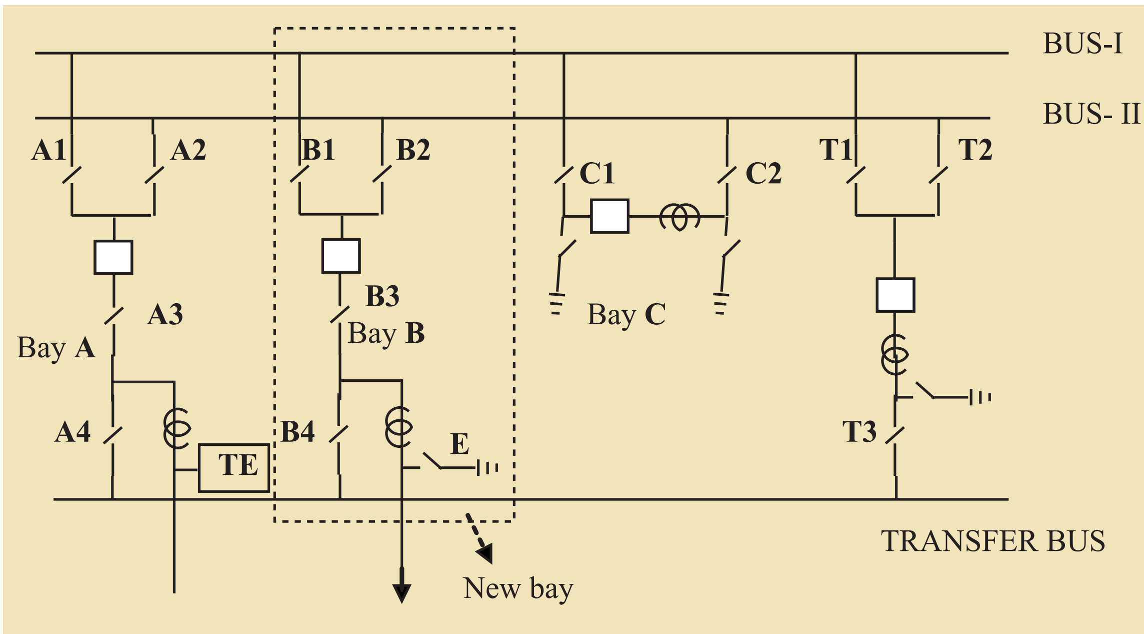
13. After ensuring the above stop injecting the current and normalize the system.

14. Open isolators and earthing which are closed for testing and keep N/T switches in normal position.

15. Repeat the test for other two phases.

16. Repeat the above procedure for other bays to ensure the operation of CT switch relay for transfer bus.

7.7.4 Primary injection and bus bar differential stability test for Bus-I (Bay extension in existing Substation)



1. Arrange the shutdown of the one of the existing feeder or take a bay which is already in out of service as reference bay (A).
2. Arrange shutdown of the bus bar (Bus-I).
3. Close the isolator of new bay B (B1) and ensure the operation of corresponding CT switching relay.
4. Measure the resistance of the CT cores towards CT in the CT switching cubicle and it shall be equal to the resistance of the CT core and lead resistance. If the resistance towards CT core is more, then check the CT circuit and corresponding CT switching relay.
5. Close the isolator B3 and breaker in bay B and isolators A1, A3 and breaker in bay A for connecting the CTs to Bus-I.
6. Inject primary current using primary injection testing kit from bay A.
7. Measure the current at both CT marshalling boxes (both cores used for main and check zone) and relay terminals in the control room in case of low impedance protection or measure voltage across cores in CT MB and differential relay terminals incase of high impedance differential protection.
8. The measured spill voltage/current at relay terminals shall be very less compared to the primary current/corresponding voltage (around 2%).
9. If Spill current/voltage is more (almost twice the CT secondary current) at the relay terminals:

a. Stop injecting the primary current and check CT paralleling connections after the CT switching relay. If every thing is correct then reverse the secondary terminals of CT at bay '**B'.**

b. Start injecting primary current and Measures the current/voltage at both CT marshalling boxes and relay terminals at control room and observe the spill current/ voltage magnitude shall be very less compared to the primary current/corresponding voltage (around 2%).

10. Stop injecting primary current and then create in-zone fault in primary side (by providing earthing between two Cts.

11. Start injecting primary current and Measures the current at both CT marshalling boxes (both cores used for main and check zone) and at the relay terminals at control room and observe the spill current/ voltage of considerable magnitude corresponding to the injected primary current.

12. After ensuring the above stop injecting the current and normalize the system.

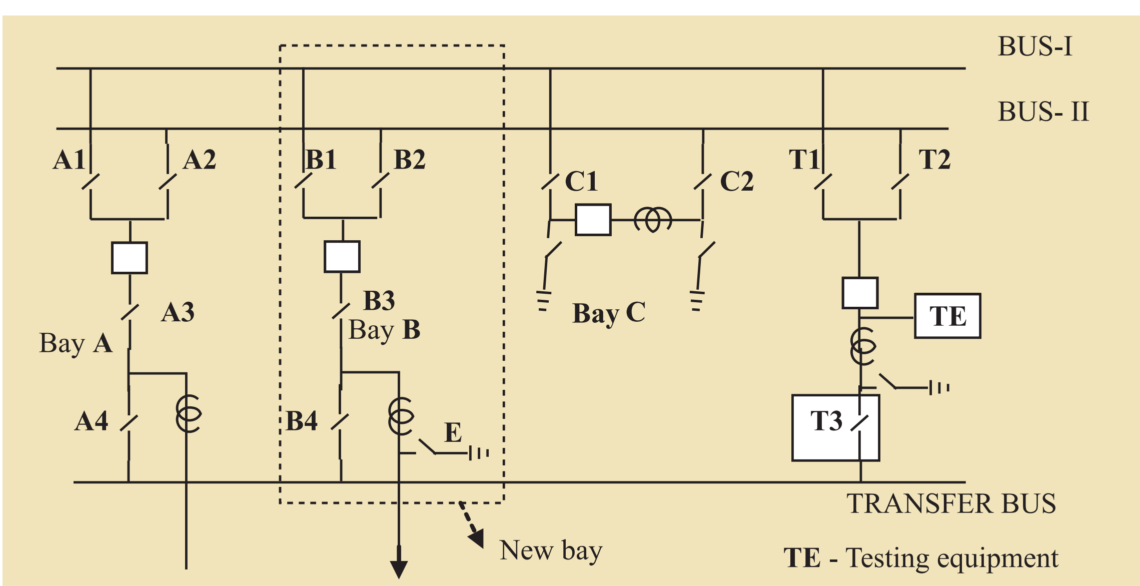
13. Open the breaker and isolator A1 in bay A and breaker and isolator B1 in bay B.

14. Repeat the above procedure for other phases.

15. Repeat the testing of the other newly adding bays (if any) taking this stability tested new bay (B) as the reference bay to avoid outage of old reference bay A for longer periods.

16. Repeat the above procedure of stability testing for new bay w.r.t. Bus-II by selecting of appropriate section (i.e. isolators A2 & B2) with Bus-II shutdown.

7.7.5 Primary injection and bus bar differential stability test w.r.t to transfer bus (Bay extension in existing Substation):



1. Arrange shutdown of transfer bus.
2. Take transfer bus T as reference bus.
3. Close isolator B4 and keep N/T switch in transfer position and ensure the operation of corresponding CT switching relay.
4. Measure the resistance of the CT cores towards CT in the CT switching cubicle and it shall be equal to the resistance of the CT core and lead resistance. If the resistance towards CT core is more, then check the CT circuit and corresponding CT switching relay.
5. Close isolator T3 and breaker in bay T.
6. Inject primary current using primary injection testing kit from bay T.
7. Measure the current at both CT marshalling boxes and relay terminals in the control room in case of low impedance protection or measure voltage across cores in CT MB and differential relay terminals incase of high impedance differential protection.
8. The measured spill voltage/current at relay terminals shall be very less compared to the set value (around 2%).
9. If Spill current/voltage is more (almost twice the CT secondary current) at the relay terminals.
   a. Stop injecting the primary current and Check CT paralleling connections after the CT switching relay.
   b. Start injecting primary current and Measures the current/voltage at both CT marshalling boxes and relay terminals at control room and observe the spill current/ voltage magnitude shall be very less compared to the set value (around 2%).
10. Stop injecting primary current and then create in-zone fault in primary side (by providing earthing between two CTs.
11. Start injecting primary current and Measures the current at both CT marshalling boxes and at the relay terminals at control room and observe the spill current/ voltage of considerable magnitude corresponding to the injected primary current.
12. After ensuring the above stop injecting the current and normalize the system.
13. Start injecting primary current and measure the current/voltage at relay terminals and ensure that its magnitude is very less compared to the primary current.
14. Open isolators and earthing which are closed for testing and keep N/T switches in normal position.
15. Repeat the test for other two phases.

7.8 Scheme checking of bus bar protection & DC trip logic. (New substation & Bay extension)

7.8.1 Two Main protection philosophy

1. Test the relay by secondary injection.
2. Check the tripping of the corresponding selected breakers and bus coupler breaker (in case of Bus-I & Bus-II only) and non tripping of other breakers.
3. Check initiation of LBB relays of the selected breakers corresponding to particular bus.
4. Check blocking of the bus bar protection on operation of CT supervision relay.
5. Ensure that operation of CT supervision relay should not initiate bus bar tripping.
6. Check initiation of bus bar tripping by operation of corresponding breaker LBB relays.(Back Trip feature)
7. Check the direct tripping scheme on operation of bus bar protection.
8. Test CT supervision relays and ensure for triggering control panel annunciation and event logger triggering as per approved scheme.
9. Check bus bar IN/OUT switch for correctness of wiring as per the drawing.

7.8.2 Main and Check zone philosophy

1. Test the both main (i.e. Bus-I, Bus-II and Transfer Bus) and check zone relays by secondary injection.
2. Ensure bus bar should not initiate tripping for operation of either main or check zone alone.
3. For checking the tripping scheme, bypass the check zone contact.
4. Check the tripping of the corresponding selected breakers and bus coupler breaker (in case of Bus-I & Bus-II only) and non tripping of other breakers.
5. Check initiation of LBB relays of the breakers corresponding to particular bus.
6. Check blocking of the bus bar protection on operation of CT supervision relay.
7. Ensure operation of CT supervision relay should not initiate bus bar tripping.
8. Check initiation of bus bar tripping by operation of corresponding breaker LBB relays.(Back Trip feature)
9. Check the direct tripping scheme on operation of bus bar protection.
10. Test CT supervision relays and ensure for triggering control panel annunciation and event logger triggering as per approved scheme.
11. Check bus bar IN/OUT switch for correctness of wiring as per the drawing.
12. Repeat the above for check zone and CT supervision schemes.

7.9 AMP testing of bus bar protection and scheme

1. Arrange bus bar shutdown for off line testing and scheme checking.
2. While switching all the loads from one bus to other bus observe the operation and resetting of corresponding CT switching relays in accordance to the operation of isolators.
3. CT switching discrepancy alarm shall not appear in the control panel.
4. Check tripping scheme of bus bar (2 Main/ Main and check scheme), in case of main and check scheme, operation of one relay should not initiate bus bar trip.
5. Check annunciations and DR triggering as per the drawings
6. After completion of the above checks, normalise the connections and take bus bar into service.
7. Insert the test block after shorting the incoming current terminals for on line testing.
8. Test the relays.