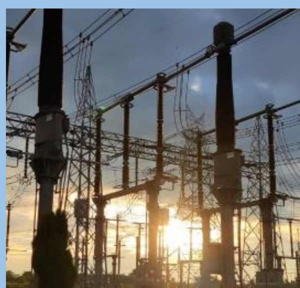
Pre-Commissioning Procedures and Formats for

Substation Equipment & Protection System



Power Grid Corporation of India Ltd.
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For Internal Circulation Only

Pre-Commissioning Procedures and Formats

for

Substation Equipment & Protection System

Corporate Asset Management

Power Grid Corporation of India Ltd.

Pre-Commissioning Procedures and Formats
for
Substation Equipment & Protection System

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01	CC/OS	05.11.1999	Sd/	Sd/
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Revision History

Sl.No.	Pages	Revision	Remarks
01	All Pages	06	Transformer, CSD configuration, Protection commissioning format revised

TABLE OF CONTENTS

PRE-COMMISSIONING PROCEDURES FOR SWITCHYARD EQUIPMENTS

1.1. Introduction

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 equipment along with associated auxiliary equipment.

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. Constitution of Pre-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 Chief Manager
(iii) T&C executive not below Dy.Manager

1.3. 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
b. line/bay equipment as per I.E. rules.
c. P.T.C.C. clearance.
d. Copy of notification informing public/administration regarding charging of the line.
e. 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)

1.4. 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 AM 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.

1.5. 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)

1.6. 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 AM, 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-AM and CC-AM for charging clearance and CC-AM shall give the final charging clearance after reviewing of the test results.

1.7. 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.

1.8. General Procedures during Pre-commissioning of Substation Bay 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.

1.9. 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-7	ICT
2.	No. CF/SR/02/ R-7	SHUNT REACTOR
3.	No. CF/CB/03/ R-7	CIRCUIT BREAKER
4.	No. CF/CSD/04/R-7	CSD
5.	No. CF/CT/05/ R-7	CURRENT TRANSFORMER
6.	No. CF/CVT/06/ R-7	CVT
7.	No. CF/BAY/07/ R-7	BAY/FEEDER
8.	No. CF/ISO/08/ R-7	ISOLATOR/GROUND SWITCH
9.	No. CF/SA/09/ R-7	SURGE ARRESTOR
10.	No. CF/WT/10/ R-7	WAVE TRAP
11.	No. CF/C&P/11/ R-7	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.

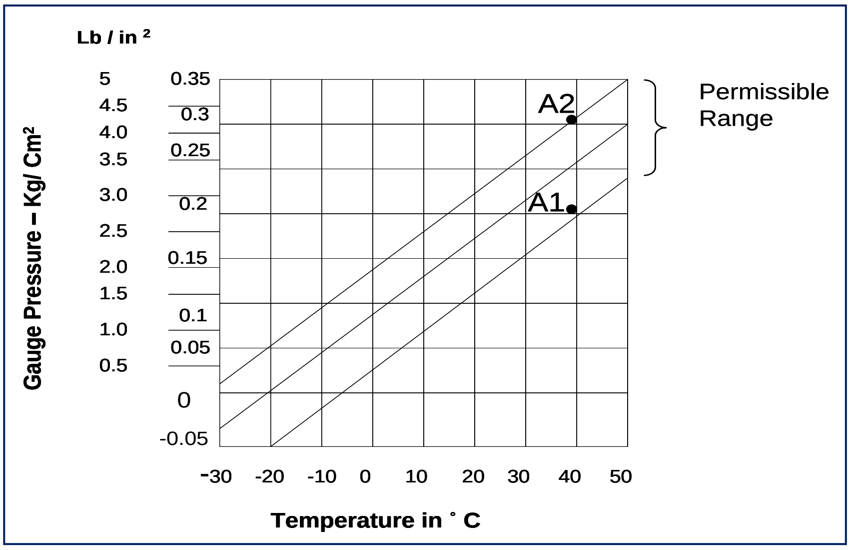
TRANSFORMER & REACTOR

SECTION-A

This section provides guidance & recommended practices for installation, testing & commissioning requirement for oil-immersed Power Transformer, Reactor with voltage rating 66kV above.

A.1.1 Checks on Arrival at Site:

A.1.1. Generally, Power transformers are transported with dry air/ dry N2 filled condition with necessary pressure gauge to monitor the drop in pressure during transit. Upon receipt of Transformer/Reactor at Site, pressure and dew point of N2/ dry air needs to be checked and can be compared with the value recorded at factory during dispatch. Generally, the gas pressure should remain positive even in the coldest weather. If the gas pressure is zero, there is a possibility that outside air and moisture may have entered the tank. In such case, the manufacturer should be notified. It can be assumed that the transformer has not been exposed to outside air or moisture during transit if the dew point of the gas indicates a relative humidity of less than 1 % and gas pressure should be within permissible band (as per graph provided by manufacturer & given below in Fig-1).



Graph-1: Variation of Pressure v/s Temperature of gas for gas filled unit during Transportation 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.

A.1.2. During transportation of the Transformer and reactors, these are fitted with Electronic impact recorders at least 2 numbers for 400 kV Class Transformer and 1 number for below 400 kV class Transformers/ reactors to measure the magnitude and duration of the impact in all three directions. Upon receipt at site, setting of impact recorder needs to be checked. In case of any abnormality, site needs to refer the matter to RHQ-AM/CC-AM:

Table-I: Impact Recorder Setting

Events	Setting	Events	Setting
Start recording	1g	Drop Out	1g
Warning	2g	Threshold	5g to 10g
Alarm	3g		

Acceptance criteria and limits of impact for the Transformer during transportation and handling in all three directions shall not exceed **"3g" for 50 milli Sec (20Hz)** or as per contractor standard, whichever is lower.

The data of impact recorder shall be analyzed jointly in association with the manufacturer. . Impact Recorder should be detached from the Transformer/ Reactor preferably when the main unit has been placed on its foundation.

In case the impact experienced by the Transformer/ Reactor is more than the above limiting value, then following are recommended:

i) The Core Insulation test shall be carried out.

ii) Thorough external and internal inspection to be carried out by site and OEM representative and observations to be recorded and photographs to be taken.

iii) SFRA of the unit to be carried out before oil filling and same has to be compared with factory SFRA (without oil filling).

iv) In case no abnormality observed in aforesaid tests, undertaking from OEM to be obtained for oil filling in equipment and proceed for pre-commissioning activity in consultation with RHQ-AM. All the observations along with undertaking from OEM may be attached with pre-commissioning format and to be forwarded to CC-AM.

v) In case of any abnormality observed in item i), ii) & iii) then matter is to be referred to CC-AM, CC-Engg and CC-QA&I for further course of action.

A.1.3. Core Insulation Test shall be carried out to check insulation between Core (CC &CL) and Ground. (Not applicable for Air Core Reactors).

A.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 is to be ensured after unpacking. Fragile instruments like oil level gauges, temperature indicators, etc. are to be stored indoors. Any damaged or missing components should be reported to the equipment manufacturer and insuring agency so that the same can be investigated or shortage made up as per the terms/ conditions of the contract.

A.1.2 Storage of the main unit and the accessories at site:

- If erection work cannot 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 dry air/ N2 filled condition. Dry air/ N2 pressure to be monitored on daily basis so that chances of exposure of active part to atmosphere are avoided. In case of drop in dry air/ N2 pressure, dew point of dry air/ N2 has to be measured to check the dryness of the Transformer/ Reactor. If there is drop in dew point, fresh dry air/ nitrogen need to be filled. Leaks are to be identified and rectified and dry air/ 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 with the required specification and ppm ≤ 5ppm and BDV ≥ 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 six 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.

A.1.3 Insulating Oil

Generally oil is supplied in steel drum, tankers or flexi bags. In case oil is supplied in drums then special precaution needs to be taken while handling at site. Seal of each drum needs to be checked while receipt at site. Suspected oil drums needs to be identified and shall be kept separately. Oil from these drums shall be tested for BDV, PPM and Tanδ for acceptance. 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. It is advisable to check the oil parameters from the oil drums/ tanker. In new commissioning of Transformer, it is the responsibility of the Contractor/ Manufacturer to check the oil parameters from the drums. While transferring oil from drum to tank, 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 transferred to each storage tank. It is mandatory to check oil parameters of each lot/ storage tank in nearest POWERGRID oil laboratory/ NABL accredited laboratory. In case of violation of oil parameters oil from the drum to be treated till the oil parameters are within limit.

Table-2: Desired parameters from the drum oil:

Parameters	Desired Value
BDV	> 50 kV
Water	< 40 PPM
Tan delta	< 0.0025 @ 90 °C

In case sample is collected by the Manufacturer from the oil drum, then precaution needs to be taken. 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 lower most 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. If the oil is delivered in 200 litres drums, the following scheme for checking is recommended, however in case of any doubt the number of drums may be increased.

Number of drums delivered	No. of drums to be checked
2 to 5	02
6 to 20	03
21 to 50	04
51 to 100	07
101 to 200	10
201 to 400	15
Above 400	18

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

A.1.4 Internal Inspection

Before erection is started, 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. The transformer should not be opened under circumstances that permit the entrance of moisture, such as on days of high relative humidity (60% or higher), without precautions to limit the ingress of moisture. If the transformer is brought to a location warmer than the transformer itself, the transformer should be allowed to stand until all signs of external condensation have disappeared.

If the unit is transported in dry nitrogen, there is a possibility of trapped nitrogen pockets. In this case, a sufficient vacuum should be held for a predetermined period of time and the vacuum released and refilled with dry air. Dry air should be continuously supplied into the transformer while the access cover is being removed, and whenever anyone is inside. During the entire internal inspection process with personnel inside the tank, a minimum flow of 9.4×10^{-3} m3/s (20 cfm) of breathable dry air with additional 2.4×10^{-3} m3/s (5 cfm) for each additional person is required to purge the tank.

To avoid any foreign objects falling into the transformer, all loose articles should be removed from the pockets of anyone working in the open transformer tank.

Prior to making any entry into the transformer tank, establish a foreign material exclusion program to avoid the danger of any foreign objects falling into the transformer:

- Any loose articles like Jewellery, watches, pens, coins and knives etc. should be removed from the pockets of anyone working on the transformer cover.
- Protective clothing/ Apron 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/ transportation 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 Dead End Tap Changer 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 OEM, CC-Engg., CC-QA&I & CC-AM immediately before start of erection activities.

Detailed photographs of important parts/ connections, components, may be taken during internal inspection and to be attached with pre-commissioning report.

A.1.5 Precautions during erection

During erection, efforts have 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 the 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 N_2 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.

A.1.6 Final tightness test with dry air purging

After all parts have been assembled, the tank should be sealed and pressure tested to ensure that all joints are tight. Main tank shall be purged with dry N2 / dry air till pressure of 4- 5psi (0.3 kg/cm^2) is achieved and shall be retained for 24 hours. After 24 hours of dry air purging cycle, dew point and pressure of dry air needs to be measured. Suspected leaks may be detected with leak detection instruments/ with soap water or with plastic bags tightened around valves (being inflated by leaking air). In case pressure remains same, then proceed for vacuum drop test. In case of drop in pressure, leakages must be attended and pressure test needs to be carried out again. Further, dew point of N2 / dry air after 24 hours of pressure test as illustrated in Table-3 can provide a preliminary information regarding requirement of further Vacuum cycle. However, graph-2&3 needs to be referred to for evaluation of degree of dryness as illustrated in A.1.9.

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

A.1.7 Final tightness test with vacuum (i.e. leakage test or Vacuum Drop Test)

While a vacuum is being drawn on the transformer, any air leakage into the transformer tank may seriously contaminate the transformer insulation. Air, when drawn into a vacuum, expands and drops in temperature, consequently releasing moisture. If the core and coils are cold, the moisture released from the air will condense on these parts and will be absorbed into the paper insulation. To avoid this hazard, all leaks should be eliminated before starting the fine vacuum processing. A vacuum drop test must be carried out to ensure that there are no leaks on the tank. 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 up to the pressure of 50 mbar (5 kPa or about 2 mm of Hg)
- Shut the vacuum valve and stop the pump.
- Wait for an hour and take a first vacuum reading – say P1. The first 60 min is allowed for de-absorption of gasses from the insulation
- Take a second reading 30 minutes later- say P2
- Note the volume of the tank (quantity of oil required according to the rating plate).
- Take the difference between P2 and P1, and multiply this with the oil quantity V in litres.

$$\text{Leakage Rate} = \frac{V(P_{90} - P_{60})(\text{mmHgLiters})}{30 \text{ Minutes}}$$

- Allowable Leakage of less than 150 mm Hg liters per minute (20 m^3Pa/min). If the leakage rate exceeds 20 m^3Pa/min or the vacuum does not hold, then the leak in the transformer system shall be located and arrested.

A.1.8 Vacuum treatment

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 continued for the time given in **Table-4** and should also maintain during the subsequent oil filling operations by continuous running of the vacuum pumps. The main requirement of adequate vacuum treatment is to remove trapped air and moisture from the insulation and enable the insulation to attain its full dielectric strength. Small gas bubbles have much lower dielectric strength than the dielectric liquid and may lead to failure, if it is present nearby high stress zone. By application of vacuum for desired period, gas bubbles/ trapped air can be removed. Vacuum alone may not be adequate for excessive moisture removal and heating of the core and coils may also be required at lower ambient temperatures.

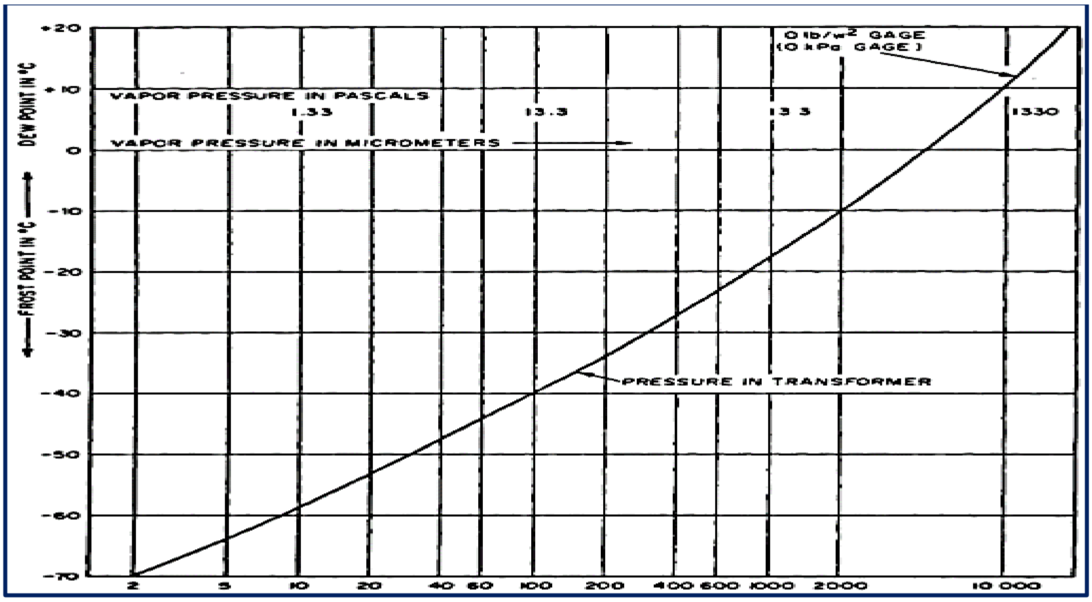
In case the transformer is provided with an On Load Tap Changer (OLTC), while evacuating the main transformer tank, the diverter switch compartment may also be evacuated simultaneously so that no undue pressure is allowed on the tap changer chamber. While releasing vacuum, the tap changer chamber vacuum 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.

Rated Voltage (in kV)	Application of Vacuum & holding for (before oil filling) (in Hours)
66 kV	12 HRS
Up to 145 kV	24 HRS
Up to 220 kV	
Up to 420 kV	Up to 48 HRS
765 kV	

Table-4: Vacuum Hold Period

A.1.9 Determination of insulation dryness by dry Air Purging Cycle

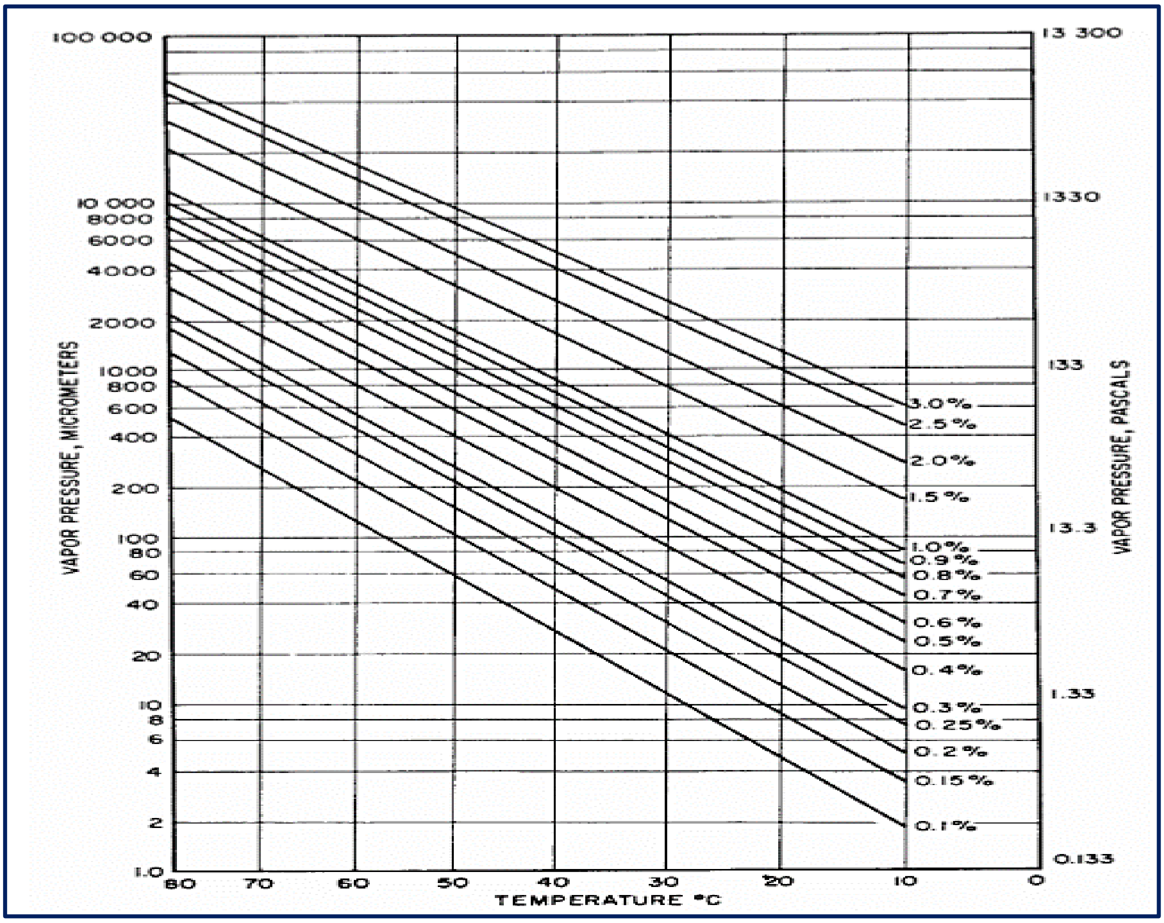
The vacuum is broken with dry Nitrogen/ Air. The dew point of dry air/ nitrogen at the inlet is to be measured and should be of the order of - 50 °C or better. When the dry air/ nitrogen comes to the positive pressure of 0.15 kg/cm2, it is stopped and kept for 24 hours. Heating from outside may be carried out during dry air/ N2 circulation is in progress. After 24 hours, measure %RH of dry air/ N2. If the dryness of 0.5% is achieved, then final vacuum to be started for oil filling. If not, again the transformer is taken for vacuum treatment and then dry air/ nitrogen is admitted as mentioned above and tested. The cycle is to be continued till desired dew point as per Graph -2 and 3 is achieved.



Graph 2- Conversion from dew point or frost point to vapor pressure

The dew point within a closed vessel is responsive to the surface moisture on the insulation. A reliable measurement requires that a state of equilibrium be achieved between the surface moisture level and that of the surrounding gas space. Equilibrium is reached in 6–12 h. At a uniform temperature, moisture migration can be accelerated somewhat by creating a “super-dry” surface moisture condition.

Knowing the dew point in degrees Celsius, Graph-2 can be used to obtain the vapour pressure. If the total pressure at the dew point instrument is different from the tank pressure, the measured vapour pressure must be corrected by multiplying the measured value by the ratio of the absolute tank pressure to the absolute pressure at the dew point instrument. Some knowledge of the duration of the exposure to moisture must enter into the determination of the vacuum processing period used to remove the surface moisture prior to measurement. A surface moisture determination of **0.5% (As per graph-3)** in the stage of equilibrium is completely satisfactory for EHV transformers.



Graph 3- Moisture equilibrium chart (Moisture content in % of dry weight of insulation)

Note: If the total pressure at the dew point instrument is different from the tank pressure, the measured vapour pressure must be corrected by multiplying the measured value by the ratio of the absolute tank pressure to the absolute pressure at the dew point instrument.

The following example clarifies the procedure (Source – IEEE Std. C57.152-2013)

Measured dew point = –45 °C

Insulation temperature = 20 °C
Pressure in tank = 2.0 psig (13.8 kPa)
Atmospheric pressure = 14.7 psi (101.325 kPa)

On Graph-2, read the vapor pressure corresponding to a dew point of –45°C as 60 micrometer (8 Pa). Correct this vapor pressure for the overpressure in the tank of 2.0 psig (13.8 kPa) as follows:

[(14.7 + 2.0) x 60]/14.7 = 68 micrometer or [(101.325 + 13.8) x 8]/101.325 = 9.1 Pa

Now using the moisture equilibrium chart, Graph-3, find the intersection of 20°C insulation temperature and 68 µm (9.1 Pa) of vapor pressure. Read the moisture content of approximately 0.6% from the diagonal lines labeled in percent moisture content.

A.1.10 Oil Filling

Oil is transferred to oil storage tank for oil filtration before filling inside the transformer. The drums or trailer tanks shall not be emptied completely to the last drop - a sump of an inch or so is left, to avoid possible solid dirt or water on 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 and prior to filling in main tank, oil sample is tested as per the following to meet POWERGRID specification. Oil parameters of each storage tank after oil treatment prior to filling in main tank to be tested in nearest POWERGRID oil laboratory.

Break Down voltage (BDV)	70kV (min.)
Moisture content	5 ppm (max.)
Tan-delta at 90 °C	<0.0025(Max)
Interfacial tension	> 0.04 N/m

Table-5: Oil Parameter Limits
(Prior to filling in main tank at site)

For transformer dispatched with gas (N2)/ dry air 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). 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 -50 °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.

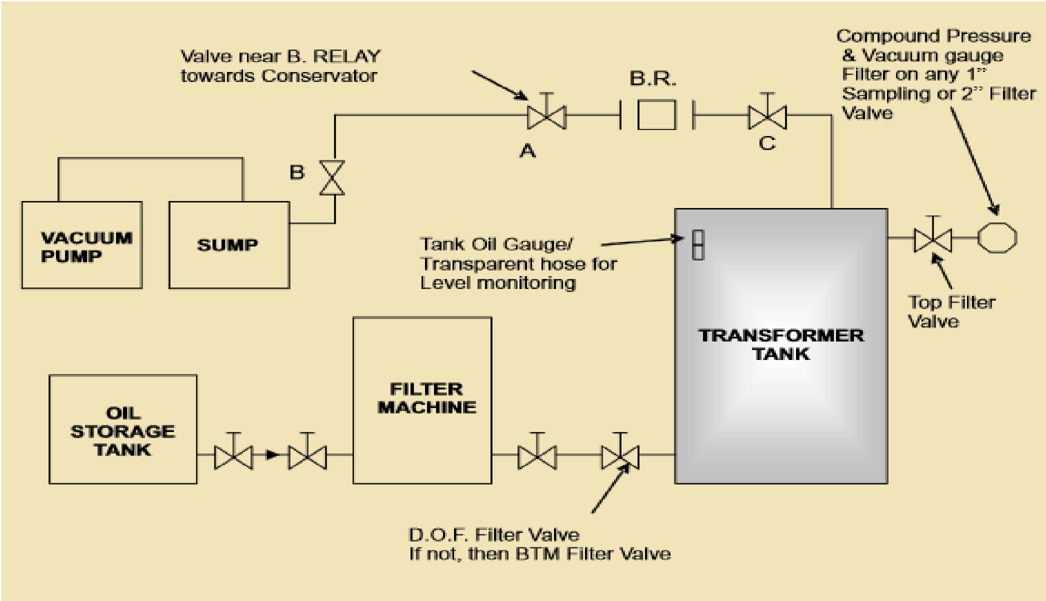


Figure-1: Arrangement for Evacuation and Oil filling up to tank Oil gauge & Conservator

When oil filling of the transformer & 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 unbanked 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 in the conservator, the air cell needs to be checked for any leakage by inflating it to 0.5 PSIG i.e. 0.035 kg /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.

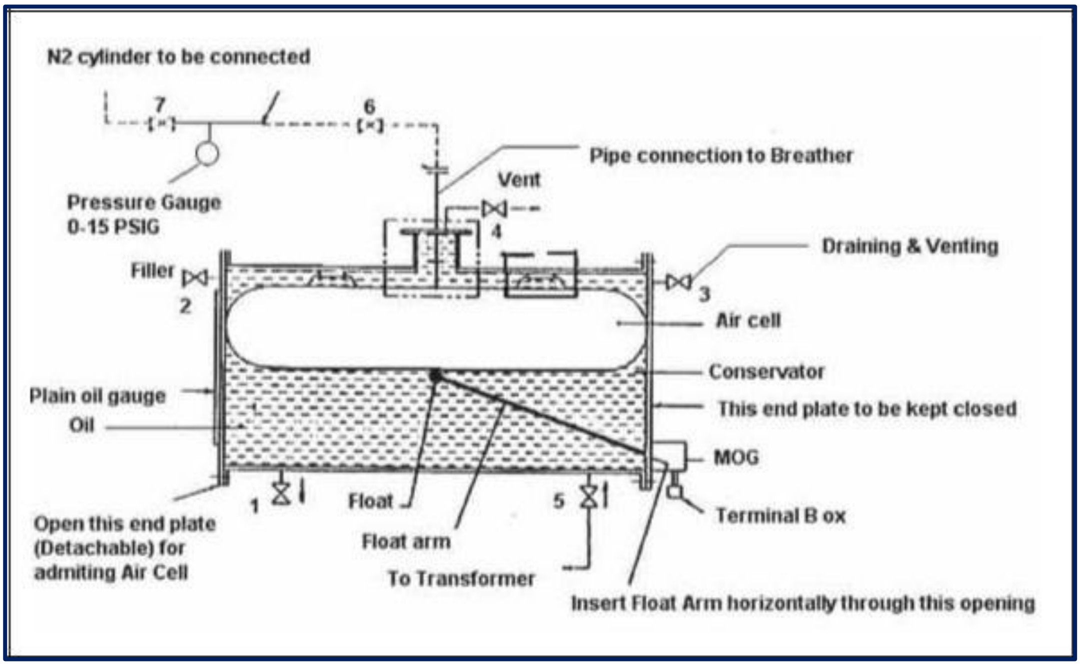


Figure-2 : General Arrangement For Oil Conservator

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.

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:

- If Transformer/ Reactor received at site without positive N2 pressure.
- If Dry air not used during exposure while doing erection activities
- 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 A.1.12.

A.1.11 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 vacuum filter and with circulation direction as shown in Fig.-3.

The circulation procedure for the main tank is as follows.

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. The temperature of the oil from the filter to the Transformer should be around 60 ˚ C and in no case it should go beyond 65˚C otherwise this may cause oxidation of oil.

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).

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

   i. Break Down voltage (BDV) : 70 kV (min.)
   ii. Moisture content : 5 PPM (max.)
   iii. Tan-delta at 90 °C : 0.005 (max.)
   iv. Total Gas Content : < 1%
   v. Interfacial tension : 0.04 N/m (min.)
   vi. Particle Count :1000 particle /100 ml with size ≥ 5µm (max) and 130 particle /100 ml with size ≥ 15µm (max)
   (As per ISO 4406: 1000 particles per 100 ml equal to or larger than 6 µm(c) and 130 particles per 100 ml equal to or larger than 14 micron)
   vii. 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.)
   viii. Total PCB content : Not detectable (less than 2 mg/kg total)

Oil sample from the equipment, after filling in main tank prior to energisation should be tested for oil parameters and DGA in nearest POWERGRID Oil laboratory.

* For Sr. No. vii & vii test, separate oil sample shall be taken, and test can be done in NABL accredited oil laboratory and test results shall be submitted within 45 days after commissioning for approval of POWERGRID.

A.1.12 Procedure for dry out of wet winding of Transformer/ Reactor by application of vacuum, Dry air/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 dry out 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.

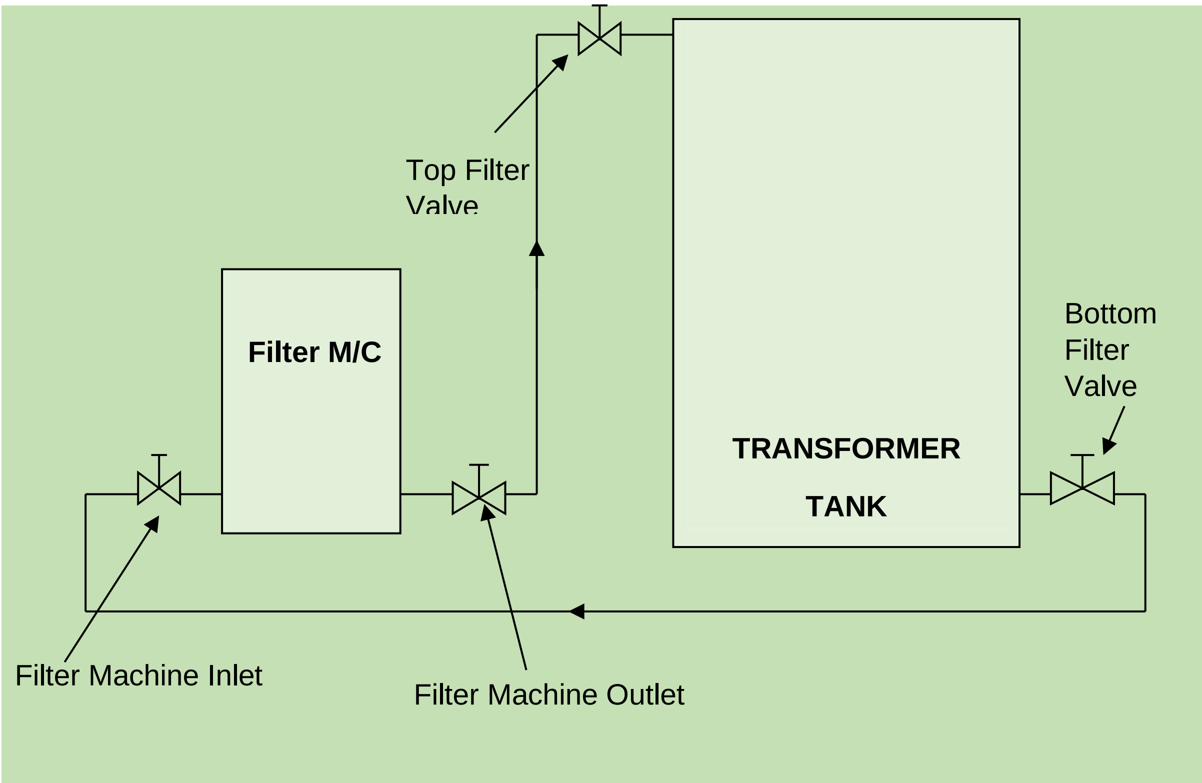


Figure-3: Hot oil circulation using High Vacuum Oil Filter Machine

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 due to heat and inflammable oil involved.

A.12.1. 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.

A.12.2. Procedure

a. Fill the main transformer/ reactor tank with Dry air/ Nitrogen (dew point better than -50°C) until it comes to a positive pressure of 0.15 Kg/cm2. It is kept for about 48 hrs.

At the end of 48 hrs, dew point of Dry air/ N2 at outlet is measured. If the dew point is not within acceptable limits as per Table-3, dry out method should be continued.

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

c. After ascertaining that there is no leakage, pull out vacuum and keep the transformer/reactor under near absolute vacuum (1 Torr) and keep under vacuum for about 48 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 air/ nitrogen. The dew point of dry air/ 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/cm2, it is stopped and kept for 24 hours. Heating from outside is to be continued while dry air/ N2 circulation is in progress. Then the dry air/ nitrogen pressure is released and the outlet dry air/ nitrogen dew point is measured. If the dew point is within acceptable limits as per Table-3 then the dryness of transformer is achieved. If not, again the transformer is taken for vacuum treatment and then dry air/ nitrogen cycle is to be continued till desired dew point as per Table-3 is achieved.

e. Periodicity of vacuum cycle may vary between 48-96 hrs. Initially two dry air/ 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-6 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.

Rated Voltage n kV)	STANDING TIME After Oil circulation and before energising (in Hours)
Up to 220 kV	24 HRS
Above 220 to 420 kV	48 Hrs.
765 kV	72 HRS

Table-6: Transformer/Reactor Settling Time

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.

Refer pre-commissioning test procedures given in next section for all required tests to be performed.

A.1.13 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

$$^{\circ}C = \frac{5}{9} * (^{\circ}F - 32)$$

$$^{\circ}F = \frac{9}{5} * (^{\circ}C) + 32$$

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
1 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

A.2.1 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 in Table-8:

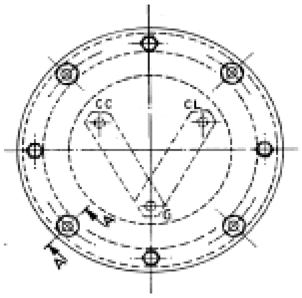
Table:8

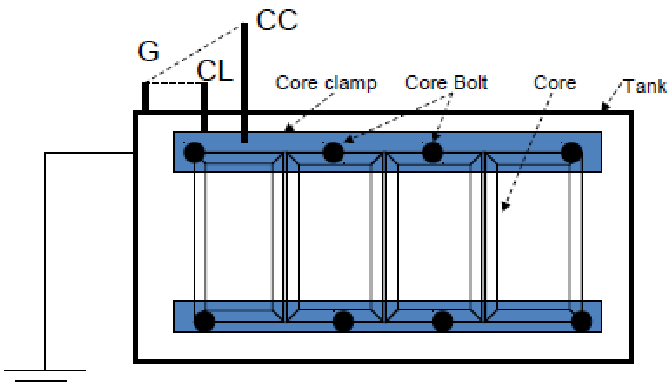
Sr. No.	Name of Test/ Check point	Purpose of test/ check
1.	Core insulation tests	Allows for investigating accidental grounds which results in circulating currents if there is more than one connection between the core and ground.
2.	Earth pit resistance measurement	To check the resistance of earth pit provided for Transformer. In case, the resistance is more, proper treatment is to be given.
3.	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)
4.	Capacitance and Tan δ measurement of bushings including VFTD	Measurement of C1 & C2 Capacitance and Tanδ in UST mode and GSTg mode respectively. 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.
5.	Capacitance and Tan δ 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
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
7.	Vector Group & Polarity	To determine the phase relationship and polarity of transformers
8.	Magnetic Balance test	This test is conducted only in three phase transformers to check the imbalance in the magnetic circuit
9.	Floating Neutral point measurement	This test is conducted to ascertain possibility of short circuit in a winding.
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.

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
12.	Operational checks on OLTCs	To ensure smooth & trouble free operation of OLTC during operation.
13.	Tests/ Checks on Bushing Current Transformers (BCTs)	To ascertain the healthiness of bushing current transformer at the time of erection
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
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.
16.	Frequency Response Analysis (FRA) measurement	To assess the mechanical integrity of the transformer. Transformers while experiencing severity of short circuit current loses 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.
17.	Winding resistance measurement	To check for any abnormalities due to loose connections, broken strands and high contact resistance in tap changers
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

A.2.2 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.





CL- Connected to Core Lamination
CC-Connected to Core Clamp
G-Connected to Tank(Earth)

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 2.5 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 500 MΩ for new Transformer at the time of commissioning.*

A.2.3 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.

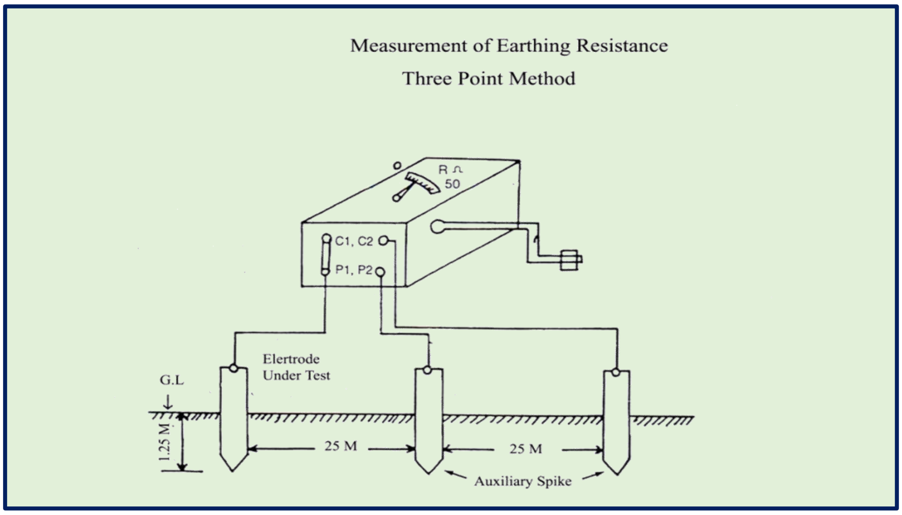


Figure-5

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):-
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 with grid and without grid 10 Ω.*

A.2.4 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	

Table-9

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

Acceptable Limits: *Unless otherwise recommended by the manufacturer, IR values of* 500 *MΩ(one minute measurements) may be considered as the minimum acceptable values at 30°C at the time of commissioning for all 66kV and above Transformer.*

Insulation resistance varies inversely with temperature and is normalized to a standard temperature (usually 20°C) using the factor k i.e T_{20} = k*T 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

Table-10

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 10mim insulation resistance value. The polarization index is the ratio of the 10 min to the 1 min mega ohm readings.

PI= R10 / R1 (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
Above 2.0	Good

Table-11

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 may be investigated in consultation with OEM. For bushings, an IR value of above 10,000 MΩ is considered satisfactory.

A.2.5 Capacitance and Tan δ measurement of Bushings

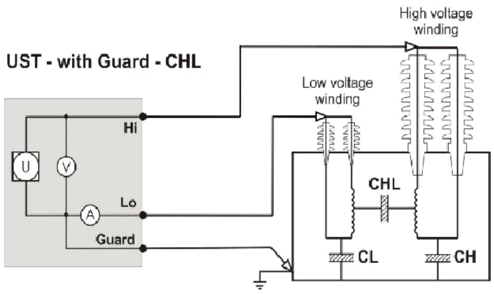
Dissipation Factor

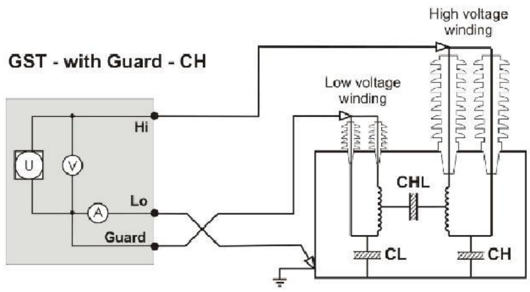
Dissipation factor/loss factor (Tan delta) is defined as the ratio of resistive component (I_r) of current to that of capacitive current (I_C) flowing in an insulating material.

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.

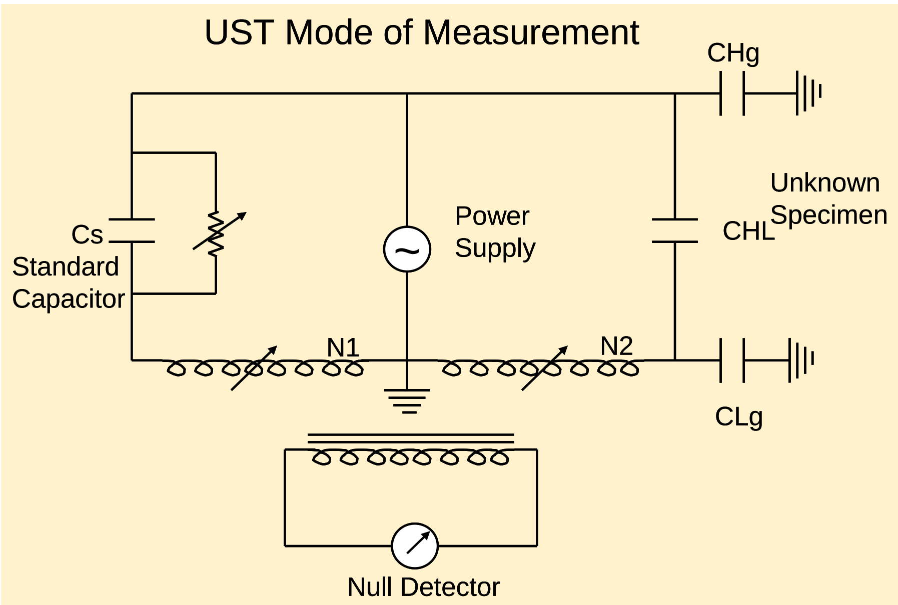
GSTg: This test is used to separate the total values of a GST test into separate parts for better analysis. Often this test is used with GST test to confirm the test readings made using the UST mode.

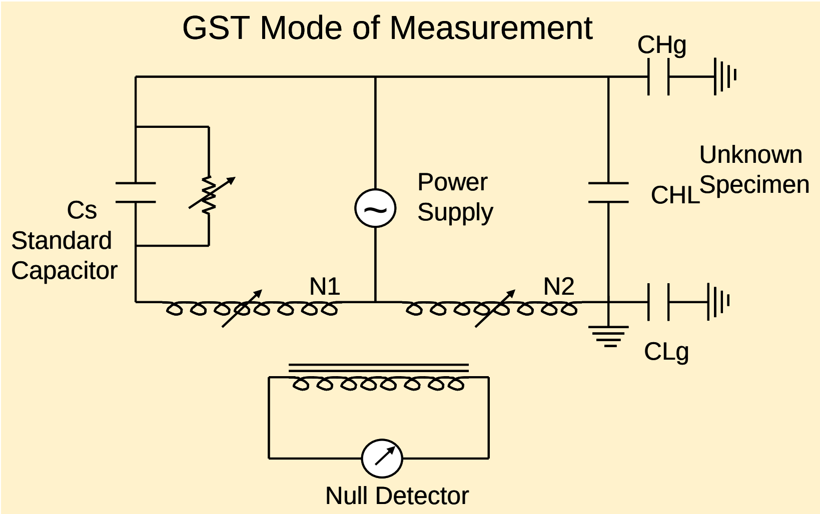
TEST EQUIPMENT:

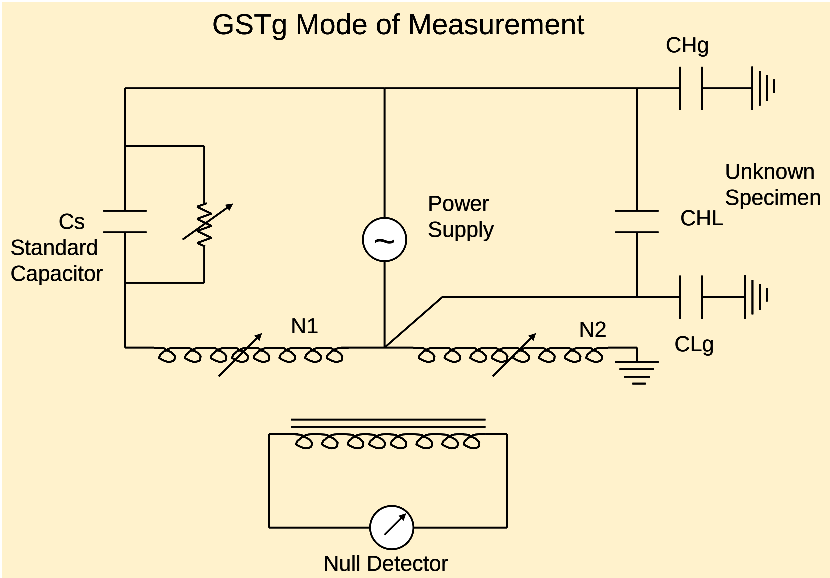
10 KV or 12 KV fully automatic Capacitance and Tan delta test kit to be used for accurate measurement and repeatability of test results.

TESTING PROCEDURE

Typical arrangement for Tan δ measurement is given below:







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/12kV), 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 & TAN δ 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.

i. 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.

ii. 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.***

iii. 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.

iv. 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.

v. 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 RIP/RIS bushings and 0.4% for OIP bushings.*

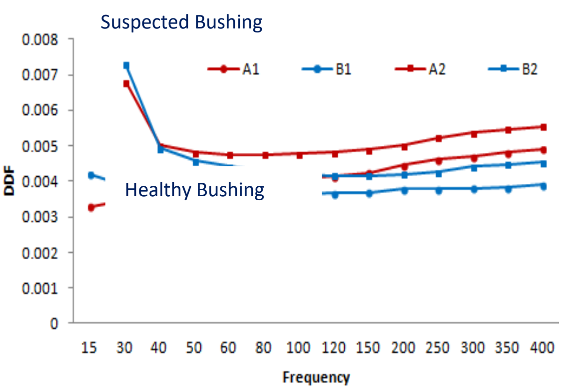
Description	*Acceptable Limit*
OIP Bushing	*Max 0.4%*
RIP Bushing	*Max 0.5%*

In addition to power frequency Tanδ measurement, Tan δ in frequency sweep shall be carried out for all condenser bushings which provides additional information about the condition of the bushing. The measurement of Dissipation/Power Factor at low frequencies (15/17 Hz) enables the detection of moisture with high sensitivity. Dissipation/Power Factor Measurement on bushings between 15 Hz and 400 Hz.

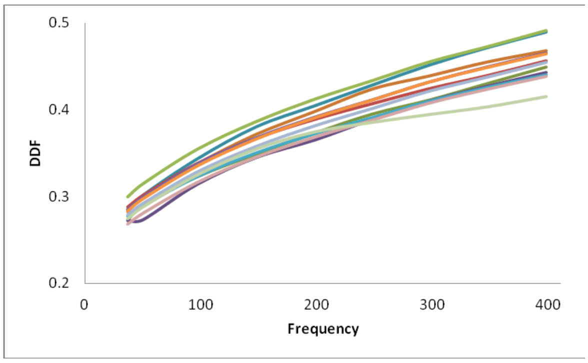
Sometimes disturbances may be observed in Tan δ response near power frequency due to unfavourable weather conditions such as relative humidity, dust etc. Surface of porcelain bushings needs to be cleaned and dried to minimize the effects of surface leakage. To have a standard selection, following frequencies to be chosen:

Frequency in Hz	**17**	**25**	**34**	**43**	**68**	**85**	**102**	**119**	**136**	**187**	**255**	**323**	**391**
Tan delta													
Capacitance													

Samples Response of Healthy and suspected bushing



OIP Bushing Response of Healthy and suspected Bushing



RIP Bushing Response of Healthy Bushing

In case of RIP bushing, rising Tan δ response with increase in frequency is observed. However, for both OIP and RIP bushing, increase in Tanδ at low frequency from 50 Hz value beyond permissible limit may be an indication of fault in the bushing. As a guide, indicative limits for Dissipation/Power Factor in new OIP bushings at 17 Hz, 50Hz and 391 Hz are given in the following table.

Frequency	**Tan δ in %****	**Capacitance in pF**
17 Hz	0.5 Max for OIP 0.6 Max for RIP	± 3 pf from 50Hz results
50 Hz	0.4 Max for OIP 0.5 Max for RIP	
391 Hz	0.5 Max for OIP 0.6 Max for RIP	

** For limit, latest document for permissible limit for substation equipment to be referred.

CAPACITANCE AND TAN δ MEASUREMENT OF WINDINGS

The combination for C & tanδ 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

Combination for C & tanδ measurement of winding for various transformers/ Shunt Reactor

vi. Ensure that test specimen is isolated from other equipment. **Removal of Jumpers from Bushings is Pre-Requisite for C & Tan δ Measurement of Windings.**

vii. **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:

Winding Combination	***Test mode***	***Cap Symbol***	***Test lead Connection***	***Remarks***
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	
HV-IV/ LV+G	GST	$C_{HL}+C_{HG}$	-do-	
HV-IV / LV with Guard	GST_g	C_{HG}	- do-	LV to be Guarded
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	
LV/ HV-IV +G	GST	$C_{HL}+C_{LG}$	-do-	
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*

viii. Measurement inter-check can be done by calculating $C_1= C_2-C_3$ & $C_4= C_5- C_6$ & $DF_1=C_2DF_2-C_3DF_3 / C_2-C_3= C_4DF_4-C_5DF_5 / C_4-C_5$ 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.

ix. **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 Delta 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.*

A.2.6 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.

A.2.7 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.

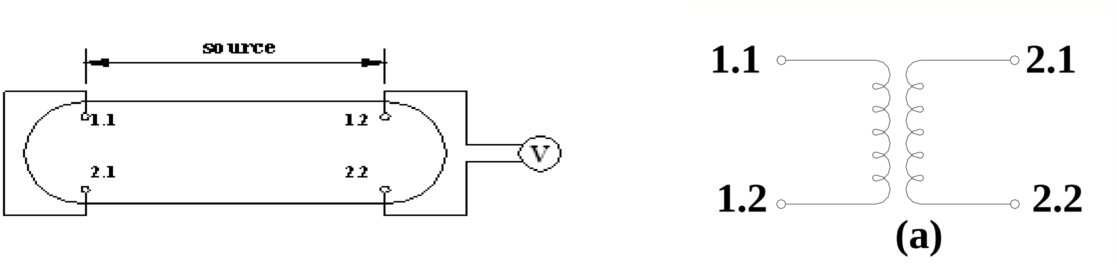


Figure-7

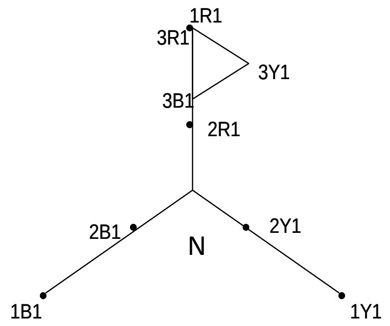
For a single-phase transformer having a ratio of transformation of 30 to 1 or less, the polarity test shall be done as follows. The line terminal of high voltage winding (1.1) shall be connected to the adjacent line terminal low-voltage winding (2.1) as shown in figure 7.

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.



- Connect neutral point and LV phase with Earth and join 1R1 & 3R1 Terminals
- Apply 415 , 3-ϕ 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.

Fig 8: For HV-Star Auto / LV-Delta Transformer (Example for YNa0d11)

Please Note: *Most of the auto transformers in POWERGRID are of* ***YNa0d11*** *configuration.*

A.2.8 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.

<u>**Acceptable Limit:**</u> 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.

A.2.9 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.

A.2.10 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.

A.2.11 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.

A.2.12 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)	Test 10	H1-H0X0	H1-H0X0 Short (X1-H0X0)
	Test 11	H2-H0X0	

Short (X1-X2-X3)	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

During pre-commissioning, SFRA is to be compared with factory signature. Snapshots with super imposition of both signatures for each combination have to be attached in pre-commissioning report. SFRA signature in Machine readable format (.fra/.sfra/.frax etc) is to be forwarded (both site and factory test signature) to CC-AM along with pre-commissioning results.

A.2.13 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.

A.2.14 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.

A.2.15 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-energized, 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)

A.2.16 TESTS/ CHECKS ON BUSHING CURRENT TRANSFORMERS (BCTS)

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

A.2.17 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) Marshaling 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.)

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.

A.2.18 CHECK LIST FOR ENERGISATION OF TRANSFORMER/ REACTOR

a. 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 need be.

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

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 : 0.005 (max.)
4. Total Gas Content : < 1%
5. Interfacial tension : 0.04 N/m (min.)
6. Particle count : 1000 particle /100 ml with size ≥ 5µm (max) and 130 particle /100 ml with size ≥ 15µm (max)
   (As per ISO 4406: 1000 particles per 100 ml equal to or larger than 6 µm(c) and 130 particles per 100 ml equal to or larger than 14 micron)
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.)
8. *Total PCB content : Not detectable (less than 2 mg/kg total)

Oil sample from the equipment, after filling in main tank prior to energisation should be tested for oil parameters and DGA in nearest POWERGRID Oil laboratory.

* For Sr. No. 7 & 8, separate oil sample shall be taken and test results shall be submitted within 45 days after commissioning for approval of POWERGRID

11. Check that equalizing link between OLTC tank and Main tank is removed.

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

b. 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.

Differential & REF Stability:

Before starting the Differential stability test, it is to be ensured that Bay Stability of HV/IV bays is completed. The following shall be ensured for Turret CT Cores before starting the Differential/REF stability test.

1. Measure the CT loop resistance phase wise for each Turret CT circuit cores. For this, CT link at CT MB to be isolated and CT link at CRP panels to be closed. The loop resistance of CT wires towards CRP side and CT side needs to be noted down.

Bay Reference	CT Cores	Phase	Loop Resistance CRP side (in Ohm)	Loop Resistance CT side (in Ohm)
	Core 1 . . . Core X	R-N		
		Y-N		
		B-N		

2. After measurement of CT loop resistance, CT links shall be closed at CT MB.
3. Verify the CT neutral formation for all cores with reference to CT ratio, according to the protection and metering scheme.
4. Verify that CT neutral is earthed only at single CRP panels. CT spare cores if any, is to be shorted and earthed at CT JB.
5. After verification of above step, Single phase CT primary injection shall be started.

*** Voltage across CT secondary terminals to be measured (in CT MB) and compared phase wise for each core to identify any loose connections in CT circuit.**

Ensure that ICT/Reactor neutral is properly grounded, connection of neutral bushing terminal is proper. Supply Voltage to be recorded as per the below-

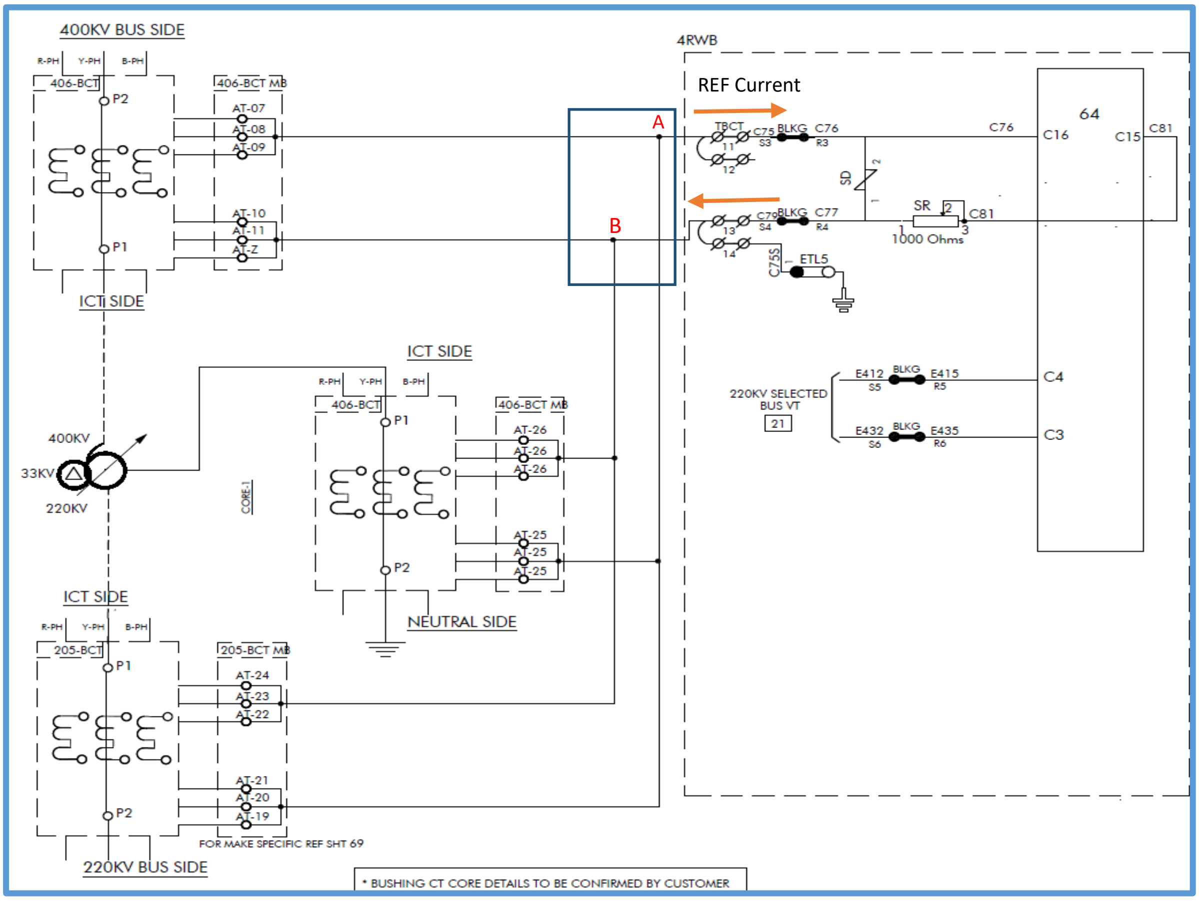
Sr. No.	Supply Voltage	Measured Voltage
1	R-N	
2	Y-N	
3	B-N	

I) Three Phase ICT Units

Single phase AC supply to be injected (phase wise) from IV bay CT and HV Bay side to be earthed (phase wise). Phase wise supply current to be noted during each case.

Supply R phase – Current (Injected Side)	
Supply Y phase – Current (Injected Side)	
Supply B Phase- Current (Injected Side)	

Indicative CT circuit diagram for REF protection is shown below, where the point A & B are CT parallel points (Here at ICT MB) and REF current is the CT summation current after parallel point A & B to REF relay.



Record the CT secondary current at ICT MB as per the below-

	R phase Injection		Y phase Injection		B phase Injection		CT Core Usage	CT Ratio adopted
	R	N	Y	N	B	N		
HV Turret								
Core 1								
Core 2								
Core 3								
Core 4								
Core 5								
Core 6								

Core n								
IV Turret								
Core 1								
Core 2								
Core 3								
Core 4								
Core 5								
Core 6								

Core n								
Neutral Turret								
Core 1								
Core 2								

Core n								

STABLE CONDITION	**Stable Condition measurements (R-Phase)**		**Stable Condition measurements (Y-Phase)**		**Stable Condition measurements (B-Phase)**		
REF Measurement	REF current to Relay at ICT MB		REF current to Relay at ICT MB		REF current to Relay at ICT MB		**Note- REF stabilizing resistor to be bypassed/Shorted at CRP**
	Relay HMI		Relay HMI		Relay HMI		
Differential Relay current Measurement	**HV Side** R- Y- B-	**IV Side** R- Y- B-	**HV Side** R- Y- B-	**IV Side** R- Y- B-	**HV Side** R- Y- B-	**IV Side** R- Y- B-	Unit of Current Measurement __________
	Differential R- Y- B-	**Restraining** R- Y- B-	**Differential** R- Y- B	**Restrainin g** R- Y- B-	**Differential** R- Y- B	**Restraining** R- Y- B-	Unit of Current Measurement (PU/mA) __________

UNSTABLE CONDITION	**REF Unstable condition (R-Phase)**		**REF Unstable condition (Y-Phase)**		**REF Unstable condition (B-Phase)**		
Neutral turret REF CT **core reversed**	**1)** NCT REF CT Core current		**1)** NCT REF CT Core current		**1)** NCT REF CT Core current		**Note- REF stabilizing resistor to be bypassed/Shorted at CRP**
	2) REF current to Relay at ICT MB		**2)** REF current to Relay at ICT MB		**2)** REF current to Relay at ICT MB		
	3) REF Relay current (HMI)		**3)** REF Relay current (HMI)		**3)** REF Relay current (HMI)		
					4) REF current to Relay at ICT MB		**Note- REF stabilizing resistor bypassing/Shorting to be removed at CRP**
					5) REF Relay current		
					6) Voltage measured across REF terminals at ICT MB		

UNSTABLE CONDITION	REF Unstable condition (R-Phase)		REF Unstable condition (Y-Phase)		REF Unstable condition (B-Phase)		
Neutral turret REF CT core Normalized	**1)** NCT REF CT Core current		**1)** NCT REF CT Core current		**1)** NCT REF CT Core current		**Note- REF stabilizing resistor to be bypassed/Shorted at CRP**
	2) HV Turret REF CT Core current		**2)** HV Turret REF CT Core current		**2)** HV Turret REF CT Core current		
	3) IV Turret REF CT Core current		**3)** IV Turret REF CT Core current		**3)** IV Turret REF CT Core current		
	4) REF current to Relay at ICT MB		**4)** REF current to Relay at ICT MB		**4)** REF current to Relay at ICT MB		
	5) REF Relay current (HMI)		**5)** REF Relay current (HMI)		**5)** REF Relay current (HMI)		
	6) Voltage measured across REF terminals at ICT MB		**6)** Voltage measured across REF terminals at ICT MB		**6)** Voltage measured across REF terminals at ICT MB		

Further, three phase Balanced AC supply to be injected IV side bay CT and HV Bay side to be earthed. Currents to be noted down as following-

Three phase injection current	Supply Current R phase – (Injected Side)	Supply Current Y phase – (Injected Side)	Supply Current B phase – (Injected Side)

Stable Condition	R	Y	B	N
HV Turret				
Core 1				
Core 2				
Core 3				
Core 4				
Core 5				
Core 6				

Core n				
IV Turret				
Core 1				
Core 2				

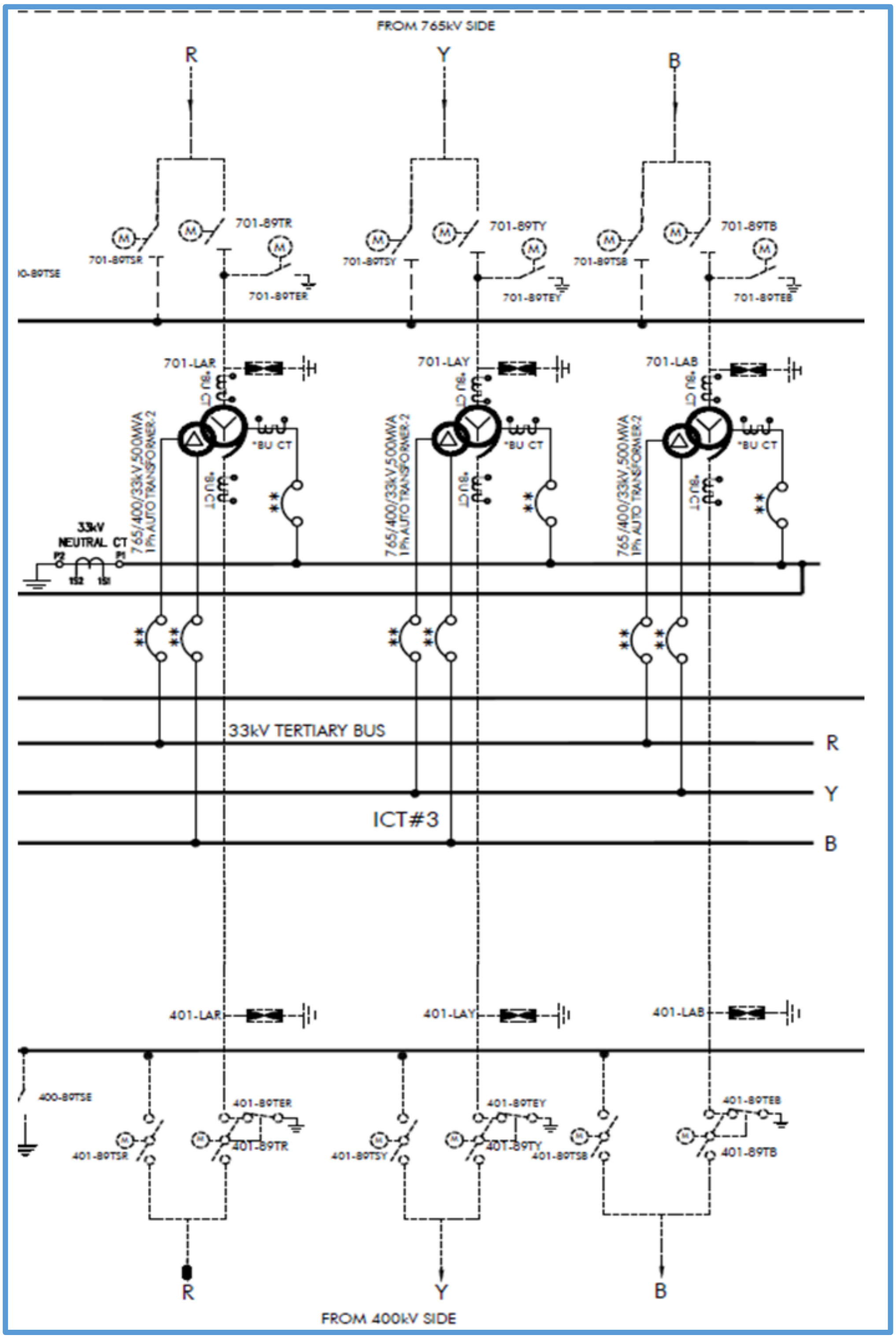
Core 3				
Core 4				
Core 5				
Core 6				

Core n				
Neutral Turret				
Core 1				
Core 2				

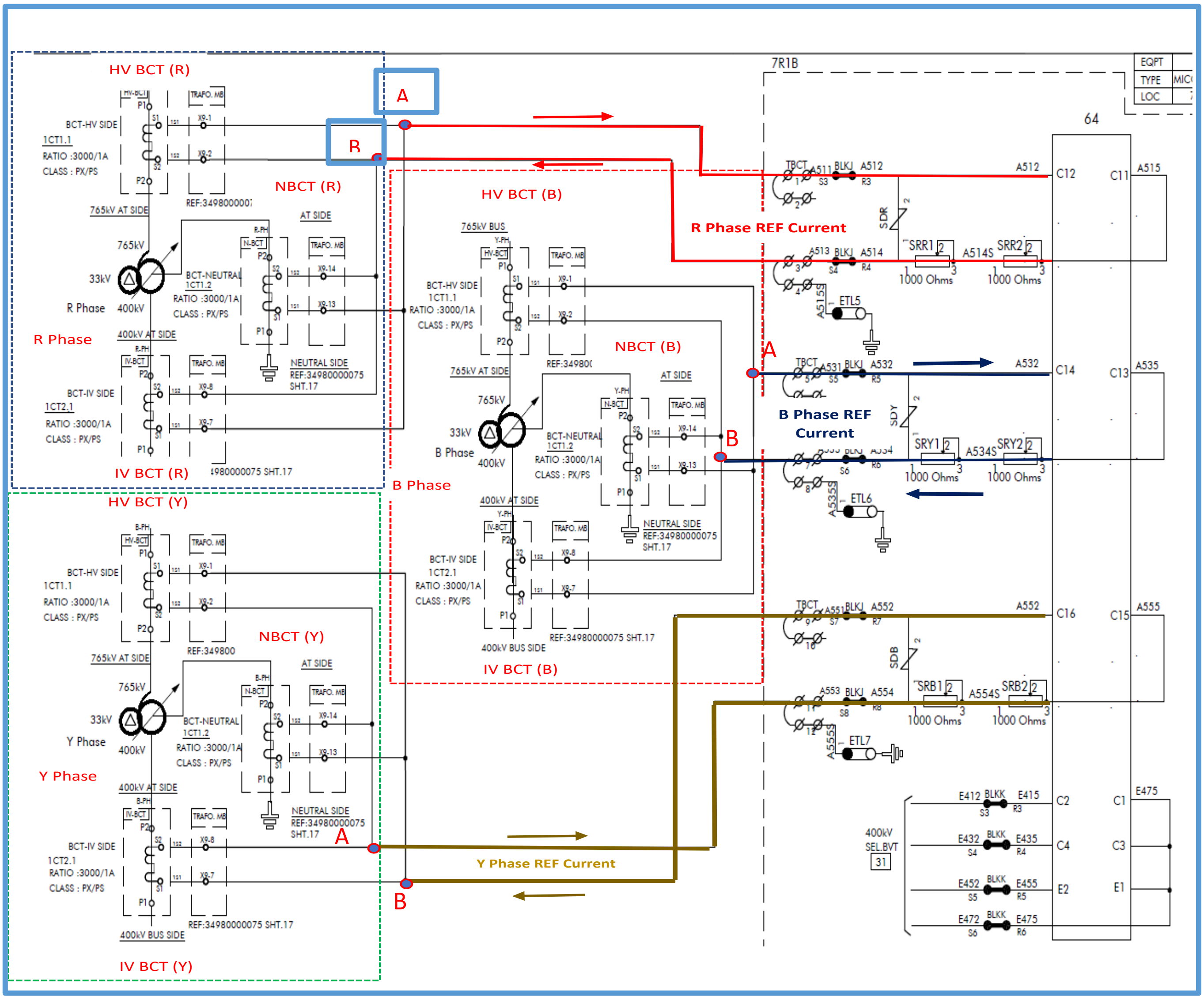
Core n				
1) REF current to Relay at ICT MB			**Note- REF stabilizing resistor <u>to be bypassed/Shorted</u> at CRP**	
2) REF Relay current (HMI)				
3) Voltage measure across REF CT wires to Relay (Across A-B as shown in Figure)				
4) REF current to Relay at ICT MB			**Note- REF stabilizing resistor <u>bypassing/Shorting to be removed</u> at CRP**	
5) REF Relay current (HMI)				
6) Voltage measure across REF CT wires to Relay (Across A-B as shown in Figure)				
7) Differential Relay Measurement	**HV Side** R- Y- B-	**IV Side** R- Y- B-	**Differential Current** R- Y- B-	**Restraining Current** R- Y- B-

II) Single phase ICT Units-

Single phase AC supply to be injected (phase wise) from IV bay CT and HV Bay side to be earthed (phase wise). Refer the figure below-



Indicative CT circuit diagram for REF protection is shown below, where the point A & B are CT parallel points (Here at ICT MB) and REF current is the CT summation current after parallel point A & B to CRP



Record the CT secondary current at ICT CMB as per the below-

	R phase Injection		Y phase Injection		B phase Injection		CT Core Usage	CT Ratio adopted
	R	N	Y	N	B	N		
HV Turret (HV BCT)								
Core 1								

Core 2									
Core 3									
Core 4									
Core 5									
Core 6									

Core n									
IV Turret (IV BCT)									
Core 1									
Core 2									
Core 3									
Core 4									
Core 5									
Core 6									

Core n									
Neutral Turret (NBCT)									
Core 1									
Core 2									

Core n									
Neutral CT External (NCT)									
Core 1									
Core 2									

Core n									

STABLE CONDITION	**Stable Condition measurements (R-Phase)**		**Stable Condition measurements (Y-Phase)**		**Stable Condition measurements (B-Phase)**		
REF Measurement	REF current to Relay at ICT MB		REF current to Relay at ICT MB		REF current to Relay at ICT MB		**Note- REF stabilizing resistor <u>to be bypassed/Shorted</u> at CRP**
	Relay HMI		Relay HMI		Relay HMI		
Differential Relay current Measurement	**HV Side** R- Y- B-	**IV Side** R- Y- B-	**HV Side** R- Y- B-	**IV Side** R- Y- B-	**HV Side** R- Y- B-	**IV Side** R- Y- B-	Unit of Current Measurement __________
	Differential R- Y- B-	**Restraining** R- Y- B-	**Differential** R- Y- B	**Restraining** R- Y- B-	**Differential** R- Y- B	**Restraining** R- Y- B-	Unit of Current Measurement (PU/mA) __________

UNSTABLE CONDITION	**REF Unstable condition (R-Phase)**		**REF Unstable condition (Y-Phase)**		**REF Unstable condition (B-Phase)**		
NBCT REF CT **core reversed**	**1)** NBCT REF CT Core current		**1)** NBCT REF CT Core current		**1)** NBCT REF CT Core current		**Note- REF stabilizing resistor to be <u>bypassed/Shorted</u> at CRP**
	2) REF current to Relay at ICT MB		**2)** REF current to Relay at ICT MB		**2)** REF current to Relay at ICT MB		
	3) REF Relay current (HMI)		**3)** REF Relay current (HMI)		**3)** REF Relay current (HMI)		
	4) REF current to Relay at ICT MB		4) REF current to Relay at ICT MB		4) REF current to Relay at ICT MB		**Note- REF stabilizing resistor <u>bypassing/Shorting to be removed</u> at CRP**
	5) REF Relay current		5) REF Relay current		5) REF Relay current		
	6) Voltage measured across REF terminals at ICT MB		6) Voltage measured across REF terminals at ICT MB		6) Voltage measured across REF terminals at ICT MB		

UNSTABLE CONDITION	REF Unstable condition (R-Phase)		REF Unstable condition (Y-Phase)		REF Unstable condition (B-Phase)		
NBCT REF CT core Normalized	**1)** NBCT REF CT Core current		**1)** NBCT REF CT Core current		**1)** NBCT REF CT Core current		**Note- REF stabilizing resistor to be bypassed/Shorted at CRP**
	2) HV Turret REF CT Core current		**2)** HV Turret REF CT Core current		**2)** HV Turret REF CT Core current		
	3) IV Turret REF CT Core current		**3)** IV Turret REF CT Core current		**3)** IV Turret REF CT Core current		
	4) REF current to Relay at ICT MB		**4)** REF current to Relay at ICT MB		**4)** REF current to Relay at ICT MB		
	5) REF Relay current (HMI)		**5)** REF Relay current (HMI)		**5)** REF Relay current (HMI)		
	6) Voltage measured across REF terminals at ICT MB		**6)** Voltage measured across REF terminals at ICT MB		**6)** Voltage measured across REF terminals at ICT MB		

Further, three phase Balance AC supply to be injected from IV bay CT and HV Bay side to be earthed. Currents to be noted down as following.

Three phase injection current	R phase Current-	Y phase Current-	B phase Current-

Stable Condition	R	Y	B	N
HV Turret (HV BCT)				
Core 1				
Core 2				
Core 3				
Core 4				
Core 5				
Core 6				

Core n				
IV Turret (IV BCT)				
Core 1				

Core 2					
Core 3					
Core 4					
Core 5					
Core 6					

Core n					
Neutral Turret (NBCT)					
Core 1					
Core 2					

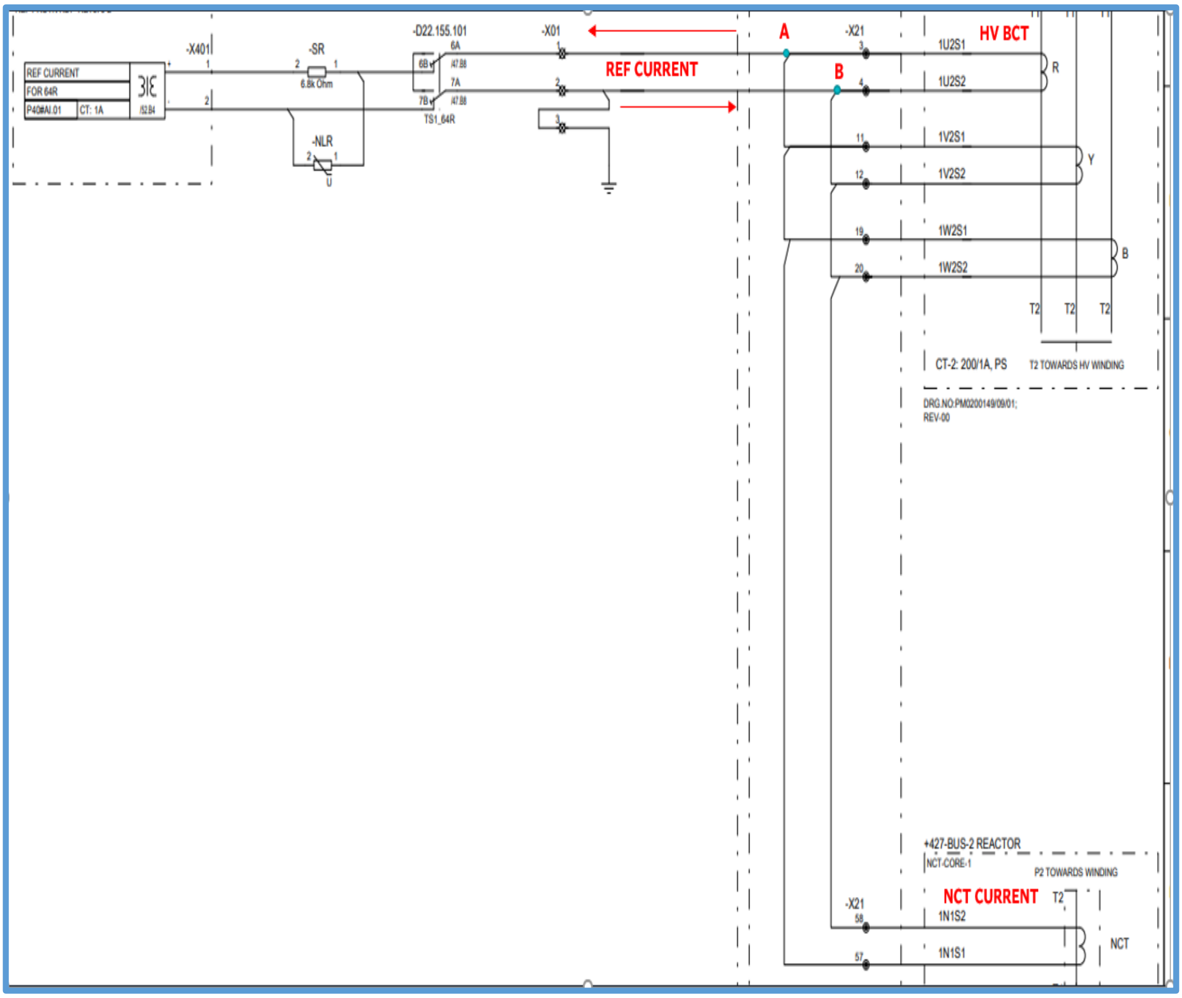
Core n					
Neutral CT External (NCT)					
Core 1					
Core 2					

Core n					
	R Phase	**Y Phase**	**B Phase**		
1) REF current to Relay at ICT MB				**Note- REF stabilizing resistor <u>to be bypassed/Shorted</u> at CRP**	
2) REF Relay current (HMI)					
3) Voltage measure across REF CT wires to Relay (Across A-B as shown in Figure)					
4) REF current to Relay at ICT MB				**Note- REF stabilizing resistor <u>bypassing/Shorting to be removed</u> at CRP**	
5) REF Relay current (HMI)					
6) Voltage measure across REF CT wires to Relay (Across A-B as shown in Figure)					
7) Differential Relay Measurement	**HV Side** R- Y- B-		**IV Side** R- Y- B-	**Differential Current** R- Y- B-	**Restraining Current** R- Y- B-

III) Bus Reactor (Three phase units)

Single phase AC supply to be injected phase wise from HV bay side. Ensure that Reactor neutral is properly grounded, connection of neutral bushing terminal is proper.

Indicative CT circuit diagram for REF protection is shown below, where the point A & B are CT parallel points (Here at reactor MB) and REF current is the CT summation current after parallel point A & B to CRP



Record the Reactor secondary current at Reactor MB as per the below-

	R phase Injection		Y phase Injection		B phase Injection		CT Core Usage	CT Ratio adopted
	R	N	Y	N	B	N		
Bushing CT-Reactor winding HV Side (HV BCT)								
Core 1								
Core 2								

Core 3								
Core 4								
Core 5								
Core 6								

Core n								
Bushing CT-Reactor winding Neutral Side (NBCT)								
Core 1								
Core 2								
Core 3								
Core 4								
Core 5								
Core 6								

Core n								
Reactor Neutral Turret CT (NCT)								
Core 1								
Core 2								

Core n								

STABLE CONDITION	**Stable Condition measurements (R-Phase)**		**Stable Condition measurements (Y-Phase)**		**Stable Condition measurements (B-Phase)**		
REF Measurement	REF current to Relay at ICT MB		REF current to Relay at ICT MB		REF current to Relay at ICT MB		**Note- REF stabilizing resistor <u>to be bypassed/Shorted</u> at CRP**
	Relay HMI		Relay HMI		Relay HMI		
Differential Relay current Measurement	**HV Side** R- Y- B-	**IV Side (NBCT)** R- Y- B-	**HV Side** R- Y- B-	**IV Side (NBCT)** R- Y- B-	**HV Side** R- Y- B-	**IV Side (NBCT)** R- Y- B-	Unit of Current Measurement ___________

	Differential R- Y- B-	Restraining R- Y- B-	Differential R- Y- B	Restraining R- Y- B-	Differential R- Y- B	Restraining R- Y- B-	Unit of Current Measurement (PU/mA) ________

UNSTABLE CONDITION	**REF Unstable condition (R-Phase)**		**REF Unstable condition (Y-Phase)**		**REF Unstable condition (B-Phase)**		
NCT REF CT **core reversed**	**1)** NCT REF CT Core current		**1)** NCT REF CT Core current		**1)** NCT REF CT Core current		**Note- REF stabilizing resistor to be bypassed/Shorted at CRP**
	2) REF current to Relay at Reactor MB		**2)** REF current to Relay at Reactor MB		**2)** REF current to Relay at Reactor MB		
	3) REF Relay current (HMI)		**3)** REF Relay current (HMI)		**3)** REF Relay current (HMI)		
					4) REF current to Relay at Reactor MB		**Note- REF stabilizing resistor bypassing/Shorting to be removed at CRP**
					5) REF Relay current		
					6) Voltage measured across REF terminals at Reactor MB		

UNSTABLE CONDITION	**REF Unstable condition (R-Phase)**		**REF Unstable condition (Y-Phase)**		**REF Unstable condition (B-Phase)**		
NCT REF CT **core Normalized**	**1)** NCT REF CT Core current		**1)** NCT REF CT Core current		**1)** NCT REF CT Core current		**Note- REF stabilizing resistor to be bypassed/Shorted at CRP**
	2) HV BCT REF CT Core current		**2)** HV BCT REF CT Core current		**2)** HV BCT REF CT Core current		
	3) REF current to Relay at Reactor MB		**3)** REF current to Relay at Reactor MB		**3)** REF current to Relay at Reactor MB		
	4) REF Relay current (HMI)		**4)** REF Relay current (HMI)		**4)** REF Relay current (HMI)		

	5) Voltage measured across REF terminals at Reactor MB		**5)** Voltage measured across REF terminals at Reactor MB		**5)** Voltage measured across REF terminals at Reactor MB		

Further, three phase Balance AC supply to be injected from HV bay side. Currents to be noted down as following-

Three phase injection current	R phase Current-	Y phase Current-	B phase Current-

Stable Condition	R	Y	B	N
HV Turret (HV BCT)				
Core 1				
Core 2				
Core 3				
Core 4				
Core 5				
Core 6				

Core n				
Reactor winding Neutral Side (NBCT)				
Core 1				
Core 2				
Core 3				
Core 4				
Core 5				
Core 6				

Core n				
Reactor Neutral Turret CT (NCT)				
Core 1				
Core 2				

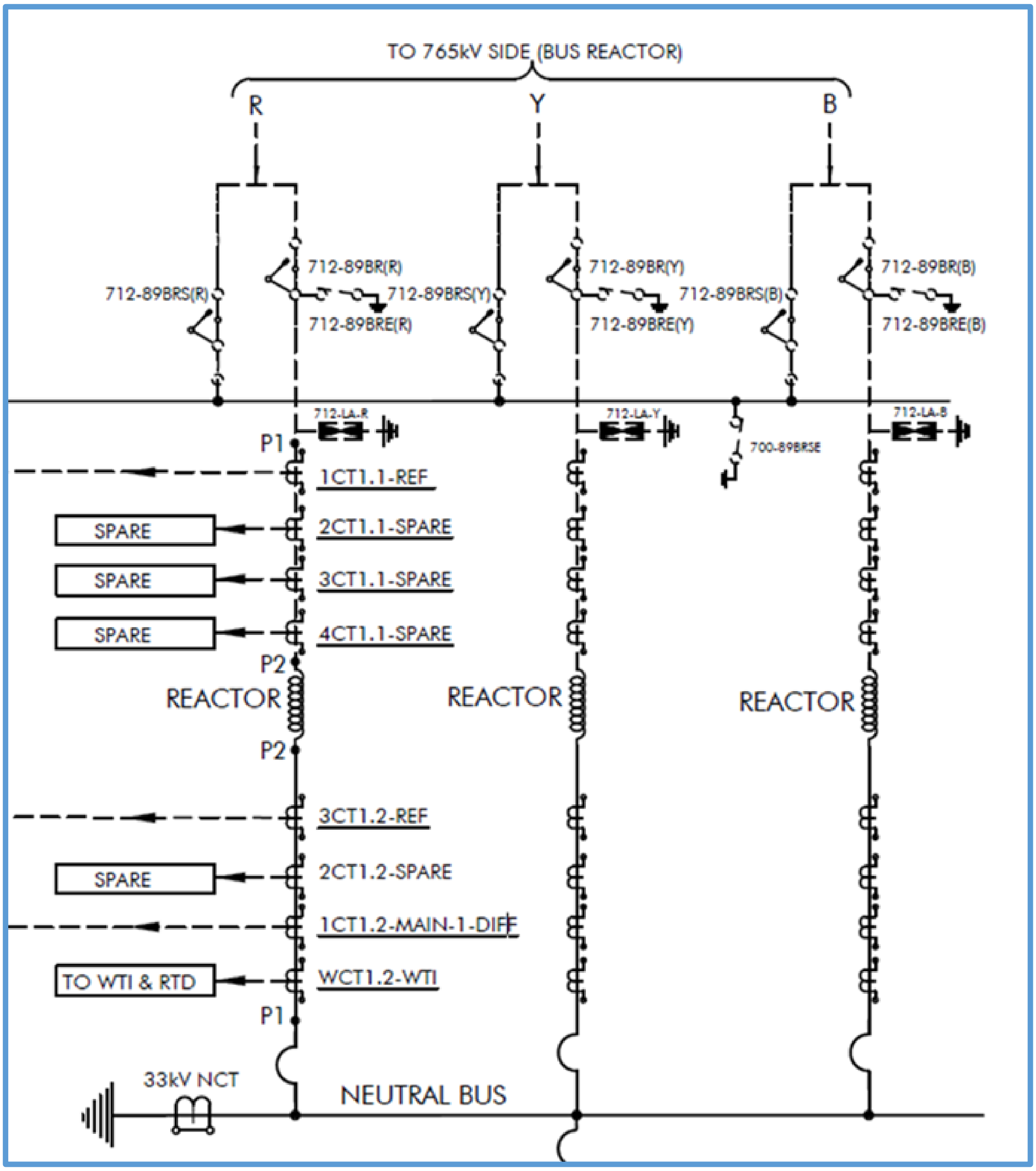
Core n				
1) REF current to Relay at Reactor MB				
2) REF Relay current (HMI)				

<table>
<tr><td>3) Voltage measure across REF CT wires to Relay (Across A-B as shown in Figure)</td><td colspan="2"></td><td colspan="2">Note- REF stabilizing resistor <u>to be bypassed/Shorted</u> at CRP</td></tr>
<tr><td>4) REF current to Relay at Reactor MB</td><td colspan="2"></td><td colspan="2" rowspan="3">Note- REF stabilizing resistor <u>bypassing/Shorting to be removed</u> at CRP</td></tr>
<tr><td>5) REF Relay current (HMI)</td><td colspan="2"></td></tr>
<tr><td>6) Voltage measure across REF CT wires to Relay (Across A-B as shown in Figure)</td><td colspan="2"></td></tr>
<tr><td>7) Differential Relay Measurement</td><td>HV Side

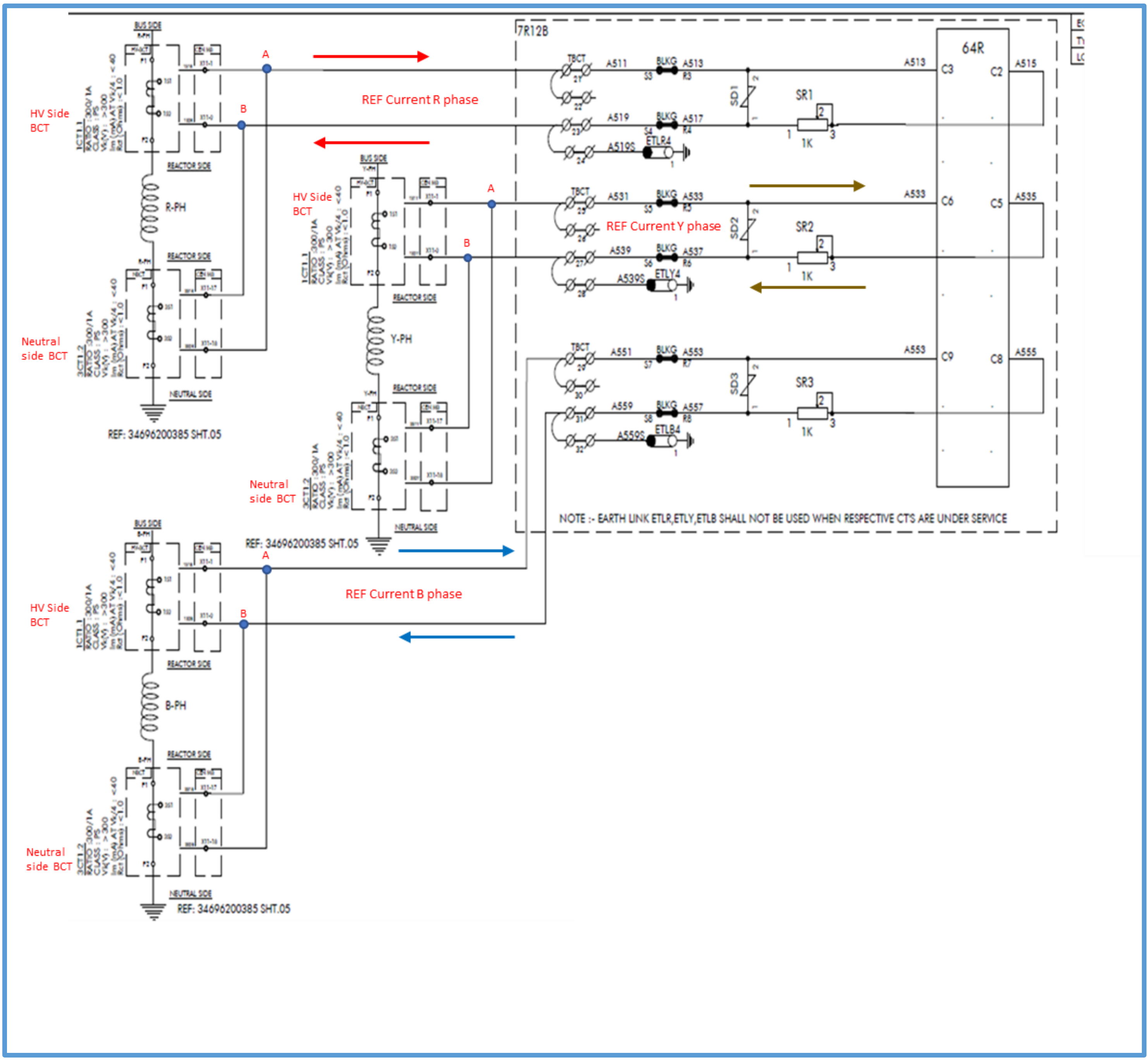
R-
Y-
B-</td><td>IV Side (NBCT)
R-
Y-
B-</td><td>Differential Current
R-
Y-
B-</td><td>Restraining Current
R-
Y-
B-</td></tr>
</table>

IV) Bus Reactor single phase units

Single phase AC supply to be injected phase wise from HV bay side. Ensure that Reactor neutral is properly grounded, connection of neutral bushing terminal is proper. Refer the figure below-



Indicative CT circuit diagram for REF protection is shown below, where the point A & B are CT parallel points (Here at reactor CMB) and REF current is the CT summation current after parallel point A & B to REF relay.


7R12B
64R
HV Side BCT
Neutral side BCT
REF Current R phase
REF Current Y phase
REF Current B phase
R-PH
Y-PH
B-PH
BUS SIDE
REACTOR SIDE
NEUTRAL SIDE
REF: 34696200385 SHT.05
SR1
SR2
SR3
SD1
SD2
SD3
1K
ETLR4
ETLY4
ETLB4
NOTE :- EARTH LINK ETLR,ETLY,ETLB SHALL NOT BE USED WHEN RESPECTIVE CTS ARE UNDER SERVICE

Record the CT secondary current at Reactor CMB as per the below-

	R phase Injection		Y phase Injection		B phase Injection		CT Core Usage	CT Ratio adopted
	R	N	Y	N	B	N		
HV Turret (HV BCT)								
Core 1								
Core 2								
Core 3								
Core 4								
Core 5								
Core 6								

Core n								
Reactor Neutral Side Bushing CT (NBCT)								
Core 1								
Core 2								
Core 3								
Core 4								
Core 5								
Core 6								

Core n								
Neutral CT External (NCT)								
Core 1								
Core 2								

Core n								

STABLE CONDITION	**Stable Condition measurements (R-Phase)**		**Stable Condition measurements (Y-Phase)**		**Stable Condition measurements (B-Phase)**		
REF Measurement	REF current to Relay at Reactor MB		REF current to Relay at Reactor MB		REF current to Relay at Reactor MB		**Note- REF stabilizing resistor <u>to be bypassed/Shorted</u> at CRP**
	Relay HMI		Relay HMI		Relay HMI		
Differential Relay current Measurement	**HV Side** R- Y- B-	**IV Side (NBCT)** R- Y- B-	**HV Side** R- Y- B-	**IV Side (NBCT)** R- Y- B-	**HV Side** R- Y- B-	**IV Side (NBCT)** R- Y- B-	Unit of Current Measurement __________
	Differential R- Y- B-	**Restraining** R- Y- B-	**Differential** R- Y- B	**Restraining** R- Y- B-	**Differential** R- Y- B	**Restraining** R- Y- B-	Unit of Current Measurement (PU/mA) __________

UNSTABLE CONDITION	**REF Unstable condition (R-Phase)**		**REF Unstable condition (Y-Phase)**		**REF Unstable condition (B-Phase)**		
NBCT REF CT **core reversed**	**1)** NBCT REF CT Core current		**1)** NBCT REF CT Core current		**1)** NBCT REF CT Core current		**Note- REF stabilizing resistor to be <u>bypassed/Shorted</u> at CRP**
	2) REF current to Relay at Reactor MB		**2)** REF current to Relay at Reactor MB		**2)** REF current to Relay at Reactor MB		
	3) REF Relay current (HMI)		**3)** REF Relay current (HMI)		**3)** REF Relay current (HMI)		
	4) REF current to Relay at Reactor MB		4) REF current to Relay at Reactor MB		4) REF current to Relay at Reactor MB		**Note- REF stabilizing resistor <u>bypassing/Shorting to be removed</u> at CRP**
	5) REF Relay current		5) REF Relay current		5) REF Relay current		
	6) Voltage measured across REF terminals at Reactor MB		6) Voltage measured across REF terminals at Reactor MB		6) Voltage measured across REF terminals at Reactor MB		

UNSTABLE CONDITION	REF Unstable condition (R-Phase)		REF Unstable condition (Y-Phase)		REF Unstable condition (B-Phase)		
NBCT REF CT core Normalized	1) NBCT REF CT Core current		1) NBCT REF CT Core current		1) NBCT REF CT Core current		Note- REF stabilizing resistor to be bypassed/Shorted at CRP
	2) HV Turret REF CT Core current		2) HV Turret REF CT Core current		2) HV Turret REF CT Core current		
	3) REF current to Relay at Reactor MB		3) REF current to Relay at Reactor MB		3) REF current to Relay at Reactor MB		
	4) REF Relay current (HMI)		4) REF Relay current (HMI)		4) REF Relay current (HMI)		
	5) Voltage measured across REF terminals at Reactor MB		5) Voltage measured across REF terminals at Reactor MB		5) Voltage measured across REF terminals at Reactor MB		

Further, three phase Balance AC supply to be injected from HV bay side. Currents to be noted down as following.

Three phase injection current	R phase Current-	Y phase Current-	B phase Current-

Stable Condition	R	Y	B	N
HV Turret (HV BCT)				
Core 1				
Core 2				
Core 3				
Core 4				
Core 5				
Core 6				

Core n				

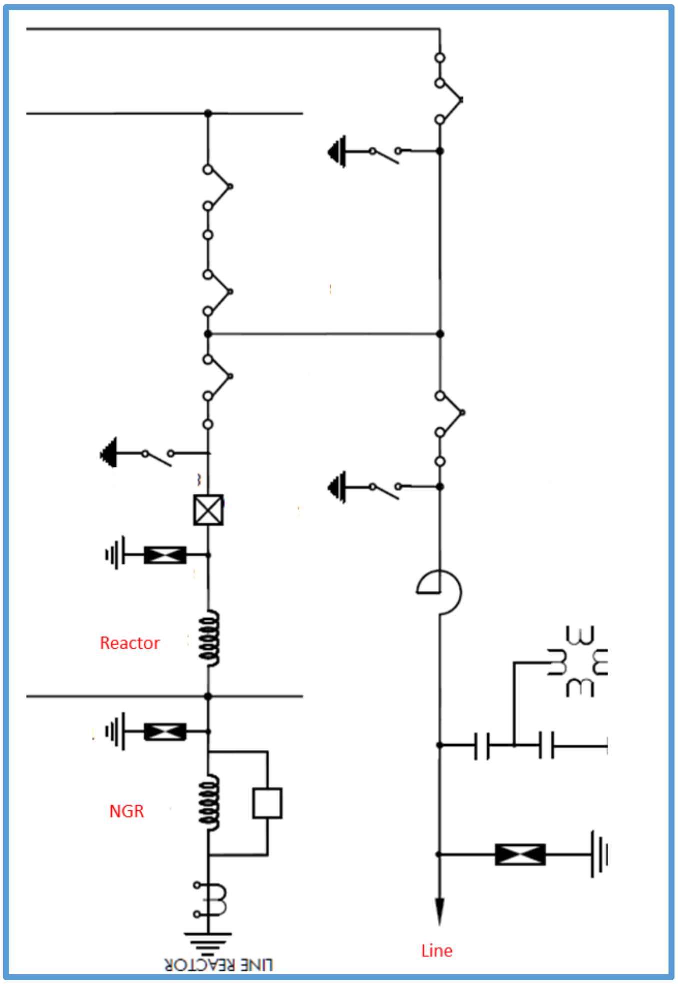
Reactor Neutral Side Bushing CT (NBCT)					
Core 1					
Core 2					
Core 3					
Core 4					
Core 5					
Core 6					

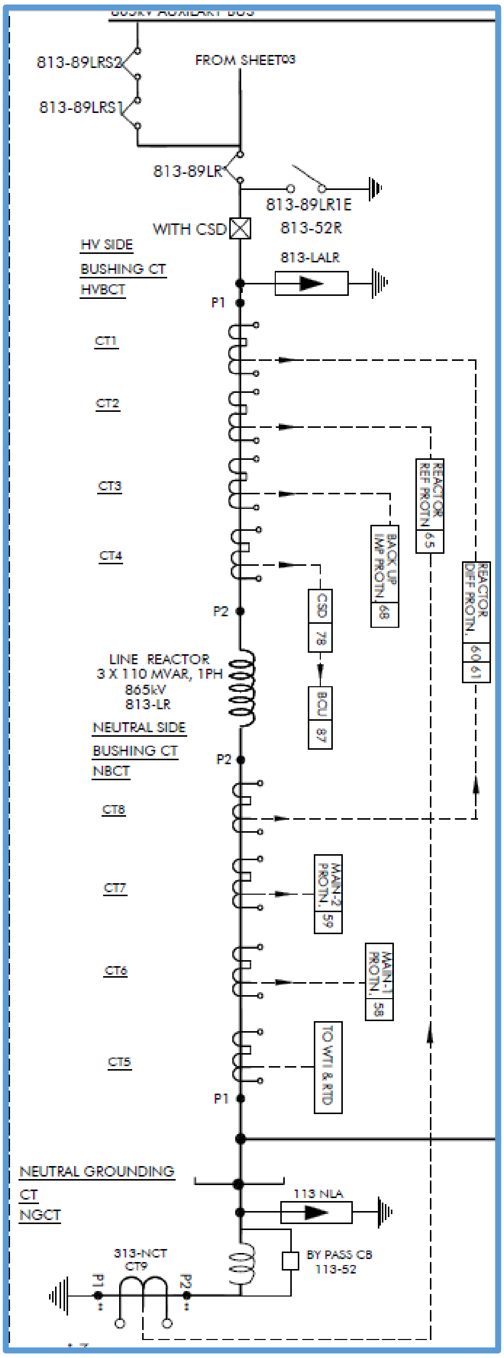
Core n					
Neutral CT External (NCT)					
Core 1					
Core 2					

Core n					
	R Phase	**Y Phase**	**B Phase**		
1) REF current to Relay at Reactor MB				**Note- REF stabilizing resistor <u>to be</u> <u>bypassed/Shorted</u> at CRP**	
2) REF Relay current (HMI)					
3) Voltage measure across REF CT wires to Relay (Across A-B as shown in Figure)					
4) REF current to Relay at Reactor MB				**Note- REF stabilizing resistor <u>bypassing/Shorting</u> <u>to be removed</u> at CRP**	
5) REF Relay current (HMI)					
6) Voltage measure across REF CT wires to Relay (Across A-B as shown in Figure)					
7) Differential Relay Measurement	**HV Side** R- Y- B-		**IV Side (NBCT)** R- Y- B-	**Differential Current** R- Y- B-	**Restraining Current** R- Y- B-

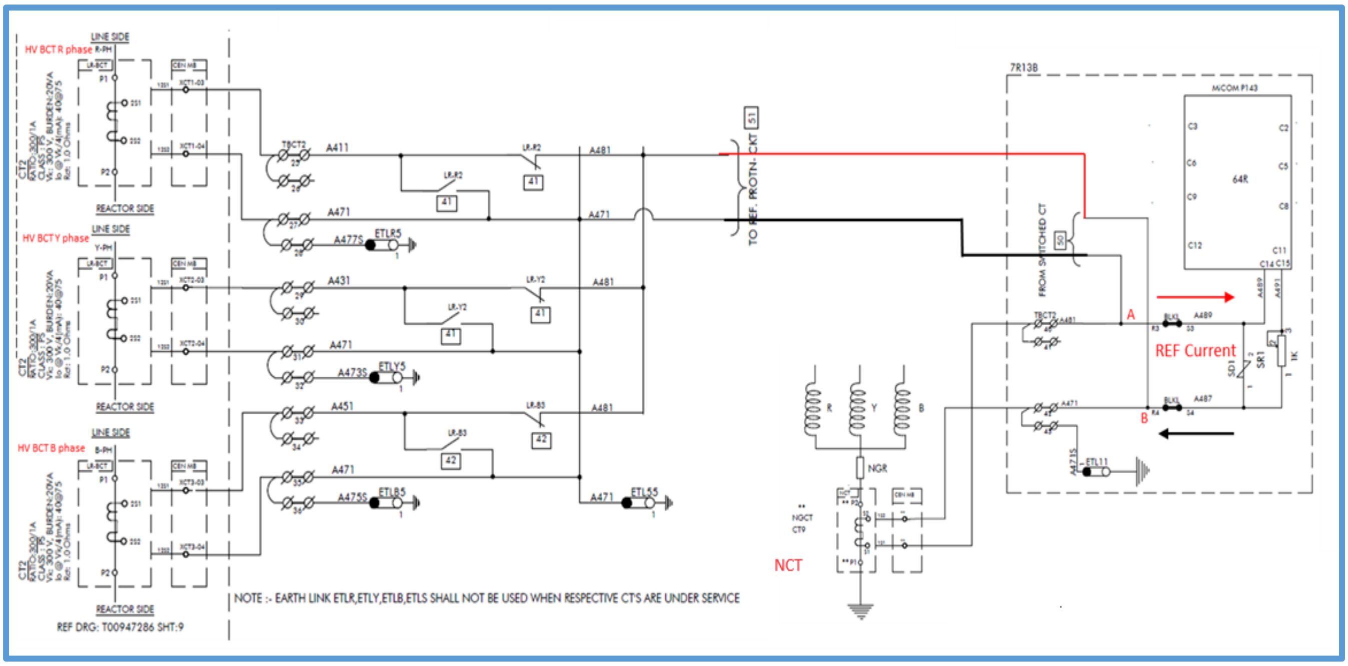
V) Line Reactor Single phase units

Single phase AC supply to be injected phase wise from HV bay side. Ensure that Reactor neutral is properly grounded, connection of neutral bushing terminal is proper. Refer the figure below-





Indicative CT circuit diagram for REF protection is shown below, where the point A & B are CT parallel points (here at Reactor CRP) and REF current is the CT summation current after parallel point A & B to Relay.



Record the CT secondary current at Reactor CMB as per the below-

	R phase Injection		Y phase Injection		B phase Injection		CT Core Usage	CT Ratio adopted
	R	N	Y	N	B	N		
Bushing CT- Reactor winding HV Side (HV BCT)								
Core 1								
Core 2								
Core 3								
Core 4								
Core 5								
Core 6								

Core n								
Bushing CT- Reactor winding								

Neutral Side (NBCT)								
Core 1								
Core 2								
Core 3								
Core 4								
Core 5								
Core 6								

Core n								
Neutral CT after NGR (NCT)								
Core 1								
Core 2								

Core n								

STABLE CONDITION	**Stable Condition measurements (R-Phase)**		**Stable Condition measurements (Y-Phase)**		**Stable Condition measurements (B-Phase)**			
REF Measurement	REF current to Relay at CRP		REF current to Relay at CRP		REF current to Relay at CRP		**Note- REF stabilizing resistor <u>to be bypassed/Shorted</u> at CRP**	
	Relay HMI		Relay HMI		Relay HMI			
Differential Relay current Measurement	**HV Side (HV BCT)** R- Y- B-	**IV Side (NBCT)** R- Y- B-	**HV Side (HV BCT)** R- Y- B-	**IV Side (NBCT)** R- Y- B-	**HV Side (HV BCT)** R- Y- B-	**IV Side (NBCT)** R- Y- B-	Unit of Current Measurement __________	
	Differential R- Y- B-	**Restraining** R- Y- B-	**Differential** R- Y- B	**Restraining** R- Y- B-	**Differential** R- Y- B	**Restraining** R- Y- B-	Unit of Current Measurement (PU/mA) __________	
Main 1 relay Line current measurement	**HV NBCT Line** R- Y- B-		**HV NBCT Line** R- Y- B-		**HV NBCT Line** R- Y- B-		**For Verification of Reactor current compensation to Line current**	
Main 2 relay Line current measurement	**HV NBCT Line** R- Y-		**HV NBCT Line** R- Y-		**HV NBCT Line** R- Y-			

	B-	B-	B-	

UNSTABLE CONDITION	REF Unstable condition (R-Phase)		REF Unstable condition (Y-Phase)		REF Unstable condition (B-Phase)		
NCT REF CT **core reversed**	**1)** NCT REF CT Core current at Reactor MB		**1)** NCT REF CT Core current at Reactor MB		**1)** NCT REF CT Core current at Reactor MB		**Note- REF stabilizing resistor to be <u>bypassed/Shorted</u> at CRP**
	2) REF current to Relay at CRP		**2)** REF current to Relay at CRP		**2)** REF current to Relay at CRP		
	3) REF Relay current (HMI)		**3)** REF Relay current (HMI)		**3)** REF Relay current (HMI)		
					4) REF current to Relay at CRP		**Note- REF stabilizing resistor <u>bypassing/Shorting to be removed</u> at CRP**
					5) REF Relay current (HMI)		
					6) Voltage measured across REF terminals at CRP		

UNSTABLE CONDITION	REF Unstable condition (R-Phase)		REF Unstable condition (Y-Phase)		REF Unstable condition (B-Phase)		
NCT REF CT **core Normalized**	**1)** NCT REF CT Core current at Reactor MB		**1)** NCT REF CT Core current at Reactor MB		**1)** NCT REF CT Core current at Reactor MB		**Note- REF stabilizing resistor <u>to be bypassed/Shorted</u> at CRP**
	2) HV BCT REF CT Core current		**2)** HV BCT REF CT Core current		**2)** HV BCT REF CT Core current		
	3) REF current to Relay at CRP		**3)** REF current to Relay at CRP		**3)** REF current to Relay at CRP		
	4) REF Relay		**4)** REF Relay		**4)** REF Relay		

	current (HMI)		current (HMI)		current (HMI)		
	5) Voltage measured across REF terminals at CRP		**5)** Voltage measured across REF terminals at CRP		**5)** Voltage measured across REF terminals at CRP		

Further, three phase Balance AC supply to be injected from HV bay side. Currents to be noted down as following.

Three phase injection current	R phase Current-	Y phase Current-	B phase Current-

Stable Condition	**R**	**Y**	**B**	**N**
HV Turret (HV BCT)				
Core 1				
Core 2				
Core 3				
Core 4				
Core 5				
Core 6				

Core n				
Reactor winding Neutral Side (NBCT)				
Core 1				
Core 2				
Core 3				
Core 4				
Core 5				
Core 6				

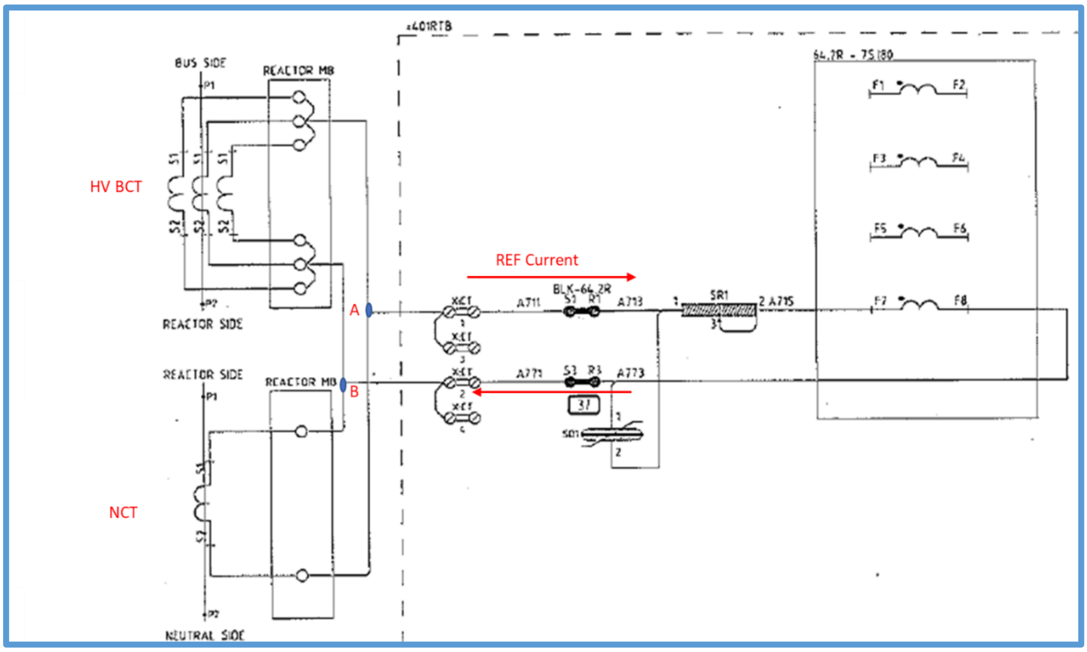
Core n				
Neutral CT after NGR (NCT)				
Core 1				
Core 2				

Core n				
1) REF current to Relay at CRP				
2) REF Relay current (HMI)				

3) Voltage measure across REF CT wires to Relay (Across A-B as shown in Figure)			**Note- REF stabilizing resistor to be bypassed/Shorted at CRP**	
4) REF current to Relay at CRP			**Note- REF stabilizing resistor bypassing/Shorting to be removed at CRP**	
5) REF Relay current (HMI)				
6) Voltage measure across REF CT wires to Relay (Across A-B as shown in Figure)				
7) Differential Relay Measurement	**HV Side (HV BCT)** R- Y- B-	**IV Side (NBCT)** R- Y- B-	**Differential Current** R- Y- B-	**Restraining Current** R- Y- B-
8) Main 1 Relay line currents	**HV NBCT Line** R- Y- B-			
9) Main 2 Relay line currents	**HV NBCT Line** R- Y- B-			

VI) Line Reactor three phase units

Single phase AC supply to be injected phase wise from HV bay side. Ensure that Reactor neutral is properly grounded, connection of neutral bushing terminal is proper. Refer the figure below Indicative CT circuit diagram for REF protection is shown below, where the point A & B are CT parallel points (here at Reactor CRP) and REF current is the CT summation current after parallel point A & B to Relay.



Record the CT secondary current at Reactor CMB as per the below-

	R phase Injection		Y phase Injection		B phase Injection		CT Core Usage	CT Ratio adopted
	R	N	Y	N	B	N		
Bushing CT-Reactor winding HV Side (HV BCT)								
Core 1								
Core 2								
Core 3								
Core 4								
Core 5								
Core 6								

Core n								
Bushing CT-Reactor winding Neutral Side (NBCT)								
Core 1								
Core 2								
Core 3								
Core 4								
Core 5								
Core 6								

Core n								
Reactor Neutral (NCTR)								
Core 1								
Core 2								

Core n								
Neutral CT after NGR (NCT)								
Core 1								

Core 2								

Core n								

STABLE CONDITION	**Stable Condition measurements (R-Phase)**		**Stable Condition measurements (Y-Phase)**		**Stable Condition measurements (B-Phase)**		
REF Measurement	REF current to Relay at Reactor MB		REF current to Relay at Reactor MB		REF current to Relay at Reactor MB		**Note- REF stabilizing resistor <u>to be</u> <u>bypassed/Shorted</u> at CRP**
	Relay HMI		Relay HMI		Relay HMI		
Differential Relay current Measurement	**HV Side (HV BCT)** R- Y- B-	**IV Side (NBCT)** R- Y- B-	**HV Side (HV BCT)** R- Y- B-	**IV Side (NBCT)** R- Y- B-	**HV Side (HV BCT)** R- Y- B-	**IV Side (NBCT)** R- Y- B-	Unit of Current Measurement __________
	Differential R- Y- B-	**Restraining** R- Y- B-	**Differential** R- Y- B	**Restraining** R- Y- B-	**Differential** R- Y- B	**Restraining** R- Y- B-	Unit of Current Measurement (PU/mA) __________
Main 1 relay Line current measurement	R- Y- B-		R- Y- B-		R- Y- B-		**For Verification of Reactor current compensation to Line current**
Main 2 relay Line current measurement	R- Y- B		R- Y- B		R- Y- B		

UNSTABLE CONDITION	**REF Unstable condition (R-Phase)**		**REF Unstable condition (Y-Phase)**		**REF Unstable condition (B-Phase)**		
NCT REF CT **core reversed**	**1)** NCT REF CT Core current at Reactor MB		**1)** NCT REF CT Core current at Reactor MB		**1)** NCT REF CT Core current at Reactor MB		**Note- REF stabilizing resistor to be <u>bypassed/Shorted</u> at CRP**
	2) REF current to Relay at Reactor MB		**2)** REF current to Relay at Reactor MB		**2)** REF current to Relay at Reactor MB		
	3) REF Relay current (HMI)		**3)** REF Relay current (HMI)		**3)** REF Relay current (HMI)		
					4) REF current to		**Note- REF stabilizing resistor**

		Relay at Reactor MB		**bypassing/Shorting to be removed at CRP**
		5) REF Relay current (HMI)		
		6) Voltage measured across REF terminals at Reactor MB		

UNSTABLE CONDITION	**REF Unstable condition (R-Phase)**		**REF Unstable condition (Y-Phase)**		**REF Unstable condition (B-Phase)**		
NCT REF CT **core Normalized**	**1)** NCT REF CT Core current at Reactor MB		**1)** NCT REF CT Core current at Reactor MB		**1)** NCT REF CT Core current at Reactor MB		**Note- REF stabilizing resistor to be bypassed/Shorted at CRP**
	2) HV BCT REF CT Core current		**2)** HV BCT REF CT Core current		**2)** HV BCT REF CT Core current		
	3) REF current to Relay at Reactor MB		**3)** REF current to Relay at Reactor MB		**3)** REF current to Relay at Reactor MB		
	4) REF Relay current (HMI)		**4)** REF Relay current (HMI)		**4)** REF Relay current (HMI)		
	5) Voltage measured across REF terminals at Reactor MB		**5)** Voltage measured across REF terminals at Reactor MB		**5)** Voltage measured across REF terminals at Reactor MB		

UNSTABLE CONDITION	**REF Unstable condition (R-Phase)**		**REF Unstable condition (Y-Phase)**		**REF Unstable condition (B-Phase)**		
NBCT core to Main 1 relay **Reversed**	**Main 1** **R-** **Y-** **B-**	**Main 2** **R-** **Y-** **B-**	**Main 1** **R-** **Y-** **B-**	**Main 2** **R-** **Y-** **B-**	**Main 1** **R-** **Y-** **B-**	**Main 2** **R-** **Y-** **B-**	**Rector Current Compensation to Main 1 & Main 2**
NBCT core to Main 1 relay **Normalized**	**Main 1** **R-** **Y-** **B-**		**Main 1** **R-** **Y-** **B-**		**Main 1** **R-** **Y-** **B-**		
NBCT core to Main 2 relay **Reversed**	**Main 1** **R-** **Y-**	**Main 2** **R-** **Y-**	**Main 1** **R-** **Y-**	**Main 2** **R-** **Y-**	**Main 1** **R-** **Y-**	**Main 2** **R-** **Y-**	

	B-	**B-**	**B-**	**B-**	**B-**	**B-**	
NBCT core to Main 2 relay **Normalized**	**Main 2** **R-** **Y-** **B-**		**Main 2** **R-** **Y-** **B-**		**Main 2** **R-** **Y-** **B-**		

Further, three phase Balance AC supply to be injected from HV bay side. Currents to be noted down as following.

Three phase injection current	R phase Current-	Y phase Current-	B phase Current-

Stable Condition	R	Y	B	N
HV Turret (HV BCT)				
Core 1				
Core 2				
Core 3				
Core 4				
Core 5				
Core 6				

Core n				
Reactor winding Neutral Side (NBCT)				
Core 1				
Core 2				
Core 3				
Core 4				
Core 5				
Core 6				

Core n				
Reactor Neutral CT (NCTR)				
Core 1				
Core 2				

Core n				
Neutral CT after NGR (NCT)				
Core 1				
Core 2				

Core n				
1) REF current to Relay at Reactor MB			**Note- REF stabilizing resistor to be bypassed/Shorted at CRP**	
2) REF Relay current (HMI)				
3) Voltage measure across REF CT wires to Relay (Across A-B as shown in Figure)				
4) REF current to Relay at Reactor MB			**Note- REF stabilizing resistor bypassing/Shorting to be removed at CRP**	
5) REF Relay current (HMI)				
6) Voltage measure across REF CT wires to Relay (Across A-B as shown in Figure)				
7) Differential Relay Measurement	**HV Side (HV BCT)** R- Y- B-	**IV Side (NBCT)** R- Y- B-	**Differential Current** R- Y- B-	**Restraining Current** R- Y- B-
8) Main 1 & Main 2 Relay line currents	**Main 1** **R-** **Y-** **B-**		**Main 2** **R-** **Y-** **B-**	

c. 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
   - Ensure presence of oil in the thermometer pockets. Follow the same procedure for the thermal replicas
3. Check the direction of installation of Buchholz relay.
4. 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
5. Check the insulation of the auxiliary circuits with respect to ground by 2 kV insulation tester for 1 min. It should withstand the test.
6. Check the earthing of the tank and auxiliaries like cooler banks at two places.
7. Measure the supply voltages of the auxiliary circuits
8. 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
9. Check that there is sufficient protection on the electric circuit supplying the accessories and tightness of all electrical connections
10. Check the heating and lighting in the cubicles

11. 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
12. Stability check for REF & Differential to be carried out

d. Energizing the transformer

After the inspection / tests are completed, the transformer may be energized from HV side on NO LOAD though CSD. The initial magnetizing current at the time of switching may be high, depending upon the particular moment in the cycle. The transformer should be kept energized condition and shall be held at rated voltage and no load for a period according to Table.

Voltage Class	Energizing Period (Hours)	Suggested minimum energizing period(Hours)
220kV-800kV	24	12
132kV-220kV	12	8
<132kV	8	8

While this period of energization at no load may not be necessary, it is helpful to understand and evaluate the Transformer in this condition prior to applying load. During this energizing period, before loading the transformer, following surveillance activities are recommended:

- Check for excessive audible noise and vibration
- Monitoring of the OTI along with ambient temperature, recording to be taken at time intervals (every hour) until stabilization
- Monitoring of WTI , recording to be taken at time intervals (every hour) until stabilization
- Operate and check performance of LTC through all positions, within rated voltages (if applicable)
- Operate and check performance of cooling pumps and fans (if applicable)
- Inspect for oil leaks and check all oil level indicators and gas detector relay (if applicable)

After that it may be checked for gas collection. Should the gas prove to be inflammable, try to detect the cause which may probably be an internal fault. If the breaker trips on differential /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/AM and manufacturer (if requested by them).

A.2.19 Post Commissioning checks/ tests for Transformers and Reactors

Sr. No.	Name of Test/ Check point	Purpose of test/ check
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.
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).
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

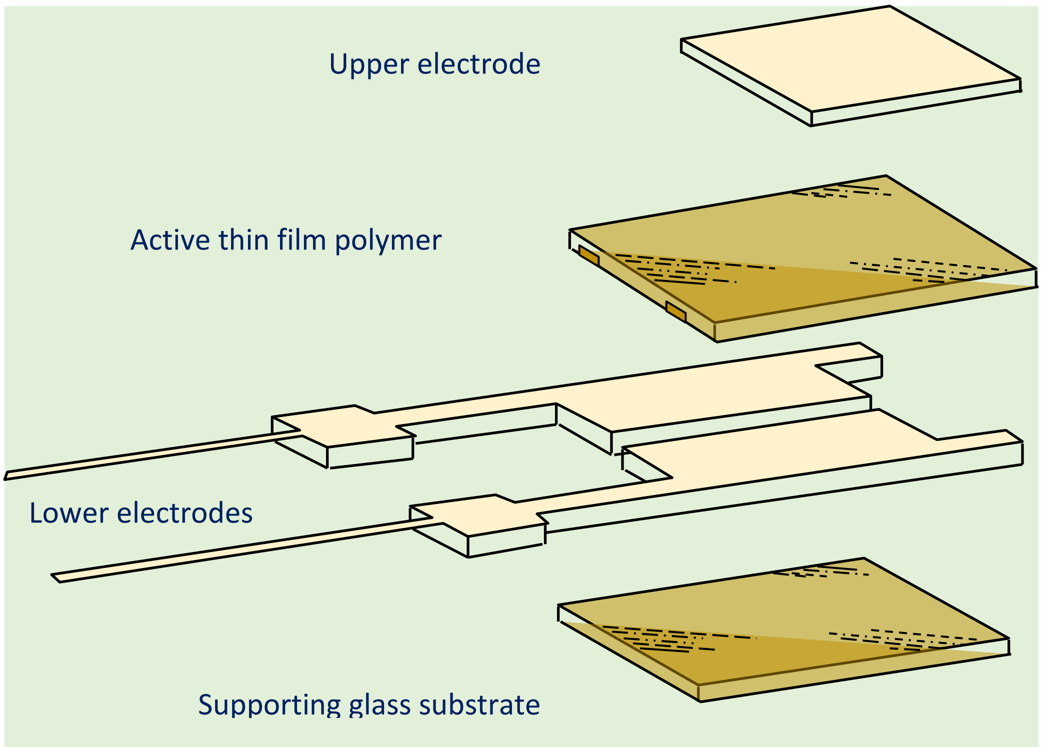
I. THERMOVISION SCANNING (IR THERMOGRAPHY)

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.

II. On Line moisture measurement

The test is performed with the transformer in service with the top oil temperature at least 50 deg.C and preferably 60 deg.C. The transformer must be operated for three days at these temperatures to get an accurate assessment of the moisture content of the solid insulation. During that time moisture will migrate from the solid insulation and the moisture content will increase even if the temperature remains constant. Moisture assessment in paper insulation of transformers can be made through on-line moisture measurement sensors (DOMINO / VAISALA).

The moisture sensor is composed of an upper and lower electrode, a thin film polymer and a support base. Water vapor penetrates the upper electrode and reaches the thin-film polymer. The amount of water vapor absorbed is dependent on the relative saturation of water in the oil. The polymer used for this application is dispersive, that is, its dielectric constant changes with changing water content. The capacitance of the polymer, which is the dielectric constant of the material divided by the dielectric constant of vacuum (which is 1), is used to determine the relative saturation of water in the dielectric liquid.



This sensor is stable in an oil environment for many years and can operate over the full range of oil temperatures in transformers (up to180 deg. C). The sensors are quite accurate, and the calibration includes low moisture contents where the sensors will operate much of the time. Because the sensor relies on the movement of water molecules to and from the thin film polymer, oil flow around the sensor greatly facilitates this process. Little or no oil flow around the sensor will give low readings below the true water content.

The moisture and temperature sensors are mounted on the end of a probe, which is placed directly in the oil. A signal cable transmits the capacitance changes from the probe to a NEMA 4 wetter-proof transmitter housing which contains the electronics for measurement & display.

The wetter the insulation the more the water-in-oil content will increase, If the top oil temperature is maintained between 60 deg-70 deg. C some solid insulation condition guidelines can be offered.

III. 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 equipment, 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 2nd 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.

SECTION-B

This section provides guidance & recommended practices for installation, testing & commissioning requirement for oil-immersed Power Transformer, Reactor with voltage rating 66kV above.

B.1. 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 equipment prior to their energization. Various major electrical tests to be performed and their significance are given below:

Sr. No.	Name of Test / Check point	Purpose of test/ check
1.	Tan δ & Capacitance measurement of CT, each stack of CVT & total capacitance, CB voltage grading capacitor	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 %.
2.	**Checks/ Tests applicable for CTs**	
I.	Polarity test for CT	To ascertain whether the polarity markings are correct or not as per drawing.
II.	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.
III.	Ratio test for CT	The ratio errors of the primary to the secondary currents should within specified ratio errors.
IV.	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.
V.	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)
VI.	Dew point & Purity measurement of SF6 gas (In case of SF6 filled CTs)	Dew point & Purity of SF6 gas is to assess quality of SF6 gas filled in CTs
3.	**Checks/ Tests applicable for Circuit Breakers**	
i.	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.

ii.	Measurement of Circuit Breaker Operating Timings including PIR Timings	To measure closing/ tripping/ CO timings. These 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.
iii.	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 AM.
iv.	Operational lockout checking for EHV Circuit Breakers	To ensure various lockout operation of CB by simulating the actual conditions at the specified pressure of operating medium.
v.	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.
vi.	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.
vii.	Checking the Anti-Condensation Heaters	To check correct operation of Thermostat provided for anti condensation heaters.
viii.	Pole discrepancy relay testing	To test tripping of CB in case of pole discrepancy more than 2.5 seconds or specified value.
4.	**Checks/ Tests applicable for CVTs**	
i.	CVT polarity, Ratio test	This test is conducted in the same manner as for CT to determine correct CVT polarity, ratio and phasor group.
ii.	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.
5.	**Checks/ Tests applicable for Isolators**	
i.	MILLIVOLT Drop test	The voltage drop gives a measure of resistance of current carrying part and contacts by injecting minimum 100 A DC current.

ii.	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.	**Checks/ Tests applicable for Surge Arrestors**	
i.	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.
ii.	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.
iii.	Checking of operation of LA counter	This test is done to check the healthiness of LA counter.
7.	**Checks/ Tests for other areas/ equipments**	
i.	Earth resistance measurement	To ensure value of earth resistance is below 1 ohm.
ii.	Secondary current injection test	Conducted for testing of protecting devices, circuit breakers, trip coils, motor overloads etc.
iii.	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.
iv.	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.

B.1.1 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.

I. CURRENT TRANSFORMERS

CTs with test taps

I. Tan delta tap to be disconnected from ground.
II. 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.
III. P1 and P2 to be shorted
IV. Porcelain surface to be thoroughly cleaned.
V. Measurements have to be taken in UST mode with fully automatic test kit.
VI. 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.
VII. It is to be ensured to connect the test tap to ground terminal after carrying out the test.

II. CB VOLTAGE GRADING CAPACITOR

I. Connect LV cable to the middle of the double interrupter.
II. Connect HV cable to the other end of the Grading capacitor to be tested.
III. The opposite end of the grading capacitor has to be grounded using earth switch.
IV. Measurements have to be taken in UST Mode with fully automatic test kit.
V. 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.
VI. Standard procedure (as specified by kit supplier) for measuring capacitance and tan delta in charged switchyard/induced voltage conditions should be followed
VII. Measurements are to be carried out at 10 kV/ 12 KV.

III. CAPACITOR VOLTAGE TRANSFORMES

i. 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.

ii. 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.

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

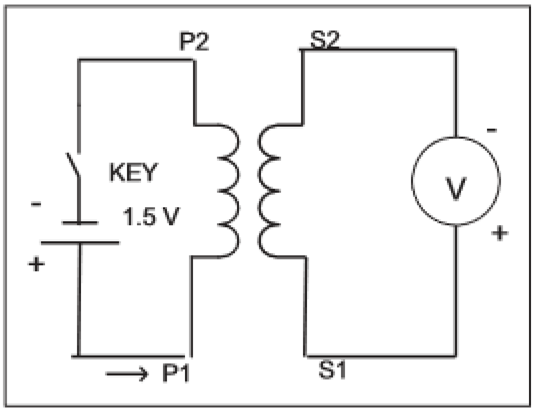
B.1.2 CHECKS/ TESTS APPLICABLE FOR CTs

B.1.2.1 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.



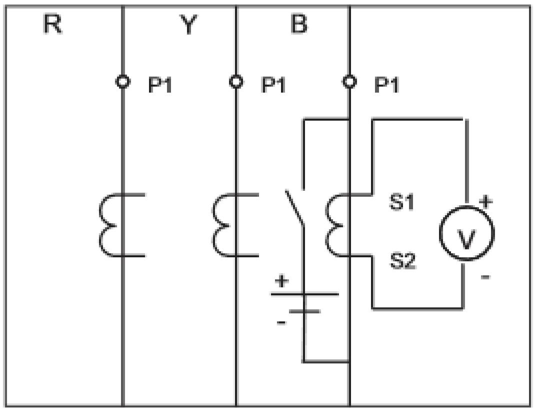


Figure-7

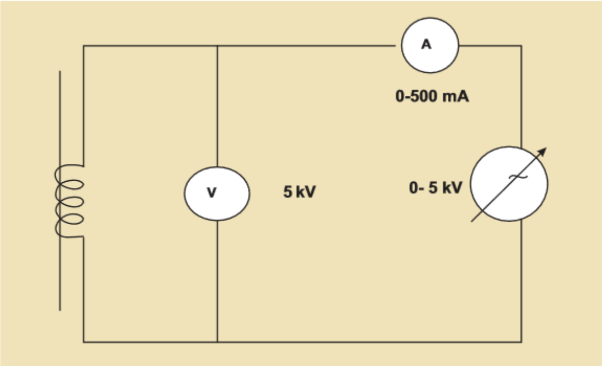
B.1.2.2 MAGNETIZATION CHARACTERISTICS OF CTs

PRECAUTIONS

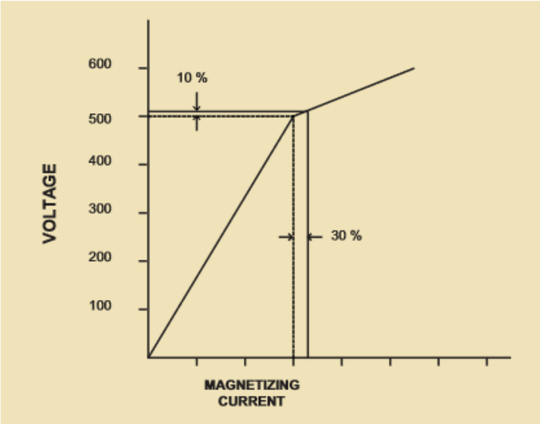
a) There should be no joints in testing leads/cables.
b) It should be ensured that whole testing equipment along with testing procedures are available at testing site. Testing must be carried out in presence of testing personnel only.

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



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:-

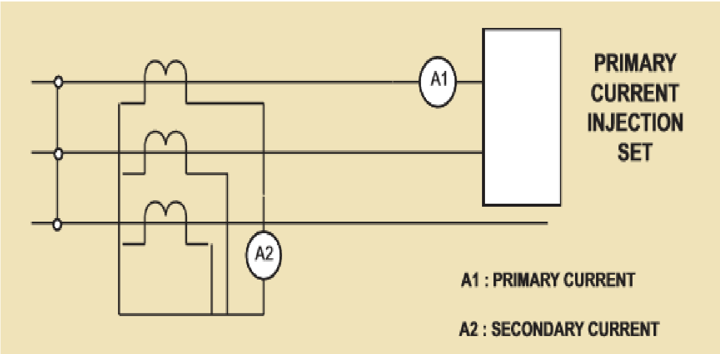


TYPICAL MAGNETIZATION CURVE

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, output of CT secondary disappears.

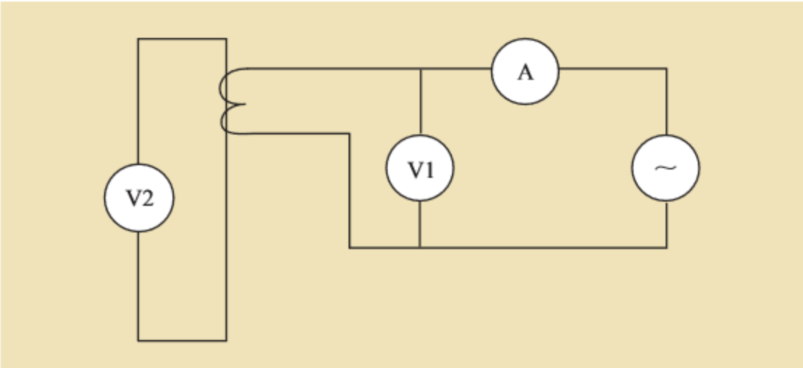
B.1.2.3. RATIO TEST FOR CURRENT TRANSFORMER

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



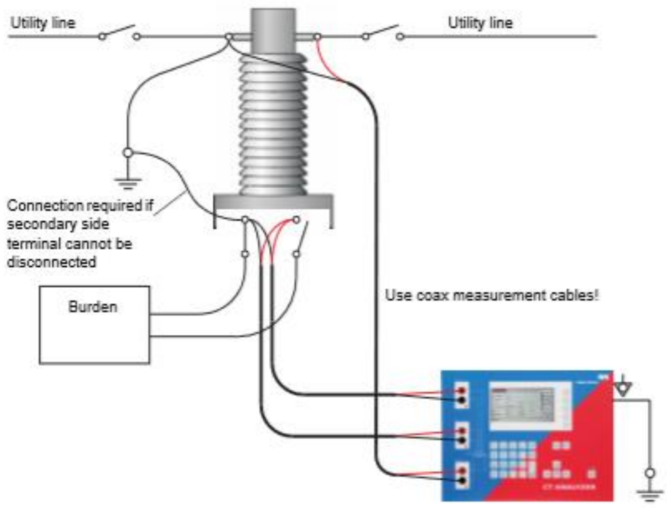
It is customary to conduct this in conjunction with the primary injection test. Current is passed through the primary circuit with the secondary winding circuit to its normal circuit load. The ratio of the primary to the secondary currents should approximate closely to that stamped under CT identification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

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



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.

Alternatively, these tests (Polarity, Magnetizing Characteristics, Ratio & Secondary Winding) can also be performed with CT Analyzer. Procedure for carrying out these tests through CT analyzer is given below:



a) Connect primary side winding of CT to primary port of CT Analyser kit using 2 wires as shown in connection arrangement above
b) Connect secondary side winding of CT to secondary port of CT Analyser kit using 2 wires as shown in connection arrangement above
c) Connect secondary side winding of CT to output port of CT Analyser kit using 2 wires as shown in connection arrangement above
d) Any Burden to secondary core should be disconnected at time of measurement
e) Enter in the test kit following data (as per CT Technical Specifications):
    - CT Bay Details
    - Relevant IEC for CT as per CT Technical Specifications
    - Core to be tested – Protection/Metering
    - Ratio of Core to be tested – 3000/1, 2000/1 etc
f) Start the test and test results (Polarity, Magnetizing Characteristics, Ratio & Secondary Winding) shall be provided by kit after some

   Aforesaid connection arrangement (point no: a to c) has been shown for Omicorn CT Analyser. Same may be done as per type of kit used during measurement.

B.1.2.4. 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.

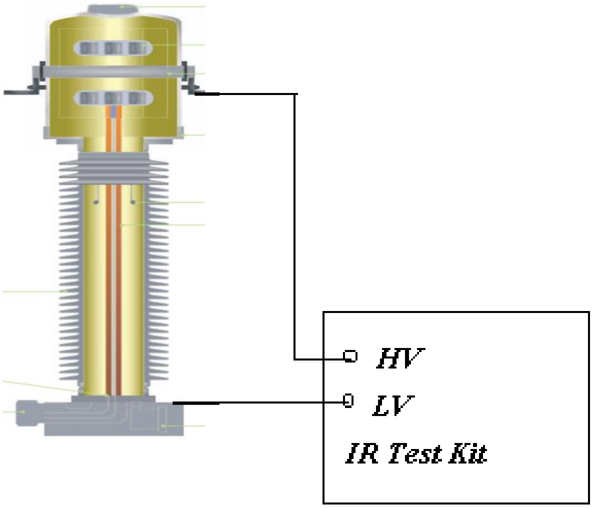


Figure-15 Typical Arrangement for IR measurement

I. 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.

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

B.1.2.5 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.

B.1.3 CHECKS/ TESTS APPLICABLE FOR CIRCUIT BREAKERS

B.1.3.1 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.

B.1.3.2 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 energized 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 Analyzer 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 color 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 analyser.
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 operations 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

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.

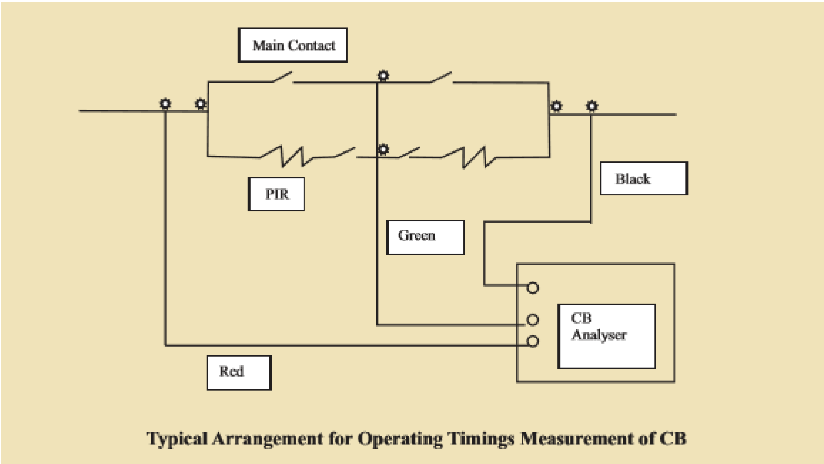


Figure-16

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.

'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.

B.1.3.4 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.

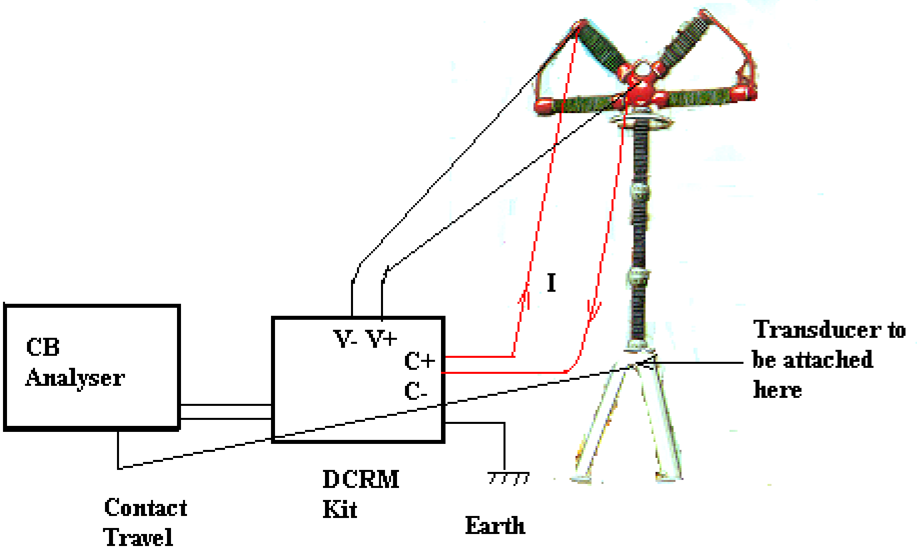
c) Earth switch of one side of CB should be in open position.

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.

B.1.3.5 OPERATIONAL LOCKOUT CHECKING FOR EHV CIRCUIT BREAKERS

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

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/cm2 of the set value (after taking into account the temperature correction factor).

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 as per latest controlled document for acceptable permissible limit for substation equipment's.

B.1.3.6 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.

B.1.3.7 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.

B.1.3.8 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.

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.

B.1.3.8 CHECKING OF CONTROLLED SWITCHING DEVICE

In power system, the traditional random switching mode of circuit breakers will generate inevitably over-voltage, inrush current, electromagnetic transient effect These effects can have detrimental consequences on the insulation and lifespan of equipment, and in some cases, even lead to protection malfunctions.

Random interruption of shunt reactor inductive currents can lead to current chopping and re-ignitions, both of which can produce over voltages (slow and fast front respectively) which is dangerous to associated substation equipment.

Random energization of shunt reactors/Transformers can lead to high asymmetrical inrush currents which in turn mechanically stress the reactor and generate long time constant, high amplitude, zero sequence currents (Protection security is endangered).

"Controlled switching" is one of several terminologies applied to the principle of coordinating the instant of opening or closing of a circuit with a specific target point on an associated voltage or current waveform. "Controlled switching" basically uses electronic control equipment **CSD (Control Switching Device**) to facilitate the operation of the contacts of the CB at pre-determined point in relation to Current/ Voltage.

Controlled switching provides many technical and economic benefits. Some of the most important advantages are the reductions of high inrush currents, dangerous switching overvoltage's, equipment failures, and maintenance of circuit breakers that are switched quite frequently thereby extending the life of electrical equipment and improving the stability of the power system.

B.1.3.8.1. Controlled Opening:

The technique of controlling the contact separation of each pole of circuit breaker with respect to the phase angle of the current and thereby controlling the arcing times in order to minimize stresses on the equipment of the power system.

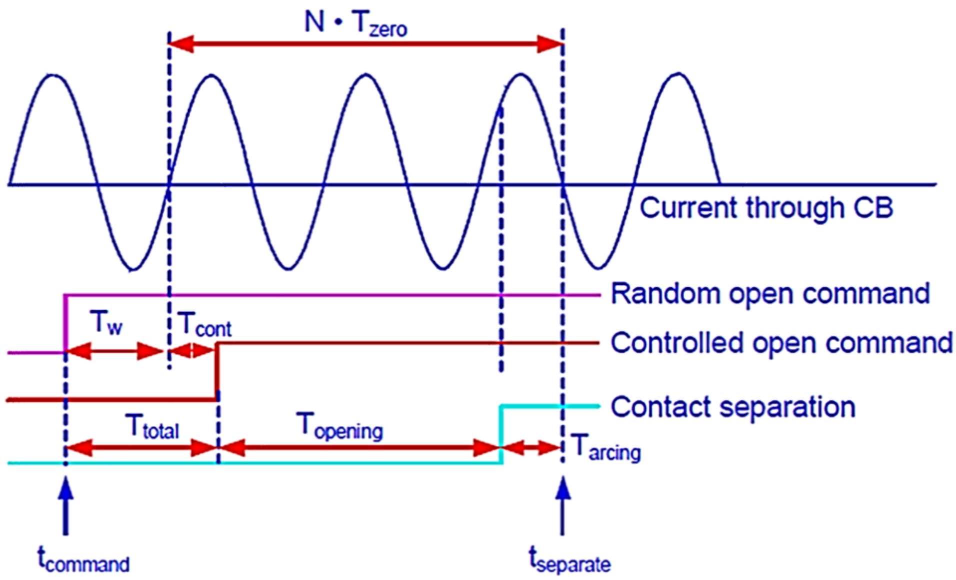


Figure: Controlled Opening

B.1.3.8.2. Controlled Closing:

The technique of controlling the instant of making of each pole of circuit breaker with respect to the phase angle of the Voltage waveform and thereby controlling the switching over voltages and inrush currents in order to minimize stresses on the equipment.

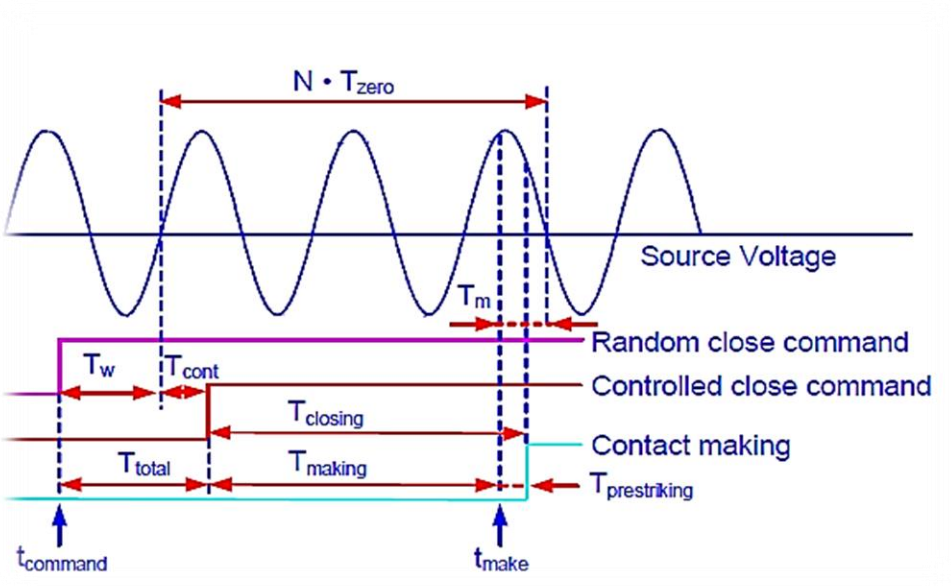


Figure: Controlled Closing

B.1.3.8.3. Inputs required for Commissioning of a CSD:

1. Voltage Signal Bus Side
2. Voltage Signal Load Side (As applicable)
3. Current Signal Load Side
4. Power On Control voltage (DC Voltage)
5. Signals from reference contacts from each pole
6. Circuit Breaker Auxiliary contact signals
7. Close-open commands from BCU

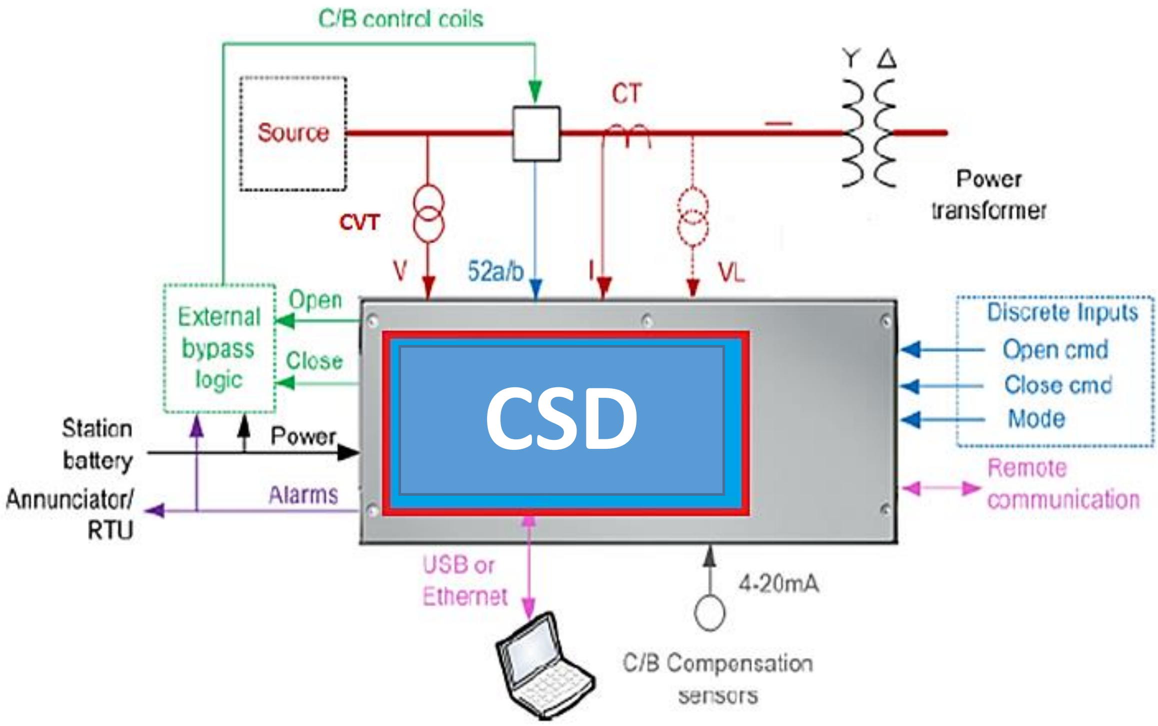


Figure: General Arrangements

B.1.3.8.4. Commissioning checks on CSD:

Key Points:

1. **Approved Drawing Connection Arrangement:** The approved drawing connection arrangement is a comprehensive diagram that illustrates the correct wiring connections between the CSD, circuit breaker, and other associated components. It ensures that the device is installed in accordance with the manufacturer's specifications and the intended design. Refer to this drawing throughout the commissioning process to ensure accurate and proper wiring.

2. **Manual Instructions:** The manual provided with the CSD contains detailed instructions on how to install, configure, and commission the device. It outlines the specific steps, settings, and parameters required for successful commissioning.

3. **Wiring Verification:** Compare the wiring connections in the approved drawing connection arrangement with the actual wiring installation. Verify that all connections match and that the wiring is correctly terminated, ensuring proper electrical continuity and insulation. Pay attention to the labeling and identification of terminals and cables as specified in the manual.

4. **Power Supply:** Follow the instructions in the manual regarding the power supply requirements for the CSD. Verify that the power supply is within the specified voltage and current ratings.

5. **Configuration and Parameter Settings:** Configure the CSD according to the recommended settings and procedure specified in this document. In case of inconsistencies, Manufacturer Manual provided with the CSD shall be referred.

6. **Functional Testing:** Conduct functional tests as specified in the manual/pre-commissioning format to verify the proper operation of the CSD such as testing the device's ability to open and close the circuit breaker, verifying communication with control systems or protection relays, and ensuring the expected response times and accuracy of signals.

7. **Documentation and Reporting:** Maintain detailed records of the commissioning process, including the approved drawing connection arrangement, manual references, test results, configurations, and any observations made.

The approved drawing connection arrangement, OEM manual and pre-commissioning format are crucial resources that guide the commissioning process and ensure the correct installation and configuration of the CSD. Adhering to these guidelines minimizes the risk of errors, enhances the device's performance, and contributes to the overall reliability and safety of the electrical system.

General Pre-commissioning checks:

1. Individually all the three phase commands carrying wires from CSD must be connected to the respective pole RYB - for Closing & Opening. For Closing operation, selective DC (+ve and -ve) should be taken from CB MB to avoid dc mixing.

2. Individually all the three phase 52a contacts (CB Aux. Contact: NO) are to be wired in correct sequence up to CSD terminal - By operating individual poles at a time, the contact changeover has to be checked.

3. Reference Voltage Source and Current Source should be connected with CSD in the correct phase sequence w.r.t R, Y & B.

4. Reference Voltage Source R & 52a contacts (CB Aux. Contact: NO) are wired correctly in the same order R, Y & B up to CSD terminal.

5. For Ex: If reference voltage is R Phase (L1), all the commands and 52a contacts should be wired in the same phase sequence i.e. RYB =L1, L2, L3.

6. Signal from reference contact from each CB pole should be connected with CSD through shielded paired cable.

7. Carry out 05 Nos. of Close & Open operations through CB Analyzer and record the timings of Main contact & Aux. Contact. Calculate the average value of close & open timings. Also calculate the shift (difference) between Main Contact & Aux Contacts timings.

8. Ensure that device data, configuration and test results are recorded in **"Pre-commissioning format for Controlled Switching Device"** available in latest revision

of **DOC: D-2-01-03-01-05- "Pre-commissioning procedures and formats for substation equipment & protection system".**

9. Ensure that Final commissioning of CSD (fine tuning) is done through on-load operation of equipment. Fine tuning of a control switching device involves making precise adjustments to optimize its performance and functionality. The objective of fine tuning a control switching device is to ensure its reliable and optimal operation as well as functionality in its intended application.

10. Check and ensure that the provision for bypassing the Controlled switching device is provided through BCU and SCADA both so that whenever, the CSD is not healthy due to any reason (including auxiliary supply failure), uncontrolled trip/close command can be extended to the circuit Breaker. Alternatively, in case of any non-operation of the CSD after receiving a close/trip command after a pre-determined time delay, the CSD should automatically be bypassed to ensure that the trip and close commands are extended to the Trip/Close coils through subsequent command.

CB Parameters:

1. **Mechanical closing time** of each CB pole is the duration between the start of coil command pulse and the time at which arcing contacts actually touch each other.

2. **Closing auxiliary time** shift of each CB pole is time interval between the instant at which NO auxiliary contacts actually close and the instant at which arcing contacts actually touch each other.

3. **Mechanical opening time** of each CB pole is duration between the start of coil command pulse and the arc starting instant (i. e. main contacts separation).

4. **Opening auxiliary time** shift of each CB pole is time interval between the arc starting instant and the instant at which NO auxiliary contacts actually open.

5. **Pre-Arcing time** is the interval of time between the initiation of current flow in a pole during close operation and the instant when the contact touches the arching contact of that pole.

6. **Arcing time** is the interval of time between the instant of the first initiation of the arc in a pole and instant of final arc extinction in that pole.

General Configuration of CSD:

1. **For close operation configuration**, enter the calculated average value of close timings, operating control voltage, pre-arcing time in CSD Configuration Software. Enter Auxiliary contact time shift/ temperature, Hydraulic Pressure (as applicable) in CSD. Finally, enter closing electrical target angle.

2. **For open operation configuration**, enter the calculated average value of open timings, operating control voltage, arcing time in CSD Configuration Page. Enter

Auxiliary contact time shift/ temperature, Hydraulic Pressure (as applicable) in CSD. Finally, enter opening electrical target angle.

Table-1: Switching of a Shunt Reactor

Switching Operation	R-Pole (Ref)	Y-Pole	B-Pole
Close Operation (Using Sync on VR)			
Star Point Grounded	**90°**	210°	150°
Star Point Ungrounded	**60°**	60°	150°
Delta Configuration	**60°**	60°	150°
Open Operation (Using Sync on VR)			
Star Point Grounded	**90°**	210°	150°
Star Point Ungrounded	**90°**	180°	180°
Delta Configuration	**90°**	180°	180°

Table-2: Switching of a Transformer

Switching Operation	R-Pole (Ref)	Y-Pole	B-Pole
Close Operation (Using Sync on VR)			
Star Point Grounded YNd	**90°**	180°	180°
Star Point Ungrounded Yd	**60°**	60°	150°
Open Operation (Using Sync on VR)			
Star Point Grounded YNd	**90°**	30°	150°
Star Point Ungrounded Yd	**90°**	180°	180°

Table-3: Switching of Shunt Capacitor

Switching Operation	R-Pole (Ref)	Y-Pole	B-Pole
Close Operation (Using Sync on VR)			
Star Point Grounded	**0°**	120°	60°
Star Point Ungrounded	**30°**	120°	30°
Delta Configuration	**30°**	120°	30°
Open Operation (Using Sync on VR)			
Star Point Grounded	**90°**	210°	150°
Star Point Ungrounded	**90°**	180°	180°
Delta Configuration	**90°**	180°	180°

Table-4: Switching of Transmission Line

Switching Operation	R-Pole (Ref)	Y-Pole	B-Pole
Close Operation (Using Sync on VR)			
Star Point Grounded	**0°**	120°+(5°…10°)	60° + 10°
Open Operation (Using Sync on VR)			
Star Point Grounded	**90°**	210°	150°

Note: For the Detailed configuration for the following devices has been described in the Annexure-II and Integration of Standardized CSD alarms has also been described in the Annexure-II.

1. **Siemens PSD**
2. **Alstom RPH3**
3. **Vizimax SynchroTeq Plus**

B.1.4 CHECKS/ TESTS APPLICABLE FOR CVTs

B.1.4.1 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.

B.1.4.2 INSULATION RESISTANCE MEASUREMENT OF PRIMARY & SECONDARY WINDING

B.1.5 CHECKS/ TESTS APPLICABLE FOR ISOLATORS

B.1.5.1 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.

B.1.5.2. 50 OPERATION TESTS

B.1.6 CHECKS/ TESTS APPLICABLE FOR SURGE ARRESTORS

B.1.6.1 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.

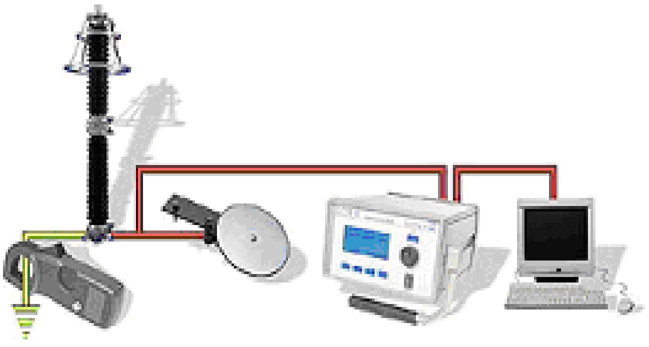
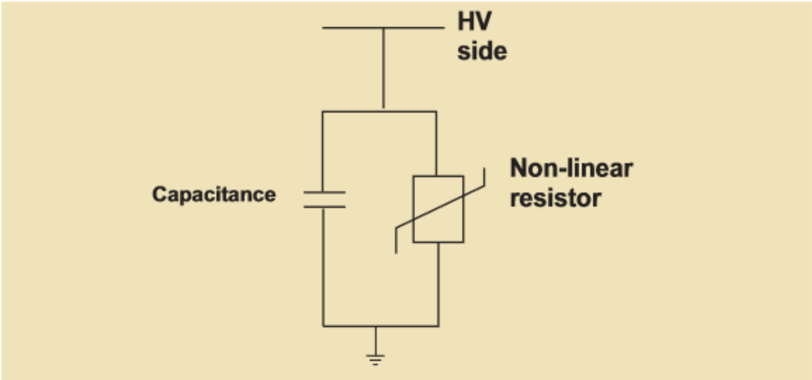


Figure- 18 Typical arrangement for THRCM Test

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.
   a) 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.



B.1.7 CHECKS/ TESTS FOR OTHER AREAS/ EQUIPMENTS

B.1.7.1 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 π a R

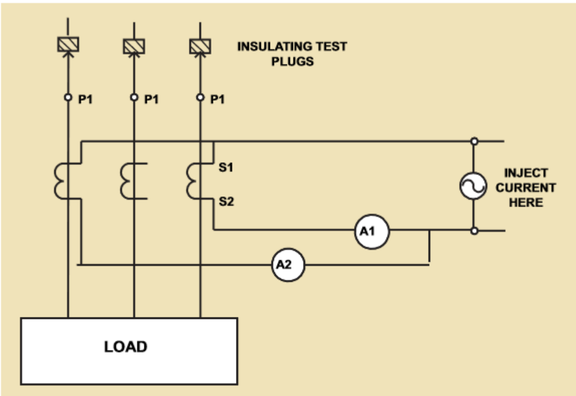
Where 'a' is the distance between the electrode

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.

B.1.7.2 SECONDARY CURRENT INJECTION TEST SETS

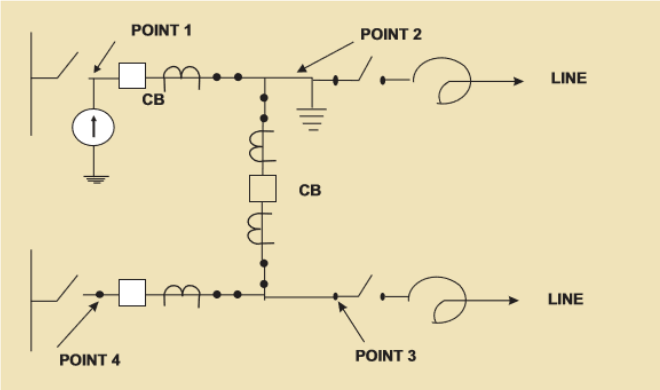
The primary test is essential when commissioning and new installation as a test the whole protection system and will detect current transformers connected with incorrect polarity or relays that have been set in the wrong sequence in differential system. Secondary current injection sets are very useful 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 the figure 20. Details of the testing will be elaborated in the relay testing.



B.1.7.3 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.



C. BUS BAR PROTECTION

C.1 Types of bus bar protection

a) High impedance
b) Low impedance

C.1.1. 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)

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.

Vf = If (Rct+2.Rl)

Vk=2Vf

Paralleling CT current should be done at CT marshalling boxes.

c) 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 112esign112. 300-500V.
- Should have a low 112esign112atio current (few milliamps)

d) 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 within 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	:$10000 \times 10^6/1.732*400000$ =14434 A
Fault current in secondary	: 7.217A
Voltage setting of the relay	: $V_{f \text{ or }} V_S = I_f(R_{ct}+2R_L)$

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

C.1.2 LOW IMPEDANCE PROTECTION:

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.

At present, all C&P protection schemes are using low impedance bus bar relays. The complete testing procedures for both DM/DMT and one and half breaker scheme (for green field and brown field project) is mentioned as below:

Green field projects with DM/DMT Scheme

C.2. Bus Bar testing in DM/DMT scheme **(**Secondary injection tests) - Greenfield

C.2.1 Differential Pickup and trip test (Test needs to be carried out for each bay)

Test Preconditions- Half of the feeders on station bus may be kept on Bus-I and remaining feeder may be kept on BUS-II, Bus Sectionalizer/Bus Coupler's Isolator and CB to be kept in the closed condition. Bay under test needs to be connected with Bus-I & Bus-II alternatively. Secondary Current injection needs to be done for Bus bar differential pickup/trip test. Record the data as per Table-1.

Note: Testing needs to be done for all bays including Bus Sectionalizer and Bus Coupler.

Table No: 1

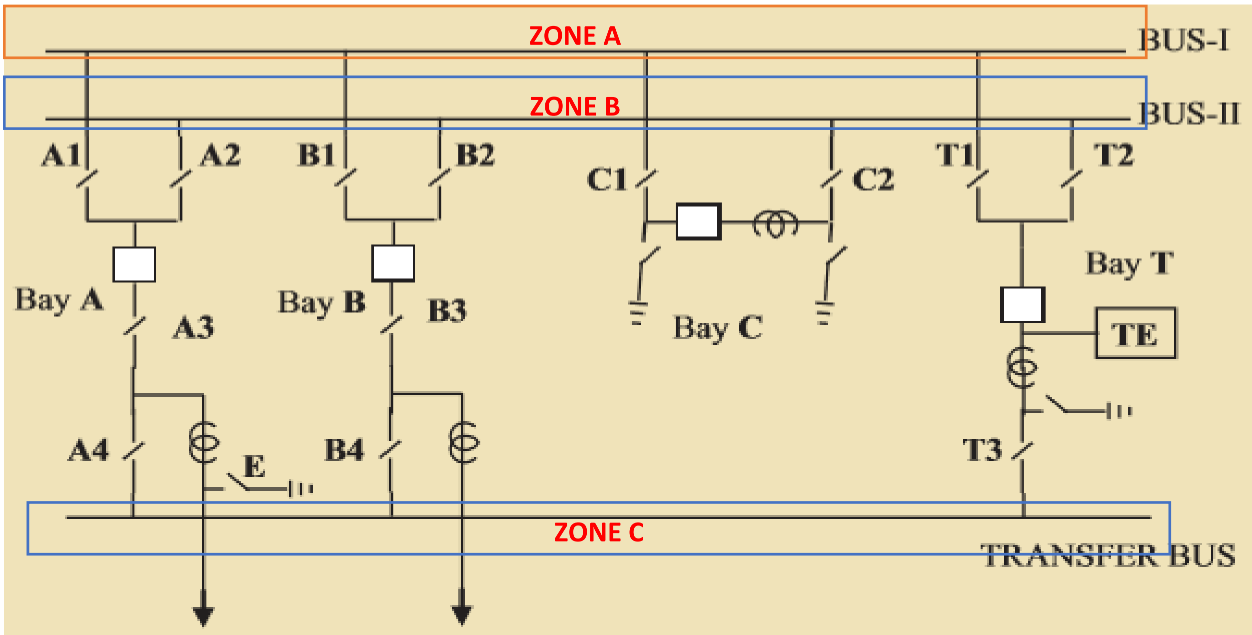
<table>
<tr><th>Sr. No.</th><th>Current Injection</th><th>Bay selected in</th><th>Other bay Bus Selection status</th><th>Tripping extended to (Mention the bay no.)</th><th>Remark</th></tr>
<tr><td rowspan="2">1</td><td rowspan="2">Bay No.________</td><td>Bus-I</td><td rowspan="4">Bays Selected on Bus-I
Bay No.

Bays Selected on Bus-II
Bay No.</td><td rowspan="2"></td><td rowspan="2">Save the Bus Bar topology file</td></tr>
<tr><td>Bus-II</td></tr>
<tr><td rowspan="2">2</td><td rowspan="2">Bay No.________</td><td>Bus-I</td><td rowspan="2"></td><td rowspan="2">Save the Bus Bar topology file</td></tr>
<tr><td>Bus-II</td></tr>
</table>

C.2.2 TBC Testing (Any two-bay having CRP panel near to TBC CRP panels may be tested for this combination)

Transfer the bay under test to the TBC (Transfer Bus Coupler) and establish its connection to Bus-I through the TBC bay (Refer fig-1). To illustrate, please refer to the figure provided below. Transfer the feeder associated with Bay A to the TBC by closing the A4 isolator. Next, close the T3 and T1 isolators in the TBC Bay (Bay T), and then close the TBC Breaker. Once completed, proceed to close the B1 isolator of Bay B.

The Bus Bar Topology needs to be verified for the bus connection status before current injection.



1. Inject stable current (Single phase) through secondary circuit of Bay A, Bay B and Bay T. Record the Injected current (magnitude & phase angles), differential and restraining current values for Zone A and Zone C, Check Zone. Record the data as per Table-2. Repeat the process for the remaining two phases. Similar test needs to be carried out for Zone-B by closing B2 and T2 isolator (Open B1 and T1 isolator) and repeat the process **(Refer Table 2)**. Current injection to be stopped after this.

fig-1 DMT Scheme

2. Inject the current (more than bus bar pickup value) only in Bay A (Bay in transfer mode), this shall trip only Zone-C.
3. Create the stable condition by injecting current (more than bus bar pickup) in Bay A, Bay B and Bay T. Create an unstable condition by changing the angle of current in Bay T, this will trip only the associated bus Zone-A and Zone-C (As Bay T is connected to Bus-I).
4. Repeat the test mentioned in **Sr. no. (3)** after opening of TBC bay T1 isolator and closing T2 isolator. Accordingly, Isolator B2 (Bay B) to be closed after the opening of B1 isolator, this shall trip only Zone-B & Zone-C.
5. Test mentioned in **Sr. no. (2)** needs to be done for each ICT/line bay after transferring it to TBC. Tests mentioned in Sr. no. 3 & 4 are TBC bay specific and need to be done once with any feeder.

Table No: 2

TBC Connected at BUS-I.

Stable Condition (R Phase Current injection)

Current Injected in		Differential Current				Restraining Current			
	Bay Current	Zone A	Zone B	Zone C	Check Zone	Zone A	Zone B	Zone C	Check Zone
Bay A									
Bay B									
Bay T									

TBC Connected at BUS-I.

Stable Condition (Y Phase Current injection)

Current Injected in		Differential Current				Restraining Current			
	Bay Current	Zone A	Zone B	Zone C	Check Zone	Zone A	Zone B	Zone C	Check Zone
Bay A									
Bay B									
Bay T									

TBC Connected at BUS-I.

Stable Condition (B Phase Current injection)

Current Injected in		Differential Current				Restraining Current			
	Bay Current	Zone A	Zone B	Zone C	Check Zone	Zone A	Zone B	Zone C	Check Zone
Bay A									
Bay B									
Bay T									

TBC Connected at BUS-II

Stable Condition (R Phase Current injection)

Current Injected in		Differential Current				Restraining Current			
	Bay Current	Zone A	Zone B	Zone C	Check Zone	Zone A	Zone B	Zone C	Check Zone
Bay A									
Bay B									
Bay T									

TBC Connected at BUS-II

Stable Condition (Y Phase Current injection)

		Differential Current				Restraining Current			

Current Injected in	Bay Current	Zone A	Zone B	Zone C	Check Zone	Zone A	Zone B	Zone C	Check Zone
Bay A									
Bay B									
Bay T									
TBC Connected at BUS-II **Stable Condition (B Phase Current injection)**									
Current Injected in		Differential Current				Restraining Current			
	Bay Current	Zone A	Zone B	Zone C	Check Zone	Zone A	Zone B	Zone C	Check Zone
Bay A									
Bay B									
Bay T									

C.2.3 Bus Coupler (Any two-bay having CRP panel near to Bus Coupler CRP panels may be tested for this combination)

1. Close A1 Isolator of Bay A, C1 & C2 isolator of Bay C and B2 isolator of Bay B. Remaining all the feeders at station bus may be kept on Bus-I & Bus-II on random basis by closing the respective isolator (89 A & 89 B) (Refer fig-2).

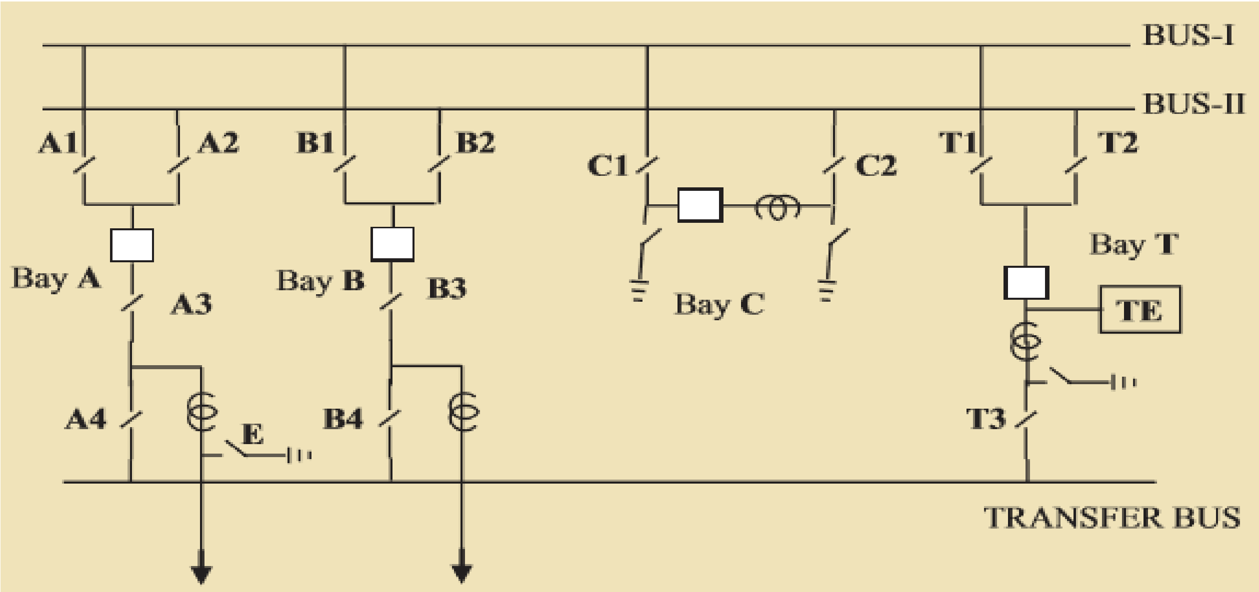


fig-2 DMT Scheme

2. Inject stable current (Single phase) in Bay A, Bay C and Bay B Bus bar CT cores. Record the Injected current with phase angles, differential and restraining current in Zone A, Zone B & Check zone. Repeat the process for the remaining two phases.
3. Create an unstable condition by changing the angle (thus creating unstable condition in Zone-A and Zone-B) of current in Bay C, this will trip the associated bus Zone-A and Zone-B. Current injection to be stopped after this. Record the data as per Table-3.

Table No: 3

Bay A and Bay B connected through Bus Coupler Stable Condition (R Phase Current injection)									
Current Injected in		Differential Current				Restraining Current			
	Bay Current	Zone A	Zone B	Zone C	Check Zone	Zone A	Zone B	Zone C	Check Zone
Bay A									
Bay B									
Bay C									
Bay A and Bay B connected through Bus Coupler Stable Condition (Y Phase Current injection)									
Current Injected in		Differential Current				Restraining Current			
	Bay Current	Zone A	Zone B	Zone C	Check Zone	Zone A	Zone B	Zone C	Check Zone
Bay A									
Bay B									
Bay C									
Bay A and Bay B connected through Bus Coupler Stable Condition (B Phase Current injection)									
Current Injected in		Differential Current				Restraining Current			
	Bay Current	Zone A	Zone B	Zone C	Check Zone	Zone A	Zone B	Zone C	Check Zone
Bay A									
Bay B									
Bay C									

C.3 Primary Injection and Busbar Stability in DM/DMT through Primary Injection - Greenfield

Before starting the CT primary injection for **Bus Bar/Bay stability work** following shall be verified.

1. Measure the CT loop resistance phase wise for each CT circuit. For this, CT link at CT MB to be isolated and CT link at CRP panels to be closed. The loop resistance of CT wires towards CRP side and CT Side needs to be noted down.

Bay Reference	**CT Cores**	**Phase**	**Loop Resistance CRP side (in Ohm)**	**Loop Resistance CT side (in Ohm)**
	Core 1 . . . Core X	R-N		
		Y-N		
		B-N		

2. After measurement of CT loop resistance, CT links shall be closed at CT MB.
3. Verify the CT neutral formation for all cores with reference to CT ratio, according to the protection and metering scheme.
4. Verify that CT neutral is earthed only in a single CRP panel. CT spare cores if any, is to be shorted and earthed at CT JB.
5. After verification of the above step, Single phase CT primary injection shall be started.
6. Following measurements to be recorded during CT primary injection test.

Bay Reference	Primary Current (In Amps)	Phase	CT Cores	Secondary Current at CT JB (in mA)		*Voltage (Ph-N) across CT secondary terminals at JB (In Volts)
				(Phase wire)	(Neutral Wire)	
		R	Core 1 . . Core X			
		Y	Core 1 . . Core X			
		B	Core 1 . . Core X			

7. Same test procedure needs to be carried out Turret CT cores of ICT and Reactors before carrying out Differential and REF stability.

*** Voltage across CT secondary terminals to be measured (in CT MB) and compared phase wise for each core to identify any loose connections in CT circuit.**

C.3.1 Feeder Bays

1. For checking the Bus bar stability of Bus-I, make the setup for bus bar stability of Bus-I by closing **A1, A3 Isolator** & **CB** in **Bay A**. Close **B1, B3 Isolator** & **CB** in **Bay B**. Earth point **E** to be closed at Bay B. (**Refer Fig-3**)
2. Check that bay isolator status is reflected properly in Bus bar topology for proper CT switching/selection.
3. Ensure that bus or line connected to bay B shall not be earthed other than at E.
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. Inject Single phase current through **Bay A** CT (from feeder side) using test kit across one phase (e.g. R Phase) and ground (Point T); don't use another phase as return path for the current.
6. Measure the current at both CT marshalling boxes.
7. Measure and record the bay currents, Differential (Spill) and restraining current in Zone-A, Zone-B, & Check Zone in Bus Bar relay. Record the data as per Table-4.
8. The measured spill current should not be more than 5%.
9. If the spill current is more (almost twice the CT secondary current), stop injecting the primary current and correct the CT polarity.
10. Again, Current injection to be started and recordings as mentioned at **Sr. no. 7 & 8** needs to be done.

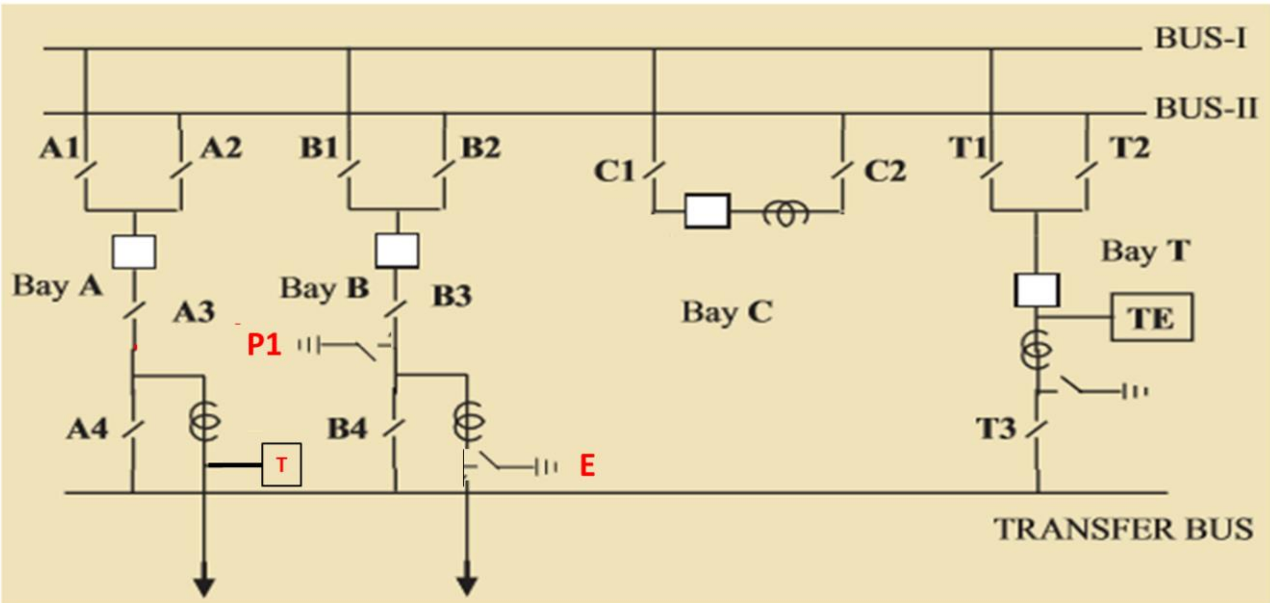


Fig-3 Bus bar stability – DM/DMT Scheme

11. Stop injecting primary current and then create in-zone fault on primary side (by providing earthing between the two CTs (For e.g. connect the earthing at P1 point).
12. Start Current injection. Measure and record the bay currents, Differential and Restraining current in Zone-A, Zone-B & Check Zone at Bus Bar CU. Observe the spill current of considerable magnitude corresponding to the injected primary current.
13. After ensuring the above step, stop the current injection and normalize the system.
14. Repeat the steps from **Sr. no. 4 to 12** for other phases as well.
15. For checking the Bus bar stability of Bus-II, Make the setup by opening A1 Isolator & CB in Bay A and B1 Isolator & CB in Bay B. Close the A2 Isolator and CB in Bay A and B2 Isolator & CB in Bay B, keep the earth point E closed at Bay B.
16. Check that bay isolator status is reflected properly in Bus bar topology for proper CT switching/selection.
17. Repeat the steps from **Sr. no. 4 to 13 for R, Y & B phases.**
18. The Bus bar stability for other bays (line & ICT feeders) needs to be repeated as per the procedure mentioned in **Sr. no. 1 to 17. Bay-A may be kept as reference.**

<u>Table No-4</u>

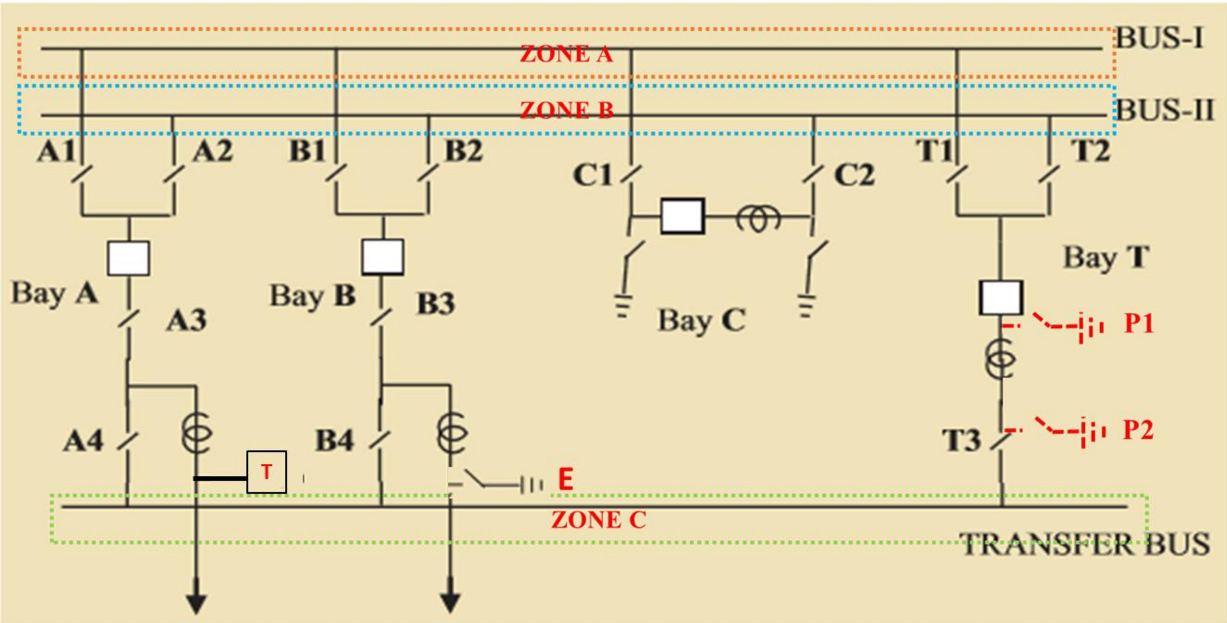
Bay A & Bay B connected through BUS-I. Stable Condition (R Phase Current injection)									
		Differential Current				Restraining Current			
	Bay Current	Zone A	Zone B	Zone C	Check Zone	Zone A	Zone B	Zone C	Check Zone
Bay A									
Bay B									
	Unstable Condition (Earth at P1)								
Bay A									
Bay B									

Bay A & Bay B connected through BUS-I. **Stable Condition (Y Phase Current injection)**									
		Differential Current				Restraining Current			
	Bay Current	Zone A	Zone B	Zone C	Check Zone	Zone A	Zone B	Zone C	Check Zone
Bay A									
Bay B									
	Unstable Condition (Earth at P1)								
Bay A									
Bay B									
Bay A & Bay B connected through BUS-I. **Stable Condition (B Phase Current injection)**									
		Differential Current				Restraining Current			
	Bay Current	Zone A	Zone B	Zone C	Check Zone	Zone A	Zone B	Zone C	Check Zone
Bay A									
Bay B									
	Unstable Condition (Earth at P1)								
Bay A									
Bay B									
Bay A & Bay B connected through BUS-II **Stable Condition (R Phase Current injection)**									
		Differential Current				Restraining Current			
	Bay Current	Zone A	Zone B	Zone C	Check Zone	Zone A	Zone B	Zone C	Check Zone
Bay A									
Bay B									
	Unstable Condition (Earth at P1)								
Bay A									
Bay B									

Bay A & Bay B connected through BUS-II **Stable Condition (Y Phase Current injection)**									
		Differential Current				Restraining Current			
	Bay Current	Zone A	Zone B	Zone C	Check Zone	Zone A	Zone B	Zone C	Check Zone
Bay A									
Bay B									
	Unstable Condition (Earth at P1)								
Bay A									
Bay B									
Bay A & Bay B connected through BUS-II **Stable Condition (B Phase Current injection)**									
		Differential Current				Restraining Current			
	Bay Current	Zone A	Zone B	Zone C	Check Zone	Zone A	Zone B	Zone C	Check Zone
Bay A									
Bay B									
	Unstable Condition (Earth at P1)								
Bay A									
Bay B									

C.3.2 TBC Bay

Precondition-For Checking the TBC bay stability wrt. to Bus-I & Transfer Bus, transfer the feeder associated with Bay A on TBC by closing **A4** isolator. Further Close **T3 & T1** Isolator in TBC Bay (Bay T) and close the TBC Breaker, after that **B1, B3** isolator & CB of Bay B to be closed. Earth point **E** to be closed at Bay B (Refer fig-4). *Ensure that Bay-A and Bay-B bus bar stability w.r.t. to Bus-I and Bus-II has already been completed.*



(fig-4: Bay Stability with Transfer Bus)

1. Check that bay isolator status is reflected properly in Bus bar topology for proper CT switching/selection.
2. Ensure that bus or line connected to bay B shall not be earthed other than at E.
3. Preferably connect the primary injection testing kit to the CT terminal pad of reference bay A (Point T) after opening the jumper from line side
4. Inject Single phase current through Bay A CT (from feeder side) using test kit across one phase (e.g. R Phase) and ground; don't use another phase as return path for the current.
5. Measure the current at TBC CT marshalling box. (As Bay A & B are already tested for bus bar stability so current measurement at Bay A & B CT marshalling boxes is not required)
6. Measure and record the bay currents, Differential (spill) and restraining current in Zone-A, Zone-C & Check Zone at Bus Bar protection relay. Record the data as per Table-5.
7. The measured spill current in any zone should not be more than 5%.

8. If the spill current is more (almost twice the CT secondary current), stop injecting the primary current and correct the CT polarity.
9. Again, Current injection to be started and recordings as mentioned at **Sr. no. 6 & 7** needs to be done.
10. **Stop the current injection and create in-zone fault for transfer bus by connecting earthing at P2 point**.
11. **Start the current injection**. Measure and record the bay currents, Differential and Restraining current in Zone-A, Zone-C & Check Zone at Bus Bar protection relay. Observe the spill current of considerable magnitude corresponding to the injected primary current (In Transfer Bus Zone).
12. After ensuring the above step, stop the current injection and remove the earth connection from P2.
13. Again, **create in-zone fault for Bus-I by connecting earthing at P1 point**.
14. Start the current injection. Measure and record the bay currents, Differential and Restraining current in Zone-A, Zone-C & Check Zone at Bus Bar protection relay. Observe the spill current of considerable magnitude corresponding to the injected primary current (In Bus-I Zone).
15. After ensuring the above step, stop the current injection and remove the earth connection from P1.
16. Repeat the steps from **Sr. no. 3 to 14** for other phases as well.
17. **Further, for checking the TBC bay stability wrt. to Bus-II,** Open the **T1** & Close the **T2** isolator in Bay **T.** Further, Open the **B1** & close the **B2** isolator in **Bay B.**
18. Check that bay isolator status is reflected properly in Bus bar topology for proper CT switching/selection.
19. Repeat the steps mentioned above from Sr. **no. 4 to 9 for ensuring the stable condition wrt to Bus-II.**
20. Stop the current injection and repeat the steps mentioned from **Sr. no. 13 to 16** for creating in-zone fault for Bus-II.

Table-5

Bay T connected through Bus ___. **Stable Condition (R Phase Current injection)**									
		Differential Current				Restraining Current			
	Bay Current	Zone A	Zone B	Zone C	Check Zone	Zone A	Zone B	Zone C	Check Zone
Bay A									
Bay B									
Bay T									
	Unstable Condition (Earth at P2)								
Bay A									
Bay B									
Bay T									
	Unstable Condition (Earth at P1)								
Bay A									
Bay B									
Bay T									
Bay T connected through Bus___. **Stable Condition (Y Phase Current injection)**									
		Differential Current				Restraining Current			
	Bay Current	Zone A	Zone B	Zone C	Check Zone	Zone A	Zone B	Zone C	Check Zone
Bay A									
Bay B									
Bay T									
Unstable Condition (Earth at P2)									
Bay A									
Bay B									
Bay T									
Unstable Condition (Earth at P1)									
Bay A									
Bay B									
Bay T									

Bay T connected through Bus___.									
Stable Condition (B Phase Current injection)									
		Differential Current				Restraining Current			
	Bay Current	Zone A	Zone B	Zone C	Check Zone	Zone A	Zone B	Zone C	Check Zone
Bay A									
Bay B									
Bay T									
Unstable Condition (Earth at P2)									
Bay A									
Bay B									
Bay T									
Unstable Condition (Earth at P1)									
Bay A									
Bay B									
Bay T									

C.3.3 Bus Coupler

Precondition- Close **A1, A3** Isolator & **CB** of Bay A. Further close **C1, C2** isolator & **CB** of Bay C. Also close the **B2, B3** isolator & **CB** of Bay B. Earth point **E** to be closed at Bay B. (Refer fig-5) Ensure that Bay-A and Bay-B bus bar stability w.r.t. to Bus-I and Bus-II has already been completed.

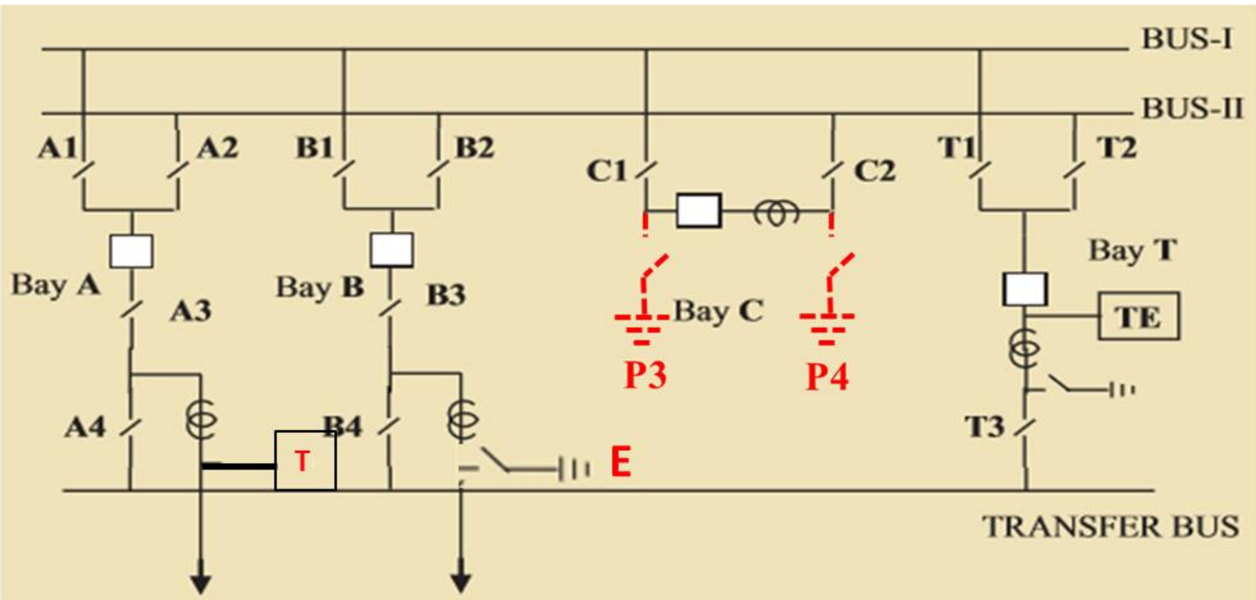


fig-5- Bus Coupler Stability

1. Check that bay isolator status is reflected properly in Bus bar topology for proper CT switching/selection.
2. Ensure that bus or line connected to bay B shall not be earthed other than at E.
3. Preferably connect the primary injection testing kit to the CT terminal pad of reference bay (A) after opening the jumper from line side.
4. Inject Single phase current through Bay A CT (from feeder side) using test kit across one phase (e.g. R Phase) and ground; don't use another phase as return path for the current.
5. Measure the current at Bus Coupler CT marshalling box. (As Bay A & B are already tested for bus bar stability so current measurement at Bay A & B CT marshalling boxes is not required). Record the data as per Table-6.
6. Measure and record the bay currents, Differential and Restraining current in Zone-A, Zone-B, Zone-C & Check Zone at Bus Bar protection relay.
7. The measured spill current in any zone should not be more than 5%.
8. If the spill current is more (almost twice the CT secondary current), stop injecting the primary current and then reverse the CT polarity.
9. Again, Current injection to be started and recordings as mentioned at Sr. no. 6 & 7 needs to be done.
10. **Stop the current injection and create in-zone fault for Bus-I by connecting earthing at P3 point.** Measure and record the bay currents, Differential and Restraining current in Zone-A, Zone-B & Check Zone at Bus Bar protection relay. Observe the spill current of considerable magnitude corresponding to the injected primary current (In Bus Zone-A).
11. After ensuring the above step, stop the current injection and remove the earth connection from P3.
12. Further, **create in-zone fault for Bus-II by connecting earthing at P4 point.** Measure and record the bay currents, Differential and Restraining current in Zone-A, Zone-B & Check Zone at Bus Bar protection relay. Observe the spill current of considerable magnitude corresponding to the injected primary current (In Bus Zone-B).
13. After ensuring the above step, stop the current injection and remove the earth connection from P4.
14. Repeat the steps from **Sr. no. 4 to 13** for other phases as well.

Table No-6

Stable Condition (R Phase Current injection)									
		Differential Current				Restraining Current			
	Bay Current	Zone A	Zone B	Zone C	Check Zone	Zone A	Zone B	Zone C	Check Zone
Bay A									
Bay B									
Bay C									
	Unstable Condition (Earth at P3)								
Bay A									
Bay B									
Bay C									
	Unstable Condition (Earth at P4)								
Bay A									
Bay B									
Bay C									
Stable Condition (Y Phase Current injection)									
		Differential Current				Restraining Current			
	Bay Current	Zone A	Zone B	Zone C	Check Zone	Zone A	Zone B	Zone C	Check Zone
Bay A									
Bay B									
Bay C									
	Unstable Condition (Earth at P3)								
Bay A									
Bay B									
Bay C									
	Unstable Condition (Earth at P4)								
Bay A									
Bay B									
Bay C									

Stable Condition (B Phase Current injection)									
		Differential Current				Restraining Current			
	Bay Current	Zone A	Zone B	Zone C	Check Zone	Zone A	Zone B	Zone C	Check Zone
Bay A									
Bay B									
Bay C									
	Unstable Condition (Earth at P3)								
Bay A									
Bay B									
Bay C									
	Unstable Condition (Earth at P4)								
Bay A									
Bay B									
Bay C									

Green Field Projects with One and Half Breaker Scheme

C.4 Bus Bar testing in One and Half Breaker scheme (Secondary injection tests) - **Greenfield**

C.4.1 Differential Pickup and trip test (Test needs to be carried out for each bay)

Test Preconditions- Connect the bays to the Buses as per the substation scheme i.e. either Bus-I or Bus-II depending on the bay connection to Bus bar. Secondary Current injection needs to be done for Bus bar differential pickup/trip test.

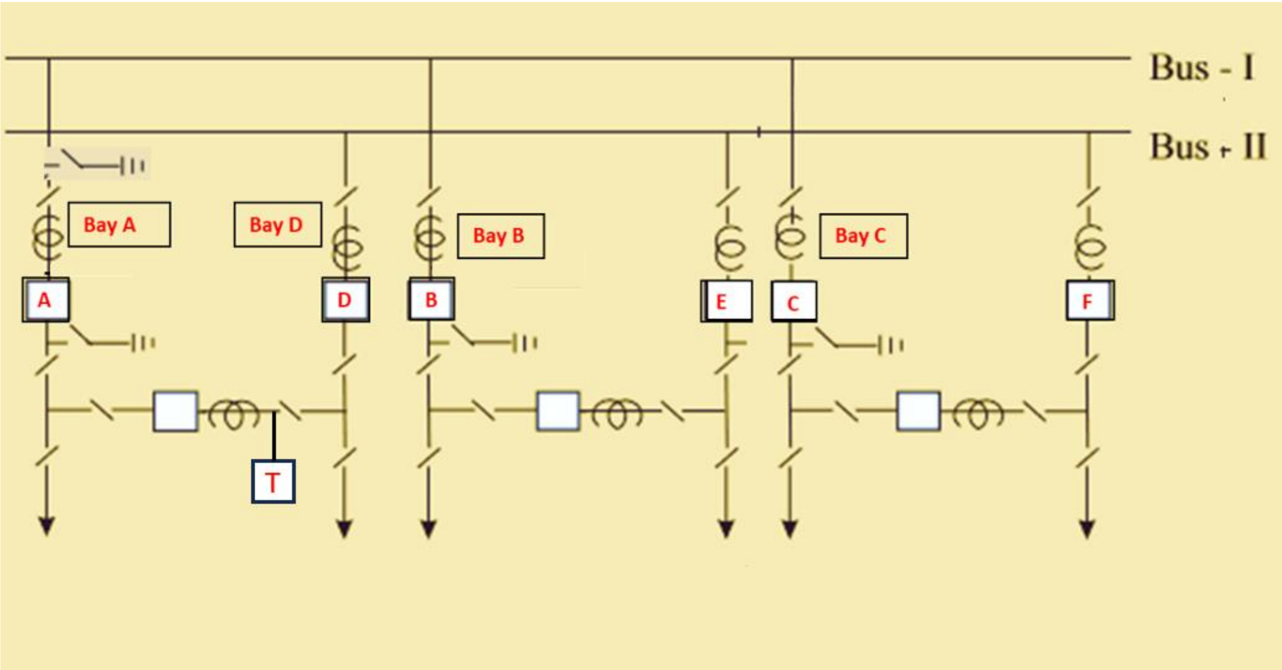


fig-6 One and Half breaker Scheme

1. Close all the breakers connected to the Bus-I as well as associated Tie CBs.
2. Inject the current only in "Bay A" (more than bus bar pickup value), this shall trip only Bus Zone-I. Repeat the test for all three phases. Record the data as per Table-7.
3. In case, the bus is connected with Bus Sectionalizer, injecting the current in one side of the bus bays shall not extend the trip to the bays connected to the other side of bus Sectionalizer. Tripping shall only be extended till Bus Sectionalizer.
4. Repeat the test for all the bays connected to as mentioned in Point 2 for all the bays connected to Bus-I.
5. The tests shall be repeated for both Main-1 and Main-2 of bus bar protection.
6. Same procedures shall be followed for the Bays connected to Bus-II. Record the data as per Table-7.

Table No: 7

Bay Connected to Bus______ Bay No.________	**Other bay bus selection status**	**Tripping extended to (Mention the bay no.)**	**Remark**
Current Injection PU A/CU A	**Bus-I** Bay No. **Bus-II** Bay No.		Save the Bus Bar topology file.
Current Injection PU B/ CU B	**Bus-I** Bay No. **Bus-II** Bay No.		Save the Bus Bar topology file

C.4.2 Differential Pickup and trip test (Half Dia)

Test Preconditions- In half dia schemes, bus tripping will be extended to the Tie breaker (Bay A) of the future bay and other bays of associated bus (Refer fig-8). It is to be ensured that Tie CT Cores are being used in Bus bar protection in which the future dia is connected.

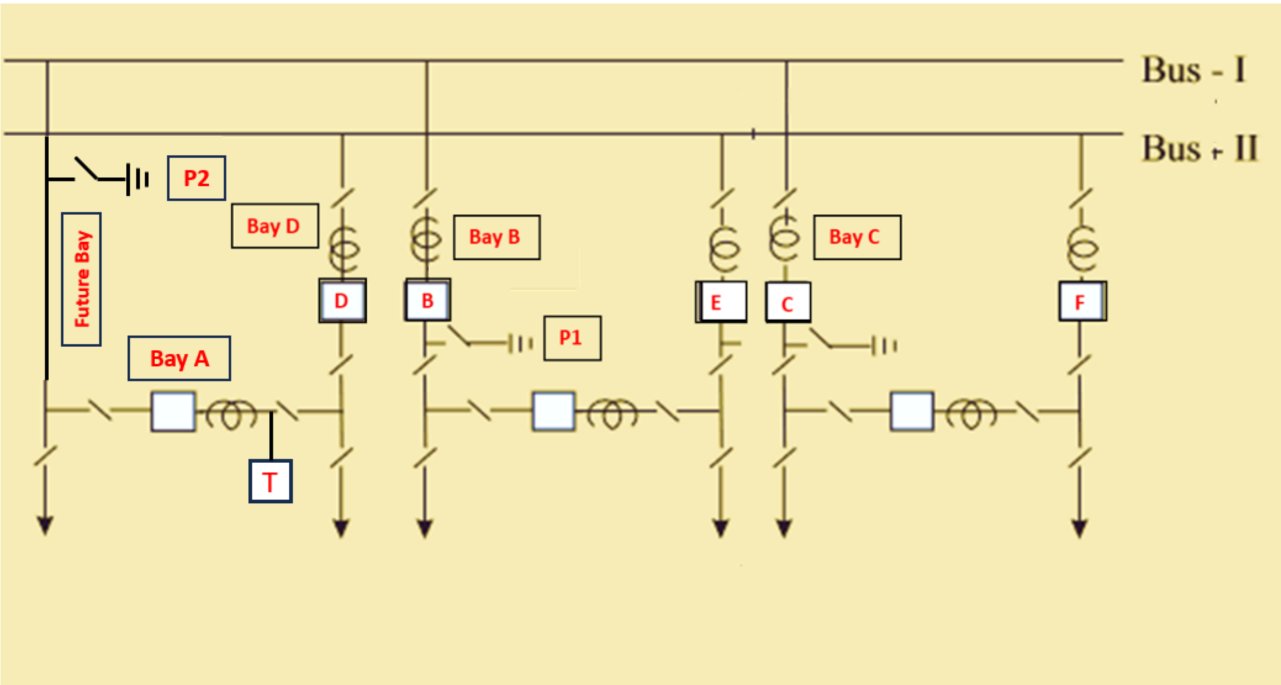


fig-8 Bus bar stability in One and half Breaker Scheme (Half Dia)

1. Connect the bays to the BUS-I as per switching scheme.
2. Close all the breakers connected to the Bus-I as well as the Tie CB.
3. Inject the current only in "Future Bay" (more than bus bar pickup value), this shall trip only Bus-1. Repeat the test for all three phases. Record the data as per Table 8.
4. Repeat the test for all the future bays as mentioned in Point 2 for all the bays connected to Bus-I.
5. The tests shall be repeated for both Bus Bar protection Main-1 and Main-2.
6. If the future dia is in Bus-II, the process of testing will remain the same.

Table No: 8

Bay Connected to Bus_______ Bay No.________	**Other bay bus selection status**	**Tripping extended to (Mention the bay no.)**	**Remark**
Current Injection in PU A/ CU A	**Bus-I** Bay No. **Bus-II** Bay No.		Save the Bus Bar topology file.
Current Injection in PU B/ CU B	**Bus-I** Bay No. **Bus-II** Bay No.		Save the Bus Bar topology file

C.5 Bus Bar Stability in One & half breaker scheme through Primary Injection - Greenfield

Before starting the CT primary injection for **Bus Bar/Bay stability work** following shall be verified.

1. Measure the CT loop resistance phase wise for each CT circuit. For this, CT link at CT MB to be isolated and CT link at CRP panels to be closed. The loop resistance of CT wires towards CRP side and CT side needs to be noted down.

Bay Reference	**CT Cores**	**Phase**	**Loop Resistance CRP side (in Ohm)**	**Loop Resistance CT side (in Ohm)**
	Core 1 . . . Core X	R-N		
		Y-N		
		B-N		

2. After measurement of CT loop resistance, CT links shall be closed at CT MB.
3. Verify the CT neutral formation for all cores with reference to CT ratio, according to the protection and metering scheme.
4. Verify that CT neutral is earthed only in a single CRP panel. CT spare cores if any, is to be shorted and earthed at CT JB.
5. After verification of the above step, Single phase CT primary injection shall be started.
6. Following measurements to be recorded during CT primary injection test.

Bay Reference	Primary Current (In Amps)	Phase	CT Cores	Secondary Current at CT JB (in mA)		*Voltage (Ph-N) across CT secondary terminals at JB (In Volts)
				(Phase wire)	(Neutral Wire)	
		R	Core 1 . . Core X			
		Y	Core 1 . . Core X			
		B	Core 1 . . Core X			

*** Voltage across CT secondary terminals to be measured (in CT MB) and compared phase wise for each core to identify any loose connections in CT circuit.**

C.5.1 Bus-I connected bays

1. For checking the Bus bar stability of Bus-I, make the setup for bus bar stability of Bus-I by selecting any two bays connected to Bus-I (eg. Bay A and Bay B as illustrated in fig-9).
2. Earth at **Point P1** by using local earth or nearby earth switch of bay B. Ensure Bus-I is earthed only at bay B (Point P1 only). Close the relevent isolators/CBs of current path between current injection point (Point T) and earthing point (Point P1).
3. Inject single phase primary current using primary current injection testing kit across one phase (eg. R Phase) and ground (From Point T); don't use another phase as return path for the current.
4. Measure the current at both CT marshalling boxes.
5. Measure and record the bay currents, Differential (Spill) and restraining current in Zone-1, 2 & Check Zone in Bus Bar relay (Both Main 1 & Main 2) as per Table 9.

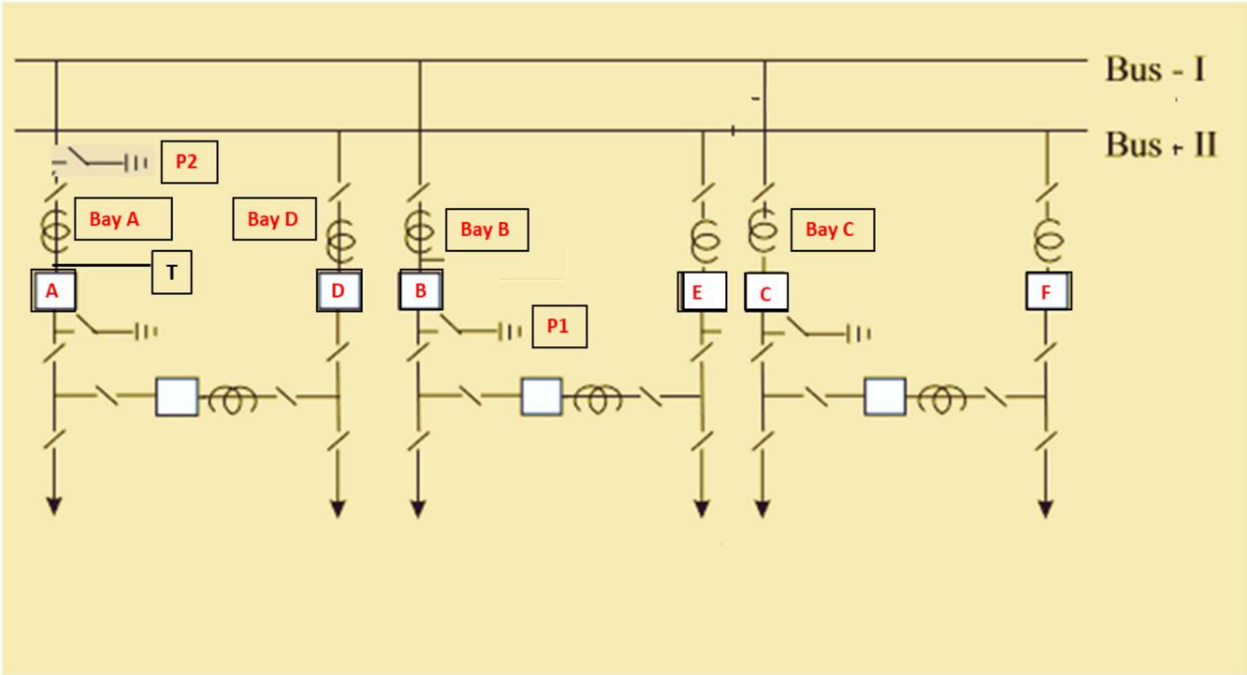


fig-9 Bus bar stability in One and half Breaker Scheme Bus-I

6. The measured spill current should not be more than 5%.
7. If the spill current is more (almost twice the CT secondary current), stop injecting the primary current and correct the CT polarity.
8. Again, Current injection is to be started and recordings as mentioned at Sr. no. 5 & 6 need to be done.
9. **Stop injecting primary current and create in-zone fault on primary side by connecting earthing at P2 point.** Start the current injection and measure and record the bay currents, Differential and Restraining current at Bus Bar relay (Both Main-1 & Main-2). Observe the spill current of considerable magnitude corresponding to the injected primary current.
10. After ensuring the above step, stop the current injection and normalize the system.
11. Repeat the steps from **Sr. no. 3 to 10** for other phases as well. Record the data in Table 8.
12. For proceeding further, Bay A/B can be taken as reference and bus bar stability test for other bays connected to Bus-I may be carried out as per the procedure mentioned in **Sr. no. 3 to 11 (Bay earthing location to be selected according to the bays under test).**

C.5.2 Bus-II connected bays

1. For checking the Bur bar stability of Bus-II, make the setup for bus bar stability by selecting any two bays connected to Bus-II (Ex: Bay D and Bay E as illustrated in figure-8)
2. Earth at **Point P1** by using local earth or nearby earth switch of bay E. Ensure Bus bar-II is earthed only at bay E (Point P1 only). Close the relevent isolators/CBs of current path between current injection point (Point T) and earthing point (Point P1).
3. Inject Single phase current using primary current injection testing kit across one phase (eg. R Phase) and ground (From Point T); do not use another phase as return path for the current.
4. Measure the current at both CT marshalling boxes.

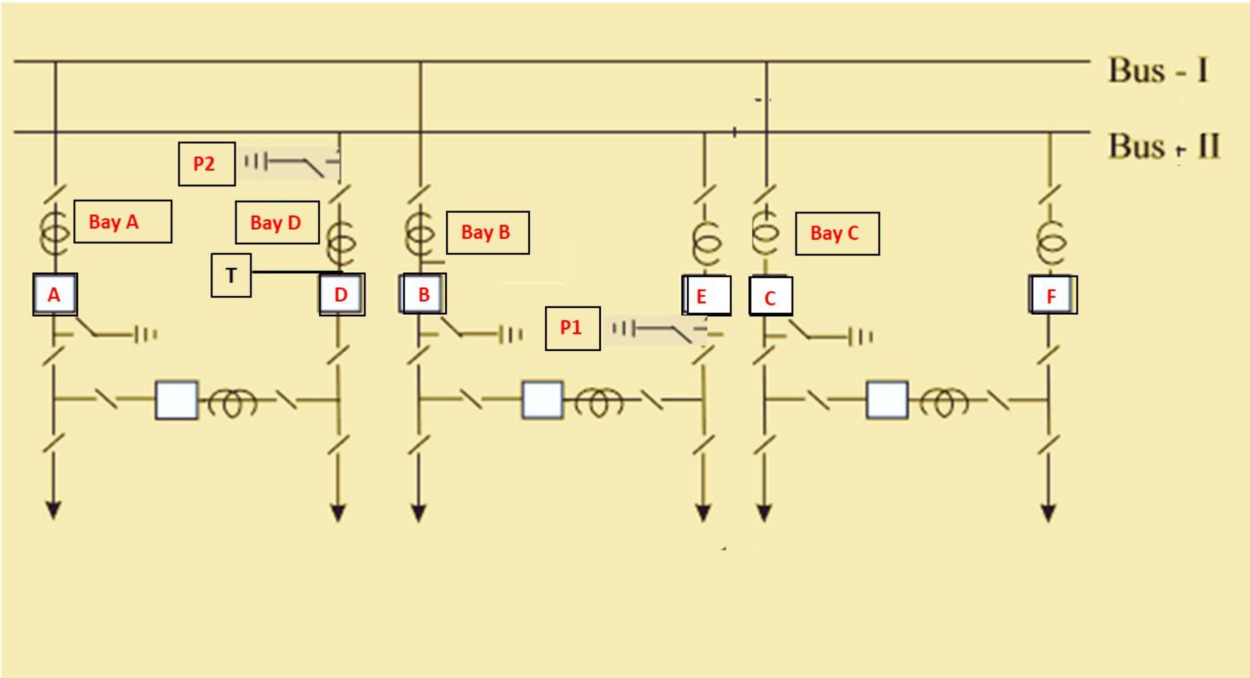


fig-8 Bus bar stability in One and half Breaker Scheme Bus-II

5. Measure and record the bay currents, Differential (Spill) and restraining current in Zone-1, 2 & Check Zone in Bus Bar relay (Both Main 1 & Main 2) as per table 8.
6. The measured spill current should not be more than 5%.
7. If the spill current is more (almost twice the CT secondary current), stop injecting the primary current and correct the CT polarity.
8. Again, Current injection to be started and recordings as mentioned at **Sr. no. 5 & 6** need to be done.
9. Stop the current injection and create in-zone fault by connecting earthing at P2 point. Measure and record the bay currents, Differential and Restraining current at Bus Bar relay. Observe the spill current

of considerable magnitude corresponding to the injected primary current (In Bus Zone-II) as per table 8.

10. After ensuring the above step, stop the current injection and remove the earth connection from P2. Repeat the steps from **Sr. no. 3 to 9** for other phases as well. Record the data as per **Table No:9**.
11. For proceeding further, Bay D/E can be taken as reference and bus bar stability test for other bays connected to Bus-II may be carried out as per the procedure mentioned in **Sr. no. 3 to 10** (Bay earthing location to be selected according to the bays under test).

Table No: 9

Bus I/II Connected Bays **Stable Condition (R Phase Current injection)**							
		Differential Current			Restraining Current		
	Bay Current (PU if applicable)	Zone 1	Zone 2	Check Zone	Zone 1	Zone 2	Check Zone
Bay ______	PUA: PUB:	CUA: CUB:	CUA: CUB:	CUA: CUB:	CUA: CUB:	CUA: CUB:	CUA: CUB:
Bay _______	PUA: PUB:						
Unstable Condition (Earth at P2)							
Bay ______	PUA: PUB:	CUA: CUB:	CUA: CUB:	CUA: CUB:	CUA: CUB:	CUA: CUB:	CUA: CUB:
Bay _______	PUA: PUB:						
Stable Condition (Y Phase Current injection)							
		Differential Current			Restraining Current		
	Bay Current	Zone 1	Zone 2	Check Zone	Zone 1	Zone 2	Check Zone
Bay ______	PUA: PUB:	CUA: CUB:	CUA: CUB:	CUA: CUB:	CUA: CUB:	CUA: CUB:	CUA: CUB:
Bay ______	PUA: PUB:						
Unstable Condition (Earth at P2)							
Bay ______	PUA: PUB:	CUA: CUB:	CUA: CUB:	CUA: CUB:	CUA: CUB:	CUA: CUB:	CUA: CUB:
Bay _______	PUA: PUB:						

Stable Condition (B Phase Current injection)							
		Differential Current			Restraining Current		
	Bay Current	Zone 1	Zone 2	Check Zone	Zone 1	Zone 2	Check Zone
Bay_______	PUA: PUB:	CUA: CUB:	CUA: CUB:	CUA: CUB:	CUA: CUB:	CUA: CUB:	CUA: CUB:
Bay_______	PUA: PUB:						
Unstable Condition (Earth at P2)							
Bay______	PUA: PUB:	CUA: CUB:	CUA: CUB:	CUA: CUB:	CUA: CUB:	CUA: CUB:	CUA: CUB:
Bay______	PUA: PUB:						

Bay Stability for One and half Breaker Scheme of Line or Transformer/Reactor Stability

Before starting the CT primary injection for Bus Bar/Bay stability work following shall be verified.

1. Measure the CT loop resistance phase wise for each CT circuit cores. For this, CT link at CT MB to be isolated and CT link at CRP panels to be closed. The loop resistance of CT wires towards CRP side and CT side needs to be noted down.

Bay Reference	CT Cores	Phase	Loop Resistance CRP side (in Ohm)	Loop Resistance CT side (in Ohm)
	Core 1 . . . Core X	R-N		
		Y-N		
		B-N		

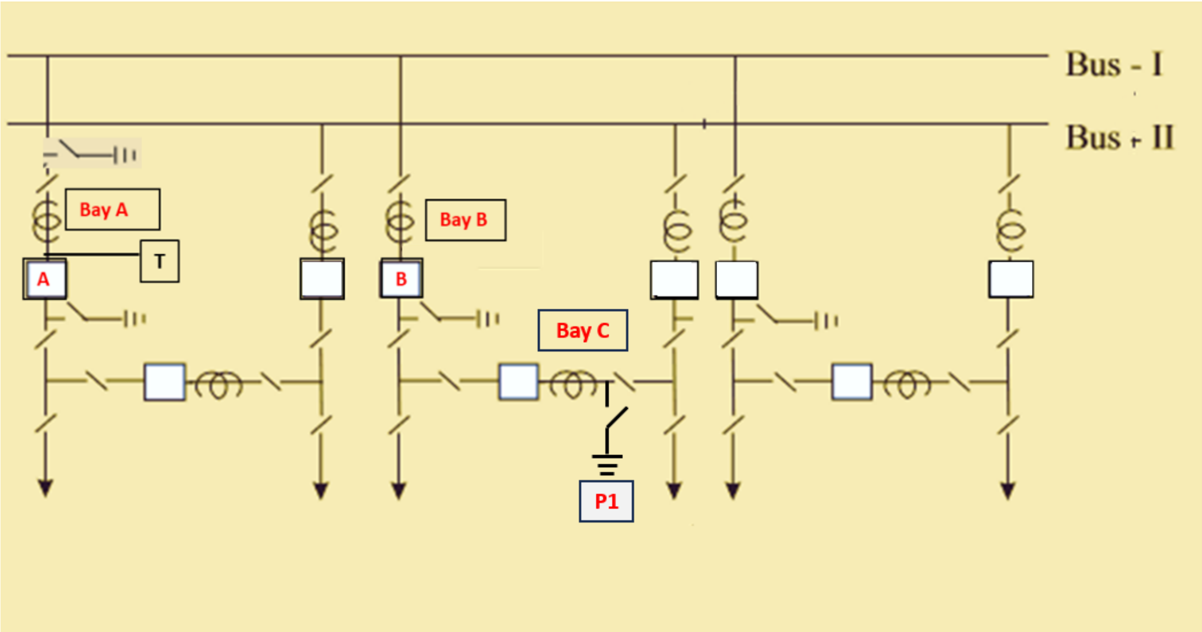
2. After measurement of CT loop resistance, CT links shall be closed at CT MB.
3. Verify the CT neutral formation for all cores with reference to CT ratio, according to the protection and metering scheme.
4. Verify that CT neutral is earthed only at single CRP panels. CT spare cores if any, is to be shorted and earthed at CT JB.
5. After verification of above step, Single phase CT primary injection shall be started.
6. Following measurements to be recorded during CT primary injection test.

Bay Reference	Primary Current (In Amps)	Phase	CT Cores	Secondary Current at CT JB (in mA)		*Voltage (Ph-N) across CT secondary terminals at JB (In Volts)
				(Phase wire)	(Neutral Wire)	
		R	Core 1 . . Core X			
		Y	Core 1 . . Core X			

		B	Core 1 . . Core X			

*** Voltage across CT secondary terminals to be measured (in CT MB) and compared phase wise for each core to identify any loose connections in CT circuit.**

Bus-I connected bays



1. For checking the Bay stability of "Bay-B", make the setup for stability by selecting any other bay connected to same bus (For eg. Bay A and Bay B as illustrated in figure above)
2. Earth at Point P1 by using local earth or nearby earth switch of bay C. Ensure earthing is at Point P1 only. Close the relevent isolators/CBs of current path between current injection point (Point T) and earthing point (Point P1).
3. Inject Single phase primary current using primary current injection testing kit across one phase (eg. R Phase) and ground (From Point T); don't use another phase as return path for the current.
4. Measure the current at both CT (Bay-B and Bay-C) marshalling boxes.
5. Measure and record the bay current in all Protection relays and Control and metering relays/devices as well as relays in Tie Bay (Bay C) as per Table-1.
6. Current to be measured in all CT circuits associated with Main-Tie bays.
7. Short the Tie Bay cores one by one on the CT side (The CRP side is to be kept in the isolated condition in CT MB Box) and record the current in protection and metering relay of the Bay B.
8. After ensuring the above step, stop the current injection and normalize the Tie CT circuit.
9. Repeat the steps from Sr. no. 3 to 9 for other phases as well. Record the data in Table-10.

Table-10

R-Phase (Normal Condition)													
		CT Cores - Main Bay						CT Cores- Tie Bay					
Tie Bay Main Bay	Bay Current CT Core)	Core-1	Core-2	Core-3	Core-4	Core-5	Core-6	Core-1	Core-2	Core-3	Core-4	Core-5	Core-6
Injected Current:	CT Ratio												
	Usage												
Protection Relays	Relay-1: .. Relay-X:												
Metering Relays	Relay-1: .. Relay-X:												
R-Phase (Tie CT Shorted Condition)													
		CT Cores - Main Bay						CT Cores- Tie Bay					
Tie Bay Main Bay	Bay Current CT Core)	Core-1	Core-2	Core-3	Core-4	Core-5	Core-6	Core-1	Core-2	Core-3	Core-4	Core-5	Core-6
Protection Relays	Relay-1: .. Relay-X:												
Metering Relays	Relay-1: .. Relay-X:												
Y-Phase (Normal Condition)													
		CT Cores - Main Bay						CT Cores- Tie Bay					
Tie Bay Main Bay	Bay Current CT Core)	Core-1	Core-2	Core-3	Core-4	Core-5	Core-6	Core-1	Core-2	Core-3	Core-4	Core-5	Core-6
Protection Relays	Relay-1: .. Relay-X:												
Metering Relays	Relay-1: .. Relay-X:												

Y-Phase (Tie CT Shorted Condition)													
Tie Bay Main Bay		CT Cores - Main Bay						CT Cores- Tie Bay					
	Bay Current CT Core)	Core-1	Core-2	Core-3	Core-4	Core-5	Core-6	Core-1	Core-2	Core-3	Core-4	Core-5	Core-6
Protection Relays	Relay-1: .. Relay-X:												
Metering Relays	Relay-1: .. Relay-X:												
B-Phase (Normal Condition)													
Tie Bay Main Bay		CT Cores - Main Bay						CT Cores- Tie Bay					
	Bay Current CT Core)	Core-1	Core-2	Core-3	Core-4	Core-5	Core-6	Core-1	Core-2	Core-3	Core-4	Core-5	Core-6
Protection Relays	Relay-1: .. Relay-X:												
Metering Relays	Relay-1: .. Relay-X:												
B-Phase (Tie CT Shorted Condition)													
Tie Bay Main Bay		CT Cores - Main Bay						CT Cores- Tie Bay					
	Bay Current CT Core)	Core-1	Core-2	Core-3	Core-4	Core-5	Core-6	Core-1	Core-2	Core-3	Core-4	Core-5	Core-6
Protection Relays	Relay-1: .. Relay-X:												
Metering Relays	Relay-1: .. Relay-X:												

For Brown field projects

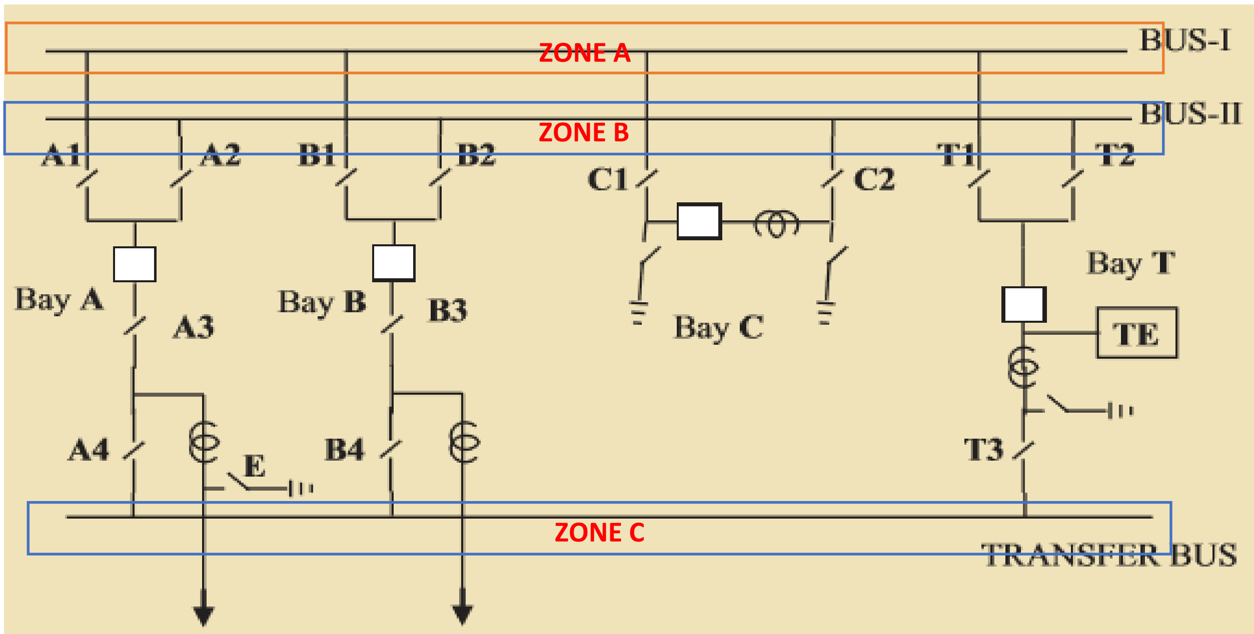
C.6 Bus Bar testing in DM/DMT scheme – Brown Field Projects

C.6.1 Differential Pickup and trip test of the new bay wrt. Bus-I & Bus-II (Secondary injection tests)

Test Preconditions-

The bay under test needs to be connected on Bus-I (Bus shall be taken under shutdown). For the Bus bar differential pickup/trip test, current needs to be injected in the "Bay A" (more than bus bar pickup value) (Refer Figure-9). Same test needs to be repeated with Bus-II for "Bay A" (Bus-II Shutdown to be taken). Connect the TBC bay (If available) to the respective bus during the testing and close respective isolator/Circuit breaker.

fig-9 Secondary Side Bay stability (DM/DMT Scheme)



Test results need to be saved as per Table-11.

Table-11

Sr. No.	Current Injection	TBC Bay Tripping (If available)	Tripping extended to (Mention the bay no.)	Remark
1	With Bus-I Bay No.________	**TBC Bay Selected on Bus I-**		Save the Bus Bar topology file

2	With Bus-II Bay No.________	**TBC Bay Selected on Bus II-**		Save the Bus Bar topology file

C.6.2 Differential Pickup and trip test of the new bay with Transfer Bus (Secondary injection tests)

Test Preconditions-

Transfer Bus differential pickup/trip test can also be carried out During the Bus-I or Bus-II shutdown. *Ensure that TBC bus bar stability w.r.t. to Bus-I and Bus-II has already been carried out.*

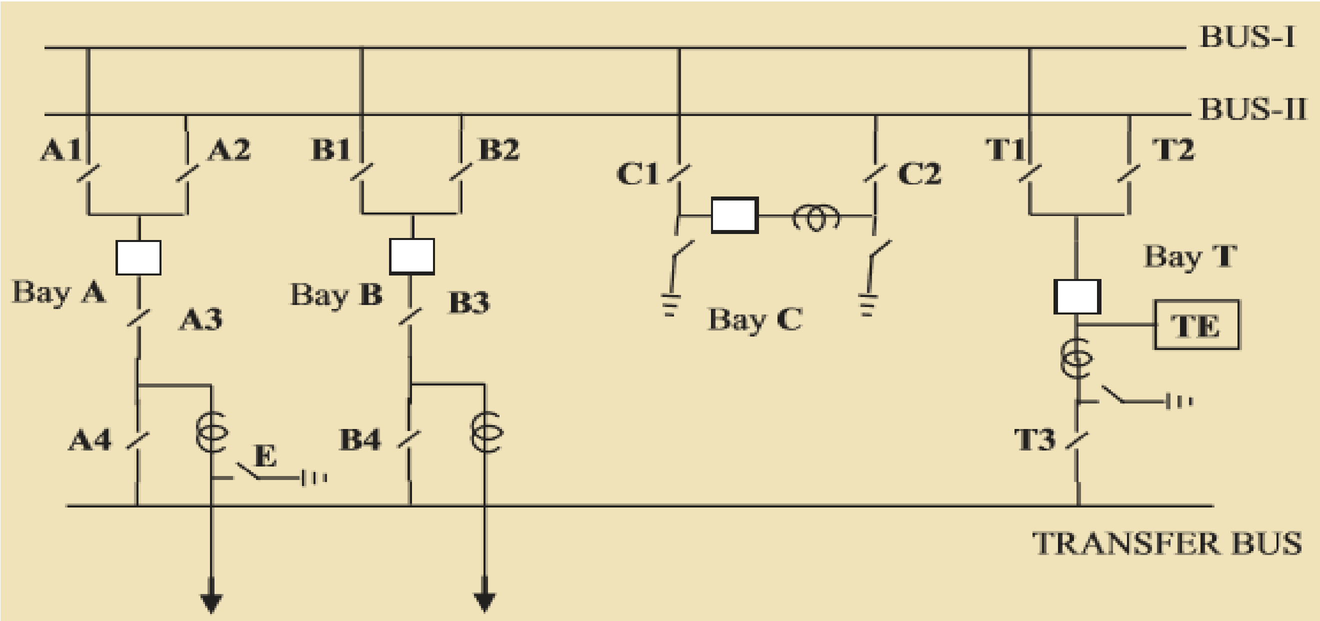


fig-10 Secondary Side Bay stability with Transfer Bus (DM/DMT Scheme)

1. Close T1 or T2 isolator (depends on the Bus which is under shutdown) of the transfer bus coupler bay (Bay T).
2. Close the A4 isolator of the Bay-A and T3 isolator & CB of Bay T. (Refer Figure-10)
3. For the Bus bar differential pickup/trip test, current needs to be injected in the “Bay A” (more than bus bar pickup value). This shall trip only Zone-C bus bar. Record the data as per table 12.

Table-12

Sr. No.	Current Injection	Other bay Bus Selection status	Tripping extended to (Mention the bay no.)	Remark
		Bays Selected on BUS-I		

1	Bay Connected in Transfer Bus Bay No.________	Bay No. **Bays Selected on Bus-II** Bay No. **Bays Selected on Transfer Bus -** Bay No.		Save the Bus Bar topology file

C.6.3 Bus Bar Stability in DM/DMT through Primary Injection

Before starting the CT primary injection for **Bus Bar/Bay stability work** following shall be verified.

1. Measure the CT loop resistance phase wise for each CT circuit. For this, CT link at CT MB to be isolated and CT link at CRP panels to be closed. The loop resistance of CT wires towards CRP side and CT side needs to be noted down.

Bay Reference	**CT Cores**	**Phase**	**Loop Resistance CRP side (in Ohm)**	**Loop Resistance CT side (in Ohm)**
	Core 1 . . . Core X	R-N		
		Y-N		
		B-N		

2. After measurement of CT loop resistance, CT links shall be closed at CT MB.
3. Verify the CT neutral formation for all cores with reference to CT ratio, according to the protection and metering scheme.
4. Verify that CT neutral is earthed only at a single CRP panel. CT spare cores if any, is to be shorted and earthed at CT JB.
5. After verification of above step, Single phase CT primary injection shall be started.
6. Following measurements to be recorded during CT primary injection test.

Bay Reference	Primary Current (In Amps)	Phase	CT Cores	Secondary Current at CT JB (in mA)		*Voltage (Ph-N) across CT secondary terminals at JB (In Volts)
				(Phase wire)	(Neutral Wire)	
		R	Core 1 . . Core X			
		Y	Core 1 . . Core X			
		B	Core 1 . . Core X			

*** Voltage across CT secondary terminals to be measured (in CT MB) and compared phase wise for each core to identify any loose connections in CT circuit.**

Ensure that TBC bus bar stability w.r.t. to Bus-I and Bus-II has already been carried out.

1. Make the setup for bus bar stability of Bus-I (Bus shall be taken under shutdown) by closing **A1, A3 Isolator** & **CB** in **Bay A**. Close **T1 Isolator** & **CB** in **Transfer bus coupler (Bay T)**. Earth point E to be closed at **Bay T**.

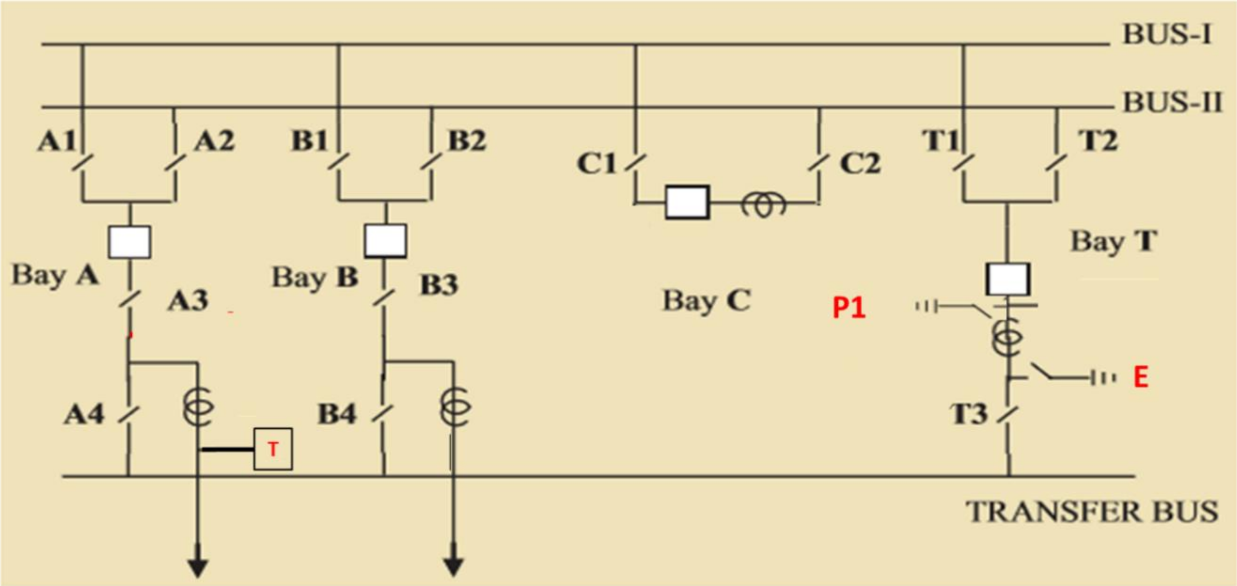


fig-11 Primary Side Bay stability (DM/DMT Scheme)

2. Check that bay isolator status is reflected properly in Bus bar topology for proper CT switching/selection.
3. Ensure that bus or line connected to bus-I shall not be earthed other than at E.
4. Preferably connect the primary injection testing kit to the CT terminal pad of "Bay A" (Point T) after opening the jumper from line side.
5. Inject Single phase current through "Bay A" CT (from feeder side) using test kit across one phase (e.g. R Phase) and ground; don't use another phase as return path for the current.
6. Measure the current at CT marshalling box of Bay A and Transfer bus coupler bay.
7. Measure and record the bay currents, Differential (Spill) and restraining current in Zone-A, Zone-B, Zone C & Check Zone at Bus Bar relay.
8. The measured spill current in bus zones should not be more than 5%. (**Note**-The primary injection setup might create unstable current in transfer Bus zone in the mentioned case)

9. If the spill current is more (almost twice the CT secondary current), stop injecting the primary current and correct the CT polarity in bay 'A'.
10. Again, Current injection to be started and recordings as mentioned at **Sr. no. 7 & 8** need to be done. Record the data in Table No: 13.
11. Stop injecting primary current and then **create in-zone fault** on primary side (by providing earthing between the two CTs (For e.g. connect the earthing at P1 point, refer fig-11).
12. Start Current injection. Measure and record the bay currents, Differential and Restraining current in Zone-A, Zone-B, Zone-C & Check Zone at Bus Bar relay. Observe the spill current corresponding to the injected primary current.
13. After ensuring the above step, stop the current injection and normalize the system.
14. Repeat the steps from **Sr. no. 4 to 12** for other phases as well.
15. For checking the Bus bar stability w.r.t **Bus-II**, Make the setup for bus bar stability of Bus-II (Bus shall be taken under shutdown) by opening **A1 Isolator** & **CB** in **Bay A** and **T1 Isolator** & **CB** in **Bay T**. Close the **A2 Isolator** and **CB** in **Bay A** and **T2 Isolator** & **CB** in **Bay T**, keep the earth point E closed at Bay T
16. Check that bay isolator status is reflected properly in Bus bar topology for proper CT switching/selection.
17. Repeat the steps from Sr. no. 4 to 14 and record the data as per Table-13.
18. Stop the current injection and normalize the system.

<u>Table- 13</u>

<table>
<tr><td colspan="6">Bay A & Bay T connected through BUS-I.</td><td colspan="4">Stable Condition (R Phase Current injection)</td></tr>
<tr><td rowspan="2"></td><td></td><td colspan="4">Differential Current</td><td colspan="4">Restraining Current</td></tr>
<tr><td>Bay Current</td><td>Zone A</td><td>Zone B</td><td>Zone C</td><td>Check Zone</td><td>Zone A</td><td>Zone B</td><td>Zone C</td><td>Check Zone</td></tr>
<tr><td>Bay A</td><td></td><td rowspan="2"></td><td rowspan="2"></td><td rowspan="2"></td><td rowspan="2"></td><td rowspan="2"></td><td rowspan="2"></td><td rowspan="2"></td><td rowspan="2"></td></tr>
<tr><td>Bay T</td><td></td></tr>
<tr><td></td><td colspan="8">Unstable Condition (Earth at P1)</td><td></td></tr>
<tr><td>Bay A</td><td></td><td rowspan="2"></td><td rowspan="2"></td><td rowspan="2"></td><td rowspan="2"></td><td rowspan="2"></td><td rowspan="2"></td><td rowspan="2"></td><td rowspan="2"></td></tr>
<tr><td>Bay T</td><td></td></tr>
<tr><td colspan="6">Bay A & Bay T connected through BUS-I.</td><td colspan="4">Stable Condition (Y Phase Current injection)</td></tr>
<tr><td></td><td></td><td colspan="4">Differential Current</td><td colspan="4">Restraining Current</td></tr>
</table>

	Bay Current	Zone A	Zone B	Zone C	Check Zone	Zone A	Zone B	Zone C	Check Zone
Bay A									
Bay T									
	Unstable Condition (Earth at P1)								
Bay A									
Bay T									
Bay A & Bay T connected through BUS-I.						**Stable Condition (B Phase Current injection)**			
		Differential Current				Restraining Current			
	Bay Current	Zone A	Zone B	Zone C	Check Zone	Zone A	Zone B	Zone C	Check Zone
Bay A									
Bay T									
	Unstable Condition (Earth at P1)								
Bay A									
Bay T									
Bay A & Bay T connected through BUS-II						**Stable Condition (R Phase Current injection)**			
		Differential Current				Restraining Current			
	Bay Current	Zone A	Zone B	Zone C	Check Zone	Zone A	Zone B	Zone C	Check Zone
Bay A									
Bay T									
	Unstable Condition (Earth at P1)								
Bay A									
Bay T									
Bay A & Bay T connected through BUS-II						**Stable Condition (Y Phase Current injection)**			
		Differential Current				Restraining Current			
	Bay Current	Zone A	Zone B	Zone C	Check Zone	Zone A	Zone B	Zone C	Check Zone
Bay A									
Bay T									
	Unstable Condition (Earth at P1)								
Bay A									
Bay T									
Bay A & Bay T connected through BUS-II						**Stable Condition (B Phase Current injection)**			
		Differential Current				Restraining Current			

	Bay Current	Zone A	Zone B	Zone C	Check Zone	Zone A	Zone B	Zone C	Check Zone
Bay A									
Bay T									
	Unstable Condition (Earth at P1)								
Bay A									
Bay T									

C.7 Busbar Testing in One & Half Breaker Scheme – Brown field Projects

C.7.1 Differential Pickup and trip test through Secondary Injection (Test needs to be carried out for each bay)

Test Preconditions- Arrange shutdown of bus under test i.e. either Bus-I or Bus-II depending on the bay connection to Bus bar. Secondary Current injection needs to be done for Bus bar differential pickup/trip test.

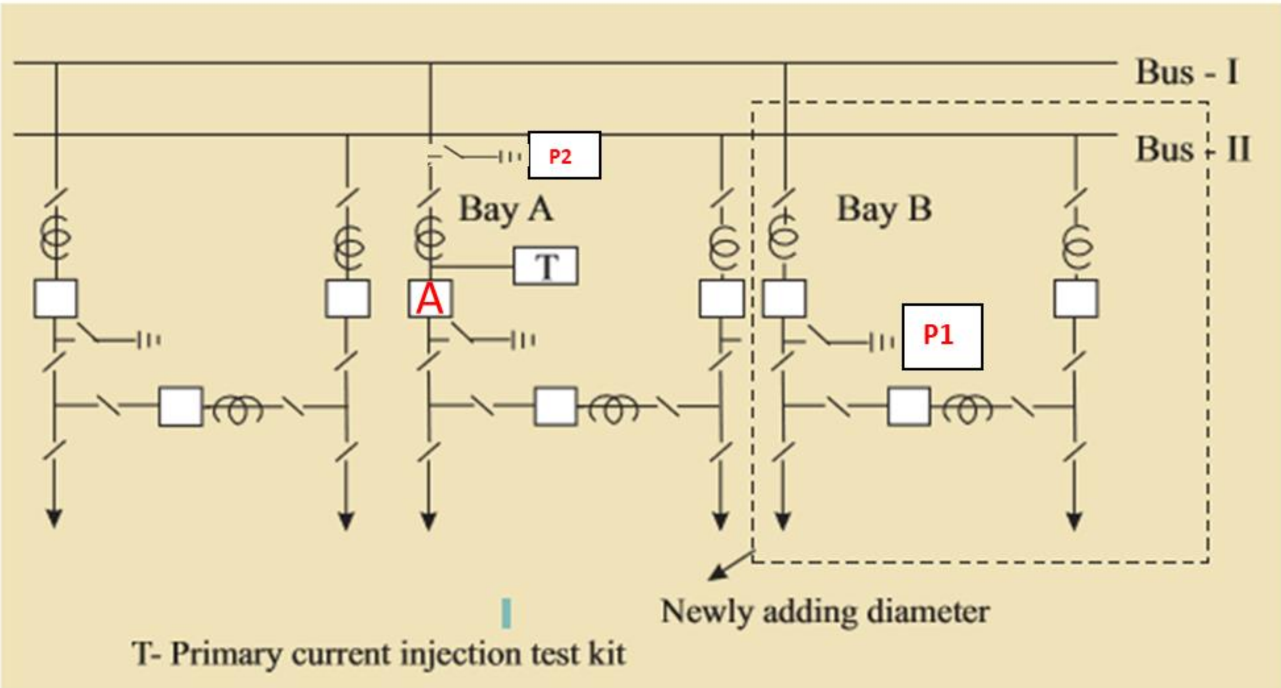


fig-12 Bus bar stability-One and Half breaker Scheme

1. Arrange the shutdown for Bus-I (If the additional bay is connected to Bus-I), close all the breakers connected to the Bus-I. Isolators of "Bay under shutdown" (connected to Bus-I) are to be kept in "Open" condition.
2. Inject the current only in "Bay B" (more than bus bar pickup value), this shall trip only Bus Zone-I. Repeat the test for all three phases. Record the data as per Table-14.

3. In case, the bus is connected with Bus Sectionalizer, injecting the current in one side of the bus bays shall not extend the trip to the bays connected to the other side of bus Sectionalizer. Tripping shall only be extended till Bus Sectionalizer.
4. The tests shall be repeated for both Main-1 and Main-2 bus bar protection.

Table-14

Bay Connected to Bus______ Bay No.________	**Other bay bus selection status**	**Tripping extended to (Mention the bay no.)**	**Remark**
Current Injection in PU A/CU A	**Bus-I** Bay No. **Bus-II** Bay No.		Save the Bus Bar topology file.
Current Injection in PU B/ CU B	**Bus-I** Bay No. **Bus-II** Bay No.		Save the Bus Bar topology file

C.7.2 Bus Bar Stability through Primary Injection (One & Half Breaker Scheme)

New Diameter extension

Before starting the CT primary injection for **Bus Bar/Bay stability work** following shall be verified.

10. Measure the CT loop resistance phase wise for each CT circuit. For this, CT link at CT MB to be isolated and CT link at CRP panels to be closed. The loop resistance of CT wires towards CRP side and CT side needs to be noted down.

Bay Reference	**CT Cores**	**Phase**	**Loop Resistance CRP side (in Ohm)**	**Loop Resistance CT side (in Ohm)**
	Core 1 . . . Core X	R-N		
		Y-N		
		B-N		

11. After measurement of CT loop resistance, CT links shall be closed at CT MB.

12. Verify the CT neutral formation for all cores with reference to CT ratio, according to the protection and metering scheme.
13. Verify that CT neutral is earthed only at single CRP panels. CT spare cores if any, is to be shorted and earthed at CT JB.
14. After verification of the above step, Single phase CT primary injection shall be started.
15. Following measurements to be recorded during CT primary injection test.

Bay Reference	Primary Current (In Amps)	Phase	CT Cores	Secondary Current at CT JB (in mA)		*Voltage (Ph-N) across CT secondary terminals at JB (In Volts)
				(Phase wire)	(Neutral Wire)	
		R	Core 1 . . Core X			
		Y	Core 1 . . Core X			
		B	Core 1 . . Core X			

*** Voltage across CT secondary terminals to be measured (in CT MB) and compared phase wise for each core to identify any loose connections in CT circuit.**

Bay connected to Bus-I

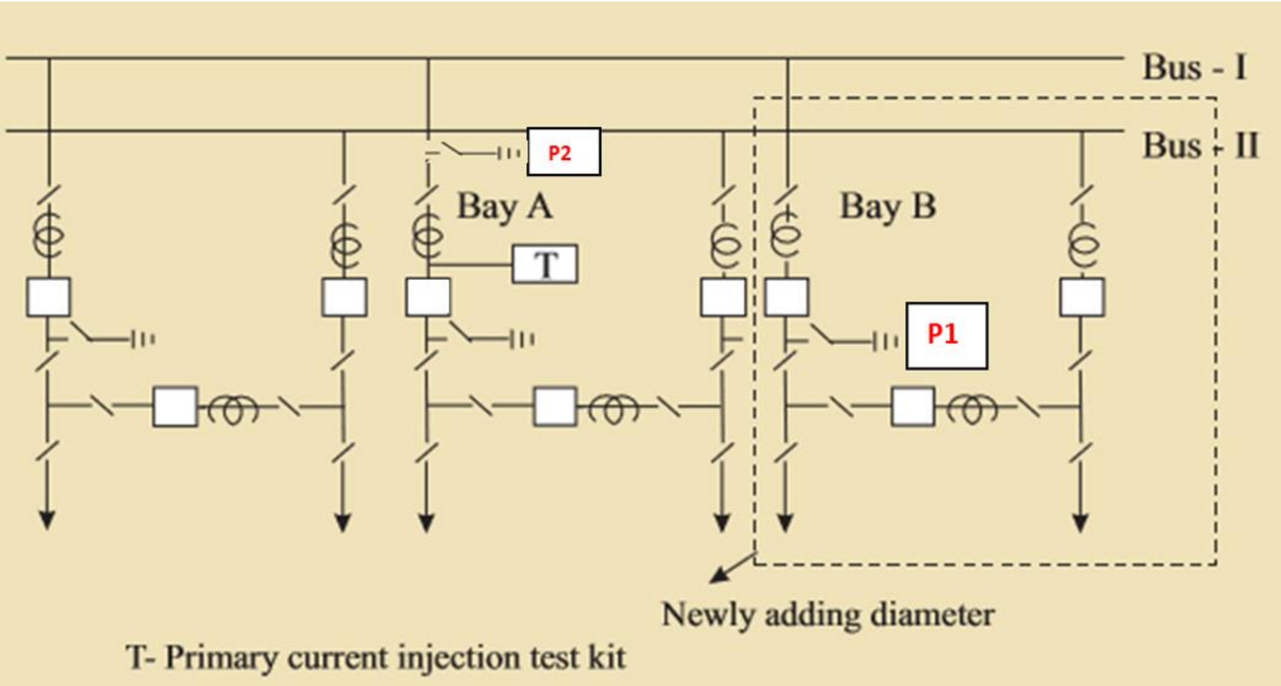


fig-13 Primary Bus bar stability-One and Half breaker Scheme

1. Arrange the shutdown of the bus bar under test (In this case Bus-I)
2. Consider one of the existing bays (A) as the reference.

3. CT core, used for the other protections (like LBB, distance or differential or O/C or metering, etc) needs to be isolated and shorted (towards CT side) at CT MB itself in “Bay A”. No CT core shall be in open condition. Bus bar core shall be kept in the connected condition as it will be used to verify the Bus bar stability process.
4. Inhibit the tripping of the breaker (Bay A & Bay B) from control room due to operation of distance or over current caused by primary current injection.
5. Earth at **Point P1** using local earth or nearby earth switch on bay B**.**
6. Ensure Bus-I is earthed only at Point P1.
7. Inject primary current using primary current injection testing kit across one phase at Point T (eg. R Phase) and ground; don't use other phases as return path for the current.
8. Measure the current at both CT marshalling boxes.
9. Measure and record the differential (spill) & restraining current for Bus zones & check zone at Bus Bar Central unit (Main 1 & Main 2) as per table-15.
10. The measured spill current in **Bus Zone-I** should not be more than 5%.
11. If the spill current is more (almost twice the CT secondary current), stop injecting the primary current and correct the CT polarity at bay 'B’.
12. Again, Current injection to be started and recordings as mentioned at **Sr. no. 9 & 10** need to be done.
13. Stop injecting primary current and then create in-zone fault on primary side (by providing earthing between the two CTs (for eg. at **point P2**). Start the current injection & measure and record the current at Bus Bar relay (Both Main 1 & 2) as per table 14. Stop the current injection.
14. Repeat the test for the other two phases also as per **Sr. no. 7 to 13**. Measure and record the current at Bus Bar Central unit (Main 1 & Main 2).
15. Stop the current injection **and normalize the CT cores of Bay “A”.**

Bay connected to Bus-II

1. Arrange the shutdown of the bus bar under test (In this case Bus-II)
2. Consider one of the existing bays (A) as the reference.

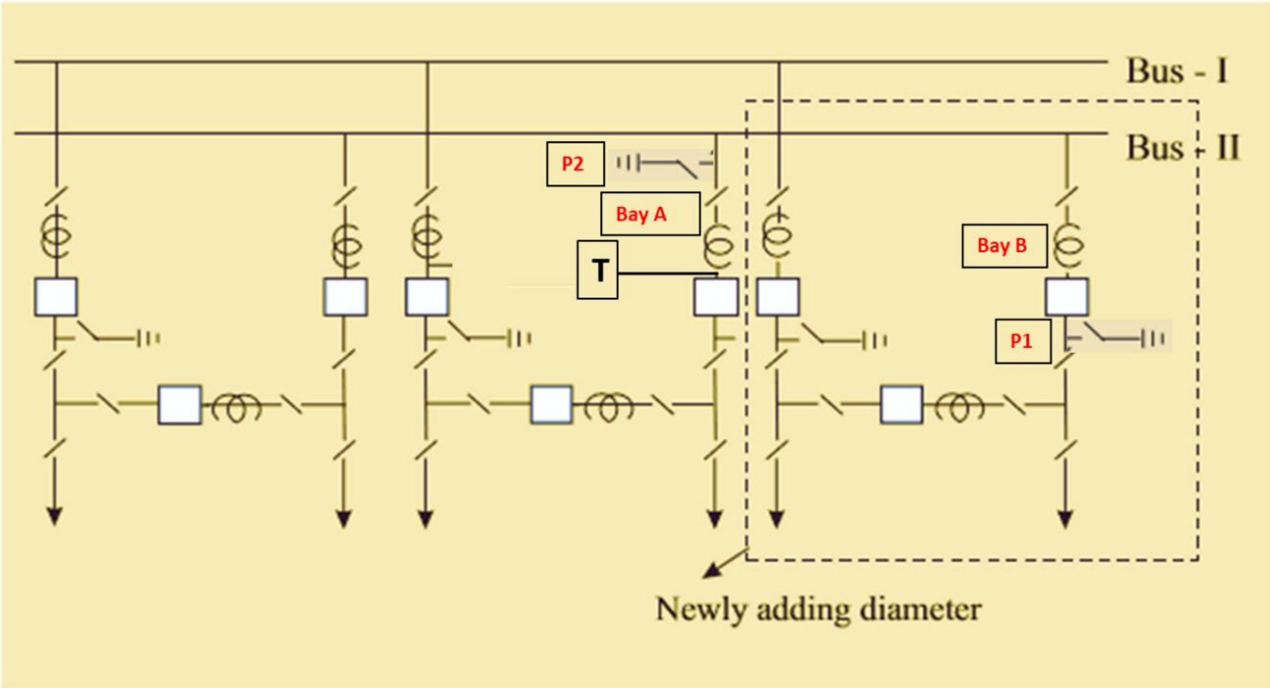


fig-14 Primary Bus bar stability-One and Half breaker Scheme

3. Short the CT cores of **"Bay A"** 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. Bus bar core shall not be shorted as it will be used to verify the Bus bar stability process (Refer fig-14).
4. Inhibit the tripping of the breaker (Bay A & Bay B) from control room due to operation of distance or over current caused by primary current injection.
5. Earth the Bus-II after CT using local earth or nearby earth switch on bay B **(Point P1).**
6. Ensure Bus-II is earthed only at point P1.
7. Inject primary current using primary current injection testing kit across one phase (eg. R Phase) and ground; don't use another phase as return path for the current.
8. Measure the current at both CT marshalling boxes.
9. Measure and record the differential (spill) & restraining current for Bus zones & check zone at Bus Bar Central unit (Main 1 & Main 2) as per table 15.
10. The measured spill current in Bus Zone-II should not be more than 5%.

11. If the spill current is more (almost twice the CT secondary current), stop injecting the primary current and correct the CT polarity at bay 'B'.
12. Again, Current injection to be started and recordings as mentioned at **Sr. no. 9 & 10** need to be done.
13. Stop injecting primary current and then create in-zone fault on primary side (by providing earthing between the two CTs (for eg. at point P2). Start current injection & measure and record the current at Bus Bar Central unit (Main 1 & Main 2). Stop the current injection.
14. Repeat the test for other two phases also as per **Sr. no. 7 to 13**. Measure and record the current at Bus Bar Central unit (Main 1 & Main 2). Record the data as per Table-14.
16. Stop the current injection **and normalize the system.**

Table-15

Stable Condition (R Phase Current injection)							
		Differential Current			Restraining Current		
	Bay Current	Zone A	Zone B	Check Zone	Zone A	Zone B	Check Zone
Bay A	PUA: PUB:	CUA:	CUA:	CUA:	CUA:	CUA:	CUA:
Bay B	PUA: PUB:	CUB:	CUB:	CUB:	CUB:	CUB:	CUB:
	Unstable Condition (Earth at P2)						
Bay A	PUA: PUB:	CUA:	CUA:	CUA:	CUA:	CUA:	CUA:
Bay B	PUA: PUB:	CUB:	CUB:	CUB:	CUB:	CUB:	CUB:
Stable Condition (Y Phase Current injection)							
		Differential Current			Restraining Current		
	Bay Current	Zone A	Zone B	Check Zone	Zone A	Zone B	Check Zone
Bay A		CUA:	CUA:	CUA:	CUA:	CUA:	CUA:
Bay B		CUB:	CUB:	CUB:	CUB:	CUB:	CUB:
	Unstable Condition (Earth at P2)						
Bay A	PUA: PUB:	CUA:	CUA:	CUA:	CUA:	CUA:	CUA:
Bay B	PUA: PUB:	CUB:	CUB:	CUB:	CUB:	CUB:	CUB:
Stable Condition (B Phase Current injection)							

		Differential Current			Restraining Current		
	Bay Current	Zone A	Zone B	Check Zone	Zone A	Zone B	Check Zone
Bay A	PUA: PUB:	CUA:	CUA:	CUA:	CUA:	CUA:	CUA:
Bay B	PUA: PUB:	CUB:	CUB:	CUB:	CUB:	CUB:	CUB:
	Unstable Condition (Earth at P2)						
Bay A	PUA: PUB:	CUA:	CUA:	CUA:	CUA:	CUA:	CUA:
Bay B	PUA: PUB:	CUB:	CUB:	CUB:	CUB:	CUB:	CUB:

C.8 Scheme checking of bus bar protection & DC trip logic. (New substation & Bay extension)

I. 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.

II. 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.

C.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, normalize 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.

PRE-COMMISSIONING FORMATS FOR SWITCHYARD EQUIPMENT

PRE-COMMISSIONING FORMATS FOR TRANSFORMER

I. GENERAL DETAILS

Region:

Sub-Station:

LOA No.:

EQUIPMENT DETAILS	
Make:	**Sr. No.:**
Equipment identification: **(For e.g. ICT-I-R phase)**	**Type:**
Year of Manufacture:	**Rating:**
Voltage Ratio:	**Cooling Type:**
Type of Neutral Grounding:	**Oil Make:**
Oil type:	**Oil quantity:**
Quantity of Radiator:	**% Impedance details for all tap (To be enclosed in a separate sheet)**
Date of Receipt at site:	**Date of Starting of Erection:**
Date of Completion of Erection and Oil filling:	**Equipment SAP ID:**

II. CHECK LIST OF ELECTRICAL TESTS CARRIED OUT FOR TRANSFORMER

Sl. No.	Name Of Test	Testing Kit Details			Test Results (Ok/Not Ok)
		Make	Rating/ Measuring Range	Date of Last Calibration	
1	Core Insulation Measurement				
2	Insulation Resistance Measurements Of Bushing CTs				
3	Continuity Test Of Bushing CTs				
4	Secondary Winding Resistance Of Bushing CTs				
5	Polarity Test Of Bushing CTs				
6	Current Ratio Test				
7	Magnetizing Curves Performance				
8	Measurement of Resistance of Earth Pit and Main Grid				

Sl. No.	Name Of Test	Testing Kit Details			Test Results (Ok/Not Ok)
		Make	Rating/ Measuring Range	Date of Last Calibration	
9	Frequency Response Analysis				
10	Magnetization Current of Windings				
11	Vector Group Test & Polarity Check				
12	Short Circuit Impedance Test				
13	Magnetic Balance Test (Not applicable for 1-ø)				
14	Floating Neutral Voltage Measurement				
15	Magnetization Current Test				
16	Voltage Ratio Test				
17	Core Insulation test after oil Circulation				
18	C & Tan δ Measurement Of Bushing				
19	C & Tan δ Measurement Of Windings				
20	Insulation Resistance Measurement of Winding				
21	Insulation Resistance Measurement of Cable				
22	Measurement of Winding Resistance				
23	Protection And Alarm Tests				
24	Stability Test Of Differential And REF Protection				
25	Contact Resistance Measurement				

Comments of Commissioning Team on test Results:

Comments of Corporate-AM on test Results (To be attached separately)

Manufacturer Recommendation on test Results (To be attached separately)

Signature:	**Signature:**	**Signature:**	**Signature:**
Name:	**Name:**	**Name:**	**Name:**
Desgn.:	**Desgn.:**	**Desgn.:**	**Desgn.:**
Organization: (Supplier Representative) (Wherever Applicable)	**(Erection Agency)**	**(POWERGRID Site I/C)**	**(POWERGRID Commg. Team) Members:** **1.** **2.** **3.** **4.**

III. CHECKS AFTER RECEIPT OF TRANSFORMER AT SITE:

a) *N2/ Dry Air Pressure & Dew Point Record*

Inspection Action	Date Of Meas.	N2/ Dry Air Pressure	Dew Point	Ambient Temperature	Remarks
During dispatch at factory					
After receipt at site					
Storage at site before commissioning					

Note:

i. Refer graph in A.1.1 for maintaining N2/ Dry air pressure and dew point during storage (To be maintained in a separate sheet/ Register)

ii. If Transformer is received with zero Dry air/ N2 pressure then matter to be referred to Manufacturer and Corporate-AM prior to erection

iii. Any noticeable drop in Dry air/ N2 during storage at site is observed, then matter to be referred to Manufacturer and CC-AM).

b) *Impact Recorder Analysis*

Make of Impact Recorder-1	Make of Impact Recorder-2
Type of Impact Recorder-1	**Type of Impact Recorder-2**
Journey Starts on	
Journey ends on	
Date of removal of impact recorder from equipment	

Sl.No.	Check Points	Status		Remarks
1	Functionality of Impact recorder at the time of dismantling from main unit	**On**	**Off**	
2	Joint data downloading carried out at site immediately after receipt	**Yes**	**No**	
3	Analysis of joint report received from manufacturer before charging	**Yes**	**No**	

Note:

i. Manufacturer to provide necessary software and downloading tools to respective sites so that data downloading can be carried out at site jointly by POWERGRID & Manufacturer

ii. Regarding permissible limit for maximum shock please refer A.1.2.

iii. Impact Recorder should be switched off and detached from the Transformer when the main unit has been placed on its foundation.

c) *Core Insulation Test (Immediately after Receipt at Site)*

Shorting link between CC, CL & G to be removed and IR value to be taken between CC-G, CL-G & CC-CL by applying 2.5 kV DC

Terminals	Insulation Value	Terminals	Insulation Value
CC-G		CC-CL	
CL-G		Semi-shield –G (if provided) at 1 kV	

Note:

i. Permissible value > 500 MΩ
ii. In case core insulation values are less than the permissible limit matter to be referred to OEM for corrective measures and same to be checked during internal inspection for any abnormality
iii. Ensure shorting of CC-CL & G after the completion of the testing

d) *Internal Inspection*

SL. No.	Internal Inspection	Status	
		Yes	No
1	Details photographs of all visible parts /components are taken during internal inspection.		
2	Any abnormality observed during internal inspection. In case of abnormality Matter to be referred to OEM, CC-QA&I, CC-Engg and CC-AM		

Details of abnormality observed during internal inspection (if noticed) _______________
____

IV. TRANSFORMER ERECTION

a) *Checks / Precautions During Erection :*

Sl.No.	Description	Remarks
1	Total Exposure of Active part of Transformer to atmosphere in hours (To be kept minimum)	
2	Dew point of dry air generator / dry air cylinders, during exposure of active part of Transformer	
3	Available of Oxygen in % before entering in Transformer tank	
4	N2/ Dry air pressure in PSI while Transformer is kept sealed in between different erection activities	
5	Ensure Leakage test of Air cell / bellow carried out	
6	Check Hermitically sealing is intact in all Bushings by OEM / Expert	
7	Storage of blanking plates	

b) *Evacuating And Oil Filling*

(i) Before filling oil, each drum has been physically checked for appearance and presence of free water.

Yes	No

(ii) Details of oil filter machine (As per latest TS of Transformers)

Make ______________________ Capacity_________________________

Sl.No	Description Of Works	Remarks / Reading
1	Changing of Lubricating oil of vacuum pump	
2	Cleaning/ Replacement of Filter packs	
3	Flushing of whole filter machine with fresh oil	
4	Vacuum obtained without load (milli bar)	

c) *Vacuum pump for evacuation of transformer*

Sl.No	Description of Works	Remarks / Reading
1	Changing of Lubricating oil of vacuum pump	
2	Vacuum obtained without load (milli bar)	
3	Diameter of vacuum hose (50 mm)	
4	Employ of Dry ice chamber	

d) *Oil storage tank*

Capacity________________________ Quantity____________________________

Sl.No	Description of Works	Remarks / Reading
1	Silica gel breather provided in the tank	
2	Any opening left uncovered	
3	Inside painted or not	
4	Cleanliness of inside of pipes/ hoses to the storage tank	
5	Healthiness of valves/flanges for pipe connection	

e) *Exposure during erection*

Sl.No	Description of Works	Remarks / Reading
1	First day exposure (in hrs)	
2	Second day exposure (in hrs)	
3	Third Day exposure (in hrs)	
4	N2/ Dry air pressure applied after each days erection work (in PSI)	
5	Ambient Temperature (in degC)	
6	Average Relative Humidity	
7	Weather Condition(Rainy / Stormy / Cloudy / Sunny)	

Note: Erection activities to be carried out in sunny weather and RH<60%

f) *N2/ Dry Air sealing in case of delay in oil filling*

Sl.No	Description of Works	Remarks / Reading
1	N2/Dry air admitted from bottom valve	
2	Valve at diametrically opposite end at top kept open	
3	No. of Cylinders used for building up to 4- 5 psi(.3kg/cm^2)	

g) *Leakage Test through pressure*

Sl.No	Inspection Actions	Date	Time	Remarks / Reading
1	Fill dry N2/ dry air till pressure of 4- 5psi (.3 kg/cm2) achieved			
2	To be kept for 24 Hrs			
3	In case pressure remain same, check for dew point			
4	If dew point is achieved, proceed for evacuation			
5	**In case of drop in pressure, attend the leakages and repeat the pressure test**			
6	If dew point is not OK, dry air/ N2 cycle to be carried out till desired dew point is achieved			

h) *Schedule for Vacuum & Tightness Test*

Sl. No	Inspection Actions	Date	Time	Remarks / Reading
1	Starting of evacuation on complete unit			
2	Stopping of evacuation at around the pressure of 3 kPa (30 mbar)			
3	Pressure P1 in mmHg after 1 hour of stopping evacuation			
4	Pressure P2 in mmHg after half an hour of reading pressure P1			
5	Leakage = (P2-P1) x V, V= Oil quantity in litres *If leakage<150 mmHgL/min (20 cu.m Pa/min) , continue evacuating If leakage > 150 mmHgL/min (20 cu.m Pa/min) , attend leakage and repeat process as per Sr. No. 1 to 4.			
6	Continue vacuum till 0.13kPa(1 Tor) or below achieved			
7	Break of vacuum * Vacuum process to be continued after reaching fine vacuum for 24 hrs up to 145kV, 48 hrs for 145 to 220kV and 72 hrs for 420 kV and above			

i) *Record of drying out process (if carried out)*

Sl.No	Activity	Date	Time	Remarks / Reading
1	First Dry air/ Nitrogen purging cycle			
	Pressure of Dry air/ Nitrogen 0.15 kg/cm2			
	Dew Point after 48 Hrs			
	Temperature with heaters on condition around the Transformer Tank(Refer procedure)			
2	First Vacuum cycle			
	Vacuum achieved			
	Rate of condensate collection(Hourly basis)			
	Duration of vacuum after achieving 1 to 5 torr			
3	Second Dry air/ Nitrogen purging cycle			
	Pressure of Dry air/ Nitrogen/ Dry air 0.15 kg/cm2			
	Temperature with heaters on condition around the Transformer Tank(Refer procedure)			
	Dew Point after 24 Hrs			

Note: If dew point is within the permissible limit oil filling under vacuum may be started otherwise vacuum/ Dry air/ Nitrogen purging with heating cycle to be continued till desired dew point is achieved.

j) *Schedule for Oil filling and Settling*

Sl.No	INSPECTION ACTIONS	DATE	TIME	REMARKS / READING
1	Ensure measurement of Particle counts during oil filtration in oil tanks(If specified in the contracts)			
2	Oil Filling in Main Tank			
3	Oil filling in Conservator tank			
4	Oil filling in diverter switch			
5	Hot oil circulation (minimum 2 cycles or depending on oil parameters) at oil temperature 60-65 deg C.			
6	Start of oil settling			
7	End of oil settling *** Minimum settling time to be given 12 hrs for 145 KV , 48 hrs for 220kV & 420kV and 72 hrs for 765 kV & above**			

V. PRE-COMMISSIONING CHECKS:

Sl. No.	Description Of Activity	Status		Deficiencies, If Any
		Yes	No	
1	ICT and its Auxiliaries are free from visible defects on physical Inspection			
2	All fittings as per out line General Arrangement Drawing			
3	Check Main Tank has been provided with double earthing			
4	Check neutral is grounded through separate connections. Ensure metallic requirements as per specification (e.g. Cu) in earthing strips used			
5	Check that Marshalling Box, T/C Driving Gear, Diverter, Radiator Bank Pump & Fan Motor etc. has been earthed			
6	All nuts and bolts are tightened correctly as per specified torque (as per manufacturers recommendation)			
7	Check tightness of Terminal Connectors			
8	Check leveling of Transformer and its accessories			
9	Erection Completion Certificate along with list of outstanding activities reviewed			
10	Any Paint removed / scratched in transit has been touched up			
11	Bushings are clean and free from physical damages			
12	Oil level is correct on all Bushings			
13	Check brazing of all Bushings Leads			
14	Check oil leakage through any Joints / Valves etc.			
15	Check oil drain valves are properly closed and locked			
16	Check oil level in Main / OLTC Conservator tank			
17	Check oil level at conservator matches with oil temperature of transformer			
18	Check Gear box oil level in OLTC (if applicable)			
19	Check OTI and WTI pockets and replenish the oil, if required			
20	Check all valves for their opening & closing sequence			
21	Check the colour of the breather silica gel			
22	Check availability of oil in the breather cup			
23	Check all rollers are locked and tack welded with rails (wherever applicable)			
24	Check tightness of bolt if main unit placed directly on foundation and not on rollers			

Sl. No.	Description Of Activity	Status		Deficiencies, If Any
		Yes	No	
25	Check bushing test tap is grounded			
26	Check the operation of flow sensitive shut off valve between main tank & conservator, if any			
27	Check the functioning of SPR (Sudden pressure relay) ,if any			
28	Check no debris, loose T & P and oil strains on and around the Transformer			
29	Check door seals of Marshalling Box is intact and all cable gland plates unused holes are sealed			
30	Check that pressure relief valve is correctly mounted			
31	Ensure unused secondary cores of Bushing CT's, if any, has been shorted			
32	Check CT star point has been formed properly and grounded at one end only as per scheme			
33	Check that permanent and adequate lighting arrangements are ready			
34	Check that labeling and identification is permanent and satisfactory			
35	Check that Buchholz Relay is correctly mounted with arrow pointing towards conservator			
36	Check cables are properly fixed and ensure cable entry at the bottom			
37	Ensure all Power and Control cable Terminals are tightened			
38	Check all cables and Ferrules are provided with Number as per Cable Schedule (Cross Ferruling to be checked)			
39	Check that all cables are correctly glanded			
40	Check external cabling from Junction Box to Relay / Control Panel completed			
41	Check that air has been released from the Radiators and their headers/OLTC Buchholz relay/Main tank/tank/Bushing turrets etc			
42	Check Fire Protection System & Emulsifier systems is adequate & ready			
43	Check that CC-CL & G are shorted			
44	Check that neutral connection has twin conductor in case of single phase unit and the neutral of spare unit has been earthed.			
45	Check insulation sleeves are provided in case of tertiary bus arrangement			

Sl. No.	Description Of Activity	Status		Deficiencies, If Any
		Yes	No	
46	Check that all radiator bank valves on top and bottom headers are open			
47	Change over operation of ac supply from source- I to source-II checked			
48	Check the flanges of bushing & OLTC for any crack after fixing			
49	Calibration of OTI & WTI performed as per procedure			
50	Ensure RTCC is commissioned and kept in service			
51	Ensure Remote OTI and WTI data transfer to control room is taking place			
52	Ensure On-Line DGA is commissioned and kept "ON"			
53	Ensure On-Line Dry out system is commissioned and kept "ON"			
54	Ensure that rain canopies have been provided on all PRDs, Buchholz and OSRs.			
55	Ensure tripping of the transformer from Buchholz Alarm.			
56	Ensure application of Insulating coating on Buchholz, PRD TBs to prevent mal-operation due to moisture ingress			
57	Ensure healthiness of Gaskets in the MB, PRD, Buchholz, Turret CT Terminal Box etc to avoid ingress of moisture.			
58	Ensure proper dressing of cables (cables should not rest on equipment body)			
59	Check various interlocks provided with Fire Fighting as per the schematic Ref. Drg. No.____________________	Description of Interlocks		Checked

VI. MEASUREMENT OF EARTH RESISTANCE OF ELECTRODE

Location	Value
With Grid (Earth Pit -1)	
Without Grid (Earth Pit -1) (Neutral Earth)	
With Grid (Earth Pit -2)	
Without Grid (Earth Pit -2) (Neutral Earth)	

Note: Permissible limit with grid < 1 ohm

VII. PRECOMMISSIONING TESTS AFTER READINESS OF THE TRANSFORMER

1) *Frequency Response Analysis (FRA)*

Sl.No	Description	Yes	No	Remarks
1	Carried out after completion of all commissioning activities			
2	Factory FRA test report in soft form available at site			
3	Interpretation of test results carried out			
4	Test results matching with the factory results			

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	

Note:- Measurement to be carried out at Minimum, Maximum and Nominal Tap for all combination of HV & IV and Nomenclature to be made similar as mentioned in the procedure documents.

During pre-commissioning, SFRA is to be compared with factory signature. Snapshots with super imposition of both signatures for each combination have to be attached in pre-commissioning report. SFRA signature in Machine readable format (.fra/.sfra/.frax etc) is to be forwarded (both site and factory test signature) to CC-AM along with pre-commissioning results.

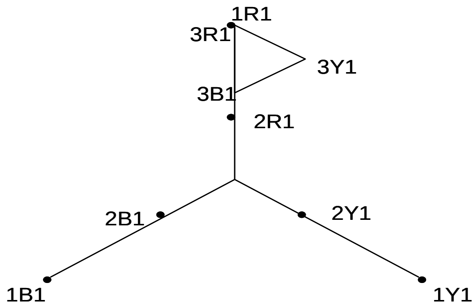
2) *Vector Group Test & Polarity Checking*

Vector Group Checks for 3Φ Transformer and Bank of 1Φ Transformer After Tertiary Formation

Connect Neutral Point with earth, join 1 RI and 3 R1 Terminals and apply 415 V. 3-phase supply to HV Terminals

Terminals	Voltage Measured (Volts)	Terminals	Voltage Measured (Volts

1R1 – 1Y1		3R1- N	
1Y1 – 1B1		3Y1 – N	
1B1 – 1R1		3B1 – N	
3Y1 – 1B1		2R1- N	
3Y1 – 1Y1		2Y1 – N	
		2B1 – N	



Vector group Ynaod11 is confirmed and polarity verified

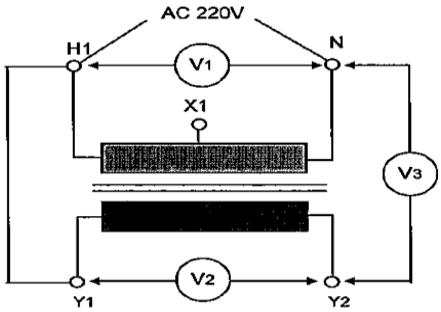
If 2R1 – N = 2Y1 – N = 2B1 – N = constant

3R1 -N > 3Y1 – N > 3B1 – N

3Y1 – 1B1 >3Y1 – 1Y1

a. **Polarity Checks for 1Ø unit**

Apply 1-phase supply to HV(1.1) and Neutral(2) Terminals

Terminals	Voltage Measured (Volts)	Remarks
HV-N, V1		
LV1(Y1)-LV2(Y2) ,V2		
LV2(Y2)-N,V3		

Remarks :If V1> V3= Subtractive,V1<V3= Additive

3) *Magnetic Balance Test (Not Applicable For Single Phase Units)*

Apply single phase 230 V across one phase of HV winding terminal and neutral then measure voltage in other two HV terminals across neutral. Repeat the test for each of the three phases.

Apply 1-Ph 230v Ac Across (1)	Voltage Measured In Volts		Remarks
	Between (2)	Between (3)	
2R1 – N:	2Y1 – N:	2B1 – N:	
2Y1 – N:	2R1 – N:	2B1 – N:	

Apply 1-Ph 230v Ac Across (1)	Voltage Measured In Volts		Remarks
	Between (2)	Between (3)	
2B1 – N:	2Y1 – N:	2R1 – N:	

Note:

i. (1)= (2) + (3), Approx.
ii. When outer phase is excited, voltage induced in the center phase shall be 50 to 90% of the applied voltage. However, when the center phase is excited then the voltage induced in the outer phases shall be 30 to 70% of the applied voltage.

4) *Floating Neutral Voltage Measurement*

a) Disconnect the Transformer neutral from the ground and apply 3 phase 415 Volts to the high voltage winding and make the measurement in the IV winding with respect to neutral and neutral point to ground

Tap Position	HV Winding	Voltage Applied	IV Winding	Voltage Measured	Remarks, If Any
Normal (__)	1R – N		2R – N		
Normal (__)	1Y – N		2Y – N		
Normal (__)	1B – N		2B – N		
			N – Earth		

b) Apply 3 phase 415 Volts to the Intermediate voltage winding and make the measurement in the Tertiary winding with respect to neutral and neutral point to ground

IV Winding	Voltage Applied	LV Winding	Voltage Measured	Remarks, If Any
2R – N		3R – N		
2Y – N		3Y – N		
2B – N		3B – N		
		N – Earth		

Note: Neutral to be reconnected to the ground after the test

Magnetization Current Test

a) Apply 1 Phase, AC supply on HV Terminals and keep IV and LV open

Tap Position	Voltage Applied (Volts)		Current Measured (mAmps)		Remarks
LOWEST	R – N		R – PH		
	Y – N		Y – PH		
	B – N		B – PH		

Tap Position	Voltage Applied (Volts)		Current Measured (mAmps)		Remarks
NORMAL	R – N		R – PH		
	Y – N		Y – PH		
	B – N		B – PH		
HIGHEST	R – N		R – PH		
	Y – N		Y – PH		
	B – N		B – PH		

b) Apply 1 phase, 240 V AC supply on IV Terminal and keep HV & LV open

Tap Position	Voltage Applied (Volts)		Current Measured (mAmp)	
Normal	2R – N		R – PH	
	2Y – N		Y – PH	
	2B –N		B – PH	

c) Apply 1 phase, 240 V AC supply on LV Terminal and keep HV & IV open

Tap Position	Voltage Applied (Volts)		Current Measured (mAmp)	
Normal	3R – 3Y		R – PH	
	3Y – 3B		Y – PH	
	3B – 3R		B – PH	

Note:

i. Excitation current < 50 mili-Amperes, then difference between two higher currents should be less than 10%.
ii. Excitation current > 50 mili-Amperes, then difference between two higher currents should be less than 15 %.
iii. Value of center leg should not be more than either outside for a three phase reactor.
iv. Results between similar single phase units should not vary more than 10%.

5) *Short Circuit Impedance Test*

Ambient Temperature ____________________ OTI Reading ________________

a) **HV TO IV**

Tap Number	1 R		1Y		1B	
	IV of R Φ and N shorted, LV open		IV of Y Φ and N shorted, LV open		IV of R Φ and N shorted, LV open	
	Voltage (Volt)	Current (Amp)	Voltage (Volt)	Current (Amp)	Voltage (Volt)	Current (Amp)
Lowest						
Nominal						
Highest						

b) IV TO LV

Supply Nominal tap	2U1-N, ……….V	2V1-N,……….V	2W1-N, ………V
Short all LVs and HV Open and measured current in Amp			

c) **HV TO LV**

Supply	Short All 3 LV Bushings, HV Open and Measured Current in Amp		
	Nominal tap	Highest tap	Lowest tap
1U1-N, ……….V			
1V1-N,……….V			
1W1-N, ………V			

Note: The measurement is performed in single phase mode.

6) *Insulation Resistance Measurement*

a) Insulation Resistance Measurement of Cable and others (Using 500 Volt Megger)

Ambient temp in º C ______________________

Sl. No.	Description	Status		Remarks, If Any
		Yes	No	
1	Control wiring			
2	Tap changer			
	a) Motor			
	b) Control			

Sl. No.	Description	Status		Remarks, If Any
		Yes	No	
3	Cooling System			
	a) Motor Fan			
	b) Motor Pump			
	c) Control wiring			

Note: Permissible limit of IR value should be > 50 M Ω

b) Insulation Resistance Measurement in MΩ(Using 5000 V Megger)

Ambient temp in º C ______________________

Main Winding	IR Value			Dielectric Absorption Coefficient DAI= 60 Sec / 15 Sec	Polarisation Index PI= 600 Sec / 60 Sec	Remarks
	15 sec	60 sec	600 sec			
Combination for Auto transformer						
a) HV+IV / LV						
b) HV+IV / E						
c) LV / E						
Combination for 3 winding transformer						
a) HV+IV / LV						
b) HV+IV / E						
b) HV+IV+LV / E						

Note:- Permissible limit of IR value should be > 500 M Ω for 66kV & above at 30°C, DAI should be >1.3 and PI should be >1.25

7) *Core Insulation Test*

Shorting link between CC, CL & G to be removed and IR value to be taken between CC-G, CL-G & CC-CL by applying 2.5 kV DC

Terminals	Insulation Value	Terminals	Insulation Value
CC-G		CC-CL	
CL-G		Semi-shield –G (if provided) at 1 kV	

Note:

i. Permissible value > 500 MΩ
ii. In case core insulation values are less than the permissible limit matter to be referred to OEM for corrective measures and same to be checked during internal inspection for any abnormality

iii. Ensure shorting of CC-CL & G after the completion of the testing

8) *Voltage Ratio Test*

a) Turn Ratio : HV / IV

Tap Position	Voltage Applied			Voltage Measured			Ratio			Factory Ratio			% Deviation		
	1R-N	1Y-N	1B-N	2R-N	2Y-N	2B-N	R	Y	B	R	Y	B	R	Y	B
1															
2															
3															
4															
5															
6															
7															
8															
9															
10															
11															
12															
13															
14															
15															
16															
17															
18															
19															
20															
21															
22															
23															
Reverse Side For All Tap Position															
TAP NO															

b) Ratio : HV / LV(For all Tap if OLTC is on Neutral side)

Tap Position	Voltage Applied			Voltage Measured			Ratio			Factory Ratio			% Deviation		
	1R-N	1Y-N	1B-N	3R-3Y	3Y-3B	3R-3B	R	Y	B	R	Y	B	R	Y	B
Lowest															
Normal															
Highest															

c) Ratio : IV / LV(For all Tap if OLTC is on Neutral side)

Tap Position	Voltage Applied			Voltage Measured			Ratio			Factory Ratio			% Deviation		
	2R-N	2Y-N	2B-N	3R-3Y	3Y-3B	3R-3B	R	Y	B	R	Y	B	R	Y	B
Lowest															
Normal															
Highest															

Note:

1. The variation of result should be within ± 0.5 % from specified values (i.e. factory test result)
2. Measurement to be done by Automatic Turns ratio meter

9) *Tan δ And Capacitance Measurement*

a) Tan Delta And Capacitance Measurement Of Bushing

BUSHING DETAILS

Details	High Voltage Side			Intermediate Voltage Side		
	R – Ø	Y – Ø	B – Ø	R – Ø	Y – Ø	B – Ø
Make						
Type						
Sl. No.						
Style No / Drawing No						

DETAILS	LOW VOLTAGE SIDE		
	R – Ø	Y – Ø	B – Ø
Make			
Type			
Sl. No.			
Style No / Drawing No			

Ambient temperature_________________________ Oil Temperature ______________________

a) HV side

VOLTAGE	CAPACITANCE (MEASURED VALUE)						REMARKS
	R – Ø		Y – Ø		B – Ø		
	SITE	FACTORY	SITE	FACTORY	SITE	FACTORY	
Measurement of C1							
2 KV							
10 KV							
Measurement of C2							

1 KV							
VOLTAGE	TAN δ (MEASURED VALUE)						REMARKS
	R – Ø		Y – Ø		B – Ø		
	SITE	FACTORY	SITE	FACTORY	SITE	FACTORY	
Measurement of C1							
2 KV							
10 KV							
Measurement of C2 Tan δ							
1 KV							

	Capacitance of HV Bushing			Tan δ of HV Bushing		
	R – Ø	Y – Ø	B – Ø	R – Ø	Y – Ø	B – Ø
17 Hz						
25 Hz						
34 Hz						
43Hz						
68Hz						
85Hz						
102Hz						
119Hz						
136Hz						
187Hz						
255 Hz						
323 Hz						
391HZ						

b) IV side

VOLTAGE	CAPACITANCE (MEASURED VALUE)						REMARKS
	R – Ø		Y – Ø		B – Ø		
	SITE	FACTORY	SITE	FACTORY	SITE	FACTORY	
Measurement of C1							
2 KV							
10 KV							
Measurement of C2							
1 KV							
VOLTAGE	TAN δ (MEASURED VALUE)						REMARKS
	R – Ø		Y – Ø		B – Ø		
	SITE	FACTORY	SITE	FACTORY	SITE	FACTORY	
Measurement of C1							
2 KV							
10 KV							
Measurement of C2 Tan δ							
1 KV							

	Capacitance of IV Bushing			Tan δ of IV Bushing		
	R – Ø	Y – Ø	B – Ø	R – Ø	Y – Ø	B – Ø
17 Hz						
25 Hz						
34 Hz						
43Hz						
68Hz						
85Hz						
102Hz						
119Hz						
136Hz						
187Hz						
255 Hz						
323 Hz						
391HZ						

c) LV side

VOLTAGE	CAPACITANCE (MEASURED VALUE)						REMARKS
	R – Ø		Y – Ø		B – Ø		
	SITE	FACTORY	SITE	FACTORY	SITE	FACTORY	
Measurement of C1							
2 KV							
10 KV							
Measurement of C2							
1 KV							

VOLTAGE	TAN δ (MEASURED VALUE)						REMARKS
	R – Ø		Y – Ø		B – Ø		
	SITE	FACTORY	SITE	FACTORY	SITE	FACTORY	
Measurement of C1							
2 KV							
10 KV							
Measurement of C2 Tan δ							
1 KV							

	Capacitance of LV Bushing			Tanδ of LV Bushing		
	R – Ø	Y – Ø	B – Ø	R – Ø	Y – Ø	B – Ø
17 Hz						
25 Hz						
34 Hz						
43Hz						
68Hz						
85Hz						
102Hz						

	Capacitance of LV Bushing			Tanδ of LV Bushing		
	R – Ø	Y – Ø	B – Ø	R – Ø	Y – Ø	B – Ø
119Hz						
136Hz						
187Hz						
255 Hz						
323 Hz						
391HZ						

b) TAN DELTA AND CAPACITANCE MEASUREMENT OF WINDING
Ambient temperature ______________________________

VOLTAGE	WINDING COMBINATION	TEST MODE	CAPACITANCE		TAN δ		REMARK
			SITE	FACTORY	SITE	FACTORY	
2 KV	HV-IV/ LV	UST					
10 KV							
2 KV	HV-IV/ LV+G	GST					
10 KV							
2 KV	HV-IV/ LV with Guard	GSTg					
10 KV							
2 KV	LV/ HV-IV	UST					
10 KV							
2 KV	LV/ HV-IV+G	GST					
10 KV							
2 KV	LV/ HV-IV with Guard	GSTg					
10 KV							

Note:

i. C2 values shall be only for record purpose.
ii. For bushing acceptable Limit for Tan δ1 should be comparable (+/- 0.001) with factory value subjected to max of 0.005 & Tan δ2:-0.01
iii. For winding acceptable Limit for Tan δ1 should be comparable (+/- 0.001) with factory value subjected to max of 0.005 & Tan δ2:-0.01
iv. Acceptable Limit for Capacitance -5% to + 10%

10) *Measurement Of Winding Resistance (In mΩ)*

Ambient temperature in º C______ OTI Reading ______ WTI reading _____

A) HIGH VOLTAGE SIDE(IN CASE OLTC IS ON LINE SIDE)

Tap Position	Winding Resistance(HV-N) / HV-IV			Resistance At 75º C			Factory Value At 75º C			% Deviation		
	1R1–2R1	1Y1–2Y1	1B1–2B1	1R1–2R1	1Y1–2Y1	1B1–2B1	1R1–2R1	1Y1–2Y1	1B1–2B1	1R1–2R1	1Y1–2Y1	1B1–2B1
1												
2												
3												
4												
5												
6												
7												
8												
9b												
10												
11												
12												
13												
14												
15												
16												
17												
18												
19												
20												
21												
22												
23												
Reverse Order For All Tap Position												
Tap Position	**Winding Resistance(HV-IV)**			**Resistance At 75º C**			**Factory Value At 75º C**			**% Deviation**		
	1R1 – 2R1	**1Y1–2Y1**	**1B1 – 2B1**	**1R1 – 2R1**	**1Y1–2Y1**	**1B1 – 2B1**	**1R1 – 2R1**	**1Y1–2Y1**	**1B1 – 2B1**	**1R1 – 2R1**	**1Y1–2Y1**	**1B1 – 2B1**

Tap Position	Winding Resistance(HV-N) / HV-IV			Resistance At 75º C			Factory Value At 75º C			% Deviation		
	1R1–2R1	1Y1–2Y1	1B1–2B1	1R1–2R1	1Y1–2Y1	1B1–2B1	1R1–2R1	1Y1–2Y1	1B1–2B1	1R1–2R1	1Y1–2Y1	1B1–2B1
TAP.....												
TAP…												
TAP…												
TAP…												

B) INTERMEDIATE VOLTAGE SIDE(FOR ALL TAP IN CASE OLTC IS ON NEUTRAL SIDE)

Between Windings	Resistance	Resistance At 75 °C In Ohms		% Deviation
	Site Value@ ----ºC	Factory	Site	
2R1 – N				
2Y1 – N				
2B1 – N				

C) LOW VOLTAGE SIDE

Between Windings	Resistance	Resistance At 75 °C In Ohms		% Deviation
	Site Value@ ----ºC	Factory	Site	
3R1 – 3B1				
3Y1 – 3R1				
3B1 – 3Y1				
Across winding (for 1-phase unit)				

NOTE:

i. Formula for calculating the resistance at 75°C: R_{75} = RT (235+75)/ (235+T), where RT = Resistance Measured At Winding Temperature T.

ii. Permissible limit: ±5% variation between phases or from Factory test results

iii. LV winding resistance at factory measured without formation of delta. However measurements carried out at site are after formation of delta. Hence a correction factor of 1.5 times to be applied in site results

11) *Oil Characteristics*

(Sample to be taken prior to charging to Transformer and it should fulfill the recommendations as per IS 1865 /IEC 60422)

DATE OF OIL SAMPLING	BREAKDOWN VOLTAGE	MOISTURE	TAN DELTA	INTERFACIAL TENSION
Permissible Limit →	**70KV(min)**	**5 PPM(Max)**	**0.005 at 90° C (Max)**	**0.04 N/m at 27°C (Min)**
Main Tank value prior to Energization				
Storage Tank Value-1				
Storage Tank Value-2				
Storage Tank Value-3				
Storage Tank Value-4				
Storage Tank Value-5				
Storage Tank Value-6				

On Line Particle Counts/ 100ml (To be carried after completion of oil filtration)

Particle Size	4µm	6 µm	10 µm	14 µm	21 µm	25 µm	38 µm	70 µm	ISO CODE
Sample-1									
Sample-2									
Sample-3									
Average Value									

Limit: As per ISO 4406 class: 9/6 to 10/7 (1000 counts per 100 ml of sampling for equal to or larger than 6 µm; 130 counts per 100 ml of sampling for equal to or larger than 14µm)

DISSOLVED GAS ANALYSIS

DISSOLVE GASES	H2	CH4	C2H4	C2H6	C2H2	CO	CO2	O2	N2	TCG
Before Charging										

Note:-

i. TCG should be below 1%
ii. One fresh oil sample per lot (from drum) shall be sent to Lab for carrying out Oxidation Stability test

12) *Operational Test and Checks of Other Equipments*

a) Test On OLTC

SL.NO	DESCRIPTION	STATUS		REMARKS
		OK	NOT OK	
1	Visual inspection of equipment			
2	Manual operation on all taps (local) with confirmation of the no. Of revolutions and locking at extreme taps			
3	Over load device of driving motor			
4	Local operation (electrical)			
5	Remote operation (electrical)			
6	Tap position indicator			
7	Check operation with master follower			
	Scheme (parallel operation)			
8	Out of step relay			
9	Step by step contactor			
10	Limit switch			
11	Winding resistance at all taps			
12	Continuity test of winding during one complete cycle of operation			

b) Checking of cooling Equipments

SL.NO	DESCRIPTION	STATUS		
		OK	NOT OK	
1	Rotation direction of Pumps			
2	Rotation direction of Fans			

c) **Protection Check**

EQUIPMENT FAN NO	SETTING VALUE	PICKUP VALUE	SINGLE PHASING PREVENTION CHECK
1			
2			
3			
-			
-			
Pump No.			
1			
2			
3			
4			

13) *Checks on Bushing CT's*

(a) Rated Data And Duty

CORE	RATIO	CLASS	BURDEN	KVP	PROTECTION / METERING
Core-I					
Core II					
Core III					
Core IV					
-					

(b) **Insulation Resistance Measurement Of Bushing Ct's(Using 500v Megger)**

Measurement Between	Unit	HV			IV		
		R – Ø	Y – Ø	B – Ø	R – Ø	Y – Ø	B – Ø
Earth – Core I	M Ω						
Earth – Core II	M Ω						
Earth – Core III	M Ω						
Earth – Core IV	M Ω						

Measurement Between	Unit	LV			Neutral
		R – Ø	Y – Ø	B – Ø	
Earth – Core I	M Ω				
Earth – Core II	M Ω				
Earth – Core III	M Ω				
Earth – Core IV	M Ω				

Measurement Between	Unit	HV			IV		
		R – Ø	Y – Ø	B – Ø	R – Ø	Y – Ø	B – Ø
Core I – Core II	M Ω						
Core I – Core III	M Ω						
Core I – Core IV	M Ω						
Core II – Core III	M Ω						
Core II – Core IV	M Ω						
Core III – Core IV	M Ω						

Measurement Between	UNIT	LV		
		R – Ø	Y – Ø	B – Ø
Core I – Core II	M Ω			
Core I – Core III	M Ω			
Core I – Core IV	M Ω			
Core II – Core III	M Ω			
Core II – Core IV	M Ω			
Core III– Core IV	M Ω			

(c) CONTINUITY TEST OF BUSHING CT'S (in Ω)

Continuity, Check between Terminals: OK / NOT OK

CORE	BETWEEN TERMINAL	HV			IV		
		R – Ø	Y – Ø	B – Ø	R – Ø	Y – Ø	B – Ø
Core – I	1S1–1S2						
Core – II	2S1–2S2						
Core – III	3S1–3S2						
Core – IV	4S1–4S2						

CORE	BETWEEN TERMINAL	LV			NEUTRAL
		R – PHASE	Y – PHASE	B – PHASE	
Core – I	1S1–1S2				
Core – II	2S1–2S2				
Core – III	3S1–3S2				
Core – IV	4S1–4S2				

(d) SECONDARY WINDING RESISTANCE OF BUSHING CT'S (IN OHM)

i. HV side

CORE	BETWEEN TERMINAL	UNIT	R – Ø		Y – Ø		B – Ø	
			FACTORY	SITE	FACTORY	SITE	FACTORY	SITE
Core I	1S1 – 1S2	Ω						
Core II	2S1 – 2S2	Ω						
Core III	3S1 – 3S2	Ω						
Core IV	4S1 – 4S2	Ω						

ii. IV side

CORE	BETWEEN TERMINAL	UNIT	R – Ø		Y – Ø		B – Ø	
			FACTORY	SITE	FACTORY	SITE	FACTORY	SITE
Core I	1S1 – 1S2	Ω						
Core II	2S1 – 2S2	Ω						
Core III	3S1 – 3S2	Ω						
Core IV	4S1 – 4S2	Ω						

iii. LV side

CORE	BETWEEN TERMINAL	UNIT	R – Ø		Y – Ø		B – Ø	
			FACTORY	SITE	FACTORY	SITE	FACTORY	SITE
Core I	1S1 – 1S2	Ω						
Core II	2S1 – 2S2	Ω						
Core III	3S1 – 3S2	Ω						
Core IV	4S1 – 4S2	Ω						

iv. Neutral Side

CORE	BETWEEN TERMINAL	UNIT	R – Ø	
			FACTORY	SITE
Core I	1S1 – 1S2	Ω		

v. External Neutral CT

CORE	BETWEEN TERMINAL	UNIT	R – Ø	
			FACTORY	SITE
Core I	1S1 – 1S2	Ω		

(e) Polarity Test Of Bushing CT's

With 1.5 V DC supply (Connect +ve at P1 and –ve at P2)

i.

CORE	BETWEEN		HV			IV		
			R – Ø	Y – Ø	B – Ø	R – Ø	Y – Ø	B – Ø
Core I	1S1 (+ve)	1S2 (-ve)						
Core II	2S1 (+ve)	2S2 (-ve)						
Core III	3S1 (+ve)	3S2 (-ve)						
Core IV	4S1 (+ve)	4S2 (-ve)						

ii.

CORE	BETWEEN		LV			NEUTRAL
			R – Ø	Y – Ø	B – Ø	
Core I	1S1 (+ve)	1S2 (-ve)				
Core II	2S1 (+ve)	2S2 (-ve)				
Core III	3S1 (+ve)	3S2 (-ve)				
Core IV	4S1 (+ve)	4S2 (-ve)				

Note: Extra row may be added for additional cores

(f) CURRENT RATIO TEST

Primary Injection through Primary Injection Kit at Primary Terminal P1 – P2

Measure current on the secondary Terminals. In case of factory fitted turret CTs, current ratio may be carried out by CT analyzer

i. HV side R – Phase side

Core S1 – S2	Primary %	Current Actual	Secondary Current	Theoretical Ratio	Actual Ratio	% Of Error
Core I (1S1 – 1S2)	20%					
	80%*					
Core II (2S1 – 2S2)	20%					
	80%*					
Core III (3S1 – 3S2)	20%					
	80%*					
Core IV (4S1 – 4S2)	20%					
	80%*					

ii. HV side Y – Phase

Core S1 – S2	Primary %	Current Actual	Secondary Current	Theoretical Ratio	Actual Ratio	% Of Error
Core I (1S1 – 1S2)	20%					
	80%*					
Core II (2S1 – 2S2)	20%					
	80%*					

Core III (3S1 – 3S2)	20%					
	80%*					
Core IV (4S1 – 4S2)	20%					
	80%*					

iii. HV side B – Phase

Core S1 – S2	Primary %	Current Actual	Secondary Current	Theoretical Ratio	Actual Ratio	% Of Error
Core I (1S1 – 1S2)	20%					
	80%*					
Core II (2S1 – 2S2)	20%					
	80%*					
Core III (3S1 – 3S2)	20%					
	80%*					
Core IV (4S1 – 4S2)	20%					
	80%*					

iv. IV side R – Phase

Core S1 – S2	Primary %	Current Actual	Secondary Current	Theoretical Ratio	Actual Ratio	% Of Error
Core I (1S1 – 1S2)	20%					
	80%*					
Core II (2S1 – 2S2)	20%					
	80%*					
Core III (3S1 – 3S2)	20%					
	80%*					
Core IV (4S1 – 4S2)	20%					
	80%*					

v. IV side Y – Phase

Core S1 – S2	Primary %	Current Actual	Secondary Current	Theoretical Ratio	Actual Ratio	% Of Error
Core I	20%					
(1S1 – 1S2)	80%*					
Core II	20%					
(2S1 – 2S2)	80%*					
Core III	20%					
(3S1 – 3S2)	80%*					
Core IV	20%					
(4S1 – 4S2)	80%*					

vi. IV side B – Phase

Core S1 – S2	Primary %	Current Actual	Secondary Current	Theoretical Ratio	Actual Ratio	% Of Error
Core I	20%					
(1S1 – 1S2)	80%*					
Core II	20%					
(2S1 – 2S2)	80%*					
Core III	20%					
(3S1 – 3S2)	80%*					
Core IV	20%					
(4S1 – 4S2)	80%*					

Note:-Minimum current shall be 1000A or 80% whichever is achieved. In case of any abnormality, ratio test to be carried out at 40% and 60% also.

Permissible limit: Protection core-± 3% and metering core ±0.5%.

(a) MAGNETISING CURVES PERFORMANCE (Not to be done for metering Core)
Knee Point Voltage (KVp) = ……………….Volt; Current: …….

i. HV Side R – Phase

Voltage		Unit	Current Measurement			
To Be Applied	Actual Value		Core – I 1S1-1S2	Core – II 2S1-2S2	Core – III 3S1-3S2	Core – IV 4S1-4S2

0.25 x KVp		mA				
0.50 x KVp		mA				
0.75 x KVp		mA				
1.00 x KVp		mA				
1.10 x KVp		mA				

ii. HV Side Y – Phase

Voltage		Unit	Current Measurement			
To Be Applied	Actual Value		Core – I 1S1-1S2	Core – II 2S1-2S2	Core – III 3S1-3S2	Core – IV 4S1-4S2
0.25 x KVp		mA				
0.50 x KVp		mA				
0.75 x KVp		mA				
1.00 x KVp		mA				
1.10 x KVp		mA				

iii. HV Side B – Phase

Voltage		Unit	Current Measurement			
To Be Applied	Actual Value		Core – I 1S1-1S2	Core – II 2S1-2S2	Core – III 3S1-3S2	Core – IV 4S1-4S2
0.25 x KVp		mA				
0.50 x KVp		mA				
0.75 x KVp		mA				
1.00 x KVp		mA				
1.10 x KVp		mA				

iv. **IV Side R – Phase**

Voltage		Unit	Current Measurement			
To Be Applied	Actual Value		Core – I 1S1-1S2	Core – II 2S1-2S2	Core – III 3S1-3S2	Core – IV 4S1-4S2
0.25 x KVp		mA				
0.50 x KVp		mA				
0.75 x KVp		mA				
1.00 x KVp		mA				
1.10 x KVp		mA				

v. **IV Side Y – Phase**

Voltage		Unit	Current Measurement			
To Be Applied	Actual Value		Core – I 1S1-1S2	Core – II 2S1-2S2	Core – III 3S1-3S2	Core – IV 4S1-4S2
0.25 x KVp		mA				
0.50 x KVp		mA				
0.75 x KVp		mA				
1.00 x KVp		mA				
1.10 x KVp		mA				

vi. **IV Side B – Phase**

Voltage		Unit	Current Measurement			
To Be Applied	Actual Value		Core – I 1S1-1S2	Core – II 2S1-2S2	Core – III 3S1-3S2	Core – IV 4S1-4S2
0.25 x KVp		mA				
0.50 x KVp		mA				
0.75 x KVp		mA				
1.00 x KVp		mA				
1.10 x KVp		mA				

Note:-

a) Test to be carried out by Automatic CT analyzer

b) CT should not saturate at 110% of Knee Point Voltage (KVp)

c) If Knee Point Voltage is not mentioned then Knee Point Current may be taken into consideration.

14) *Protection related setting And Alarms*

a) Protection alarms

SL.NO	DEVICE	SET FOR		PROVED	
		ALARM	TRIP	ALARM	TRIP
1	Excessive winding temperature	**100**	**110**		
2	Excessive oil temperature	**90**	**100**		
3	Oil flow failure		NA		NA
4	Pressure relief valve	NA		NA	
5	Main tank Buchholz relay				
6	OLTC Buchholz relay	NA		NA	
7	Fan failure		NA		NA
8	Low oil level (MOG)		NA		NA
9	Differential relay	NA		NA	
10	Over load relay		NA		NA
11	Restricted Earth fault relay (ref)	NA		NA	
12	Back up O/C & EF relay (HV & IV)	NA		NA	
13	Inter trip , if any	NA		NA	
14	Trip free check	NA		NA	
16	Over flux (HV & IV)				
17	SPR relay (if provided)				
18	On line DGA	NA	NA	NA	NA

b) Protection setting applied as per Engg. Approved settings

Yes	No	Remarks

c) Stability test of differential and REF protection

Ok	Not Ok	Remarks

NOTE : Prove the tripping of associated breakers by actual operation of the various devices and relays as per the schemes.

d) Delta formation of single phase units and spare switching arrangement scheme checked

Yes	No	Remarks

15) *Final Documentation Review*

a) Factory test results are available

Yes	No

b) All electrical test results compared with factory test results & found to be in order

Yes	No

c) Final documents of Pre- Commissioning checks reviewed and approved

Yes	No

d) Document regarding spares equipment, O&M manuals etc available at site

Yes	No

e) After modification, if any, "As built Drawings" are available at site

Yes	No

1) *Checks After Charging of Transformer*

Record the following after charging

a) Any abnormal sound emanating from the transformer

Yes	No	Remarks

b) No load current at relay terminal

R – Ø	A
Y – Ø	A
B – Ø	A

c) Temperature at the time of charging

OTI	º C
WTI	º C
AMBIENT	º C

d) Maximum temperature after 24 hours____________º C

e) OLTC electrical operation checked in idle charged condition from minimum position to maximum position & back to normal position

Yes	No	Remarks

f) Thermo vision scanning done at least after 24 hours of loading & repeated after one week.

Yes	No	Remarks

g) Dissolve gas Analysis

Dissolve gases	24 hrs after charging	7 days after charging	15 days after charging	1 month after charging	3 month after charging
H_2					
CH_4					
CO					
CO_2					

Dissolve gases	24 hrs after charging	7 days after charging	15 days after charging	1 month after charging	3 month after charging
C_2H_4					
C_2H_6					
C_2H_2					
O2					
N2					
TCG					

Note: If any abnormal increase in fault gasses observed after 24 Hrs. of charging, immediate oil sampling to be sent to Lab for confirmation and matter shall be referred to OEM

Comments of Commissioning Team on test Results:

Comments of Corporate-AM on test Results (To be attached separately)

Manufacturer Recommendation on test Results (To be attached separately)

Signature:	**Signature:**	**Signature:**	**Signature:**
Name:	**Name:**	**Name:**	**Name:**
Desgn.:	**Desgn.:**	**Desgn.:**	**Desgn.:**
Organization: (Supplier Representative) (Wherever Applicable)	**(Erection Agency)**	**(POWERGRID Site I/C)**	**(POWERGRID Commg. Team) Members:** **1.** **2.** **3.** **4.**

PRE-COMMISSIONING FORMAT FOR REACTOR

I. GENERAL DETAILS

Region:

Sub-Station:

LOA:

EQUIPMENT DETAILS	
Sr. No.:	Type:
Equipment identification No.:	Make:
Year of Manufacture:	Rating:
Voltage Class :	Cooling Type:
Type of Neutral Grounding:	Oil Make:
Oil type:	Oil quantity:
Quantity of Radiator	Date of Receipt at site:
Date of Starting of Erection:	Date of Completion of Erection and Oil filling:
Equipment SAP ID:	

II. SEQUENCE OF TESTS TO BE CARRIED OUT FOR REACTOR

SL. NO.	NAME OF TEST	TESTING KIT DETAILS			TEST RESULTS Ok/Not Ok
		MAKE	MEASURING RANGE	DATE OF LAST CALIBRATION	
1	Core Insulation Measurement upon arrival of equipment at site				
2	Insulation Resistance Measurements Of Bushing CTs				
3	Continuity Test Of Bushing CTs				
4	Secondary Winding Resistance Of Bushing CTs				

SL. NO.	NAME OF TEST	TESTING KIT DETAILS			TEST RESULTS Ok/Not Ok
		MAKE	MEASURING RANGE	DATE OF LAST CALIBRATION	
5	Polarity Test Of Bushing CTs				
6	Current Ratio Test				
7	Magnetizing Curves Performance				
8	Measurement of Resistance of Earth Pit and Main Grid				
9	Frequency Response Analysis				
10	Magnetization Current of Windings				
11	C & Tan δ Measurement Of Bushing				
12	C & Tan δ Measurement Of Windings				
13	C & Tan δ Measurement Of NGR Windings(If any)				
14	Insulation Resistance Measurement of Winding				
15	Insulation Resistance Measurement of Cable				
16	Core Insulation Measurement after oil filling				
17	Measurement of Winding Resistance				
18	Measurement of Winding Resistance of NGR				
19	Protection And Alarm Tests				
20	Stability Test Of Differential And Ref Protection				
21	Contact Resistance Measurement				
22	Vibration Measurement				

III. CHECKS AFTER RECEIPT OF REACTOR AT SITE:

b. *N2/ Dry Air Pressure & Dew Point Record*

Inspection Action	Date Of Meas.	N2/ Dry Air Pressure	Dew Point	Ambient Temperature	Remarks
During dispatch at factory					
After receipt at site					
Storage at site before commissioning					

Note:

i. Refer POWERGRID doc no d-2-03-xx-01-01 rev-01 (latest revision) for maintaining N2/ Dry air pressure and dew point during storage(To be maintained in a separate sheet/ Register)

ii. Any noticeable drop in Dry air/ N2 during storage at site is observed, then matter to be referred to Manufacturer and CC-AM.

iii. If Reactor is received with zero dry air/ N2 pressure then matter to be referred to Manufacturer and Corporate-AM prior to erection

B) *Impact Recorder Analysis*

No of Impact Recorder installed: ______________________________

Make of Impact Recorder(s) ______________________________

Type of Impact Recorder(s) ______________________________

Date of removal of impact recorder from equipment ______________________________

Sl. No.	Check Points	Status		Remarks
1	Functionality of Impact recorder at the time of dismantling from main unit	**On**	**Off**	
2	Joint data downloading carried out at site immediately after receipt	**Yes**	**No**	
3	Analysis of joint report received from manufacturer before charging	**Yes**	**No**	

Note:

i. Manufacturer to provide necessary software and downloading tools to respective sites so that data downloading can be carried out at site jointly by POWERGRID & Manufacturer
ii. Regarding permissible limit for maximum shock please refer procedure……
iii. Impact Recorder should be switched off and detached from the Reactor when the main unit has been placed on its foundation.

c. ***Core Insulation Test (Immediately after Receipt at Site)***

Shorting link between CC, CL & G to be removed and IR value to be taken between CC-G, CL-G & CC-CL by applying 2.5 kV DC

Terminals	**Insulation Value**	**Terminals**	**Insulation Value**
CC-G		CC-CL	
CL-G		Semi-shield –G (if provided) at 1 kV	

Note:

i. Permissible value > 500 MΩ
ii. In case core insulation values are less than the permissible limit matter to be referred to OEM for corrective measures and same to be checked during internal inspection for any abnormality
iii. Ensure shorting of CC-CL & G after the completion of the testing

d. ***Internal Inspection***

SL. No.	**Internal Inspection**	**Status**	
		Yes	**No**
1	Details photographs of all visible parts /components are taken during internal inspection.(refer procedure2.1.6)		
2	Any abnormality observed during internal inspection		
3	Matter referred to manufacturing, CC-QA & I , CC-ENGG and CC-OS		

Details of abnormality observed during internal inspection (if noticed) _______________
____
____

IV. REACTOR ERECTION

a) *Checks / Precautions During Erection :*

Sl. No.	Description	Remarks
1	Total Exposure of Active part of Reactor to atmosphere in hours (To be kept minimum)	
2	Dew point of dry air generator / dry air cylinders, during exposure of active part of Reactor	
3	Available of Oxygen in % before entering in Reactor tank	
4	N2/ Dry air pressure in PSI while Reactor is kept sealed in between different erection activities	
5	Ensure Leakage test of Air cell / bellow carried out	
6	Check Hermitically sealing is intact in all Bushings by OEM / Expert	

b) *Evacuating And Oil Filling*

(iii) Before filling oil, each drum has been physically checked for free moisture and appearance

Yes	No

(iv) Details of oil filter machine (As per latest TS of Reactors)

Make ______________________ Capacity_________________________

Sl.No	Description Of Works	Remarks / Reading
1	Changing of Lubricating oil of vacuum pump	
2	Cleaning of Filter packs	
3	Flushing of whole filter machine with fresh oil	
4	Vacuum obtained without load (milli bar)	

(v) Vacuum pump for evacuation of Reactor

Sl.No	Description of Works	Remarks / Reading
1	Changing of Lubricating oil of vacuum pump	
2	Vacuum obtained without load (milli bar)	
3	Diameter of vacuum hose (50 mm)	
4	Employ of Dry ice chamber	

(vi) Oil storage tank

Capacity______________________ Quantity__________________________

Sl.No	Description of Works	Remarks / Reading
1	Silica gel breather provided in the tank	
2	Any opening left uncovered	
3	Inside painted or not	
4	Cleanliness of inside of pipes/ hoses to the storage tank	

(vii) Exposure during erection

Sl.No	Description of Works	Remarks / Reading
1	First day exposure (in hrs)	
2	Second day exposure (in hrs)	
3	Third Day exposure (in hrs)	
4	Dry air/ N2 pressure applied after each days erection work (in PSI)	
5	Ambient Temperature (in degC)	
6	Average Relative Humidity	
7	Weather Condition(Rainy / Stormy / Cloudy / Sunny)	

Note:

i. Erection activities to be carried out in sunny weather and RH<60%

(viii) N2/ Dry Air sealing in case of delay in oil filling

Sl.No	Description of Works	Remarks / Reading
1	No. of Cylinders used for displacing the air inside the tank	
2	Dry air/ N2 admitted from bottom valve	
3	Valve at diametrically opposite end at top kept open	
4	No. of Cylinders used for building up to 4- 5 psi(.3kg/cm^2)	

(ix) Leakage Test through pressure

Sl.No	Inspection Actions	Date	Time	Remarks / Reading
1	Fill dry N2/ dry air till pressure of 4- 5psi (.3 kg/cm^2) achieved			
2	To be kept for 24 Hrs			
3	In case pressure remain same, check for dew point			
4	If dew point is achieved, proceed for evacuation			
5	**In case of drop in pressure, attend the leakages and repeat the pressure test**			
6	If dew point is not OK, dry air/ N2 cycle to be carried out till desired dew point is achieved			

(x) Schedule for Vacuum & Tightness Test

Sl.No	Inspection Actions	Date	Time	Remarks / Reading
1	Starting of evacuation on complete unit			
2	Stopping of evacuation below the pressure of 5 kPa (50 mbar)			
3	Pressure P1 in mmHg after 1 hour of stopping evacuation			
4	Pressure P2 in mmHg after half an hour of reading pressure P1			
5	Leakage = (P2-P1) x V , V= Oil quantity in litres ***If leakage<** 150 mmHgL/min (20 cu.m Pa/min)**, continue evacuating** **If leakage >** 150 mmHgL/min (20 cu.m Pa/min)**, attend leakage and repeat process as per Sr. No. 1 to 4.**			

Sl.No	Inspection Actions	Date	Time	Remarks / Reading
6	Start of Vacuum reaching below 0.13kPa(1 Torr)			
7	Break of vacuum *** Vacuum process to be continued for 24 hrs Up to 145 KV, 48 hrs for 145 to 220kV and 72 hrs for 420 kV and above**			

(xi) Record of drying out process (if carried out)

Sl. No	Activity	Date	Time	Remarks / Reading
1	**First Dry air/ Nitrogen purging cycle**			
	Pressure of Dry air/ Nitrogen 0.15 kg/cm2			
	Dew Point after 48 Hrs			
	Temperature with heaters on condition around the Reactor Tank(Refer procedure)			
2	**First Vacuum cycle**			
	Vacuum achieved			
	Rate of condensate collection(Hourly basis)			
	Duration of vacuum after achieving 1 to 5 torr			
3	**Second Dry air/ Nitrogen purging cycle**			
	Pressure of Dry air/ Nitrogen 0.15 kg/cm2			
	Temperature with heaters on condition around the Reactor Tank(Refer procedure)			
	Dew Point after 24 Hrs			

Note: If dew point is within the permissible limit oil filling under vacuum may be started otherwise vacuum/ Nitrogen purging with heating cycle to be continued till desired dew point is achieved.

(xii) Schedule for Oil filling and Settling

Sl. No	INSPECTION ACTIONS	DATE	TIME	REMARKS / READING
1	Ensure measurement of Particle counts during oil filtration in oil tanks(If specified in the contracts)			
2	Oil Filling in Main Tank			
3	Oil filling in Conservator tank			

4	Oil filling in diverter switch			
5	Hot oil circulation (minimum 2 cycles or depending on oil parameters) at oil temperature 55-60 deg C.			
6	Start of oil settling			
7	End of oil settling *** Minimum settling time to be given 24 hrs for up to 220 kV, 48 HRS for 220 to 420 kV and 48 Hrs for 765 kV & above.**			

V. PRE-COMMISSIONING CHECKS:

Sl. No.	Description Of Activity	Status		Deficiencies , If Any
		Yes	No	
1	Reactor and its Auxiliaries are free from visible defects on physical Inspection			
2	All fittings as per out line General Arrangement Drawing			
3	Check Main Tank has been provided with double earthing			
4	Check neutral is grounded through separate connections. Ensure metallic requirements as per specification (e.g. Cu) in earthing strips used			
5	Check that Marshalling Box, , Radiator Bank & Fan(if any) etc. has been earthed			
6	All nuts and bolts are tightened correctly as per specified torque (as per manufacturers recommendation)			
7	Check tightness of Terminal Connectors			
8	Check leveling of Reactor and its accessories			
9	Erection Completion Certificate along with list of outstanding activities reviewed			
10	Any Paint removed / scratched in transit has been touched up			
11	Bushings are clean and free from physical damages			
12	Oil level is correct on all Bushings			
13	Check brazing of all Bushings Leads			
14	Check oil leakage through any Joints / Valves etc.			
15	Check oil drain valves are properly closed and locked			
16	Check oil level in Main Conservator tank			
17	Check oil level at conservator matches with oil temperature of Reactor			
18	Check OTI and WTI pockets and replenish the oil, if required			

19	Check all valves for their opening & closing sequence			
20	Check the colour of the breather silica gel			
21	Check availability of oil in the breather cup			
22	Check tightness of bolt of main unit after placed on foundation			
23	Check busing test tap is grounded			
24	Check the operation of flow sensitive shut off valve between main tank & conservator, if any			
25	Check the functioning of SPR (Sudden pressure relay) ,if any			
26	Check no debris, loose T & P and oil strains on and around the Reactor			
27	Check door seals of Marshalling Box is intact and all cable gland plates unused holes are sealed			
28	Check that pressure relief valve is correctly mounted			
29	Ensure unused secondary cores of Bushing CT's, if any, has been shorted			
30	Check CT star point has been formed properly and grounded at one end only as per scheme			
31	Check that permanent and adequate lighting arrangements are ready			
32	Check that labeling and identification is permanent and satisfactory			
33	Check that Buchholz Relay is correctly mounted with arrow pointing towards conservator			
34	Check cables are properly fixed and ensure cable entry at the bottom			
35	Ensure all Power and Control cable Terminals are tightened			
36	Check all cables and Ferrules are provided with Number as per Cable Schedule (Cross Ferruling to be checked)			
37	Check that all cables are correctly glanded			
38	Check external cabling from Junction Box to Relay / Control Panel completed			
39	Check that air has been released from the Radiators and their headers/ Buchholz relay/Main tank/tank/Bushing turrets etc			
40	Check Fire Protection System & Emulsifier systems is adequate & ready			
41	Check that CC-CL & G are shorted			
42	Check that neutral connection has twin conductor in case of single phase unit			

43	Check that all radiator bank valves on top and bottom headers are open			
44	Change over operation of ac supply from source- I to source-II checked			
45	Check the flanges of bushing for any crack after fixing			
46	Calibration of OTI & WTI performed as per procedure			
47	Ensure Remote OTI and WTI data transfer to control room is taking place			
48	Ensure On-Line DGA is commissioned and kept "ON"			
49	Ensure On-Line Dry out system is commissioned and kept "ON"			
50	Ensure that rain canopies have been provided on all PRDs, Buchholz and OSRs.			
51	Ensure tripping of the transformer from Buchholz Alarm.			
52	Ensure application of Insulating coating on Buchholz, PRD TBs to prevent mal-operation due to moisture ingress			
53	Ensure healthiness of Gaskets in the MB, PRD, Buchholz, Turret CT Terminal Box etc to avoid ingress of moisture.			
54	Ensure proper dressing of cables (cables should not rest on equipment body)			
55	Ensure that Ground Overcurrent or Broken Conductor protection is enabled to prevent damage to NGR during single phasing.			
56	Check various interlocks provided with Fire Fighting as per the schematic Ref. Drg. No.____________________	Description of Interlocks		Checked

VI. MEASUREMENT OF EARTH RESISTANCE OF ELECTRODE

Location	Value
With Grid (Earth Pit -1)	
Without Grid (Earth Pit -1) (Neutral Earth)	
With Grid (Earth Pit -2)	
Without Grid (Earth Pit -2) (Neutral Earth)	

Permissible limit with grid < 1 ohm

VII. PRECOMMISSIONING TESTS AFTER READINESS OF THE REACTOR

1. Frequency Response Analysis (FRA)

Sl.No	Description	Yes	No	Remarks
1	Carried out after completion of all commissioning activities			
2	Factory FRA test report in soft form available at site			
3	Interpretation of test results carried out			
4	Test results matching with the factory results			

Note:- During pre-commissioning, SFRA is to be compared with factory signature. Snapshots with super imposition of both signatures for each combination have to be attached in pre-commissioning report. SFRA signature in Machine readable format (.fra/.sfra/.frax etc) is to be forwarded (both site and factory test signature) to CC-AM along with pre-commissioning results.

2. Magnetization Current Test

Ambient temperature ______________________ Temperature of oil______________________

Voltage Applied (Volts)		Current Measured (mAmp)		Remark
R – N		R – PH		
Y – N		Y – PH		
B – N		B – PH		
NGR				

Note:

a. ***Excitation current < 50 milli-Amperes, then difference between two higher currents should be less than 10%.***
b. ***Excitation current > 50 milli-Amperes, then difference between two higher currents should be less than 15 %.***
c. ***Value of centre leg should not be more than either outside for a three phase reactor.***
d. ***Results between similar single phase units should not vary more than 10%.***

3. Tan δ And Capacitance Measurement

a) Tan Delta And Capacitance Measurement Of Bushing

BUSHING DETAILS

Details	High Voltage Side			Neutral	NGR
	R – Ø	Y – Ø	B – Ø		
Make					
Type					
Sl. No.					
Style No / Drawing No					

Ambient temperature_________________________ Oil Temperature _____________________

b) HV side

VOLTAGE	CAPACITANCE (MEASURED VALUE)						REMARKS
	R – Ø		Y – Ø		B – Ø		
	SITE	FACTORY	SITE	FACTORY	SITE	FACTORY	
Measurement of C1							
2 KV							
10 KV							
Measurement of C2							
1 KV							
VOLTAGE	**TAN δ (MEASURED VALUE)**						**REMARKS**
	R – Ø		**Y – Ø**		**B – Ø**		
	SITE	**FACTORY**	**SITE**	**FACTORY**	**SITE**	**FACTORY**	
Measurement of C1							
2 KV							
10 KV							
Measurement of C2 Tan δ							
1 KV							

	Capacitance of HV Bushing			Tan δ of HV Bushing		
	R – Ø	Y – Ø	B – Ø	R – Ø	Y – Ø	B – Ø
17 Hz						
25 Hz						
34 Hz						
43Hz						
68Hz						
85Hz						
102Hz						
119Hz						
136Hz						
187Hz						
255 Hz						
323 Hz						
391HZ						

c) NGR Bushing

VOLTAGE	CAPACITANCE (MEASURED VALUE)						REMARKS
	SITE	FACTORY	SITE	FACTORY	SITE	FACTORY	
Measurement of C1							
2 KV							
10 KV							
Measurement of C2							
1 KV							
VOLTAGE	**TAN δ (MEASURED VALUE)**						**REMARKS**
	SITE	**FACTORY**	**SITE**	**FACTORY**	**SITE**	**FACTORY**	
Measurement of C1							
2 KV							
10 KV							
Measurement of C2 Tan δ							
1 KV							

	CAPACITANCE	TAN δ
17 Hz		
25 Hz		
34 Hz		
43Hz		
68Hz		
85Hz		
102Hz		
119Hz		
136Hz		
187Hz		
255 Hz		
323 Hz		
391HZ		

d) TAN DELTA AND CAPACITANCE MEASUREMENT OF WINDING

Ambient temperature ______________________________

VOLTAGE	WINDING COMBINATION	TEST MODE	CAPACITANCE		TAN δ		REMARK
			SITE	FACTORY	SITE	FACTORY	
2 KV	HV-IV/ LV	UST					
10 KV							
2 KV	HV-IV/ LV+G	GST					
10 KV							

VOLTAGE	WINDING COMBINATION	TEST MODE	CAPACITANCE		TAN δ		REMARK
			SITE	FACTORY	SITE	FACTORY	
2 KV	HV-IV/ LV with Guard	GSTg					
10 KV							
2 KV	LV/ HV-IV	UST					
10 KV							
2 KV	LV/ HV-IV+G	GST					
10 KV							
2 KV	LV/ HV-IV with Guard	GSTg					
10 KV							

Note:

i. C2 values shall be only for record purpose.

ii. For bushing acceptable Limit for Tan δ1 should be comparable (+/- 0.001) with factory value subjected to max of 0.005 & Tan δ2:-0.01

iii. For winding acceptable Limit for Tan δ1 should be comparable (+/- 0.001) with factory value subjected to max of 0.005 & Tan δ2:-0.01

iv. Acceptable Limit for Capacitance -5% to + 10%

4. Insulation Resistance Measurement

a) Insulation Resistance Measurement of Cable and others (Using 500 Volt Megger)

Ambient temp in º C ______________________

SL. NO.	DESCRIPTION	STATUS		REMARKS, IF ANY
		YES	NO	
A	Control wiring			
B	Cooling System			
	a) Motor Fan			
	b) Motor Pump			
	c) Control wiring			

**** Permissible limit of IR value should be > 50 M Ω***

b) Insulation Resistance Measurement in MΩ (Using 5000 V Megger)

Ambient temp in º C ________________________

Main Winding	Ir Value			Dielectric Absorption Coefficient(DAI) = 60 Sec / 15 Sec	Polarisation Index(PI) = 600 Sec / 60 Sec	Remarks
	15 Sec	60 Sec	600 Sec			
a) HV / E						
b)NGR WINDING						

Permissible limit of IR value should be > 500 M Ω for 66kV & above at 30°C, DAI should be >1.3 and PI should be >1.25 To 2.

5. Measurement Of Winding Resistance (In Ohm)

Ambient temperature in º C______ OTI Reading ______ WTI reading ______

i. WINDING RESISTANCE OF REACTOR WINDING

Winding Resistance(HV-N)			Resistance At 75º C			Factory Value At 75º C			% Deviation		
R	Y	B	R	Y	B	R	Y	B	R	Y	B

ii. WINDING RESISTANCE OF NGR WINDING

Winding Resistance(HV-N)			*Resistance At 75º C			*Factory Value At 75º C			% Deviation		
R	Y	B	R	Y	B	R	Y	B	R	Y	B

<u>NOTE:</u>

i. Formula for calculating the resistance at 75°C: R_{75} = RT (235+75)/ (235+T), where RT = Resistance Measured At Winding Temperature T.

ii. Permissible limit: ±5% variation between phases or from Factory test results

6. CORE INSULATION TEST

Shorting link between CC, CL & G to be removed and IR value to be taken between CC-G, CL-G & CC-CL by applying 2.5 kV DC

Terminals	Insulation Value	Terminals	Insulation Value
CC-G		CC-CL	
CL-G		Semi-shield –G (if provided) at 1 kV	

Note:

i. Permissible value > 500 MΩ

ii. Ensure shorting of CC-CL & G after the completion of the testing

7. Oil Characteristics

(Sample to be taken prior to charging to Reactor and it should fulfill the recommendations as per IS 1865 /IEC 60422)

DATE OF OIL SAMPLING	B.D.V.	MOISTURE	TAN DELTA	INTERFACIAL TENSION
Permissible Limit →	**70KV(min)**	**5 PPM(Max)**	**0.005 at 90°C (Max)**	**0.04 N/m at 27°C (Min)**

On Line Particle Counts/ 100ml (To be carried after completion of oil filtration)

Particle Size	4µm	6 µm	10 µm	14 µm	21 µm	25 µm	38 µm	70 µm	ISO CODE
Sample-1									
Sample-2									
Sample-3									
Average Value									

Limit: As per ISO 4406 class: 9/6 to 10/7 (1000 counts per 100 ml of sampling for equal to or larger than 6 µm; 130 counts per 100 ml of sampling for equal to or larger than 14 µm)

DISSOLVED GAS ANALYSIS

Gasses	H2	CH4	C2H4	C2H6	C2H2	CO	CO2	O2	N2	TCG

Note:-

i. TCG should be below 1%
ii. One fresh oil sample per lot (from drum) shall be sent to Lab for carrying out Oxidation Stability test

8. Operational Test Of Other Equipments

i. Checking of cooling Equipments

SL.NO	DESCRIPTION	STATUS	
		OK	NOT OK
1	Rotation direction of Fans		

9. Checks on Bushing CT's

a) Rated Data And Duty

	Core	Ratio	Class	Burden	Kvp	Protection / Metering
HV	Core-I					
	Core II					
	Core III					
	Core IV					
Neutral	Core-I					
	Core II					
	Core III					
	Core IV					

b) Insulation Resistance Measurement Of Bushing CTs(Using 500v Megger)

MEASUREMENT BETWEEN	UNIT	HV		
		R – Ø	Y – Ø	B – Ø
Earth – Core I	M Ω			
Earth – Core II	M Ω			
Earth – Core III	M Ω			
Earth – Core IV	M Ω			

MEASUREMENT BETWEEN	UNIT	HV		
		R – Ø	Y – Ø	B – Ø
Core I – Core II	M Ω			
Core I – Core III	M Ω			
Core I – Core IV	M Ω			
Core II – Core III	M Ω			
Core II – Core IV	M Ω			
Core III – Core IV	M Ω			

c) **Continuity Test Of Bushing Ct's (In Ω)**

Continuity, Check between Terminals OK / NOT OK

CORE	BETWEEN TERMINAL	HV		
		R – Ø	Y – Ø	B – Ø
Core – I	1S1–1S2			
Core – II	2S1–2S2			
Core – III	3S1–3S2			
Core – IV	4S1–4S2			

d) Secondary Winding Resistance Of Bushing CT's (In Ω)

HV side

CORE	BETWEEN TERMINAL	UNIT	R – Ø		Y – Ø		B – Ø	
			FACTORY	SITE	FACTORY	SITE	FACTORY	SITE
Core I	1S1 – 1S2	Ω						
Core II	2S1 – 2S2	Ω						
Core III	3S1 – 3S2	Ω						
Core IV	4S1 – 4S2	Ω						

Neutral Side

CORE	BETWEEN TERMINAL	UNIT	R – Ø	
			FACTORY	SITE
Core I	1S1 – 1S2	Ω		

External Neutral CT

CORE	BETWEEN TERMINAL	UNIT	R – Ø	
			FACTORY	SITE
Core I	1S1 – 1S2	Ω		

e) Polarity Test Of Bushing CT'S

With 1.5 V DC supply (Connect +ve at P1 and –ve at P2)

CORE	BETWEEN		HV		
			R – Ø	Y – Ø	B – Ø
Core I	1S1 (+ve)	1S2 (-ve)			
Core II	2S1 (+ve)	2S2 (-ve)			
Core III	3S1 (+ve)	3S2 (-ve)			
Core IV	4S1 (+ve)	4S2 (-ve)			

f) Current Ratio Test

Primary Injection through Primary Injection Kit at Primary Terminal P1 – P2

Measure current on the secondary Terminals

HV side R – Phase side

CORE S1 – S2	PRIMARY %	CURRENT ACTUAL	SECONDARY CURRENT	THEORETICAL RATIO	ACTUAL RATIO	% OF ERROR
Core I (1S1 – 1S2)	20%					
	40%					
	80%					
Core II (2S1 – 2S2)	20%					
	40%					
	80%					
Core III (3S1 – 3S2)	20%					
	40%					

	80%					
Core IV (4S1 – 4S2)	20%					
	40%					
	80%					

vii. HV side Y – Phase

CORE S1 – S2	PRIMARY %	CURRENT ACTUAL	SECONDARY CURRENT	THEORETICAL RATIO	ACTUAL RATIO	% OF ERROR
Core I (1S1 – 1S2)	20%					
	40%					
	80%					
Core II (2S1 – 2S2)	20%					
	40%					
	80%					
Core III (3S1 – 3S2)	20%					
	40%					
	80%					
Core IV (4S1 – 4S2)	20%					
	40%					
	80%					

viii. HV side B – Phase

CORE S1 – S2	PRIMARY %	CURRENT ACTUAL	SECONDARY CURRENT	THEORETICAL RATIO	ACTUAL RATIO	% OF ERROR
Core I (1S1 – 1S2)	20%					
	40%					
	80%					
Core II (2S1 – 2S2)	20%					
	40%					

	80%					
Core III (3S1 – 3S2)	20%					
	40%					
	80%					
Core IV (4S1 – 4S2)	20%					
	40%					
	80%					

g) Magnetising Curves Performance (Not to be done for metering Core)

Knee Point Voltage (KVp) = ……………….Volt; Current: …………..

vii. HV Side R – Phase

VOLTAGE		UNIT	CURRENT MEASUREMENT			
TO BE APPLIED	ACTUAL VALUE		CORE – I 1S1-1S2	CORE – II 2S1-2S2	CORE – III 3S1-3S2	CORE – IV 4S1-4S2
0.25 x KVp		mA				
0.50 x KVp		mA				
0.75 x KVp		mA				
1.00 x KVp		mA				
1.10 x KVp		mA				

viii. HV Side Y – Phase

VOLTAGE		UNIT	CURRENT MEASUREMENT			
TO BE APPLIED	ACTUAL VALUE		CORE – I 1S1-1S2	CORE – II 2S1-2S2	CORE – III 3S1-3S2	CORE – IV 4S1-4S2
0.25 x KVp		mA				
0.50 x KVp		mA				
0.75 x KVp		mA				
1.00 x KVp		mA				
1.10 x KVp		mA				

ix. HV Side B – Phase

VOLTAGE		UNIT	CURRENT MEASUREMENT			
TO BE APPLIED	ACTUAL VALUE		CORE – I 1S1-1S2	CORE – II 2S1-2S2	CORE – III 3S1-3S2	CORE – IV 4S1-4S2
0.25 x KVp		mA				
0.50 x KVp		mA				
0.75 x KVp		mA				
1.00 x KVp		mA				
1.10 x KVp		mA				

Note: 1.0 CT should not saturate at 110% of Knee Point Voltage (KVp)

e. If Knee Point Voltage is not mentioned then Knee Point Current may be taken into consideration.

10. Contact Resistance Measurement at 100 Amps

CONTACT RESISTANCE	UNITS	R – Ø	Y – Ø	B – Ø
Across HV Bushing Terminal Joint	μ Ω			
Across Neutral Bushing terminal joint	μ Ω			
NGR terminal connector	μ Ω			

The value of Contact Resistance should not be more than 10 Micro – ohms per Joint / Connector

11. Protection And Alarms

SL NO	DEVICE	SET FOR		PROVED	
		ALARM	TRIP	ALARM	TRIP
1	EXCESSIVE WINDING TEMPERATURE.				
2	EXCESSIVE OIL TEMPERATURE.				
3	PRESSURE RELIEF VALVE (MAIN TANK)	NA		NA	
4	PRESSURE RELIEF VALVE (NGR)	NA		NA	
5	MAIN TANK BUCHHOLZ RELAY				
6	NGR BUCHHOLZ RELAY				
7	FAN FAILURE\		NA		NA
8	LOW OIL LEVEL (MAIN TANK)		NA		NA
9	LOW OIL LEVEL (NGR)		NA		NA
10	HIGH OIL LEVEL (MAIN TANK)		NA		NA

SL NO	DEVICE	SET FOR		PROVED	
		ALARM	TRIP	ALARM	TRIP
11	OTI (MAIN TANK)	**90**	**100**		
12	OTI (NGR)				
13	WTI (MAIN TANK)	**100**	**110**		
14	DIFFERENTIAL	NA		NA	
15	BACKUP IMPEDENCE RELAY	NA		NA	
16	EARTH FAULT RELAY (REF)	NA		NA	
17	INTER TRIP , IF ANY	NA		NA	
18	TRIP FREE CHECK	NA		NA	
19	TEED PROTECTION				
20	On Line DGA alarm				

a) Protection setting applied as per approved settings

Yes	No	Remarks

b) Stability test of differential and REF protection (at 10 kV)

Ok	Not Ok	Remarks

c) Delta formation of single phase units and spare switching arrangement scheme checked

Yes	No	Remarks

NOTE : Prove the tripping of associated breakers by actual operation of the various devices and relays as per the schemes.

VIII. Final Documentation Review

a) Factory test results are available

Yes	No

b) All electrical test results compared with factory test results & found to be in order

Yes	No

c) Final documents of Pre- Commissioning checks reviewed and approved

Yes	No

d) Document regarding spares equipment, O&M manuals etc available at site

Yes	No

IX. Checks After Charging Of Reactor

Record the following after charging

a) Any abnormal sound emanating from the reactor

Yes	No	Remarks

b) No load current at relay terminal

R – Ø	A
Y – Ø	A
B – Ø	A

c) Temperature at the time of charging

OTI	º C
WTI	º C
AMBIENT	º C

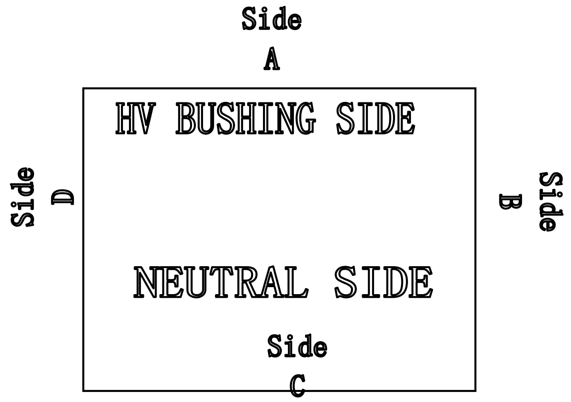
d) Maximum temperature after 24 hours_____________º C

e) Thermo vision scanning done at least after

24 hours of loading & repeated one week.

Yes	No	Remarks

f) VIBRATION MEASUREMENT TEST



Vibration measurements are to be carried out after energization of the reactor. This will be a Reference data for future Measurements.

- Various locations are to be shown in the diagram with x,y co-ordinates for easy identification.

SL. NO	DATE OF MEASUREMENT	LOCATION	VALUE	REMARKS

Comments of Commissioning Team on test Results:

Comments of Corporate-AM on test Results (To be attached separately)

Manufacturer Recommendation on test Results (To be attached separately)

Signature:	**Signature:**	**Signature:**	**Signature:**
Name:	**Name:**	**Name:**	**Name:**
Desgn.:	**Desgn.:**	**Desgn.:**	**Desgn.:**
Organization: (Supplier Representative) (Wherever Applicable)	**(Erection Agency)**	**(POWERGRID Site I/C)**	**(POWERGRID Commg. Team) Members:** **1.** **2.** **3.** **4.**

PRE-COMMISSIONING FORMATS FOR CIRCUIT BREAKER

I. General Details

Equipment Details	
Region:	**Sub-Station:**
Feeder Name:	**LOA No. :**
Make:	**Year of Manufacture:**
Equipment Designation: **Ex: 452**	
Sr. No.:	**Type:**
Rating:	**Rated Breaking Capacity(kA):**
Operating Voltage:	**Control Voltage (DC) :**
Date of Receipt at site:	**Date of Erection:**
Date of Energisation:	

II. Pre-Commissioning Checks:

Sl	Description	Status		Remarks
		Yes	No	
1	Interrupter, Pole Column & Mechanism Box serial number should be identical.			
2	Equipment is free from dirt/dust/rust/ foreign materials etc.			
3	Equipment is free from all visible defects on physical inspection			

4	Support structures, marshalling box has been provided with double earth			
5	All nuts and bolts are tightened correctly as per specified torque			
6	Equipment erection is complete in all respect & erection completion certificate along with list of outstanding activities reviewed (attach remaining activities, if any)			
7	Permanent pole leveling and identification is done			
8	Leveling and alignment of structure and base frame is checked			
9	Control box / marshalling kiosk is free from any physical defects			
10	Tightness of nuts bolts of terminal connectors are checked			
11	Auxiliary contacts and relays have been cleaned and free from rust / damage			
12	All spare wires to be kept with ferrules but not terminated at the terminal blocks			
13	Check all the valves in the sf6 pipe line are tightened, DILO coupling are tightened.			
14	Terminal Clamps should be connected on CB terminal pads prior to filling of SF6 Gas			
15	Slow and power closing operation and opening done (wherever applicable)			

III. Spring Operating System

a. Motor details

Make		Volt	
Sl no		Amperes	
Type		Hp/kw	
Year of Manufacture		Setting (thermal overload)	

Current taken by motor for charging the spring (amp)		IR of spring charging motor	

b. Details of relays/contactors used : schematic drawing no

Circuit Reference	Make	Serial No.	Type	No+Nc
Closing lockout				
Auto reclosing lockout				
General lockout				
Pole discrepancy timer				

c. Spring operating time

Details	R- Ø				Y- Ø				B- Ø			
	Factory		Site		Factory		Site		Factory		Site	
Charging Time												

Factory test report ref no: ___________________________________

IV. SF6 Gas

a. Density Monitor Details

	R- Ø		Y- Ø		B- Ø	
	R1 Ø	R2 Ø	Y1 Ø	Y2 Ø	B1 Ø	B2 Ø
Make						
Model						
Sl.no						
Year of manufacture						
Final filling pressure						

b. SF6 density monitor settings

SF6 gas filled at _________ bar at ______ deg. C on ___/___/___

Phase (Ø)	Details	Blocking		De-blocking	
		Factory	Site	Factory	Site
R1 Ø	Low Pressure alarm				
(Bus side)	Lock out pressure				
R2 Ø	Low Pressure alarm				
(Line side)	Lock out pressure				
Y1 Ø	Low Pressure alarm				
(Bus side)	Lock out pressure				
Y2 Ø	Low Pressure alarm				
(Line side)	Lock out pressure				
B1 Ø	Low Pressure alarm				
(Bus side)	Lock out pressure				
B2 Ø	Low Pressure alarm				
(Line side)	Lock out pressure				

Factory test report ref no: ___________________________________

c. Measurement of dew point of SF6 gas

Sl. No	**CB pole**	**Measured Value (To be filled at atmospheric pressure)**
1	R1 Ø (Bus side)	
2	R2 Ø (Line side)	
3	Y1 Ø (Bus side)	
4	Y2 Ø (Line side)	
5	B1 Ø (Bus side)	
6	B2 Ø (Line side)	

Note:

Dew point measurement of SF6 gas needs to be done pole wise in close loop method without any wastage of SF6 gas

Permissible Value Dew point : - 36 deg C or less

d. Leakage check

SL.NO	INTERVALS	UNIT	
A	Initial filling of SF6 gas at ____deg C (As per temp. Correction chart)	BAR	
B	Drop in sf6 gas pressure in 24 hrs :	BAR	
C	Final SF6 pressure at _____deg. C after all testing	BAR	
D	Additional leakage test by covering individual joint with polythene	YES	NO

V. COIL INSULATION RESISTANCE MEASUREMENT (Using 500 V Megger)

COIL DETAILS	MEASURED IR VALUE IN MΩ					
	R1- Ø	R2- Ø	Y1- Ø	Y2- Ø	B1- Ø	B2- Ø
TRIP COIL- I						
TRIP COIL-II						
CLOSE COIL						

Permissible Value(Min.): 50 MΩ

VI. CIRCUITRY / OPERATIONAL CHECKS

Sl No	Circuit Reference	Circuitry Check		Operational Check	
		Local	Remote	Local	Remote
A	Tripping Through TC-I				
B	Tripping Through TC-II				
C	Closing Circuit				
D	Anti-hunting Feature				

Sl No	Circuit Reference	Circuitry Check		Operational Check	
		Local	Remote	Local	Remote
	(Close Open Operation)				
E	Pole Discrepancy Feature				
F	Breaker Position Indication				
G	Heater In Switch Cubicle				
H	Heater In Control Cubicle				
I	Illum. In Switch Cubicle				
J	Illum. In Control Cubicle				

Note: In case wiring for remote operation is not ready, please indicate terminal number along with wire ferrule number in switch cubicle where remote cables shall be terminated. Remote operation can be checked from these terminals.

VII. OPERATING TIME (IN MILLI-SECONDS)

Phase (Ø)	Break	Close (Max 150ms)	Trip (Max 25ms 400kV& 765 kV,35ms 220kV, 40ms 132kV/66kV)		Close Trip (Min. 35 ms)	
			Trip – I	Trip – II	Trip – I	Trip – II
R- Ø main contact	Break -1					
R- Ø PIR						
Auxiliary contact						
R – Ø main contact	Break -2					
R – Ø PIR						
Auxiliary contact						
R – Ø main contact	Break – 3					
R – Ø PIR						
Auxiliary contact						
R – Ø main contact	Break – 4					
R – Ø PIR						

Auxiliary contact						
Y – Ø main contact	Break -1					
Y – Ø PIR						
Auxiliary contact						
Y – Ø main contact	Break -2					
Y – Ø PIR						
Auxiliary contact						
Y – Ø main contact						
Y – Ø PIR	Break – 3					
Auxiliary contact						
Y – Ø main contact						
Y – Ø PIR	Break – 4					
Auxiliary contact						
B – Ø main contact	Break -1					
B – Ø PIR						
Auxiliary contact						
B – Ø main contact						
B – Ø PIR	Break -2					
Auxiliary contact						
B – Ø main contact						
B – Ø PIR	Break – 3					
Auxiliary contact						
B – Ø main contact						
B – Ø PIR	Break – 4					
Auxiliary contact						

NOTE: for 765 kV, take measurements for four breaks

VIII. IR VALUE OF CONTROL CIRCUIT(USING 500 VOLT MEGGER)

Coil Details	Unit	Measurement Value	
		Pole – I	Pole – II
R – Ø TRIP COIL – I	MΩ		
R – Ø TRIP COIL – II	MΩ		
R – Ø CLOSE COIL	MΩ		
Y – Ø TRIP COIL – I	MΩ		
Y – Ø TRIP COIL – II	MΩ		
Y – Ø CLOSE COIL	MΩ		
B – Ø TRIP COIL – I	MΩ		
B – Ø TRIP COIL – II	MΩ		
B – Ø CLOSE COIL	MΩ		

CAUTION: Isolate necessary dc for trip coil I and trip coil II , closing coil before meggaring.

MINIMUM VALUE 50 MΩ

XIV. IR VALUE WITH BREAKER OPEN(USING 5000 VOLT MEGGER)

PHASE	ACROSS OPEN CONTACT BREAK 1	ACROSS OPEN CONTACT BREAK 2	ACROSS OPEN CONTACT BREAK 3	ACROSS OPEN CONTACT BREAK 4
R				
Y				
B				

MINIMUM VALUE 1000 MΩ

XV. IR VALUE WITH RESPECT TO EARTH WITH BREAKER CLOSED, EARTH SWITCH AND ISOLATOR OPEN

MEASURED IR VALUE IN MΩ					
R1 Ø –G	R2 Ø -G	Y1 Ø -G	Y2 Ø -G	B1Ø – G	B2Ø-G

MINIMUM VALUE 1000 MΩ

XVI. GRADING CAPACITOR

a. Details

Details	Interrupter 1			Interrupter 2		
	R	Y	B	R	Y	B
MAKE						
SERIAL NO.						
CAPACITANCE VALUE						
FACTORY VALUE						
YEAR OF MANUFAC.						
Details	**Interrupter 3**			**Interrupter 4**		
	R	**Y**	**B**	**R**	**Y**	**B**
MAKE						
SERIAL NO.						
CAPACITANCE VALUE						
FACTORY VALUE						
YEAR OF MANUFAC.						

1. Capacitance And Tan Delta Measurement (To Be Done In UST Mode)

Capacitance	Interrupter 1			Interrupter 2		
	R	Y	B	R	Y	B
SITE						
-FACTORY						
% DEVIATION						
TAN DELTA						
SITE						
-FACTORY						
% DEVIATION						

Capacitance	Interrupter 3			Interrupter 4		
	R	Y	B	R	Y	B
SITE						
-FACTORY						
% DEVIATION						
TAN DELTA						
SITE						
-FACTORY						
% DEVIATION						

Permissible Limits

a) For GE (ALSTOM) & SIEMENS make CBs, decision regarding replacement of Grading Capacitors are to be taken on basis of Capacitance and measurement of Tan delta is being carried out only for reference purpose.

b) Other make CBs : Tan Delta of grading capacitors : 0.005 (max,)

b) Capacitance of grading capacitors within ±5% of the factory value

XVII. CONTACT RESISTANCE MEASUREMENT (MICRO OHM)

PHASE	ACROSS EACH POLE		PHASE	ACROSS EACH POLE	
	FACTORY	SITE		FACTORY	SITE
R1- Ø			Y3- Ø		
R2- Ø			Y4- Ø		
R3- Ø			B1- Ø		
R4- Ø			B2- Ø		
Y1 – Ø			B3- Ø		
Y2 – Ø			B4 – Ø		

a) Contact Resistance of CB (in Micro-Ω)

765 kV	400kV	220kV	132kV
75 µΩ/ break	75 µΩ/ break	75 µΩ	100 µΩ

f. Contact Resistance of CB terminal connector 10 Micro-Ω per connector

Factory test report ref no :_______________________

XVIII. BREAKER OPERATION COUNTER READING

Counter Type	Put √ Mark
ELECTRICAL	
MECHANICAL	

Sl.No	Phase	Reading	Date
A	R-Ø		
B	Y-Ø		
C	B-Ø		

XIX. CHECK FOR ANNUNCIATION IN CONTROL ROOM AS PER THE FOLLOWING FORMATS AND RECORD THE READING

Sl No	Description Of Test	Source Of Initiation	Window Description	Result		Remarks
				OK	NOT OK	
A	Switch off the dc switch in Control cubicle	Control cubicle dc Switch on/off	Source I/II dc fail / ac fail			
B	Switch off the ac Switch in control Cubicle	Control cubicle ac Switch on/off	Source I/II dc fail / ac fail			
C	Short the alarm contacts of sf6 Gas density monitor (R-Ø)	Density monitor	Sf6 gas density low			

D	Short the alarm contacts of sf6 Gas density monitor (Y-Ø)	Density monitor	Sf6 gas density low			
E	Short the alarm contacts of sf6 Gas density monitor (B-Ø)	Density monitor	Sf6 gas density low			
F	Remove the cable connected to density monitor (R-Ø)	Density monitor	Operation/c losing lockout			
G	Remove the cable connected to density monitor (Y-Ø)	Density monitor	Operation/c losing lockout			
H	Remove the cable connected to density monitor (B-Ø)	Density monitor	Operation/c losing lock out			
I	Give tripping command to R-ph only and check the operation of pole discrepancy relay	Pole discrepancy relay at breaker Cubicle	Breaker pole discrepancy			
J	Give tripping command to Y-Ø Only and check the operation of pole discrepancy relay	Pole discrepancy relay at breaker Cubicle	Breaker pole discrepancy			
K	Give tripping Command to B-ph only and check the operation of pole discrepancy relay	Pole discrepancy relay at breaker cubicle	Breaker pole discrepancy			
L	Check other alarms as per plant Circuit diagram					
M	Close the breaker and trip through Protection which are applicable	protection relay as per scheme	Breaker auto trip			

NOTE : The tripping details are to be checked as per the Scheme approved by engineering.

XX. DYNAMIC CONTACT RESISTANCE & TRAVEL MEASUREMENT

Phase (Ø)	Factory	Site	Remarks	Approval From CC/AM Obtained
R				
Y				
B				

XXI. OPERATION TIME MEASUREMENT OF POLE DISCREPANCY RELAY

Pole discrepancy relay	Setting	Actual

Note- 2.5 Sec for CBs with Auto Reclose Function & 0.5 Sec for CBs without Auto Reclose Function.

XXII. LOCAL CLOSE OPERATION INTERLOCK CHECKED (WITH EARTH SWITCH)

Yes	No

XXIII. Final Documentation Review

a) Final documents of Pre- Commissioning checks reviewed and approved

Yes	No

b) Document regarding spares equipment, O&M manuals etc available at site for O&M purpose

Yes	No

c) After modification, if any, "As built Drawings" are available at site

Yes	No

Signature:	**Signature:**	**Signature:**	**Signature:**
Name:	**Name:**	**Name:**	**Name:**
Desgn.:	**Desgn.:**	**Desgn.:**	**Desgn.:**
Organization: (Supplier Representative) (Wherever Applicable)	**(Erection Agency)**	**(POWERGRID Site I/C)**	**(POWERGRID Commg. Team) Members: 1. 2. 3. 4.**

PRE-COMMISSIONING FORMAT FOR CONTROLLED SWITCHING DEVICE

I. General Details

Equipment Details	
Region:	**Sub-Station:**
Bay Name & Number :	**LOA No:**
CSD Make:	**CSD Year of Manufacturer:**
CSD Sr. No:	**Date of Energisation:**
CSD Type:	**Breaker Type:**
Breaker Serial Number:	**Breaker Make:**
ICT/ Reactor Rating:	**Rated Current (whichever applicable) :** **Reactor –** **ICT HV -** **ICT IV -**

II. Details of Voltage & Current Transformer Core used in CSD:

Equipment	CT/VT Details (Location, Sr No)	Core No	Ratio	Class	R phase	Y phase	B phase
Voltage Transformer							
Current Transformer							

Installation Instructions

- Inputs for Sensors like Temperature, Reference Contact etc shall come from the field only by shielded twisted pair cable.

III. Pre – Commissioning Data

Setting Configuration: Shunt Reactor/Transformer (please tick one)

Phase	Closing time (ms)	Opening time (ms)	Pre Arcing time for Closing (ms)	Arcing time for Opening (ms)	Auxiliary Contact Timing/Auxiliary time shift - Open	Auxiliary Contact Timing/Auxiliary time shift – Close
R						
Y						
B						

Note:

- Generally, Arcing & Pre-arcing time for a particular Make of Circuit Breaker is constant.
- Closing & Opening time to be entered in CSD should be after considering 5 close/open operations (minimum).

IV. Sensor Details

Sensor Type	Make	Serial Number	Value at 4 mA	Value at 20 mA
Temperature Sensor			Deg C	Deg C
Reference Contact				
Pressure			Bar	Bar
Any Other (Please Specify)				

V. Alarms

Alarm Details	Checked
Reference Voltage failure	Ok/Not Ok
Control Voltage – Minimum	Ok/Not Ok
Control Voltage – Maximum	Ok/Not Ok
Frequency – Minimum	Ok/Not Ok
Frequency – Maximum	Ok/Not Ok
Drive Mechanism Failure	Ok/Not Ok

Self test error	Ok/Not Ok
Power Supply Failure	Ok/Not Ok
Controlled Operation Time Exceeded	Ok/Not Ok

VI. Other Checks

Feature	Checked
Bypass operation check in case of internal bypass conditions	Ok/Not Ok
Bypass operation check in case of manual bypass option	Ok/Not Ok
Communication from SCADA and access of setting files and stored record in CSD	Ok/Not Ok
Checking of CSD events and alarm mapping in SCADA	Ok/Not Ok

VII. Final Commissioning Data (Online Operations required for fine tuning)

Following Information should be stored as final commissioning data and to be attached with pre – commissioning report

Documents	Attached/Available
Soft files for Switching Operations (Close/Open) during online switching operations	Yes/No
Print Outs for Switching Operations. Separate print out for individual phases to be stored	Yes/No
Print Outs for CSD Settings downloaded from CSD device after fine tuning	Yes/No

Transformer Inrush Current

Sl	Phase	Inrush Current during Closing (in Ampere)				
		Close – 1	Close – 2	Close – 3	Close – 4	Close – 5
1	R					
2	Y					
3	B					

Inrush Current Limit – 1.0 p.u. or less

Reactors

Sl	Phase	Re-ignition Voltage observed or not during Opening
1	R	OK/Not OK
2	Y	OK/Not OK
3	B	OK/Not OK

Controlled Timing (Close): Transformer/Reactor

Phase		Close-1	Close-2	Close-3	Close-4	Close-5
R	Target					
	Actual					
Y	Target					
	Actual					
B	Target					
	Actual					

Controlled Timing (Open): Transformer/Reactor

Phase		Open-1	Open-2	Open-3	Open-4	Open-5
R	Target					
	Actual					
Y	Target					
	Actual					
B	Target					
	Actual					

Signature:	**Signature:**	**Signature:**	**Signature:**
Name:	**Name:**	**Name:**	**Name:**
Desgn.:	**Desgn.:**	**Desgn.:**	**Desgn.:**
Organization: (Supplier Representative) (Wherever Applicable)	**(Erection Agency)**	**(POWERGRID Site I/C)**	**(POWERGRID Commg. Team) Members: 1. 2. 3. 4.**

PRE-COMMISSIONING FORMAT FOR CURRENT TRANSFORMER

I. General Details

Equipment Details	
Region:	**Sub-Station:**
LOA No. :	**Make:**
Sr. No.: **R Ø:-** **YØ:-** **BØ:-**	**Type:**
Year of Manufacture: **R Ø:-** **YØ:-** **BØ:-**	**Rating:**
Date of Receipt at site: **R Ø:-** **YØ:-** **BØ:-**	**Date of Erection:** **R Ø:-** **YØ:-** **BØ:-**
Date of Energisation:	

II. Rated Data & Duty

Core	Ratio	Class	Burden	KVp	Protection / Metering
Winding I					
Winding II					
Winding III					
Winding IV					
Winding V					
Winding VI					

kVp : Knee Point Voltage

III. Pre – Commissioning Checks

Sl. No	Description	Status		Remark
		Yes	No	Record Deficiencies, If Any
1	Equipment is cleaned and free from dust / dirt foreign materials etc.			
2	Equipment is free from all visible defects on physical inspection			
3	Check ct tank has been provided with double earthing (dead tank CT's)			
4	Check that ct junction box is earthed.			
5	All nuts and bolts are tightened correctly as per specified torque			
6	Check tightness of terminal connector			
7	All fittings as per out line general arrangement drawing.			
8	Leveling and alignment of structure and base frame is checked			
9	Erection completion certificate along with list of outstanding activities reviewed			
10	Any paint removed / scratched in transit has been touched up			
11	Check primary polarity of CTs erected as per relevant drawing.			
12	Check hermetically sealing is intact			
13	Check the oil level and leakage through any joints / sec. Terminals			
14	Check oil drain valve is properly closed and locked.			
15	Oil level & oil sampling			
16	N2 pressure checked (wherever applicable)			
17	Oil level on top chamber gauge glass			

18	BDV of oil sample taken from tank bottom drain valve (only if Nitrogen pressure is measured zero)			
19	All the cable identification tags provided and all cores are provided with identification ferrules at MB.			
20	Check secondary cable end box is properly fixed and ensure cable entry at the bottom and unused holes sealed			
21	Ensure inter pole cabling is completed and check the continuity.			
22	Check the IR value of secondary cable			
23	Check external cabling from junction- box to relay / control panel completed			
24	Ensure unused secondary cores, if any, has been shorted and earthed			
25	Check star point has been formed properly and grounded at one end only			
26	Check spark gap setting in p1 terminal (wherever provided/ possible) permanent Pole leveling and identification markings made			
27	Check tan delta test tap is properly earthed			
28	Check that lugs used in secondary circuit are of ring type			
29	Check direction of primary (P1/ P2) w.r.t. Bus/ line on erection			
30	Provision of bimetallic strips (cu +al) ensured wherever applicable			
31	Physically open the bellow cover and check the oil in bellow			
32	Ensure the proper sealing of the CT MB against moisture ingress			

IV. Insulation Resistance Measurement

A. Using 5kV Megger

Make & Sl. No of testing kit ______________________

Date of last calibration of the kit ______________________

Ambient temp in º C ______________________

Remove the connected earthing to system involving ct under test and disconnect the connected terminals of ct marshalling box.

Core	Unit	Phase		
		R	Y	B
PRIMARY – CORE I	M Ω			
PRIMARY – CORE II	M Ω			
PRIMARY – CORE III	M Ω			
PRIMARY – CORE IV	M Ω			
PRIMARY – CORE V	M Ω			
PRIMARY – CORE VI	M Ω			
PRIMARY – EARTH	M Ω			

Permissible limit of IR value should be > 1000 M Ω

B. Insulation Resistance Measurement (Using 500 V Megger)

Make & Sl. No of testing kit ______________________

Date of last calibration of the kit ______________________

Ambient temp in º C ______________________

Between	Unit	Phase		
		R Ø	Y Ø	B Ø
SECONDARY CORE I - EARTH	M Ω			
SECONDARY CORE II - EARTH	M Ω			
SECONDARY CORE III – EARTH	M Ω			
SECONDARY CORE IV - EARTH	M Ω			
SECONDARY CORE V - EARTH	M Ω			
SECONDARY CORE VI - EARTH	M Ω			

Permissible limit of IR value should be > 50 M Ω

Between	Unit	Phase		
		R Ø	Y Ø	B Ø
CORE I - CORE II	M Ω			
CORE I - CORE III	M Ω			
CORE I - CORE IV	M Ω			
CORE I - CORE V	M Ω			
CORE I - CORE VI	M Ω			
CORE II - CORE III	M Ω			
CORE II - CORE IV	M Ω			
CORE II - CORE V	M Ω			
CORE II - CORE VI	M Ω			
CORE III – CORE IV	M Ω			
CORE III- CORE V	M Ω			
CORE III- CORE VI	M Ω			
CORE IV - CORE V	M Ω			
CORE IV - CORE VI	M Ω			
CORE V- CORE VI	M Ω			

Permissible limit of IR value should be > 50 M Ω

V. Measurement Of Secondary Winding Resistance (In Ohm)

Make & Sl. No of testing kit ________________________

Date of last calibration of the kit ________________________

Ambient temp in º C ________________________

Core	Terminal	Unit	R Ø		Y Ø		B Ø	
			Factory	Site	Factory	Site	Factory	Site
CORE I	1S1 – 1S2	Ω						

	1S1 – 1S3	Ω						
	1S1 – 1S4	Ω						
CORE II	2S1 – 2S2	Ω						
	2S1 – 2S3	Ω						
	2S1 – 2S4	Ω						
CORE III	3S1 – 3S2	Ω						
	3S1 – 3S3	Ω						
	3S1 – 3S4	Ω						
CORE IV	4S1 – 4S2	Ω						
	4S1 – 4S3	Ω						
	4S1 – 4S4	Ω						
CORE V	5S1 – 5S2	Ω						
	5S1 – 5S3	Ω						
	5S1 – 5S4	Ω						
CORE VI	6S1 – 6S2	Ω						
	6S1 – 6S3	Ω						
	6S1 – 6S4	Ω						

VI. POLARITY TEST

Core	Between		Phase		
			R Ø	Y Ø	B Ø
CORE I	1S1 (+VE)	1S2 (-VE)			
	1S1 (+VE)	1S3 (-VE)			
	1S1 (+VE)	1S4 (-VE)			
CORE II	2S1 (+VE)	2S2 (-VE)			
	2S1 (+VE)	2S3(-VE)			
	2S1 (+VE)	2S4 (-VE)			
CORE III	3S1 (+VE)	3S2(-VE)			
	3S1 (+VE)	3S3(-VE)			
	3S1 (+VE)	3S4(-VE)			
CORE IV	4S1 (+VE)	4S2(-VE)			
	4S1 (+VE)	4S3(-VE)			
	4S1 (+VE)	4S4(-VE)			
CORE V	5S1 (+VE)	5S2(-VE)			
	5S1 (+VE)	5S3(-VE)			
	5S1 (+VE)	5S4(-VE)			
CORE VI	6S1 (+VE)	6S2(-VE)			
	6S1 (+VE)	6S3(-VE)			
	6S1 (+VE)	6S4(-VE)			

VII. Tan Delta And Capacitance Measurement

Make & Sl. No of testing kit ______________________

Date of last calibration of the kit ______________________

Ambient temp in º C ______________________

Capacitance

Across Stack	Pre Commissioning Values			Factory Values			% Deviation		
	R Ø	Y Ø	B Ø	R Ø	Y Ø	B Ø	R Ø	Y Ø	B Ø
2kV									
10 kV									

Tan Delta

Across Stack	Pre Commissioning Values			Factory Values			% Deviation		
	R Ø	Y Ø	B Ø	R Ø	Y Ø	B Ø	R Ø	Y Ø	B Ø
2kV									
10 kV									

Permissible Limits Tan δ 0.005 (max.)

Deviation of Capacitance value from factory value should be within ± 5% of the factory value

Factory Test Report Ref. No:____

VIII. Current Ratio Test

Make & Sl. No of testing kit ______________________

Date of last calibration of the kit ______________________

R Phase-

Core	Between		Theoretical Ratio	Actual Ratio	Percentage Error
CORE I	1S1	1S2			
	1S1	1S3			
	1S1	1S4			
CORE II	2S1	2S2			
	2S1	2S3			
	2S1	2S4			
CORE III	3S1	3S2			
	3S1	3S3			

	3S1	3S4			
CORE IV	4S1	4S2			
	4S1	4S3			
	4S1	4S4			
CORE V	5S1	5S2			
	5S1	5S3			
	5S1	5S4			
CORE VI	6S1	6S2			
	6S1	6S3			
	6S1	6S4			

Y Phase-

Core	Between		Theoretical Ratio	Actual Ratio	Percentage Error
CORE I	1S1	1S2			
	1S1	1S3			
	1S1	1S4			
CORE II	2S1	2S2			
	2S1	2S3			
	2S1	2S4			
CORE III	3S1	3S2			
	3S1	3S3			
	3S1	3S4			
CORE IV	4S1	4S2			
	4S1	4S3			
	4S1	4S4			
CORE V	5S1	5S2			
	5S1	5S3			
	5S1	5S4			
CORE VI	6S1	6S2			

	6S1	6S3			
	6S1	6S4			

B Phase-

Core	Between		Theoretical Ratio	Actual Ratio	Percentage Error
CORE I	1S1	1S2			
	1S1	1S3			
	1S1	1S4			
CORE II	2S1	2S2			
	2S1	2S3			
	2S1	2S4			
CORE III	3S1	3S2			
	3S1	3S3			
	3S1	3S4			
CORE IV	4S1	4S2			
	4S1	4S3			
	4S1	4S4			
CORE V	5S1	5S2			
	5S1	5S3			
	5S1	5S4			
CORE VI	6S1	6S2			
	6S1	6S3			
	6S1	6S4			

IX. Magnetizing Curves Performance

R Phase-

R Phase-Core	Between		Rated Knee Point Voltage	Measured Knee Point Voltage	Max. Ext. Current at Rated Knee Point Voltage	Measured Ext. Current at Actual Knee point Voltage
*CORE I	1S1	1S2				
	1S1	1S3				
	1S1	1S4				
*CORE II	2S1	2S2				
	2S1	2S3				
	2S1	2S4				
*CORE V	5S1	5S2				
	5S1	5S3				
	5S1	5S4				
*CORE VI	6S1	6S2				
	6S1	6S3				
	6S1	6S4				

Y Phase-

Core	Between		Rated Knee Point Voltage	Measured Knee Point Voltage	Max. Ext. Current at Rated Knee Point Voltage	Measured Ext. Current at Actual Knee point Voltage
*CORE I	1S1	1S2				
	1S1	1S3				
	1S1	1S4				
*CORE II	2S1	2S2				
	2S1	2S3				
	2S1	2S4				
*CORE V	5S1	5S2				
	5S1	5S3				

	5S1	5S4				
*CORE VI	6S1	6S2				
	6S1	6S3				
	6S1	6S4				

B Phase-

Core	Between		Rated Knee Point Voltage	Measured Knee Point Voltage	Max. Ext. Current at Rated Knee Point Voltage	Measured Ext. Current at Actual Knee point Voltage
*CORE I	1S1	1S2				
	1S1	1S3				
	1S1	1S4				
*CORE II	2S1	2S2				
	2S1	2S3				
	2S1	2S4				
*CORE V	5S1	5S2				
	5S1	5S3				
	5S1	5S4				
*CORE VI	6S1	6S2				
	6S1	6S3				
	6S1	6S4				

Note: To be carried out only for protection cores. Format has been designed considering a six core CT. Format may be modified by site depending upon number of Cores.

X. Dissolve Gas Analysis

Duration	H2	CH4	C2H4	C2H6	C2H2	CO	CO2	O2	N2	TGC

After one month of charging										

XI. SF6 Gas and Density Monitor Test (In case of SF6 Filled CTs)

Feature	Set Value			Measured		
	R	Y	B	R	Y	B
Loss of SF6 Alarm						
SF6 lockout/trip						

XII. SF6 Gas Testing (In case of SF6 Filled CTs)

Phase	Dew Point at Atmospheric Pressure
R Phase	
Y Phase	
B Phase	

Permissible Limit: Dew Point: - 36 deg C or less

XIII. Shock Indicator impact values (in G) (In case of SF6 Filled CTs)

R Phase	
Y Phase	
B Phase	

Note: Shock recorder value to be filled in case digital recorder or in case of mechanical type shock recorder and OK/Not OK to be mentioned.

XIV. Final Documentation Review

a) Final documents of Pre- Commissioning checks reviewed and approved

Yes	No

b) Document regarding spares equipment, O&M manuals etc available at site for O&M purpose

Yes	No

c) After modification, if any, "As built Drawings" are available at site

Yes	No

Signature:	**Signature:**	**Signature:**	**Signature:**
Name:	**Name:**	**Name:**	**Name:**
Desgn.:	**Desgn.:**	**Desgn.:**	**Desgn.:**
Organization: (Supplier Representative) (Wherever Applicable)	**(Erection Agency)**	**(POWERGRID Site I/C)**	**(POWERGRID Commg. Team) Members:** **1.** **2.** **3.** **4.**

PRE-COMMISSIONING FORMAT FOR CAPACTIVE VOLTAGE TRANSFORMER

I. General Details

Equipment Details	
Region:	**Sub-Station:**
Feeder name	**LOA No. :**
Make:	**Type:**
Sr. No.: **R Ø:-** **YØ:-** **BØ:-**	**Primary Voltage rating**
Secondary Voltage rating: **Winding-I** **Winding-II** **Winding III**	**Secondary Voltage Burden:** **Winding-I** **Winding-II** **Winding III**
Voltage Class: **Winding-I** **Winding-II** **Winding III**	**Purpose of** **Winding-I** **Winding-II** **Winding III**
Rating:	**Feeder name:**
Year of Manufacture: **R Ø:-** **YØ:-** **BØ:-**	**Date of Receipt at site:** **R Ø:-** **YØ:-** **BØ:-**
Date of Erection: **R Ø:-** **YØ:-** **BØ:-**	**Date of Energisation:**

II. Pre-Commissioning Checks:

Sl.	Description	Status		Remarks Record Deficiencies, If Any
		YES	NO	
1	Sl. No of HV capacitors for all stacks should be identical to the sl.no mentioned on rating & dig. Plate			
2	Equipment is cleaned and free from dust / dirt foreign materials etc.			
3	Equipment is free from all visible defects on physical inspection			
4	Check CVT tank has been provided with double earthing			
5	Check that CVT marshalling box is earthed correctly as per specified torque			
6	All nuts and bolts are tightened			
7	Check tightness of terminal connector			
8	All fittings as per outline general arrangement drawing.			
9	Labeling and identification marking is carried out			
10	Leveling and alignment of structure and base frame is checked			
11	Erection completion certificate along with list of outstanding activities reviewed			
12	Any paint removed / scratched in transit has been touched up			
13	Ensure brass vent plug between stacks of CVT's is removed			
14	Check the oil level and leakage through any joints / sec. Terminals			
15	Check oil drain valve is properly closed and locked.			
16	Oil level on tank gauge glass			
17	BDV of oil sample taken from tank bottom drain valve			
18	Check secondary cable end box is properly fixed and ensure cable entry at the bottom.			

19	Ensure HF terminal of unused phases has been earthed and no mechanical load on HF terminal bushing			
20	Check rating / healthiness of fuses at CVT marshalling box and CVT terminal box.			
21	Check and ensure that the neutral point is earthed at single point only			
22	Ensure interpole cabling is completed and check the continuity.			
23	Check the IR value of secondary cable (> 50 m ohms for control cables)			
24	Check external cabling from m.b to relay / control panel completed			
25	All the cable identification tags provided and all cores are provided with identification ferrules at m.b.			
26	Check all the fuse/ MCB			

III. HF Point Connection

Ensure that HF point of CVT is connected to LMU with 6 sq mm Cu cable as single core cable & wrapped with a 11kV insulation grade tape as mentioned in Technical Specifications (PLCC) – **Yes /No**

IV. Continuity Of Winding

(After removing Earth Link 1, 2 & 3)

i. Between terminals 1a – 1n

Yes	No

ii. Between terminals 2a – 1n

Yes	No

iii. Between terminals 3a – 1n

Yes	No

I. Insulation Resistance Measurement

USING A MEGGER OF 5KV

Between	Unit	Measured Value		
		R Ø	Y Ø	B Ø
Primary – secondary core 1	MΩ			
Primary – secondary core 2	MΩ			
Primary – secondary core 3	MΩ			
Primary – earth	MΩ			

Permissible Limit should be MIN 1000 MΩ

V. Secondary Winding Resistance

Phase	Core 1		Core 2		Core 3		Remarks
	Factory	Site	Factory	Site	Factory	Site	
R Ø							
Y Ø							
B Ø							

Factory test report ref. No: ____

VI. INSULATION RESISTANCE MEASUREMENT

Using A Megger Of 500 Volt

Between	Unit	Measured Value		
		R Ø	Y Ø	B Ø
Secondary core 1 – earth	MΩ			
Secondary core 2 – earth	MΩ			
Secondary core 3 – earth	MΩ			
Core 1 – core 2	MΩ			
Core 1 – core 3	MΩ			
Core 2 – core 3	MΩ			

Permissible Limit should be MIN 50 MΩ

VII. VOLTAGE RATIO TEST

<table>
<tr><th rowspan="2">Phase</th><th rowspan="2">Primary Voltage</th><th colspan="2">Secondary Voltage</th><th rowspan="2">Theoretical Ratio</th><th colspan="2">Actual Ratio</th><th>%</th></tr>
<tr><th>Between</th><th>Value</th><th>Factory</th><th>Site</th><th>Error</th></tr>
<tr><td rowspan="3">R</td><td></td><td>1a – 1 n</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td></td><td>2a – 2 n</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td></td><td>3a – 3 n</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td rowspan="3">Y</td><td></td><td>1a – 1 n</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td></td><td>2a – 2 n</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td></td><td>3a – 3 n</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td rowspan="3">B</td><td></td><td>1a – 1 n</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td></td><td>2a – 2 n</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td></td><td>3a – 3 n</td><td></td><td></td><td></td><td></td><td></td></tr>
</table>

Permissible Limit should be as follows:

- Metering Core (0.2 Class Core) – 0.2 %
- Protection Core (3P Class Core) - +/-6 % (If applied primary voltage is less than 5 % of rated voltage of CVT)
- Protection Core (3P Class Core) - +/-3 % (If applied primary voltage is more than 5 % of rated voltage of CVT)

Note:-

- Apply voltage of the order of 10 kV across line capacitor (top flange) to earth link
- Ensure all earth links connected

VIII. OTHER CHECKS

i. All terminal blocks closed in the secondary after all testing

Yes	No

ii. Phasing (phase relationship) of CVT by measuring voltage between R-phase, Y-phase and B-phase at incoming terminal in control cubicle, for one circuit of the checked CVT and output terminals R-phase, Y-phase and B-ph of a reference circuit (existing CVT) with known phasing

Reference Circuit	Measured Value		
	R Ø	Y Ø	B Ø
R Ø			
Y Ø			
B Ø			

IX. TAN DELTA AND CAPACITANCE MEASUREMENT

Make of testing kit ______________________________

Date of calibration _______________________________

Ambient temperature _______________________________

Capacitance

Across Stack	Pre Commissioning Values			Factory Values			% Deviation		
	R Ø	Y Ø	B Ø	R Ø	Y Ø	B Ø	R Ø	Y Ø	B Ø
TOP									
MIDDLE 1									
MIDDLE 2									
MIDDLE 3									
BOTTOM									
TOTAL									

TAN DELTA

Across Stack	Pre Commissioning Values			Factory Values			% Deviation		
	R Ø	Y Ø	B Ø	R Ø	Y Ø	B Ø	R Ø	Y Ø	B Ø
TOP									
MIDDLE 1									
MIDDLE 2									
MIDDLE 3									
BOTTOM									
TOTAL									

Permissible Limits Tan δ 0.005 (max.)

Deviation of Capacitance value from factory value should be within ± 5% of the rated value
For bottom stack, the measured values shall be considered as base value and may not match factory test results.

Factory Test Report Ref. No:____

X. Final Documentation Review

a) Final documents of Pre- Commissioning checks reviewed and approved

Yes	No

b) Document regarding spares equipment, O&M manuals etc available at site for O&M purpose

Yes	No

c) After modification, if any, "As built Drawings" are available at site

Yes	No

Signature:	**Signature:**	**Signature:**	**Signature:**
Name:	**Name:**	**Name:**	**Name:**
Desgn.:	**Desgn.:**	**Desgn.:**	**Desgn.:**
Organization: (Supplier Representative) (Wherever Applicable)	**(Erection Agency)**	**(POWERGRID Site I/C)**	**(POWERGRID Commg. Team) Members:** **1.** **2.** **3.** **4.**

PRE-COMMISSIONING FORMATS FOR BAY/FEEDER

I. GENERAL DETAILS

DETAILS	
Region	**Sub-Station**
Feeder Name	**Voltage Level**
Date of Starting of Erection	**Date of Completion of Erection and Oil filling**

II. DETAILS OF EQUIPMENT INVOLVED

EQUIPMENT	R – PHASE		Y – PHASE		B – PHASE		MAKE
	ID NO	SL NO	ID NO	SL NO	ID NO	SL NO	
CT							
CVT							
LA							
BREAKER							
TRANSFORMER							
REACTOR							
ISOLATOR							

EQUIPMENT	R – PHASE		Y – PHASE		B – PHASE		MAKE
	ID NO	SL NO	ID NO	SL NO	ID NO	SL NO	
CT							
EARTH SWITCH							
LINE TRAP							

III. DETAILS OF CR PANEL AND PLCC

PANEL DETAILS	IDENTIFICATION		IDENTIFICATION		IDENTIFICATION		MAKE
	NAME	NUMBER	NAME	NUMBER	NAME	NUMBER	
Control Panel							
Relay Panel							
PLCC Panel							
RTU Panel							

RECORDING INSTRUMENTS	IDENTIFICATION	
	NAME	NUMBER
Fault Locator		
Event Logger		

Disturbance Recorder		
Time Synchronization		
Strip Chart Recorder		

IV. PROTOCOL DOCUMENTATION

Equipment	ID No	All Pre Commissioning Tests as per FQP (Yes/No)	All test results within limit (Yes/No)	Joint Protocols of Eqp involved in charging are documer signed by all concerned (Yes/No)	Remarks
CT/NCT/Bushing/CT					
CVT					
LA					
CB					
TRANSFORMER					
REACTOR					
ISOLATOR					
EARTH SWITCH					
LINE TRAP					
RELAY PANEL					
CONTROL PANEL					
PLCC PANEL					

RTU PANEL					

V. CHECK OF BAY MARSHALLING KIOSK

Identification No_____________

DETAILS	STATUS			REMARKS,IFANY
	OK/NOT OK	OK/NOT OK	OK/NOT OK	
ILLUMINATION AND HEATER				
5 /15 AMP SOCKET				
ALL SPECIFIED FUSES IN POSITION				
EARTHING AT 2 LOCATION				
ALL CABLES TIGHTNESS				
ALL CABLES ARE PROPERLY GLANDED				
ALL CABLES HAVE IDENTIFICATION NO				
ALL CORES HAVE IDENTIFICATION NO				
SHIELDING WIRES ARE EARTHED				
FREE FROM DUST AND DAMAGE				
DOOR HINGES AND LOCKING				
PAINTS				
UNUSED HOLES ARE SEALED				

VI. AVAILABILITY OF THE FOLLOWING

SL. NO.	DESCRIPTION OF ACTIVITY	STATUS		REMARK DEFICIENCIES/TEMPORARY ARRANAGEMENT IF ANY
		YES	NO	
1	Firefighting system commissioned			
2	Fire protection including alarms			
3	Fire hydrant system			
4	Fire deluge (sprinkler) system			

SL. NO.	DESCRIPTION OF ACTIVITY	STATUS		REMARK DEFICIENCIES/TEMPORARY ARRANAGEMENT IF ANY
		YES	NO	
5	Portable fire extinguishers are in position			
6	Fire tenders can be made available for any eventuality			
7	All equipment erection as per general arrangement drawing issued by engg.			
8	Equipment identification name plate are properly fixed			
9	All bus post insulators are cleaned and free from dust / dirt foreign materials etc.			
10	All earthing points have been earthed			
11	All nuts and bolts of bus bar are tightened correctly as per specified torque			
12	All clamps and connectors are as per the drawings issues by Engineering. Department and correctly tightened as per specified torque			
13	Any paint removed / scratched in yard equipments have been touched up			
14	Bay identification and designation plate are on position with R,Y,B phase marking			
15	Gravel filling in the yard (if designed) has been done			
16	The ladders / tools / vehicles / work bench/ temporary earthing etc. Removed from the area which is to be energized			
17	DC emergency light in operation and in auto			
18	DG set is available and in operation			
19	Switching sequences with procedures are documented and available in the control room			
20	Regular operation in the control room is manned round the clock with regular operation staff			

SL. NO.	DESCRIPTION OF ACTIVITY	STATUS		REMARK DEFICIENCIES/TEMPORARY ARRANAGEMENT IF ANY
		YES	NO	
21	All PTW issued earlier are cancelled and nothing are pending			
22	Operation data log sheets, PTW and other standard formats of Powergrid are available for regular operation			
23	Confirm color coding of all equipment and phase marking			
24	Check star points of CT & CVT secondary and associated links if any			
25	Check that treated earth pits are covered and numbered			
26	Check the tightness of the connecting links of treated earth pits			
27	Core wise secondary injection test for both CTs and PTs inputs from secondary terminal box of CT/PT done to detect any mixing/ interchanging of cores/ phases			
28	Fuse fail protection checked for m1, m2, backup impedance etc			
29	Necessary clearances as applicable have been obtained			
30	Charging clearance is received from grid operation CPCC / IOCC / REB vide msg no :_________ Time___________Dated___________			

VII. MEASUREMENT OF EARTH RESISTANCE

Sl No	LOCATION DESCRIPTION	DISTANCE BETWEEN ELECTRODE	RESISTANCE
Location – 1			
Location – 2			
Location – 3			
Location – 4			

Permissible Limit : 10 ohm (max.) without grid

VIII. Ratio checking By Primary Injection

Injected Current: In Primary Amps:

CT number	Core ref	Application	Adapted Ratio	Current measured in CT Secondary(mA)	Relay/BCU ref	Measured current in Primary(A)

IX. MEASUREMENT OF SOIL RESISTIVITY DONE EARLIER PRIOR TO COMMISSIONING

DATE	DISTANCE BETWEEN ELECTRODE	SOIL RESISTIVITY	REMARK

X. CHECK THE MINIMUM CLEARANCE BETWEEN LIVE PARTS W.R.T GROUNG AND BETWEEN LIVE PARTS

VOLTAGE	PHASE TO GROUND	PHASE TO PHASE	REMARK , IF ANY
132 kV	1270 mm	1473 mm	
220 kV	2082 mm	2368 mm	
400 kV	3065 mm	5750 mm	
765 KV	6400 mm	9400 mm	

Note : All the clearance between phases & phase to ground are to be checked as per the drgs. Issued by Engg. Dept.

XI. CHECKING OF INTERLOCKS

i. Please refer the relevant plant circuit diagram for checking the interlocks of various equipment's to be energized.

ii. All isolators and ground switches Inter locking checked

Yes	No	Remarks

XII. TRIP TEST

All breakers are tested and all the trip test as per the required plant circuit diagrams are carried out as per the document No CF/CB/05

Yes	No	Remarks

XIII. STABILITY TEST FOR BAY

During Primary stability/Primary injection ensure the healthiness of each **Bay CT, Bushing CT, Neutral CT, WTI CT core, etc** & associated Ratio at each IED/Devices connected.

The secondary current measurement must be recorded for all connected IEDs/Devices wherever applicable.

XIV. FINAL TRIP TEST

The trip test must be repeated prior to energization as per approved scheme.

Tripping operation to be checked for both the trip coils from local/ remote/ protection from each protection relays to ensure the wirings after Pre-commissioning

i. DC source 1 off

One and Half Busbar Scheme

SL. NO	PROTECTION RELAYS	SIMULATION METHOD	CB TRIP RESPONSE		REMARK
			MAIN	TIE	
Line Protection					
I	Main - I				
II	Main - II				
III	Over voltage(If applicable)				
IV	Carrier inter tripping				
V	LBB				
VI	Bus bar				
VII	Tee differential 1/2(If applicable)				
Transformer Protection					
I	Differential				
II	Restricted earth fault				
III	Backup OC & EF (HV/IV)				
IV	Backup impedance (HV/IV)				
V	Busbar				
VI	LBB				
VII	Over fluxing(if applicable)				
VIII	OTI trip				
IX	WTI trip				
X	Buchholz trip/Alarm (MAIN)				
XI	Buchholz trip/Alarm (OLTC)				
XII	PRD				

Double Main/Double Main Transfer Schematic

ii. DC source 2 off

One and Half Busbar Scheme

SL. NO	PROTECTION TYPE	SIMULATION METHOD	CB TRIP RESPONSE		REMARK
			MAIN	TBC	
Line Protection					
I	Main - I				
II	Main - II				
III	Over voltage(If applicable)				
IV	Carrier inter tripping				
V	LBB				
VI	Bus bar				
Transformer Protection					
I	Differential				
II	Restricted earth fault				
III	Backup OC & EF				
IV	Backup impedance				
V	Busbar				
VI	LBB				
VII	Over fluxing				
VIII	OTI trip				
IX	WTI trip				
X	Buchholz trip/Alarm (main)				
XI	Buchholz trip/Alarm (OLTC)				
XII	PRD				
Buscoupler					
I	LBB				
II	Busbar				

Operational Constraints if any

I. Final Documentation Review

a) Final documents of Pre- Commissioning checks reviewed and approved

Yes	No

b) Document regarding spares equipment, O&M manuals etc available at site for O&M purpose

Yes	No

c) After modification, if any, “As built Drawings” are available at site

Yes	No

Signature:	**Signature:**	**Signature:**	**Signature:**
Name:	**Name:**	**Name:**	**Name:**
Desgn.:	**Desgn.:**	**Desgn.:**	**Desgn.:**
Organization: (Supplier Representative) (Wherever Applicable)	**(Erection Agency)**	**(POWERGRID Site I/C)**	**(POWERGRID Commg. Team) Members: 1. 2. 3. 4.**

PRE-COMMISSIONING FORMATS FOR ISOLATOR AND GROUNDING SWITCH

II. General Details

Equipment Details	
Region:	**Sub-Station:**
Feeder name	**LOA No. :**
Make:	**Type:**
Sr. No.: **R Ø:-** **YØ:-** **BØ:-**	**Operating Voltage rating**
Control Voltage:	**Current Carrying capacity:**
Year of Manufacture: **R Ø:-** **YØ:-** **BØ:-**	**Date of Receipt at site:** **R Ø:-** **YØ:-** **BØ:-**
Date of Erection: **R Ø:-** **YØ:-** **BØ:-**	**Date of Energisation:**

III. Pre-Commissioning Checks:

Sl.No	Description	Status		Remark / Record Deficiencies, If Any
		YES	NO	
1	Equipment is free from dirt/dust foreign materials etc.			
2	Equipment is free from all visible defects on physical inspection			
3	Support structures, marshalling box has been provided with two earthing pads / points			

Sl.No	Description	Status		Remark / Record Deficiencies, If Any
		YES	NO	
4	All nuts and bolts are tightened correctly as per specified torque			
5	Equipment erection is complete in all respect as per instruction Manual (attach remaining activities, if any)			
6	Permanent isolator leveling and identification is done			
7	Leveling and alignment of structure and base frame is checked			
8	Mechanism box / marshalling box is free from any physical defects.			
9	Components found during transit/storage rusted to be replaced/rectified.			
10	Mechanism box/Marshalling box is free from dust & closed properly.			
11	Tightness of nuts bolts of terminal connectors are checked			
12	Number of bolting points in terminal pad matches with terminal connector.			
13	Auxiliary contacts and relays have been cleaned and free from rust / damage			
14	Corona rings are provided and properly fixed			
15	Cable termination and tightness checked and unused holes sealed			
16	External cabling is completed in all respect			
17	All the cable identification tags-provided and all cores are provided with identification ferrules at M.B			
18	All moving parts are lubricated			
19	Alignment of isolator already made and locking bolt provided, if any			

Sl.No	Description	Status		Remark / Record Deficiencies, If Any
		YES	NO	
20	Blocking of Manual Operation Handle in case mechanical interlock is not through			
21	Freeness of manual operation is ok			
22	Greasing has been made on the main contacts according to the manufacturers instruction			
23	Functional checking of auxiliary contacts for indications and interlocks			
24	Erection completion certificate along with list of Outstanding activities reviewed			
25	Supervision of Erection done by Original Equipment Manufacturer (OEM) Engineer in line with Tech Spec			
26	All spare wires to be kept with ferrules but not terminated at the terminal blocks			
27	Earth switch connected to earth through braided wires with earthing risers directly			
28	Interlocks checked as per approved scheme with all combinations			
29	Check that earth switch blade alignment in condition is at sufficient distant from isolator			
30	Check that operation and positioning of the limit switch & the auxiliary contacts assembly are ok			
31	Check that all three phase isolators are closing & opening at a time			
32	Check all 3 earth switches close at the same time			
33	Provision of bimetallic strips ensured wherever applicable			

Motor Details

	Phase		
	R Ø	Y Ø	B Ø
Make			
Serial number			
Type			
Year of manufacturer			
Volt			
Amperes			
Hp/ kW			
O/L setting (Thermal Over load)*			

*Over Load (O/L) relay to be set in way that motor should trip in less than 10 sec while attempting motorized closing of Earth Switch when Isolator is already closed due to mechanical interlock.

IV. Insulation Resistance Measurement

Make of testing kit ______________________________

Date of calibration _______________________________

Ambient temperature _______________________________

Using 500 volt megger measure resistance between the winding of motor and earth

Sl. No	Between	Phase		
		R Ø	Y Ø	B Ø
1	Winding to Earth			

PERMISSIVE VALUE > 1000 M.OHM

V. Operational Checks

i) Operate the isolator and record the motor current

Isolator Operation	Motor Current					
	R – Ø		Y – Ø		B – Ø	
	Factory	Site	Factory	Site	Factory	Site
Close						
Open						

ii) Operation of isolator from local / remote Ok/Not Ok

Isolator Operation	Control Panel	
	Local	Remote
Close		
Open		

g. Measurement of operating time

Operation	Unit	Phase		
		R – Ø	Y – Ø	B – Ø
Opening Time				
Closing Time				

h. Auxiliary Contacts Checking

ISOLATOR OPERATION	AUXILLARY RELAY TYPE	OPERATION TIME					
		R – Ø		Y – Ø		B – Ø	
		NO	NC	NO	NC	NO	NC
CLOSE							
OPEN							

Reference drawing no:

i. **Operation On Under Voltage Condition**

Condition	Coil	Unit	Phase		
			R – Ø	Y – Ø	B – Ø
PICK UP VOLTAGE	CLOSING	VOLT DC			
	OPENING	VOLT DC			
	INTERLOCK	VOLT DC			
DROP VOLTAGE	CLOSING	VOLT DC			
	OPENING	VOLT DC			
	INTERLOCK				

VI. Insulation Resistance Measurement (By 5kV Megger)

Make of testing kit ______________________________

Date of calibration _______________________________

Ambient temperature _______________________________

Isolator open condition

Between	Phase		
	R Ø	Y Ø	B Ø
MALE SIDE TO GROUND			
FEMALE SIDE TO GROUND			
MALE SIDE TO FEMALE SIDE			

*****PERMISSIVE VALUE > 1000 M.OHM***

VII. CONTACT RESISTANCE MEASUREMENT

(To be measured after 50 operations)

Make of testing kit ______________________________

Date of calibration _______________________________

i. **Isolator Close condition**

Contact Resistance	Units	R – Ø	Y – Ø	B – Ø
Connector 1	µ Ω			
Connector2	µ Ω			
Main Contact 1	µ Ω			

Main Contact 2	μ Ω			

The value of Contact Resistance should not be more than 10 Micro – ohms per / Connector
The value of Contact Resistance should not be more than 150 Micro – ohms per / break

ii. Isolator Open condition and grounding switch close condition

Contact Resistance	Units	R – Ø	Y – Ø	B – Ø
Main Contact(Male & Female) Ground Switch	μ Ω			

The value of Contact Resistance should not be more than 150 Micro – ohms per / break

VIII. COIL RESISTANCE MEASUREMENT

i. Resistance of operating coil ________________________________

ii. Resistance of interlocking coil_________________________________

IX. MECHANICAL INTERLOCK CHECKING

a) Whether Mechanical Interlock is able to stop motorized operation & manual closing of Earth Switch when Isolator is closed

Yes	No

b) Whether Mechanical Interlock is able to stop motorized operation & manual closing of Isolator when Earth Switch is closed

Yes	No

c) O/L relay trips in case of mechanical interlock condition of Isolator & E/S

Yes	No

X. Final Documentation Review

d) Final documents of Pre- Commissioning checks reviewed and approved

Yes	No

e) Document regarding spares equipment, O&M manuals etc available at site for O&M purpose

Yes	No

f) After modification, if any, "As built Drawings" are available at site

Yes	No

Signature:	**Signature:**	**Signature:**	**Signature:**
Name:	**Name:**	**Name:**	**Name:**
Desgn.:	**Desgn.:**	**Desgn.:**	**Desgn.:**
Organization: (Supplier Representative) (Wherever Applicable)	**(Erection Agency)**	**(POWERGRID Site I/C)**	**(POWERGRID Commg. Team) Members:** **1.** **2.** **3.** **4.**

PRE-COMMISSIONING FORMATS FOR SURGE ARRESTOR

I. General Details

Equipment Details	
Region:	Sub-Station:
Feeder name	LOA No. :
Make:	Type:
Sr. No.: R Ø:- YØ:- BØ:-	Voltage rating
Rating:	Feeder name:
Year of Manufacture: R Ø:- YØ:- BØ:-	Date of Receipt at site: R Ø:- YØ:- BØ:-
Date of Erection: R Ø:- YØ:- BØ:-	**Date of Energisation:**

II. Pre-Commissioning Checks:

Sl.No	Description	Status		Remark Record Deficiencies, If Any
		Yes	No	
1	Equipment is free from dirt / dust foreign materials etc.			
2	Equipment is free from all visible defects on physical inspection			
3	Support structures have been provided with double earth			
4	All nuts and bolts are tightened correctly as per specified torque			
5	Equipment erection is complete in all respect (attach remaining activities, if any)			
6	Permanent surge arrestor leveling and identification is done			
7	Leveling and alignment of structure and base frame is checked			
8	All insulators & surge counter are free from any physical defects			
9	Tightness of nuts bolts of terminal connectors are checked			
10	Erection completion certificate along with list of outstanding activities reviewed			
11	Check one end of surge counter is connected to the bottom of la stack and one end of surge counter has been earthed			
12	The direction of the exhaust vent ports away from the protected equipment and other arrester poles			
13	Clearance from the arrester to earthed objects and from the arrester pole to another arrester pole			

	maintained as per outline drawing and all erection has been done as per drawing issued by engg. Dept.			
14	Operation of LA counter checked by applying appropriate voltage			
15	Check the serial no. And sequence of la parts for erection in multi stack LA			
16	Check the alignment of corona ring			
17	Check on charging, the surge counter pointer is in green zone			
18	Ensure that Connecting cable/flat between Surge Monitor Counter & Surge Arrester Base is having 75 sq mm cross section			
19	Check the LA counter cable to CRP properly insulated and terminated and ensure no moisture ingress			
20	Stacks should be similar (serial number)			

III. **Insulation Resistance Measurement : (Using 5kV Megger)**

Sl. No	Between	Unit	Phase		
			R Ø	Y Ø	B Ø
1	1st stack & earth	MΩ			
2	2nd stack & earth	MΩ			
3	3rd stack & earth	MΩ			
4	4th stack & earth	MΩ			
5	5th stack & earth	MΩ			
6	6th stack & earth	MΩ			

****MIN VALUE > 1000 M OHMS per stack***

IV. **Surge Counter Reading**

Sl.No	Reading	R Ø	Y Ø	B Ø
1	Counter sr. No.			
2	Counter make			
3	Counter reading			

V. Checking Of Healthiness Of Surge Monitor

Refer manufacturer's catalogue for detail checking of surge monitor

Yes	No

VI. Third Harmonic Resistive Current Measurement

Ambient Temperature ___________________ System Voltage______________________________

Phase	Total Current	3rd Harmonic Resistive Current (I3R) In micro amp	Remarks
R Ø			
Y Ø			
B Ø			

Maximum permissible values for third harmonic current for newly commissioned Surge Arresters:

a. 120kV, 216kV & 390kV – 30 µA
b. 336kV – 60 µA
c. 624kV – 100 µA

VII. Final Documentation Review

a) Final documents of Pre- Commissioning checks reviewed and approved

Yes	No

b) Document regarding spares equipment, O&M manuals etc available at site for O&M purpose

Yes	No

c) After modification, if any, "As built Drawings" are available at site

Yes	No

Signature:	**Signature:**	**Signature:**	**Signature:**
Name:	**Name:**	**Name:**	**Name:**
Desgn.:	**Desgn.:**	**Desgn.:**	**Desgn.:**
Organization: (Supplier Representative) (Wherever Applicable)	**(Erection Agency)**	**(POWERGRID Site I/C)**	**(POWERGRID Commg. Team) Members:** **1.** **2.** **3.** **4.**

PRE-COMMISSIONING FORMATS FOR WAVE TRAP

I. General Details

Details	
Region:	Sub-Station:
Feeder name	LOA No. :
Make:	Type:
Sr. No.: R Ø:- YØ:- BØ:-	Voltage rating
mH Rating:	Current Rating:
Band Width:	
Year of Manufacture: R Ø:- YØ:- BØ:-	Date of Receipt at site: R Ø:- YØ:- BØ:-
Date of Erection: R Ø:- YØ:- BØ:-	Date of Energisation:

II. Pre-Commissioning Checks

Sl No	Description	Status		Record Deficiencies, If Any
		Yes	No	
1	Equipment is free from dirt / dust foreign materials etc.			
2	Equipment is free from all visible defects on physical inspection			
3	Support structures has been provided with double earth			
4	All nuts and bolts are tightened correctly as per specified torque			
5	Permanent labeling and identification is done			
6	Leveling and alignment of structure and base frame is checked			
7	All insulators & line matching unit are free from any physical defects			
8	Tightness of nuts / bolts of terminal connectors are checked			
9	Erection completion certificate along with list of outstanding Activities reviewed			
10	Check that the tuning unit and arrestor are properly tightened and free from any damage			

III. Insulation Resistance Measurement

Make of testing kit ______________________________

Date of calibration ______________________________

Ambient temperature ______________________________

Sl. No	Between	Megger	Phase			Permissive Value
			R Ø	Y Ø	B Ø	
1	UPPER TEMINAL AND EARTH	5000 V				> 1000 M.OHM
2	LA OF THE WAVE TRAP	500 V				> 1 M.OHM

IV. Contact Resistance Measurement

Make of testing kit ______________________________

Date of calibration _______________________________

Contact Resistance	Units	R – Ø	Y – Ø	B – Ø
Across Terminal P1	µ Ω			
Across Terminal P2	µ Ω			

The value of Contact Resistance should not be more than 5 Micro – ohms per Joint / Connector

V. Final Documentation Review

a) Final documents of Pre- Commissioning checks reviewed and approved

Yes	No

b) Document regarding spares equipment, O&M manuals etc available at site for O&M purpose

Yes	No

c) After modification, if any, "As built Drawings" are available at site

Yes	No

Signature:	**Signature:**	**Signature:**	**Signature:**
Name:	**Name:**	**Name:**	**Name:**
Desgn.:	**Desgn.:**	**Desgn.:**	**Desgn.:**
Organization: (Supplier Representative) (Wherever Applicable)	**(Erection Agency)**	**(POWERGRID Site I/C)**	**(POWERGRID Commg. Team) Members:** **1.** **2.** **3.** **4.**

PRE-COMMISSIONING FORMATS FOR CONTROL & PROTECTION INCLUDING PLCC

General Commissioning Instructions

I. General Details

Region:	Sub-Station:
Feeder Name:	LOA No. :
Date of testing:	Date of Energisation:

1. Commissioning Procedure for Control wiring and Associated DC system.

1.1 Ensure that all the wiring for the dia / bay has been completed.

1.2 Check the implemented wiring as per the Schematic diagram; highlight the wiring portions which have been checked.

1.3 Note and correct the discrepancies in the wiring diagram.

1.4 Ensure that all MCBs are ON and all the fuses are of correct rating.

1.5 Identify the TB where the main DC supply (coming from DCDB) is terminated. Measure the insulation resistance of the panel side wiring at 500V. Record results in Table 1.A

1.6 Switch on DC supply only if the insulation values are above permissible limits.

1.7 Switch on DC Source-I. Check DC voltage at DCDB MCB wired to DC Source-2. No DC voltage should be present. Switch off DC Source-I.

1.8 Switch on DC Source-II. Check DC voltage at DCDB MCB wired to DC Source-1. No DC voltage should be present. Switch off DC Source-II.

1.9 Switch on DC Source-I and DC Source-II. Record results in Table 1.B.

1.10 DC Earth fault simulation after completion of all pre-commissioning test to be carried out as per below mentioned procedure.

1.10.1. Switch on all the MCBs and connect all the Fuses.

1.10.2. Check the DC voltages on Source-1 and Source-2.

1.10.3. At any location in the Switchyard, earth the +ve terminal of DC source-1, note the DC voltages at DC MCB in DCDB.

1.10.4. Remove +ve earth fault of Source-1, earth the –ve terminal of DC Source-1, note the DC voltages at DC MCB in DCDB

1.10.5. Remove-ve earth fault of Source-1

1.10.6. At any location in the Switchyard, earth the +ve terminal of DC source-2, note the DC voltages at DC MCB in DCDB.

1.10.7. Remove +ve earth fault of Source-2, earth the –ve terminal of DC Source-2, note the DC voltages at DC MCB in DCDB

1.10.8. Remove-ve earth fault of Source-2

1.10.9. Tabulate the results in Format 1.C

1.11. Check the double side earthing of the panel with grid

Table-1.A (Insulation Measurement)

DC Source	Panel and TB Identification No.	IR Values Prior to Switching on DC Source (at 500V)			IR Values after Pre-Commissioning tests (at 500V)		
		+ve to Earth	-ve to Earth	Remarks	+ve to Earth	-ve to Earth	Remarks
Source-I							
Source-II							

Table-1.B (DC Source Isolation test)

Voltage Checked at DCDB MCB Ref:	DC Source (Source-I/Source-II)	Measure DC Voltage (Source-I Switched on, Source-II Switched Off)(Prior to Switching on DC Source)			Measure DC Voltage (Source-I Switched on, Source-II Switched Off)(After completion of pre-commissioning tests)			Measure DC Voltage (Source-II Switched on, Source-I Switched Off) (Prior to Switching on DC Source)			Measure DC Voltage (Source-II Switched on, Source-I Switched Off) (After completion of pre-commissioning tests)		
		+ve to Earth	-ve to Earth	+ve to –ve	+ve to Earth	-ve to Earth	+ve to –ve	+ve to Earth	-ve to Earth	+ve to –ve	+ve to Earth	-ve to Earth	+ve to –ve

Table-1.C

Source Terminal Earthed	+ve prior to fault	-ve prior to fault	+ve after fault	-ve after fault	Remarks(any alarms/anomaly observed)
Source-1 +ve					
Source-1 –ve					
Source-2 +ve					
Source-2 –ve					

2. Pre commissioning procedure for protection system.

For detailed procedures on relay testing, please refer controlled document "D-2-03-20-02, Rev-X/ Testing Procedure for Transmission System protection Schemes- Vol-I and II".

2.1. Objective

The commissioning test objectives are as follows:

D. Install and integrate the system components with the current transformers (CTs), voltage transformer (VTs), sensors, communications systems, wiring, and auxiliary power supplies at site.

E. To verify that factory-supplied connections are correct and complete.

F. To ensure each component performs in accordance with vendor specifications and type testing for that component.

G. Test interactions, and overall system performance, with a sampling of test cases across the spectrum of possibilities but not a comprehensive suite as is used for factory type tests.

H. Test the overall scheme by simulating power system events that cannot be generated on demand, using techniques described in this guide. Examples include transient simulation, tests for abnormal conditions, end-to-end testing, and functional testing of applications using IEC 61850.

I. Operate other power apparatus or secondary control systems in the vicinity to show that the system is secure and/or dependable in the face of spurious environmental influences or communications traffic.

J. Verify proper mapping and operation of the protective device with other data/control systems to which it is interconnected.

2.2. Availability of all the relevant drawings and documents.

The commissioning engineer shall verify the availability of the following documents.

a) Single line Diagram

b) Protection One-line diagram (protection logic diagram)

c) Control & Protection Schematics of each feeder & Equipments

d) Auxiliary DC Schematic

e) Auxiliary AC Schematic

f) Panel arrangement diagram

g) Cable Schedule

h) SAS related documents(Architecture, Fiber optic schedule, IP schedule, etc)

i) Approved relay settings

j) FAT Reports of each equipments along with Precommisisoning reports

k) Configuration files of all the IEDs & SAS systems

l) Software of each IEDs, SAS installed in the substation

m) O&M manuals, Drawings of all the equipment in Soft & Hard copy (CT, VT, CB, Isolator, LA, Wavetrap, IEDs, SAS, CSD, Ethernet switch, etc)

2.3. Review of the relevant drawings.

The commissioning engineer shall check the drawings for following.

a. The current transformers utilized for particular relay sensing are electrically in the proper place to provide overlapping zones of protection and that their polarity conforms to standard design conventions.

b. The schematic diagram is according to the protection one-line diagram & Trip logic diagram

If any design error is encountered, same must be intimated to CC-Engg for revision of the drawings.

a. Method Statement for carrying out interface works with existing system

In case of extension/retrofitting/upgradation projects/works, the vendor/contractor shall identify all the primary/secondary interface points with the existing (commissioned) system and prepare a method statement for carrying out the interfacing of the system under commissioning with the existing system.

The method statement shall necessarily include, but not limited to following details

1. Details of All the protection/control functions which shall require an interface with existing system. Ex: Busbar protection, LBB protection, Interlocks/alarms/supervisions, Inter-trip, Carrier/DT send, Trip circuits, AR functions and CT/PT selection/input circuits etc , identify the details of existing system (Panels Ref, Terminal Blocks Number, Relay/device Details etc) which will act as interface point.
2. Mention the sequence of various pre-commissioning activities i.e. relay/device configuration, scheme checking, primary/secondary injection, any testing etc. w.r.t. interface wiring and its termination. The sequence shall take into consideration that

the tripping wirings to existing system shall be connected only after the testing of new system has been completed satisfactorily. Moreover, the sequence shall also ensure the proper coordination between primary interface and secondary system interface to avoid the requirement of multiple shutdowns and any protection maloperation.

3. Identify all the risks (tripping, blocking of protection etc) to the existing system during the interface/interconnection activities and mention the risk mitigation measures that need to be taken i.e. any isolation of primary/secondary system, safety/precautions, proper sequencing of activities etc).

The method statement shall be got approved by Regional-Engg/Regional AM of respective region. All the interface works shall be carried out strictly in accordance with the above mentioned document and under supervision of commissioning team.

2.4. DC Functional Testing.

The evaluation of each protection control scheme is performed through the functional testing of trip and close paths utilizing schematic diagrams having the details of logics.

This process involves manipulating contacts, installing and removing fuses, changing the position of test switches, and all other components represented on a DC schematic in a systematic fashion while energized from a DC source. As each component is manipulated, allowing DC current to either flow or not flow, the response of the system (e.g. Picking up or dropping out of a relay coil, etc.) is witnessed to validate whether the expected response is achieved.

It is important to note that this testing does not only attempt to get the desired response (e.g. closing a contact results in a relay coil picking up), but also verifies that no undesired responses occur. For example, if opening a specific test switch isolates or disables a specific portion of the DC circuit under test, it must also be verified that no other portions of the overall circuit are impacted in any way by the repositioning of that particular test switch.

As a result of this it needs to be verified that each component only impacts its intended part of the circuit. This type of exhaustive testing is critical to verify that the circuit is wired correctly and that no unintended circuit paths exist that may impact the overall performance of the protection and control scheme.

Methods to manipulate DC circuits:

- Actual operation of device contact is preferred.
- Jumper across device contact – typical for lockout or auxiliary tripping relays that cannot be operated due to shared equipment in service.

Procedure:

1. Take the Scheme drawing.
2. Open DC Distribution Schematic pages.
3. Identify any MCB/fuse marked in the drawing. Identify the devices for which the supply will be isolated and all the alarms that need to be generated on removal of identified MCB/fuse. Remove the fuse, check all the generated alarms. Ensure all the necessary alarms appeared and no unnecessary alarm appeared.
4. Mark the wiring portion with a Green Line.
5. Repeat for all the MCBs/fuses, Switches operation and Auxiliary relays operation, LBB/AR Initiation contacts.
6. Put the first test switch, verify that it isolates all the trip circuits as mentioned in the drawing, verify that no other trip circuit is getting isolated.
7. Repeat the process till the complete schematic has been checked.
8. The Green lined schematic along with comments mentioning any changes done, shall be jointly signed by the commissioning engineer and POWERGRID representative.

2.5. Relay Functional Testing.

Individual Relay Functional Tests shall be carried out as mentioned in

- Appendix-A: Line Protection
- Appendix-B: Circuit Breaker Panel
- Appendix-C: Line Reactor Protection
- Appendix-D: Bus Reactor Protection
- Appendix-E: Transformer Protection
- Appendix-F: Bus Bar & LBB protection
- Appendix-G: Substation Automation system

2.6. Final Pre-Energization Check-List.

Before releasing the equipment for energisation, the following checks need to be made.

2.6.1. Check that the pre-commissioning team has reviewed all the pre-commissioning test results.

2.6.2. Check the DR signal standardization as per approved/ standard scheme.

2.6.3. Check the interlock of Bus Earth Switch/ Isolator/CB as per standard/ approved scheme.

2.6.4. Check the continuity of each CT core with the earth & ensure only one earthing per CT circuit

2.6.5. Check that all the unused CT cores have been shorted and earthed.

2.6.6. Check that no alarms for the element to be charged are persisting in SCADA.

2.6.7. Validate all the signals in NTAMC/SAS as per standard / approved signal list.

2.6.8. Check that all the unused holes on the panel have been sealed.

2.6.9. Check that all the panel wiring has been properly dressed and covered with tray covers.

2.6.10. Check that all the fuse casings have fuses of appropriate rating as per scheme.

2.6.11. Check final trip test.

2.6.11.1. Close the Main and Tie CB.

2.6.11.2. Switch off DC Source-I, Operate the 86B, both the CBs shall trip.

2.6.11.3. Switch ON DC Source-I

2.6.11.4. Switch off DC Source-II, Operate the 86A, both the CBs shall trip.

2.6.11.5. Switch ON DC Source-II

2.6.12. Check all IEDs are in Time sync with GPS

2.6.13. Check that the pre-commissioning records have been sent to CC-AM and charging clearance has been received.

2.7. Check List for Element Protection system Healthiness after First Time Charging and Loading of Bays/Elements.

2.7.1. After the equipment is energised and loaded, following is to be checked and noted.

2.7.2. Measuring and confirming voltages and currents supplied from instrument transformers to IEDs, meter, recorder, etc.

2.7.3. Before energisation Temporary triggering of DR has to be enabled for Triggering Fault record in all the numerical relays associated with respective bays (Ex. For Line bays, In Main-1 & Main-2 DR function enable the CB open to be triggered low i.e., CB Close need to be triggered) and check magnitude and phase of the current and voltages.

2.7.4. Take archive data from SCADA showing all the current and voltage values, for the respective Bays, on first time load flow compulsorily.

2.7.5. Ensure the measured current & Voltage across the different devices i.e., Main protection, Backup, BCU, LBB & Busbar protection etc. as per the CT/VT ratio adopted.

2.7.6. Using the thermos-vision camera check the temperature abnormality at all CT terminals.

Example for Recording the Post charging Readings for a Bay.

Bay No: Element/Bay Name:	CT Ratio	Primary current (A)	Secondary Current (mA)	Temperature monitoring at CT TBs	Measured Main-1 Relay	………………..	………………..
Current Transformer:							
CT Core-1				OK/NOT OK			
CT Core-2				OK/NOT OK			
CT Core-3				OK/NOT OK			
………………							
………………							
Voltage Transformer							
VT Core-1				NA			
VT Core-2				NA			
VT Core-3				NA			
………………							

Note: 1. All the IEDs and Devices which have the current & voltage input should be measured for any abnormality.

Spill Current Measurement in Differential protection IEDs

PHASE	Primary current HV Side(A)	Primary current IV Side(A)	Differential/REF IED		
			Measured Spill Current(A)	Bias Current (A) (if Applicable)	REMARKS
R ph/ Zone A					
Y ph/ Zone B					
…..					

Transformer Inrush Current (Measured by CSD device)

Sl	Phase	Inrush Current during Closing (in Ampere)				
		Close – 1	Close – 2	………	………	………
1	R					
2	Y					
3	B					

****** Inrush Current Limit – 1.0 p.u. or less***

Reactors (Measured by CSD device)

Sl	Phase	Re-ignition observed or not during Opening
1	R	OK/Not OK
2	Y	OK/Not OK
3	B	OK/Not OK

***** Check that Interruption of primary current on issuing of CSD Open command**

Signature:	**Signature:**	**Signature:**	**Signature:**
Name:	**Name:**	**Name:**	**Name:**
Desgn.:	**Desgn.:**	**Desgn.:**	**Desgn.:**
Organization: (Supplier Representative) (Wherever Applicable)	**(Erection Agency)**	**(POWERGRID Site I/C)**	**(POWERGRID Commg. Team) Members:** **1.** **2.** **3.** **4.**

Appendix-A
LINE PROTECTION

General Details

Region:	**Sub-Station:**
Feeder Name:	**LOA No. :**
Date of testing:	**Date of Energisation:**

Main-I/II Protection Panel

I. Main-I /II Distance relay: (separate for Main-I & II Relays)

CT Ratio

As per Scheme: ______________, At Field: ________________, In Relay: __________________

VT Ratio

As per Scheme: ______________, At Field: ________________, In Relay: __________________

<table>
<tr><td colspan="2">I</td><td>Check for proper programming of Input / Output contacts of the relay as per approved schematics
<table><tr><td>BI or BO Number</td><td>Function as Per Scheme</td><td>Function as per Configuration</td></tr><tr><td>BI#01</td><td></td><td></td></tr><tr><td>BI#02</td><td></td><td></td></tr><tr><td>…</td><td></td><td></td></tr><tr><td>…</td><td></td><td></td></tr><tr><td></td><td></td><td></td></tr></table></td><td>Ok/ Not Ok</td></tr>
<tr><td rowspan="3">ii</td><td>A</td><td>Check for proper programming of LED’s (if applicable) of the relay and check that stickers are provided as per the configuration.</td><td>Ok/ Not Ok</td></tr>
<tr><td>B</td><td>Check Configuration / Programmable Scheme Logic of relay according to scheme (applicable for numerical relays)</td><td>Ok/ Not Ok</td></tr>
<tr><td>C</td><td>Get the print out of Configuration / PSL</td><td>Ok/ Not Ok</td></tr>
</table>

<table>
<tr><td>iii</td><td colspan="3">Get a print of relay settings and Compare with the recommended approved settings</td><td>Ok/ Not Ok</td></tr>
<tr><td></td><td colspan="3">Check IED Time synchronization configurations are implemented</td><td>Ok/ Not Ok</td></tr>
<tr><td>iv</td><td colspan="3">Check the Correctness of Mutual Compensation wiring as per the schematic (For Double circuit line)</td><td>Ok/ Not Ok</td></tr>
<tr><td>v</td><td colspan="3">Check for Reach Setting: Zone- I, II, III, IV (for all fault types)
<table>
<tr><th>Fault Type</th><th>Zone</th><th>Reach as per Setting</th><th>Reach as per Testing</th><th>Time of Operation</th></tr>
<tr><td>R-N</td><td>Z1</td><td>R1:
X1:</td><td>R1:
X1</td><td></td></tr>
<tr><td></td><td>Z2</td><td></td><td></td><td></td></tr>
<tr><td></td><td>…</td><td></td><td></td><td></td></tr>
<tr><td>…</td><td>…</td><td></td><td></td><td></td></tr>
<tr><td></td><td>…</td><td></td><td></td><td></td></tr>
</table></td><td>Ok/ Not Ok</td></tr>
<tr><td>vi</td><td colspan="3">Enclose DR and Event Logs for Each Zone Operation
a) Zone-1 with CB (R, Y, B) – With Auto Reclose
b) Carrier Aided with CB (R, Y, B) – With Auto Reclose
c) Zone-2 with CB (R, Y, B)
d) Zone-3 with 86 Operation
e) Zone-4(Reverse) with 86 Operation
f) SOTF Operation
g) PSB Operation
h) VT Fuse Fail
i) Stub Operation(If applicable)
j) BRC
k) DEF
l) OV Stage-1
m) OV Stage-2</td><td>Ok/ Not Ok</td></tr>
<tr><td>vii</td><td colspan="3">Reach test results enclosed</td><td>Yes/ No</td></tr>
<tr><td>viii</td><td colspan="3">Check polarity of send & receive for PLCC command (If Digital Channel/ Under FET operation)</td><td>Ok/ Not Ok</td></tr>
<tr><td rowspan="7">ix</td><td colspan="3">Check Permissive tripping by Carrier command receive and measure & record relay operation time for carrier aided trip (_______ ms). Also check Carrier Send command on relay tripping</td><td>Ok/ Not Ok</td></tr>
<tr><td colspan="3">Verify Respective Counter Advancement In Each Channel</td><td></td></tr>
<tr><td></td><td>Send</td><td>Recv</td><td></td></tr>
<tr><td rowspan="2">Main-I</td><td>CH….. Code………</td><td>CH….. Code………</td><td>Ok/ Not Ok</td></tr>
<tr><td>CH….. Code………</td><td>CH….. Code………</td><td>Ok/ Not Ok</td></tr>
<tr><td rowspan="2">Main-II</td><td>CH….. Code………</td><td>CH….. Code………</td><td>Ok/ Not Ok</td></tr>
<tr><td>CH….. Code………</td><td>CH….. Code………</td><td>Ok/ Not Ok</td></tr>
</table>

x	Check Blocking scheme (if applicable) along with carrier command for both send & receive.			Ok/NotOk
	Verify Respective Counter Advancement In Each Channel			
		Send	Recv	
	Main-I	CH….. Code………	CH….. Code………	Ok/NotOk
		CH….. Code………	CH….. Code………	Ok/NotOk
	Main-II	CH….. Code………	CH….. Code………	Ok/NotOk
		CH….. Code………	CH….. Code………	Ok/NotOk
xi	Check SOTF Logic. Check Manual close input taken from Control switch (TNC) & BCU Close command to Relay input			Ok/NotOk
xii	Check Weak-end in-feed & Current Reversal logic(If Applicable)			Ok/NotOk
xiii	Check Selective Phase tripping (R Ph fault to R-Ph Trip etc) for each phase separately			Ok/NotOk
xiv	Check Power swing blocking feature			Ok/NotOk
xv	Check trip Block in case of CVT Fuse Failure			Ok/NotOk
xvi		Check Auto Reclose Initiation Contacts for		
	a	Transient Single-Phase Earth fault (Zone-1&Carrier Aided Trip)		Ok/NotOk
	b	1 phase fault in Zone II		Ok/NotOk
	c	Transient Ph-Ph Fault		Ok/NotOk
	d	Transient 3 Phase Faults		Ok/NotOk
	e	Permanent Faults (Prepare 3Ph Trip)		Ok/NotOk
	f	Check for dead time and reclaim time setting		Ok/NotOk
	g	Check single phase auto reclosure for all three phases one by one.		Ok/NotOk
xvii	Check for tripping command directly to CB & correct operation of tripping relays and auxiliary relays			Ok/NotOk
xviii	Check Alarm during OUT position of Carrier In/Out Switch in Control room as well as in RTAMC/NTAMC			Ok/NotOk
xix	Check PLCC carrier Switch Operation (In/Out) & Check PLCC both channel failure leads to block the AR functionality			Ok/NotOk
xx	Check Time synchronizing by altering Time Zone. Restore on confirmation.			Ok/NotOk
xxi	Check Self-diagnostic feature of the relay (if provided)			Ok/NotOk
xxii	Check metering function of the relay (if provided)			Ok/NotOk
xxiii	Verify automatic downloading feature as per Tech spec.			Ok/NotOk
xxiv	Verify open delta voltage in DR channel(If applicable)			Ok/NotOk
xxv	Verify availability of Relay configuration tool at DR PC & Ensure Relay is communicating from DR PC.			Ok/NotOk

<table>
<tr><td>xxvi</td><td>Verify Correct CT Ratio and Single Point Earthing of CT
<table><tr><td>CT Ratio as per scheme</td><td>CT ratio adopted at site</td><td>CT ratio in relay</td></tr><tr><td></td><td></td><td></td></tr></table></td><td>Ok/NotOk</td></tr>
<tr><td>xxvii</td><td>Check directionality of the relay after synchronization of the line</td><td>Ok/NotOk</td></tr>
<tr><td>xxviii</td><td>Check for DEF protection and its contacts (if applicable)</td><td>Ok/NotOk</td></tr>
<tr><td>xxix</td><td>Check Single Point earthing of CVT Secondary.</td><td>Ok/NotOk</td></tr>
<tr><td>xxx</td><td>Check Overvoltage Stage-I/II function</td><td></td></tr>
<tr><td></td><td>Check Operate Value/Reset Value/Operate timing for all phases.
<table>
<tr><td colspan="5">A. Pickup Test</td></tr>
<tr><td>OV Stage</td><td>Phase</td><td>Setting Voltage</td><td>Pickup Voltage</td><td>Reset Voltage</td></tr>
<tr><td>Stage-I</td><td>R/Y/B</td><td></td><td></td><td></td></tr>
<tr><td>Stage-II</td><td>R/Y/B</td><td></td><td></td><td></td></tr>
<tr><td colspan="5">B. Timing Test</td></tr>
<tr><td>OV Stage</td><td>Phase</td><td>Set Time Delay</td><td colspan="2">Measured Time Delay</td></tr>
<tr><td>Stage-I</td><td>R/Y/B</td><td></td><td></td><td></td></tr>
<tr><td>Stage-II</td><td>R/Y/B</td><td></td><td></td><td></td></tr>
</table></td><td>Ok/ Not Ok</td></tr>
<tr><td></td><td>Check whether it trips Main/Tie CB & sends Direct trip to remote end</td><td>Yes/ No</td></tr>
<tr><td></td><td>Check that the Grading is provided in Pick-up voltage and Timing in case of the Parallel / Multiple Circuits</td><td>Yes/No</td></tr>
</table>

II. Main-I/II(Line Differential Function)

<table>
<tr><td>i</td><td>CT secondary Circuitry Checked and Ensure that the Secondary is earthed at Single point only</td><td>Ok/ Not Ok</td></tr>
<tr><td>ii</td><td>Check Operate Value (mA)/ Operate Timing (ms) for all phases
<table><tr><td>Phase</td><td>Set Pickup Value</td><td>Test pickup Value</td><td>Operating Time</td></tr><tr><td>R-N</td><td></td><td></td><td></td></tr><tr><td>Y-N</td><td></td><td></td><td></td></tr></table></td><td>Ok/ Not Ok</td></tr>
</table>

B-N			
---			

iv	Carry out stability test by simulating external and internal faults and measure spill currents (mA) in Differential circuit for both ends.(**to be carried out through end to end testing)**	Ok/ Not Ok

Phase	External Faults		Internal Faults	
	Spill Current Calculated	Spill Current Actual	Spill Current Calculated	Spill Current Actual
R-N				
…				
R-Y				
…				

vi	Check Biasing percentage, Operate Value at inflection points of characteristic boundary including High set feature (if applicable) for all Phase combinations. (all values in Amps)	Ok/ Not Ok

Phase	Operating Current Calculated	Restraining Current Calculated	Operating Current Actual	Restraining Current Actual
R-N				
..				
..				
R-Y				
..				
..				
R-Y-B				

vii	Check the communication of Differential relay by removing the Channel-1 & channel-2(if Applicable). Ensure failure of communication should enable the Distance Zone-1 protection.	Yes/No
viii	Enclose one DR each for Diff Trip.	Yes/No
ix	Enclose event log after completion of testing.	Ok/ Not Ok
x	Check for proper programming of Input / Output contacts of the relay as per approved schematics.	

BI or BO Number	Function as Per Scheme	Function as per Configuration
BI#01		
BI#02		
…		

	...			

III. Overvoltage Stage-I/II

i	Check Operate Value/Reset Value/Operate timing for all phases.	Ok/ Not Ok

A. Pickup Test

OV Stage	Phase	Setting Voltage	Pickup Voltage	Reset Voltage
Stage-I	R/Y/B			
Stage-II	R/Y/B			

B. Timing Test

OV Stage	Phase	Set Time Delay	Measured Time Delay	
Stage-I	R/Y/B			
Stage-II	R/Y/B			

ii	Check whether it trips Main/Tie CB & sends Direct trip to remote end	Yes/ No
iii	Check that the Grading is provided in Pick-up voltage and Timing in case of the Parallel / Multiple Circuits	Yes/No

IV. Broken Conductor Check

i	Inject Three phase balance current and voltage and remove current input(one phase at a time) for simulating broken conductor. Ensure that the Broken Conductor operation is for ALARM ONLY	Ok/ Not Ok

Phase	Time Delay as per setting	Time Delay Measured	Alarm Generated in the relay(Yes/No)
R			
Y			
B			

V. Stub protection (3/4 CT scheme)

<table>
<tr><td>i</td><td>Check scheme logic</td><td>Ok/ Not Ok</td></tr>
<tr><td>ii</td><td>Check operation at set value
<table>
<tr><th>Phase</th><th>Pickup Value as per setting</th><th>Pickup Value Measured</th><th>Time Delay as per setting</th><th>Time Delay Measured</th></tr>
<tr><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td></td><td></td><td></td></tr>
</table>
</td><td>Ok/ Not Ok</td></tr>
</table>

VI. TEE Differential-I/II (5 CT scheme)

<table>
<tr><td>i</td><td>Check Operate Value / Operate Timing for all phases
<table>
<tr><th>Phase</th><th>Pickup Value as per setting</th><th>Pickup Value Measured</th><th>Operating Time Measured</th></tr>
<tr><td></td><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td></td><td></td></tr>
</table>
</td><td>Ok/ Not Ok</td></tr>
<tr><td>ii</td><td>Check tripping of Main/Tie CB & send Direct trip to remote end</td><td>Ok/ Not Ok</td></tr>
<tr><td>iii</td><td>Check stability for out zone fault</td><td>Ok/ Not Ok</td></tr>
</table>

VII. Fault Locator

Inject FL & Distance relay with same Voltage & Current from test Kit. Simulate Zone-I/II, Single Ph/ Ph-Ph/ 3Ph Fault to Main-I/II Distance relay.

<table>
<tr><td>I</td><td>Check initiation by Distance relay</td><td>Ok/ Not Ok</td></tr>
<tr><td>ii</td><td>Compare Fault location measured Vs Test value
<table>
<tr><th>Fault Type</th><th>Fault Location as per test Kit (in % of Line Length)</th><th>Fault Location as per Relay (in % of Line Length)</th></tr>
<tr><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td></td></tr>
</table>
</td><td>Ok/ Not Ok</td></tr>
<tr><td>iii</td><td>Repeat the above for 5 locations up to 100% of line length</td><td>Ok/ Not Ok</td></tr>
<tr><td>iv.</td><td>Check healthiness of mutual compensation circuit</td><td>Ok/ Not Ok</td></tr>
</table>

VIII. Disturbance Recorder (Stand-alone/Inbuilt)

i	Check analog & digital channels are connected as per approved/ Standard signal list	Ok/ Not Ok
ii	Check threshold value of analog triggering (including open delta voltage).	Ok/ Not Ok
iii	Check triggering on digital inputs	Ok/ Not Ok
iv	Check automatic downloading feature	Ok/ Not Ok
v	Check time synchronizing feature	Ok/ Not Ok
vi	Verify open delta voltage in DR channel	Ok/ Not Ok
vii	Check diagnostic feature (if provided)	Ok/ Not Ok

IX. Final Documentation Review

S.No.	Description	Status (Yes/	Remarks(Record deficiencies, if any)
1.	Final document of Pre-commissioning checks reviewed and approved		
2.	Documents regarding spares, equipment, factory reports, O&M manuals etc. available at site for O&M purpose		
3.	After modification, if any, "As built drawing" are available at site		

Signature:	**Signature:**	**Signature:**	**Signature:**
Name:	**Name:**	**Name:**	**Name:**
Desgn.:	**Desgn.:**	**Desgn.:**	**Desgn.:**
Organization: (Supplier Representative) (Wherever Applicable)	**(Erection Agency)**	**(POWERGRID Site I/C)**	**(POWERGRID Commg. Team) Members:** **1.** **2.** **3.** **4.**

Appendix-B
CIRCUIT BREAKER PANEL

General Details

Region:	**Sub-Station:**
Feeder Name:	**LOA No. :**
Date of testing:	**Date of Energisation:**

1. **Auto-reclose Scheme:** (Checks applicable for Distance/Differential protection scheme with auto re-closure function as well)

<table>
<tr><td rowspan="8">i</td><td colspan="2">Check auto reclose initiation/Block contacts for</td><td></td></tr>
<tr><td>a</td><td>Transient Single-Phase Earth fault & Carrier Aided Trip</td><td>Ok/ Not Ok</td></tr>
<tr><td>b</td><td>1 phase fault in Zone II</td><td>Ok/ Not Ok</td></tr>
<tr><td>c</td><td>Transient Ph-Ph Fault</td><td>Ok/ Not Ok</td></tr>
<tr><td>d</td><td>Transient 3 Phase Faults</td><td>Ok/ Not Ok</td></tr>
<tr><td>e</td><td>Permanent Faults</td><td>Ok/ Not Ok</td></tr>
<tr><td>f</td><td>Check for dead time and reclaim time setting</td><td>Ok/ Not Ok</td></tr>
<tr><td>g</td><td>Check single phase auto reclosure for all three phases one by one.</td><td>Ok/ Not Ok</td></tr>
<tr><td colspan="2">ii</td><td>Simulate Zone-I, Single Ph Transient E/F to Main-I/II Distance relay Check AR for all 3 Phases, one by one</td><td>Ok/ Not Ok</td></tr>
<tr><td colspan="2">iii</td><td>Simulate Zone-II, Single Ph Transient E/F to Main-I/II Distance relay and CR. Check AR for all 3 Phases one by One</td><td>Ok/ Not Ok</td></tr>
<tr><td colspan="2">iv</td><td>Check settings & operation of Synchronizing/DLC relays

Synchronizing Function
<table>
<tr><td>Parameter</td><td>Value as per Settings</td><td>Value as per Test</td></tr>
<tr><td>Δf</td><td></td><td></td></tr>
<tr><td>ΔV</td><td></td><td></td></tr>
<tr><td>ΔΘ</td><td></td><td></td></tr>
</table>
DLC Function
<table>
<tr><td>Parameter</td><td>Value as per Settings</td><td>Value as per Test</td></tr>
<tr><td>Voltage</td><td></td><td></td></tr>
</table></td><td>Ok/ Not Ok</td></tr>
<tr><td colspan="2">v</td><td>Measure Dead Time setting (ms)
<table>
<tr><td>Timer</td><td>Set Point</td><td>Measured</td></tr>
<tr><td>Dead Time</td><td></td><td></td></tr>
</table></td><td>Ok/ Not Ok</td></tr>
<tr><td colspan="2">vi</td><td>Measure Reclaim Timer setting (ms)</td><td>Ok/ Not Ok</td></tr>
</table>

		Timer | Set Point | Measured Recaim Time | |	
vii		Check AR does not take place within reclaim time	Ok/ Not Ok
viii		Check AR does not take place in case of fault on Line Charging.	Ok/ Not Ok
ix		Check AR does not take place in case of Failure of PLCC Carriers	Ok/ Not Ok
x		Further, check AR Block in case of	
	a	Pole discrepancy	Ok/ Not Ok
	b	Direct trip received	Ok/ Not Ok
	c	Over-voltage stage-I/II trips	Ok/ Not Ok
	d	Reactor protection trips for Non-Switchable Line reactor	Ok/ Not Ok
	e	CB Troubles	Ok/ Not Ok
xi		In a one & half / Two CB scheme, Check AR does not take place for any one of the CBs under S/D.	Ok/ Not Ok
xii		Check Logics of AR switch Operation (NA/1Ph/2Ph/3Ph).	Ok/ Not Ok
xiii		Check priority circuitry. Priority circuit of Tie CB should be bypassed is any of the main CB is kept in Non-Auto mode/ Open condition/ Unhealthy condition.	Ok/ Not Ok
xiv		A/R should not take place in NON-AUTO mode	Ok/ Not Ok
XV		Enclose one DR for successful Auto reclose	Yes/No
XVI		Enclose SCADA event log generated during the complete testing of AR	Yes/No
XVII		Simulate Trip Coil Faulty by Opening wire from each Trip Coil, one by one. Repeat for Pre-close and Post Close Supervision. Check that TC Faulty alarm appears in the SCADA	Ok/Not Ok

2. Local Breaker Back Up Protection:

i	Check Operate Value/Reset Value/Operate Timing for all phases	Ok/ Not Ok

A.	Pickup Test (in mA)			
LBB	Phase	Setting Current	Pickup Current	Reset Current
Stage-I (re-trip)	R/Y/B			

	Stage-II(Backtrip)	R/Y/B			

B. Timing Test (in ms)

LBB	Phase	Set Time Delay	Measured Time Delay	
Stage-I (re-trip)	R/Y/B			
Stage-II	R/Y/B			

ii	**Ensure LBB Retrip & Backtrip timers should start only after LBB Current pickup along with LBB initiation. Reset of LBB Current should reset LBB function.**	Ok/ Not Ok
iii	Check adjacent CB's as well as concerned Bus-Bar Trip relays operate during operation of LBB relay Stage-II(Backtrip) only.	Ok/ Not Ok
iv	Check Direct trip Transfer takes place only for feeder under testing during LBB Stage-II operation.	Ok/ Not Ok
v	Check only own CB trips during operation of LBB Stage-I (re-trip)	Ok/ Not Ok
vi	For bays commissioned in the extension projects have Tie-LBB wiring changed from "Tripping the bus" to "Tripping the Main CB"	Ok/ Not Ok
vii	Enclose one DR each for Retrip and Backtrip	Ok/ Not Ok
viii	Enclose SCADA event log generated during the complete testing of LBB relay	Ok/ Not Ok
ix	Check/measure phase wise current in LBB/PU relay Adopted CT ratio:	Ok/ Not Ok

Phase	Injected Value (mA)	Measured Value (mA)
R-N		
Y-N		
B-N		

x	Check all the initiation signals coming to the LBB relay, by actual operation of relays(strike off the relays which are not applicable)	

Relay name	Initiation received in LBB relay(ok/not ok)

	M1-R phase M1-Y phase M1-B phase M2-R phase M2-Y phase M2-B phase Master Trip Relay-1 Master Trip Relay-2 Busbar Trip Relay-1 Busbar Trip Relay-2 Enclose SCADA event log for the testing.	

M1-R phase	
M1-Y phase	
M1-B phase	
M2-R phase	
M2-Y phase	
M2-B phase	
Master Trip Relay-1	
Master Trip Relay-2	
Busbar Trip Relay-1	
Busbar Trip Relay-2	

Enclose SCADA event log for the testing.

3. Under-voltage in BCU

i	Check Operate Value /Operate Timing for all phases	Ok/ Not Ok
ii	Check E/S interlock operation during under voltage condition & vice versa	Ok/ Not Ok

A. Pickup Test (in %)

	Phase	Setting Voltage	Pickup voltage
UV	R/Y/B		

B. Timing Test (in ms)

	Phase	Set Time Delay	Measured Time Delay
UV	R/Y/B		

4. Direct Trip Transfer

a. Check Direct trip transfer in case of:

i	Over-voltage relay stage-1 & 2 operations	Ok/ Not Ok
ii	Non-Switchable Line Reactor Protection trip operations.	Ok/ Not Ok
iii	Manual trip to One CB(Main/Tie) when another CB(Tie/Main) in same dia is under open condition(Operation from TNC	Ok/ Not Ok
iv	Check DT not extended While Manual trip to One CB(Main/Tie) when another CB(Tie/Main) in same dia is under Close condition(Operation from TNC Switch)	Ok/ Not Ok

v	LBB relay Stage-II Trip: for both the Main & Tie CB's	Ok/ Not Ok
vi	Busbar Trip to One CB(Main/Tie) when another CB(Tie/Main) in	Ok/ Not Ok
vii	Check DT not extended While Busbar Trip to One CB(Main/Tie) when another CB(Tie/Main) in same dia is under open condition	Ok/ Not Ok
viii	TEE Diff Protection trip	Ok/ Not Ok
ix	Direct trip Transfer through 1st Channel	Ok/ Not Ok
x	Direct trip Transfer through 2nd Channel	Ok/ Not Ok
xi	Check DT is not resulted by 1st Channel permissive trip	Ok/ Not Ok
xii	Check DT is not resulted by 2nd Channel permissive trip	Ok/ Not Ok

b. Summary of Code Transfer for PLCC

Ch-1 Code-I……… Ch-1 Code-2 ……… Ch-2 Code-I ……… Ch-2 Code-2 ………

i	Check individual Code Transfer to be as per scheme	Ok/ Not Ok
ii	Ch-1 Code-I	Ok/ Not Ok
iii	Ch-1 Code-2	Ok/ Not Ok
iv	Ch-1 Code-3	Ok/ Not Ok
v	Ch-2 Code-I	Ok/ Not Ok
vi	Ch-2 Code-2	Ok/ Not Ok
vii	Ch-2 Code-3	Ok/ Not Ok
viii	Check if signal through One code is not transferred to another at Remote end	Ok/ Not Ok

5. CB Troubles

i	Simulate all the Alarms pertaining to CB (by actuating initiating Contacts from field). (CB LOW Air/Oil pressure, Pole discrepancy, spring discharge, DC fail, etc.) and check the Events/Alarms in SCADA	Ok/ Not Ok
ii	Enclose event log	Yes/No

6. Final Documentation Review

S.No.	Description	Status (Yes/ No)	Remarks(Record deficiencies, if any)
1.	Final document of Pre-commissioning checks reviewed and approved		

2.	Documents regarding spares, equipment, factory reports, O&M manuals etc. available at site for O&M purpose		
3.	After modification, if any, "As built drawing are available at site		

Signature:	**Signature:**	**Signature:**	**Signature:**
Name:	**Name:**	**Name:**	**Name:**
Desgn.:	**Desgn.:**	**Desgn.:**	**Desgn.:**
Organization: (Supplier Representative) (Wherever Applicable)	**(Erection Agency)**	**(POWERGRID Site I/C)**	**(POWERGRID Commg. Team) Members:** **1.** **2.** **3.** **4.**

Appendix-C

LINE REACTOR PROTECTION

General Details

Region:	**Sub-Station:**
Feeder Name:	**LOA No. :**
Date of testing:	**Date of Energisation:**
Capacity in MVAR:	

1. Differential Protection

CT Ratio

HV: As per Scheme: ______________, At Field: ________________, In Relay: __________________

LV : As per Scheme: ______________, At Field: ________________, In Relay: __________________

i	CT secondary Circuitry Checked and Ensure that the Secondary is earthed at Single point only	Ok/ Not Ok
ii	Check connection of stabilizing resistance & metrosil (wherever applicable)	Ok/ Not Ok
iii	Check connection of stabilizing resistance & metrosil (wherever applicable). Measure Value of Stabilizing Resistor: As per Setting (in Ohms): Value Measured (in Ohms):	Ok/ Not Ok
iv	Check CT Circuits so that summation of same phases (R-R, Y-Y, B-B) is taking place (Sometimes R-B & B-R summations are observed due to wrong Wirings)	Ok/ Not Ok
v	Check IED Time synchronization configurations are implemented	Ok/ Not Ok
vi	Check Operate Value (mA)/ Operate Timing (ms) for all phases	Ok/ Not Ok

Phase	Set Pickup Value	Test pickup Value	Operating Time
R1-N			
Y1-N			
B1-N			

<table>
<tr><td>vii</td><td>Carry out Primary stability test by simulating external and internal faults and measure spill currents (mA) in Differential circuit for all windings w.r.t reference winding.

<table>
<tr><th rowspan="2">Phase</th><th colspan="2">External Faults</th><th colspan="2">Internal Faults</th></tr>
<tr><th>Injected Current</th><th>Spill Current Actual</th><th>Injected Current</th><th>Spill Current Actual</th></tr>
<tr><td>R-N</td><td></td><td></td><td></td><td></td></tr>
<tr><td>…</td><td></td><td></td><td></td><td></td></tr>
<tr><td>R-Y</td><td></td><td></td><td></td><td></td></tr>
<tr><td>…</td><td></td><td></td><td></td><td></td></tr>
</table>
</td><td>Ok/ Not Ok</td></tr>
<tr><td>viii</td><td>Check Biasing percentage, Operate Value at inflection points of characteristic boundary including High set feature if applicable for all Phase combinations & for each pair of windings. (all values in Amps)

<table>
<tr><th>Phase</th><th>Operating Current Calculated</th><th>Restraining Current Calculated</th><th>Operating Current Actual</th><th>Restraining Current Actual</th></tr>
<tr><td>R-N</td><td></td><td></td><td></td><td></td></tr>
<tr><td>..</td><td></td><td></td><td></td><td></td></tr>
<tr><td>..</td><td></td><td></td><td></td><td></td></tr>
<tr><td>R-Y</td><td></td><td></td><td></td><td></td></tr>
<tr><td>..</td><td></td><td></td><td></td><td></td></tr>
<tr><td>..</td><td></td><td></td><td></td><td></td></tr>
<tr><td>R-Y-B</td><td></td><td></td><td></td><td></td></tr>
</table>
</td><td>Ok/ Not Ok</td></tr>
<tr><td>ix</td><td>Check Blocking of tripping on Harmonic Restraints Feature (2nd & 5th harmonics) for each pair of winding (all values in %)

<table>
<tr><th rowspan="2">Phase</th><th colspan="2">2nd Harmonic</th><th colspan="2">5th Harmonic</th></tr>
<tr><th>Restraint set value</th><th>Restraint Test value</th><th>Restraint set value</th><th>Restraint Test value</th></tr>
<tr><td>R-N</td><td></td><td></td><td></td><td></td></tr>
<tr><td>Y-N</td><td></td><td></td><td></td><td></td></tr>
<tr><td>B-N</td><td></td><td></td><td></td><td></td></tr>
<tr><td>---</td><td></td><td></td><td></td><td></td></tr>
</table>
</td><td>Ok/ Not Ok</td></tr>
<tr><td>x</td><td>Enclose one DR each for following: Diff Trip, Harmonic Block and Cross block.</td><td>Yes/No</td></tr>
<tr><td>xi</td><td>Enclose event log after completion of testing.</td><td>Yes/No</td></tr>
</table>

2. Restricted Earth-Fault Protection:

CT Ratio

Phase Side: As per Scheme: ___________, At Field: ____________, In Relay: ______________

Neutral Side: As per Scheme: ___________, At Field: ____________, In Relay: ______________

<table>
<tr><td>i</td><td>Check Operate Value (mA)/Operate Timing (ms) for all phases.
<table>
<tr><th>Phase</th><th>Set Pickup Value</th><th>Test pickup Value</th><th>Operating Time</th></tr>
<tr><td>R1-N</td><td></td><td></td><td></td></tr>
<tr><td>Y1-N</td><td></td><td></td><td></td></tr>
<tr><td>B1-N</td><td></td><td></td><td></td></tr>
<tr><td>---</td><td></td><td></td><td></td></tr>
</table></td><td>Ok/ Not Ok</td></tr>
<tr><td>ii</td><td>CT secondary Circuitry Checked and Ensure that the Secondary is earthed at Single point only</td><td>Ok/ Not Ok</td></tr>
<tr><td>iii</td><td>Check connection of stabilizing resistance & metrosil (wherever applicable). Measure Value of Stabilizing Resistor:

As per Setting (in Ohms):
Value Measured (in Ohms):</td><td>Ok/ Not Ok</td></tr>
<tr><td>iv</td><td>Check CT Circuits so that summation of same phases (R-R, Y-Y, B-B) is taking place (Sometimes R-B & B-R summations are observed due to wrong Wirings).</td><td>Ok/ Not Ok</td></tr>
<tr><td>v</td><td>Carry out stability test by simulating external and internal faults by primary injection and measure spill currents in REF relay (all values in mA)
<table>
<tr><th rowspan="2">Phase</th><th colspan="2">External Faults</th><th colspan="2">Internal Faults</th></tr>
<tr><th>Injected Current</th><th>Spill Current Actual</th><th>Injected Current</th><th>Spill Current Actual</th></tr>
<tr><td>R-N</td><td></td><td></td><td></td><td></td></tr>
<tr><td>…</td><td></td><td></td><td></td><td></td></tr>
<tr><td>R-Y</td><td></td><td></td><td></td><td></td></tr>
<tr><td>…</td><td></td><td></td><td></td><td></td></tr>
</table></td><td>Ok/ Not Ok</td></tr>
</table>

3. Back-Up Impedance Relay

Type:………

CT Ratio

As per Scheme: ______________, At Field: ________________, In Relay: __________________

VT Ratio

As per Scheme: ______________, At Field: ________________, In Relay: _________________

<table>
<tr><td>i</td><td>Print Adopted relay settings to PDF file and enclose.</td><td>Ok/ Not Ok</td></tr>
<tr><td>ii</td><td>Compare with recommended setting</td><td>Ok/ Not Ok</td></tr>
<tr><td>iii</td><td>Check for Reach Setting
<table>
<tr><th>Fault Type</th><th>Zone</th><th>Reach as per Setting</th><th>Reach as per testing</th><th>Time of Operation (in ms)</th></tr>
<tr><td>R-N</td><td>Z1</td><td>R1:
X1:</td><td>R1:
X1</td><td></td></tr>
<tr><td></td><td>Z2</td><td></td><td></td><td></td></tr>
<tr><td></td><td>…</td><td></td><td></td><td></td></tr>
<tr><td>…</td><td>…</td><td></td><td></td><td></td></tr>
<tr><td></td><td>…</td><td></td><td></td><td></td></tr>
</table></td><td>Ok/ Not Ok</td></tr>
<tr><td>iv</td><td>Enclose one DR each for Back-up impedance tripping and trip blocking during VT Fail Blocking & Blocking as per latest Technical circular.</td><td>Ok/ Not Ok</td></tr>
<tr><td>v</td><td>Enclose event log for complete test.</td><td>Yes/No</td></tr>
<tr><td>vi</td><td>Check the VT connection and ensure single point earthed.</td><td>Ok/ Not Ok</td></tr>
<tr><td>vii</td><td>Check trip Block in case of CVT Fuse Failure.</td><td>Ok/ Not Ok</td></tr>
<tr><td>viii</td><td>Check the CT connection and ensure single point earthed.</td><td>Ok/ Not Ok</td></tr>
<tr><td>ix</td><td>Check Time synchronizing by altering Time Zone. Restore on confirmation</td><td>Ok/ Not Ok</td></tr>
<tr><td>x</td><td>Check Self-diagnostic feature of the relay (if provided)</td><td>Ok/ Not Ok</td></tr>
<tr><td>xi</td><td>Check metering function of the relay (if provided)</td><td>Ok/ Not Ok</td></tr>
<tr><td>xii</td><td>Verification of Directionality</td><td>Ok/ Not Ok</td></tr>
<tr><td>xiii</td><td>Check for NGR bypass/ protection scheme as per latest Technical circular</td><td>Ok/ Not Ok</td></tr>
<tr><td>xiv</td><td>Check for proper programming of Input / Output contacts of the relay as per approved schematics
<table>
<tr><th>BI or BO Number</th><th>Function as Per Scheme</th><th>Function as per Configuration</th></tr>
<tr><td>BI#01</td><td></td><td></td></tr>
</table></td><td>Ok/ Not Ok</td></tr>
</table>

	BI#02			
	…			
	…			

4. Electromechanical Relays:

Check operation of:

i	Buchholz Alarm & trip	Ok/ Not Ok
ii	WTI Alarm & trip	Alarm……… Trip………..
iii	OTI Alarm & trip	Alarm……… Trip………..
iv	PRD Trip	Ok/ Not Ok
v	MOG (LOL/Low Oil Level) Alarm	Ok/ Not Ok
vi	Ensure that the Buchholz-I and II are connected to relays powered through different DC source(similarly check for PRD I & II as well)	Ok/Not Ok.
Vii	Ensure Latest Technical circular regarding mechanical trip complied	Ok/Not Ok.

5. Direct Trip Transfer

i	In all cases of non-switchable reactors, Direct trip to remote end is sent along with tripping of Main/Tie CB's	Ok/ Not Ok
ii	Direct trip: From line Reactor LBB in case of switchable reactor	Ok/ Not Ok

6. Selection Scheme for Protection & Metering

i	Ensure Voltage inputs at specific terminals from		
	a	Line CVT	Ok/ Not Ok
	b	Bus-I CVT (say connected to CB-1)	Ok/ Not Ok
	c	Bus-II CVT (say connected to CB-2)	Ok/ Not Ok
ii	Check all NO/NC contacts for voltage selection logic if applicable.		Ok/ Not Ok
	a	Voltage selection logic needs to be checked as per standard/ approved scheme.	Ok/ Not Ok
	b	Voltage selection logic needs to be checked to avoid any condition of no VT selection or multiple VT selection.	Ok/ Not Ok
	Check all NO/NC contacts for spare selection logic if applicable.		Ok/ Not Ok

iii	a	Spare selection logic needs to be checked as per standard/ approved scheme.	Ok/ Not Ok
	b	Spare selection output stability should be checked during / after BCU restart and intermediate state of associated BCU binary inputs.	Ok/ Not Ok

7. Check Remote WTI/OTI on Control panel

i	Remote WTI/OTI checked on control panel	Ok/ Not Ok

8. Final Documentation Review

S.No	Description	Status (Yes/ No)	Remarks(Record Deficiencies, If Any)
1.	Final document of Pre-commissioning checks reviewed and approved		
2.	Documents regarding spares, equipment, factory reports, O&M manuals etc. available at site for O&M purpose		
3.	After modification, if any, "As built drawing are available at site		

Signature:	**Signature:**	**Signature:**	**Signature:**
Name:	**Name:**	**Name:**	**Name:**
Desgn.:	**Desgn.:**	**Desgn.:**	**Desgn.:**
Organization: (Supplier Representative) (Wherever Applicable)	**(Erection Agency)**	**(POWERGRID Site I/C)**	**(POWERGRID Commg. Team) Members:** **1.** **2.** **3.** **4.**

Appendix-D
BUS REACTOR PROTECTION

General Details

Region:	**Sub-Station:**
Feeder Name:	**LOA No. :**
Date of testing:	**Date of Energisation:**
Capacity in MVAR	

1. Differential Protection

CT Ratio

HV: As per Scheme: ______________, At Field: ________________, In Relay: __________________

LV : As per Scheme: ______________, At Field: ________________, In Relay: __________________

i	CT secondary Circuitry Checked and Ensure that the Secondary is earthed at Single point only.	Ok/ Not Ok
ii	Check connection of stabilizing resistance & metrosil (wherever applicable)	Ok/ Not Ok
iii	Check connection of stabilizing resistance & metrosil (wherever applicable). Measure Value of Stabilizing Resistor: As per Setting (in Ohms): Value Measured (in Ohms):	Ok/ Not Ok
iv	Check CT Circuits so that summation of same phases (R-R, Y-Y, B-B) is taking place (Sometimes R-B & B-R summations are observed due to wrong Wirings)	Ok/ Not Ok
v	Check Operate Value (mA)/ Operate Timing (ms) for all phases	Ok/ Not Ok
vi	Carry out stability test by simulating external and internal faults	Ok/ Not Ok

Phase	Set Pickup Value	Test pickup Value	Operating Time
R1-N			
Y1-N			
B1-N			

<table>
<tr><td></td><td>and measure spill currents in Differential circuit for all windings w.r.t reference winding (all values in mA).
<table>
<tr><td rowspan="2">Phase</td><td colspan="2">External Faults</td><td colspan="2">Internal Faults</td></tr>
<tr><td>Spill Current Calculated</td><td>Spill Current Actual</td><td>Spill Current Calculated</td><td>Spill Current Actual</td></tr>
<tr><td>R-N</td><td></td><td></td><td></td><td></td></tr>
<tr><td>…</td><td></td><td></td><td></td><td></td></tr>
<tr><td>R-Y</td><td></td><td></td><td></td><td></td></tr>
<tr><td>…</td><td></td><td></td><td></td><td></td></tr>
</table></td><td></td></tr>
<tr><td>vii</td><td>Check Biasing percentage, Operate Value at inflection points of characteristic boundary including High set feature if applicable for all Phase combinations & for each pair of windings (all values in Amps)
<table>
<tr><td>Phase</td><td>Operating Current Calculated</td><td>Restraining Current Calculated</td><td>Operating Current Actual</td><td>Restraining Current Actual</td></tr>
<tr><td>R-N</td><td></td><td></td><td></td><td></td></tr>
<tr><td>..</td><td></td><td></td><td></td><td></td></tr>
<tr><td>..</td><td></td><td></td><td></td><td></td></tr>
<tr><td>R-Y</td><td></td><td></td><td></td><td></td></tr>
<tr><td>..</td><td></td><td></td><td></td><td></td></tr>
<tr><td>..</td><td></td><td></td><td></td><td></td></tr>
</table></td><td>Ok/ Not Ok</td></tr>
<tr><td>viii</td><td>Check Blocking of tripping on Harmonic Restraints Feature (2^{nd} & 5^{th} harmonics) for all windings in %.
<table>
<tr><td rowspan="2">Phase</td><td colspan="2">2^{nd} Hormonic</td><td colspan="2">5^{th} Hormonic</td></tr>
<tr><td>Restraint set value</td><td>Restraint Test value</td><td>Restraint set value</td><td>Restraint Test value</td></tr>
<tr><td>R1-N</td><td></td><td></td><td></td><td></td></tr>
<tr><td>Y1-N</td><td></td><td></td><td></td><td></td></tr>
<tr><td>B1-N</td><td></td><td></td><td></td><td></td></tr>
<tr><td>---</td><td></td><td></td><td></td><td></td></tr>
</table></td><td>Ok/ Not Ok</td></tr>
<tr><td>ix</td><td>Enclose one DR each for following: Diff Trip, Harmonic Block and Cross block.</td><td>Yes/No</td></tr>
<tr><td>x</td><td>Enclose event log after completion of testing</td><td>Yes/No</td></tr>
<tr><td>xi</td><td>Check for proper programming of Input / Output contacts of the relay as per approved schematics
<table>
<tr><td>BI or BO Number</td><td>Function as Per</td><td>Function as per</td></tr>
</table></td><td>Ok/ Not Ok</td></tr>
</table>

	Scheme	Configuration
BI#01		
BI#02		
…		
…		

2. Restricted Earth-Fault Protection:

CT Ratio

HV: As per Scheme: _____________, At Field: _______________, In Relay: _________________

LV : As per Scheme: _____________, At Field: _______________, In Relay: _________________

<table>
<tr><td>i</td><td>Check Operate Value (mA)/ Operate Timing (ms) for all phases
<table><tr><th>Phase</th><th>Set Pickup Value</th><th>Test pickup Value</th><th>Operating Time</th></tr><tr><td>R1-N</td><td></td><td></td><td></td></tr><tr><td>Y1-N</td><td></td><td></td><td></td></tr><tr><td>B1-N</td><td></td><td></td><td></td></tr><tr><td>---</td><td></td><td></td><td></td></tr></table></td><td>Ok/ Not Ok</td></tr>
<tr><td>ii</td><td>CT secondary Circuitry Checked and Ensure that the Secondary is earthed at Single point only</td><td>Ok/ Not Ok</td></tr>
<tr><td>iii</td><td>Check connection of stabilizing resistance & metrosil (wherever applicable)

As per Setting (in Ohms):
Value Measured (in Ohms):</td><td>Ok/ Not Ok</td></tr>
<tr><td>iv</td><td>Check CT Circuits so that summation of same phases (R-R, Y-Y, B-B) is taking place (Sometimes R-B & B-R summations are observed due to wrong Wirings).</td><td>Ok/ Not Ok</td></tr>
<tr><td>v</td><td>Carry out stability test by simulating external and internal faults by primary injection and measure spill currents in REF relay (all values in mA)
<table><tr><th rowspan="2">Phase</th><th colspan="2">External Faults</th><th colspan="2">Internal Faults</th></tr><tr><th>Spill Current Calculated</th><th>Spill Current Actual</th><th>Spill Current Calculated</th><th>Spill Current Actual</th></tr><tr><td>R-N</td><td></td><td></td><td></td><td></td></tr></table></td><td>Ok/ Not Ok</td></tr>
</table>

<table>
<tr><td></td><td><table><tr><td>…</td><td></td><td></td><td></td><td></td></tr><tr><td>R-Y</td><td></td><td></td><td></td><td></td></tr><tr><td>…</td><td></td><td></td><td></td><td></td></tr></table></td><td></td></tr>
<tr><td>vi</td><td>Check for proper programming of Input / Output contacts of the relay as per approved schematics<table><tr><td>BI or BO Number</td><td>Function as Per Scheme</td><td>Function as per Configuration</td></tr><tr><td>BI#01</td><td></td><td></td></tr><tr><td>BI#02</td><td></td><td></td></tr><tr><td>…</td><td></td><td></td></tr><tr><td>…</td><td></td><td></td></tr></table></td><td>Ok/ Not Ok</td></tr>
</table>

3. Back-Up Impedance Relay

Type: ....

CT Ratio

As per Scheme: ______________, At Field: ________________, In Relay: __________________

VT Ratio

As per Scheme: ______________, At Field: ________________, In Relay: __________________

<table>
<tr><td>i</td><td>Print Adopted relay settings to PDF file and enclose.</td><td>Ok/ Not Ok</td></tr>
<tr><td>ii</td><td>Compare with recommended setting</td><td>Ok/ Not Ok</td></tr>
<tr><td>iii</td><td>Check for Reach Setting<table><tr><td>Fault Type</td><td>Zone</td><td>Reach as per Setting</td><td>Reach as per testing</td><td>Time of Operation (in ms)</td></tr><tr><td>R-N</td><td>Z1</td><td>R1:
X1:</td><td>R1:
X1</td><td></td></tr><tr><td></td><td>Z2</td><td></td><td></td><td></td></tr><tr><td></td><td>…</td><td></td><td></td><td></td></tr><tr><td>…</td><td>…</td><td></td><td></td><td></td></tr><tr><td></td><td>…</td><td></td><td></td><td></td></tr></table></td><td>Ok/ Not Ok</td></tr>
<tr><td>iv</td><td>Enclose one DR each for Back-up impedance tripping and trip blocking during VT Fail Blocking & Blocking as per latest Technical circular.</td><td>Ok/ Not Ok</td></tr>
<tr><td>v</td><td>Enclose event log for complete test.</td><td>Yes/No</td></tr>
<tr><td>vi</td><td>Check the VT connection and ensure single point earthed.</td><td>Ok/ Not Ok</td></tr>
<tr><td>vii</td><td>Check trip Block in case of CVT Fuse Failure.</td><td>Ok/ Not Ok</td></tr>
<tr><td>viii</td><td>Check Communication to PC (If available)</td><td>Ok/ Not Ok</td></tr>
</table>

ix	Check Time synchronizing by altering Time Zone. Restore on confirmation	Ok/ Not Ok
x	Check Self-diagnostic feature of the relay (if provided)	Ok/ Not Ok
xi	Check metering function of the relay (if provided)	Ok/ Not Ok
xii	Verification of Directionality	Ok/ Not Ok
xiii	Check for proper programming of Input / Output contacts of the relay as per approved schematics	Ok/ Not Ok

BI or BO Number	Function as Per Scheme	Function as per Configuration
BI#01		
BI#02		
…		
…		

4. Electromechanical Relays

i	Buchholz Alarm & trip	Ok/ Not Ok
ii	WTI Alarm & trip	Alarm……… Trip………..
iii	OTI Alarm & trip	Alarm……… Trip………..
iv	PRD Trip	Ok/ Not Ok
v	MOG (LOL/Low Oil Level) Alarm	Ok/ Not Ok
vii	Ensure Latest Technical circular regarding mechanical trip complied	Ok/Not Ok.

5. Selection Scheme for Protection & Metering

i	Ensure Voltage inputs at specific terminals from		
	a	Line CVT	Ok/ Not Ok
	b	Bus-I CVT (say connected to CB-1)	Ok/ Not Ok
	c	Bus-II CVT (say connected to CB-2)	Ok/ Not Ok
ii	Check all NO/NC contacts for voltage selection logic if applicable.		Ok/ Not Ok
	a	Voltage selection logic needs to be checked as per standard/ approved scheme.	Ok/ Not Ok
	b	Voltage selection logic needs to be checked to avoid any condition of no VT selection or multiple VT selection.	Ok/ Not Ok
	Check all NO/NC contacts for spare selection logic if applicable.		Ok/ Not Ok

iii	a	Spare selection logic needs to be checked as per standard/ approved scheme.	Ok/ Not Ok
	b	Spare selection output stability should be checked during / after BCU restart and intermediate state of associated BCU binary inputs.	Ok/ Not Ok

6. Check Remote WTI/OTI on Control panel

i	Remote WTI/OTI checked on control panel	Ok/ Not Ok

7. Final Documentation Review

S.No.	Description	Status (Yes/ No)	Remarks (Record deficiencies, if any)
1.	Final document of Pre-commissioning checks reviewed and approved		
2.	Documents regarding spares, equipment, factory reports, O&M manuals etc. available at site for O&M purpose		
3.	After modification, if any, “As built drawing are available at site		

Signature:	**Signature:**	**Signature:**	**Signature:**
Name:	**Name:**	**Name:**	**Name:**
Desgn.:	**Desgn.:**	**Desgn.:**	**Desgn.:**
Organization: (Supplier Representative) (Wherever Applicable)	**(Erection Agency)**	**(POWERGRID Site I/C)**	**(POWERGRID Commg. Team) Members:** **1.** **2.** **3.** **4.**

Appendix-E
AUTO-TRANSFORMER PROTECTION

General Details

Region:	Sub-Station:
Feeder Name:	LOA No. :
Date of testing:	Date of Energisation:
MVA	

1. Differential Protection

HV: As per Scheme: ______________, At Field: ________________, In Relay: __________________

LV : As per Scheme: ______________, At Field: ________________, In Relay: __________________

<table>
<tr><td>i</td><td>CT secondary Circuitry Checked and Ensure that the Secondary is earthed at Single point only</td><td>Ok/ Not Ok</td></tr>
<tr><td>ii</td><td>Check connection of stabilizing resistance & metrosil (wherever applicable). Measure Value of Stabilizing Resistor:

As per Setting (in Ohms):
Value Measured (in Ohms):</td><td>Ok/ Not Ok</td></tr>
<tr><td>iii</td><td>Check CT Circuits so that summation of same phases (R-R, Y-Y, B-B) is taking place (Sometimes R-B & B-R summations are observed due to wrong Wirings)</td><td>Ok/ Not Ok</td></tr>
<tr><td>iv</td><td>Check IED Time synchronization configurations are implemented</td><td>Ok/ Not Ok</td></tr>
<tr><td>v</td><td>Check Operate Value /Operate Timing for all phases (all values in Amps).
<table>
<tr><th>Phase</th><th>Set Pickup Value</th><th>Test pickup Value</th><th>Operating Time</th></tr>
<tr><td>R1-N</td><td></td><td></td><td></td></tr>
<tr><td>Y1-N</td><td></td><td></td><td></td></tr>
<tr><td>B1-N</td><td></td><td></td><td></td></tr>
<tr><td>---</td><td></td><td></td><td></td></tr>
</table></td><td>Ok/ Not Ok</td></tr>
<tr><td>vi</td><td>Carry out stability test by simulating external and internal faults and measure spill currents in Differential circuit for all windings w.r.t reference winding (all values in mA).</td><td>Ok/ Not Ok</td></tr>
</table>

Phase	External Faults		Internal Faults	
	Spill Current Calculated	Spill Current Actual	Spill Current Calculated	Spill Current Actual
R-N				
…				
R-Y				
…				

vii Check Biasing percentage, Operate Value at inflection points of characteristic boundary including High set feature if applicable for all Phase combinations & for each pair of windings (all values in Amps) — Ok/ Not Ok

Phase	Operating Current Calculated	Restraining Current Calculated	Operating Current Actual	Restraining Current Actual
R-N				
..				
..				
R-Y				
..				
..				

viii Check Blocking of tripping on Harmonic Restraints Feature (2^{nd} & 5^{th} harmonics) for all windings (all values in %). — Ok/ Not Ok

Phase	2^{nd} Hormonic		5^{th} Hormonic	
	Restraint set value	Restraint Test value	Restraint set value	Restraint Test value
R1-N				
Y1-N				
B1-N				
---				

ix Check for proper programming of Input / Output contacts of the relay as per approved schematics — Ok/ Not Ok

BI or BO Number	Function as Per Scheme	Function as per Configuration
BI#01		
BI#02		
…		
…		

2. Restricted Earth-Fault Protection

CT Ratio

HV: As per Scheme: _____________, At Field: _______________, In Relay: _________________

LV : As per Scheme: _____________, At Field: _______________, In Relay: _________________

<table>
<tr><td>i</td><td>Check Operate Value /Operate Timing for all phases (all values in Amps).
<table>
<tr><th>Phase</th><th>Set Pickup Value</th><th>Test pickup Value</th><th>Operating Time</th></tr>
<tr><td>R1-N</td><td></td><td></td><td></td></tr>
<tr><td>Y1-N</td><td></td><td></td><td></td></tr>
<tr><td>B1-N</td><td></td><td></td><td></td></tr>
<tr><td>---</td><td></td><td></td><td></td></tr>
</table></td><td>Ok/ Not Ok</td></tr>
<tr><td>ii</td><td>CT secondary Circuitry Checked and Ensure that the Secondary is earthed at Single point only</td><td>Ok/ Not Ok</td></tr>
<tr><td>iii</td><td>Check connection of stabilizing resistance & metrosil (wherever applicable)

As per Setting (in Ohms):
Value Measured (in Ohms):</td><td>Ok/ Not Ok</td></tr>
<tr><td>iv</td><td>Check CT Circuits so that summation of same phases (R-R, Y-Y, B-B) is taking place (Sometimes R-B & B-R summations are observed due to wrong Wirings).</td><td>Ok/ Not Ok</td></tr>
<tr><td>v</td><td>Carry out stability test by simulating external and internal faults by primary injection and measure spill currents in REF relay (all values in mA).
<table>
<tr><th rowspan="2">Phase</th><th colspan="2">External Faults</th><th colspan="2">Internal Faults</th></tr>
<tr><th>Spill Current Calculated</th><th>Spill Current Actual</th><th>Spill Current Calculated</th><th>Spill Current Actual</th></tr>
<tr><td>R-N</td><td></td><td></td><td></td><td></td></tr>
<tr><td>…</td><td></td><td></td><td></td><td></td></tr>
<tr><td>R-Y</td><td></td><td></td><td></td><td></td></tr>
<tr><td>…</td><td></td><td></td><td></td><td></td></tr>
</table></td><td>Ok/ Not Ok</td></tr>
<tr><td>vi</td><td>Check for proper programming of Input / Output contacts of the relay as per approved schematics</td><td>Ok/ Not Ok</td></tr>
</table>

	BI or BO Number	Function as Per Scheme	Function as per Configuration	
	BI#01			
	BI#02			
	…			
	…			

3. **Back-Up Impedance Relay**

Type :…………

CT Ratio:

As per Scheme: _______________, At Field: _________________, In Relay: ___________________

VT Ratio

As per Scheme: _______________, At Field: _________________, In Relay: __________________

i	Print Adopted relay settings to PDF file and enclose.	Ok/ Not Ok
ii	Compare with recommended setting	Ok/ Not Ok
iii	Check for Reach Setting	Ok/ Not Ok

Fault Type	Zone	Reach as per Setting	Reach as per testing	Time of Operation (in ms)
R-N	Z1	R1: X1:	R1: X1	
	Z2			
	…			
…	…			
	…			

iv	Enclose one DR each for Back-up impedance tripping and trip blocking during VT Fail Blocking & Blocking as per latest Technical circular.	Ok/ Not Ok
v	Enclose event log for complete test.	Yes/No
vi	Check the VT connection and ensure single point earthed.	Ok/ Not Ok
vii	Check trip Block in case of CVT Fuse Failure.	Ok/ Not Ok
viii	Check the CT connection and ensure single point earthed.	Ok/ Not Ok
ix	Check Time synchronizing by altering Time Zone. Restore on confirmation	Ok/ Not Ok
x	Check Self-diagnostic feature of the relay (if provided)	Ok/ Not Ok
xi	Check metering function of the relay (if provided)	Ok/ Not Ok

<table>
<tr><td>xii</td><td colspan="3">Verification of Directionality</td><td>Ok/ Not Ok</td></tr>
<tr><td rowspan="7">xiii</td><td colspan="3">Check for proper programming of Input / Output contacts of the relay as per approved schematics</td><td rowspan="7">Ok/ Not Ok</td></tr>
<tr><td>BI or BO Number</td><td>Function as Per Scheme</td><td>Function as per Configuration</td></tr>
<tr><td>BI#01</td><td></td><td></td></tr>
<tr><td>BI#02</td><td></td><td></td></tr>
<tr><td>…</td><td></td><td></td></tr>
<tr><td>…</td><td></td><td></td></tr>
<tr><td></td><td></td><td></td></tr>
</table>

4. Electromechanical Relays:

Check Operations of:

i	Buchholz Alarm & trip	Ok/ Not Ok
ii	WTI Alarm & trip	Alarm……… Trip………..
iii	OTI Alarm & trip	Alarm……… Trip………..
iv	PRD Trip	Ok/ Not Ok
v	MOG (LOL/Low Oil Level) Alarm	Ok/ Not Ok
vi	Oil surge relay	Ok/ Not Ok
vii	OLTC Protections	Ok/ Not Ok
viii	Ensure Latest Technical circular regarding mechanical trip complied	Ok/Not Ok.

5. Inter Trip

i	In all cases of above tripping, Inter trip to other side is sent along with tripping of Main/Tie CB's	Ok/ Not Ok

6. Selection Scheme for Protection & Metering

<table>
<tr><td rowspan="3">i</td><td colspan="3">Ensure Voltage inputs at specific terminals from</td></tr>
<tr><td>a</td><td>Line CVT</td><td>Ok/ Not Ok</td></tr>
<tr><td>b</td><td>Bus-I CVT (say connected to CB-1)</td><td>Ok/ Not Ok</td></tr>
</table>

	c	Bus-II CVT (say connected to CB-2)	Ok/ Not Ok
ii		Check all NO/NC contacts for voltage selection logic if applicable.	Ok/ Not Ok
	a	Voltage selection logic needs to be checked as per standard/ approved scheme.	Ok/ Not Ok
	b	Voltage selection logic needs to be checked to avoid any condition of no VT selection or multiple VT selection.	Ok/ Not Ok
iii		Check all NO/NC contacts for spare selection logic if applicable.	Ok/ Not Ok
	a	Spare selection logic needs to be checked as per standard/ approved scheme.	Ok/ Not Ok
	b	Spare selection output stability should be checked during / after BCU restart and intermediate state of associated BCU binary inputs.	Ok/ Not Ok

7. Check Remote WTI/OTI on Control panel

i	Remote WTI for HV,IV,LV & OTI checked on control panel	Ok/ Not Ok

8. Over Flux Relay

HV VT Ratio

As per Scheme: ______________, At Field: ________________, In Relay: __________________

IV VT Ratio

As per Scheme: ______________, At Field: ________________, In Relay: __________________

i	HV Side Overflux: Checking of Pick up drop off value (Alarm) (all values in % / pu)	Ok/ Not Ok
ii	IV Side Overflux: Checking of Pick up drop off value (Trip) (all values in % / pu).	Ok/ Not Ok

HV Side Overflux (Alarm):

Phase	Set Pickup Value	Test pickup Value	drop off Value
R1-N			
Y1-N			
B1-N			

IV Side Overflux (Trip):

Phase	Set Pickup	Test pickup	drop off Value

		Value	Value			
	R1-N					
	Y1-N					
	B1-N					

9. **Directional Back-Up O/C & E/F Relay**

CT Ratio

As per Scheme: ______________, At Field: ________________, In Relay: __________________

VT Ratio

As per Scheme: ______________, At Field: ________________, In Relay: __________________

i	Check Voltage-Current Circuit (Ir –V……., Iy – V……., Ib – V………)	
ii	Check the measurement of Voltage and Current	Ok/ Not Ok
iii	Check Directional element Operation	Ok/ Not Ok

Over Current:

Phase	Set RCA (deg)	Set ROA (Deg)	Actual Operating Area (Deg)
R-Y			
Y-B			
B-R			
R-Y-B			

Earth Fault:

Phase	Set RCA (deg)	Set ROA (Deg)	Actual Operating Area (Deg)
R-N			
Y-N			
B-N			

iv	Check operating time (T-op) with different operating current	Ok/ Not Ok

Over Current:

Phase	Operating current	Calculated T-op (ms)	Actual T-op (ms)
R-Y	2 X Pick up Current		
	10 X Pick up Current		
Y-B			
B-R			
R-Y-B			

<table>
<tr><td></td><td>Earth Fault:
<table>
<tr><th>Phase</th><th>Operating current</th><th>Calculated T-op (ms)</th><th>Actual T-op (ms)</th></tr>
<tr><td rowspan="2">R-N</td><td>2 X Pick up Current</td><td></td><td></td></tr>
<tr><td>10 X Pick up Current</td><td></td><td></td></tr>
<tr><td>Y-N</td><td></td><td></td><td></td></tr>
<tr><td>B-N</td><td></td><td></td><td></td></tr>
</table>
</td><td></td></tr>
<tr><td>v</td><td>Attach DR and Event logs</td><td>Yes / No</td></tr>
</table>

10. Final Documentation Review

S.No.	Description	Status (Yes/ No)	Remarks(Record deficiencies, if any)
1.	Final document of Pre-commissioning checks reviewed and approved		
2.	Documents regarding spares, equipment, factory reports, O&M manuals etc. available at site for O&M purpose		
3.	After modification, if any, “As built drawing are available at site		

Signature:	**Signature:**	**Signature:**	**Signature:**
Name:	**Name:**	**Name:**	**Name:**
Desgn.:	**Desgn.:**	**Desgn.:**	**Desgn.:**
Organization: (Supplier Representative) (Wherever Applicable)	**(Erection Agency)**	**(POWERGRID Site I/C)**	**(POWERGRID Commg. Team) Members: 1. 2. 3. 4.**

Appendix-F
BUSBAR PROTECTION

General Details

Region:	**Sub-Station:**
Feeder Name:	**LOA No. :**
Date of testing:	**Date of Energisation:**
Relay Name	

CT Ratio

As per Scheme: _________________, At Field: ________________, In Relay: __________________

i	Check that the Bus-Bar Bay selection is independent of the Isolator/ CB status in One and Half CB schemes.	Ok/ Not Ok
ii	Check that CB status is permanently shorted for Close status in one and half CB scheme. The CB status shorting is specifically required wherever CB "SPS (Single Point Status)" is only available.	Ok/ Not Ok
iii	Check the operation of the Bus-Bar selector switch and correct alarms in SCADA.	Ok/ Not Ok
iv	Check the settings and Configuration of the CU with respect to approved settings/scheme	Ok/ Not Ok
v	a) Simulate PU disconnected and check for Bus Bar Block. b) Put the PU "Out of service" in CU and simulate PU Disconnected for the same PU. The Bus-bar should not get blocked.	Ok/ Not Ok
vi	For Step V above, check that relevant alarms have appeared in SCADA.	Ok/ Not Ok
vii	Check the logic as per scheme for Busbar Tripping on SF6 Gas compartment zone trip in case of GIS Station.	Ok/ Not Ok
viii	Simulate GD trip logic and check that Busbar trip is issued when associated isolator is closed, and no tripping is issued when the associated isolator is open.	Ok/ Not Ok
ix	Check the that Manual Trip enable/Disable has been provided in SCADA for Enabling & Disabling Busbar GD External Trip initiation in Busbar protection.	Ok/ Not Ok
x	Check that single phase LBB initiation is wired and configured correctly for Transmission Lines.	Ok/ Not Ok
xi	Check the logic that "re-trip" trips the same breaker.	Ok/ Not Ok

<table>
<tr><td>xii</td><td>Check the Signal Matrix/PSL/Application Configuration with respect to the Input and Output assignment as per scheme.</td><td>Ok/ Not Ok</td></tr>
<tr><td>xiii</td><td>Check the logic that “back-trip” trips the associated bus-bar.</td><td>Ok/ Not Ok</td></tr>
<tr><td>xiv</td><td>In case of half dia, check that the Tie Bay LBB instantaneously trips the Bus connected to future bay (also check the wiring).</td><td>Ok/ Not Ok</td></tr>
<tr><td>xv</td><td>For bays commissioned in the extension projects have Tie-LBB wiring changed from “Tripping the bus” to “Tripping the Main CB” and remote tripping / intertripping as applicable.</td><td>Ok/ Not Ok</td></tr>
<tr><td>xvi</td><td>Check Dead Zone/ End zone Protection is disabled</td><td>Ok/ Not Ok</td></tr>
<tr><td>xvii</td><td>Check/measure phase wise current as well as I-N Neutral current in LBB/PU relay.</td><td>Ok/ Not Ok</td></tr>
<tr><td>xviii</td><td>Simulate Zone -1 & 2 “merged/interconnected” alarm for DMT/DM /Bus Sectionalizer scheme by close status of both isolators and validate whether the same is reporting in SAS events and the relay.</td><td>Yes/ No</td></tr>
<tr><td>xix</td><td>Simulate isolator discrepancy alarm through intermediate status of isolators and validate whether the same is reporting in SAS events and the relay.</td><td>Yes/ No</td></tr>
<tr><td>xx</td><td>Check that all the Trip contacts of the PU are LATCHING type and Reset from SCADA is working.</td><td>Ok/ Not Ok</td></tr>
<tr><td>xxi</td><td>CB Close Interlock in case of BB Trip Checked for all applicable CB’s (As per scheme, wherever applicable)</td><td>Ok/ Not Ok</td></tr>
<tr><td>xxii</td><td>Standalone LBB relays should have selected DC supply source.</td><td>Ok/ Not Ok</td></tr>
<tr><td>xxiii</td><td>Check Operate Value/ Operate Timing for Differential function by phase wise current injection.
<table>
<tr><th>ZONE</th><th>Phase</th><th>Set Pickup Value (mA)</th><th>Test pickup Value (mA)</th><th>Operating Time (ms)</th></tr>
<tr><td rowspan="3">Zone-A/B/C</td><td>R - Ph</td><td></td><td></td><td></td></tr>
<tr><td>Y - Ph</td><td></td><td></td><td></td></tr>
<tr><td>B - Ph</td><td></td><td></td><td></td></tr>
<tr><td rowspan="3">Check Zone</td><td>R - Ph</td><td></td><td></td><td></td></tr>
<tr><td>Y - Ph</td><td></td><td></td><td></td></tr>
<tr><td>B - Ph</td><td></td><td></td><td></td></tr>
</table></td><td>Ok/ Not Ok</td></tr>
<tr><td>xxiv</td><td>Check Operate Value/ Operate Timing for CT supervision/ CT fail/ CT circuitry fault alarm
<table>
<tr><th>Phase</th><th>Set Pickup Value (mA)</th><th>Test pickup Value (mA)</th><th>Operating Time (s)</th></tr>
<tr><td>R – Ph</td><td></td><td></td><td></td></tr>
<tr><td>Y – Ph</td><td></td><td></td><td></td></tr>
<tr><td>B – Ph</td><td></td><td></td><td></td></tr>
</table></td><td>Ok/ Not Ok</td></tr>
</table>

<table>
<tr><td>xxv</td><td>Check the DT send Signal as per BusBar/LBB scheme
Counter Value Before Testing:
Counter Value After Testing:</td><td>Yes/ No</td></tr>
<tr><td>xxvi</td><td>Check the DT send Signal as per BusBar/LBB scheme
Counter Value Before Testing:
Counter Value After Testing:</td><td>Yes/ No</td></tr>
<tr><td>xxvii</td><td>Check the DT send Signal as per BusBar/LBB scheme
Counter Value Before Testing:
Counter Value After Testing:</td><td>Yes/ No</td></tr>
<tr><td>xxviii</td><td>Check Biasing percentage, Operate Value at inflection points of characteristic boundary including High set feature if applicable for all Phase combinations (all values are in Amps)
<table>
<tr><th>Phase</th><th>Operating Current Calculated</th><th>Restraining Current Calculated</th><th>Operating Current Actual</th><th>Restraining Current Actual</th></tr>
<tr><td>R-N</td><td></td><td></td><td></td><td></td></tr>
<tr><td>..</td><td></td><td></td><td></td><td></td></tr>
<tr><td>R-Y</td><td></td><td></td><td></td><td></td></tr>
<tr><td>..</td><td></td><td></td><td></td><td></td></tr>
<tr><td>R-Y-B</td><td></td><td></td><td></td><td></td></tr>
</table></td><td>Ok/ Not Ok</td></tr>
<tr><td>xxix</td><td>Verify stabilizing resistor & Metrosil connection (wherever applicable)</td><td>Ok/ Not Ok</td></tr>
<tr><td>xxx</td><td>Ensure LBB Retrip & Backtrip timers should start only after LBB Current pickup along with LBB initiation. Reset of LBB Current should reset LBB function.</td><td></td></tr>
<tr><td>xxxi</td><td>Check Operate Value/Reset Value/Operate Timing for all phases of LBB function for each bay and record it
Under External Initiation:
<table>
<tr><th colspan="5">A. Pickup Test (in mA)</th></tr>
<tr><td>LBB</td><td>Phase</td><td>Setting Current</td><td>Pickup Current</td><td>Reset Current</td></tr>
<tr><td>Stage-I (re-trip)</td><td>R/Y/B</td><td></td><td></td><td></td></tr>
<tr><td>Stage-II</td><td>R/Y/B</td><td></td><td></td><td></td></tr>
</table>
<table>
<tr><th colspan="4">B. Timing Test (in ms)</th></tr>
<tr><td>LBB</td><td>Phase</td><td>Set Time Delay</td><td>Measured Time Delay</td></tr>
<tr><td>Stage-I (re-trip)</td><td>R/Y/B</td><td></td><td></td></tr>
<tr><td>Stage-II</td><td>R/Y/B</td><td></td><td></td></tr>
</table></td><td>Ok/ Not Ok</td></tr>
</table>

	Under Internal Initiation: Inject current to operate Bus Bar Differential Relay till LBB Stage II operates and measure the operating time. **A. Timing Test (in ms)**	
xxxii	LBB/BFR trip checked & extended to Zone-A	
	From CB No...............	Ok/ Not Ok
	From CB No...............	Ok/ Not Ok
	From CB No...............	Ok/ Not Ok
xxxiii	LBB/BFR trip checked & extended to Zone-B	
	From CB No...............	Ok/ Not Ok
	From CB No...............	Ok/ Not Ok
	From CB No...............	Ok/ Not Ok
xxxiv	Check “Single & 3-phase LBB initiation” is getting extended to LBB relay.	Ok/ Not Ok
xxxv	Check that the LBB initiation is reaching the LBB relay for Busbar differential trip signal	
xxxvi	Check for proper programming of Input / Output contacts of the relay as per approved schematics.	Ok/ Not Ok

A. Timing Test (in ms)

LBB	Phase	Set Time Delay	Measured Time Delay
Stage-I (re-trip)	R/Y/B		
Stage-II	R/Y/B		

xxxiv:

LBB initiation contact	Initiation received at LBB relay(Yes/No)
R-phase	
Y-phase	
B-phase	

xxxv:

LBB initiation contact	Initiation received at LBB relay(Yes/No)
R-phase	
Y-phase	
B-phase	

xxxvi:

BI or BO Number	Function as Per Scheme	Function as per Configuration
BI#01		
BI#02		
…		
…		

xxxvii	DC selection working properly for DC-I & II	Yes/ No
xxxviii	DR and Event Log enclosed for each bay BB & LBB operation	Yes/ No
xxxix	Test results enclosed & accepted	Yes/ No

Signature:	**Signature:**	**Signature:**	**Signature:**
Name:	**Name:**	**Name:**	**Name:**
Desgn.:	**Desgn.:**	**Desgn.:**	**Desgn.:**
Organization: (Supplier Representative) (Wherever Applicable)	**(Erection Agency)**	**(POWERGRID Site I/C)**	**(POWERGRID Commg. Team) Members:** **1.** **2.** **3.** **4.**

Appendix-G
CHECKS FOR PLCC

Region:	**Sub-Station:**
Feeder Name:	**LOA No. :**
Date of testing:	**Make:**
Direction:	**Frequency:**
Cabinet No.	**Equipment Sr. No.**

1. General test

i	End to end Return Loss Measured (Attach separate sheet of results)	Yes/ No
ii	End to end attenuation Tests done (Attach separate sheet of results)	Yes/ No
iii	Composite loss (attenuation) measured for HF cable coupling device	Yes/ No
iv	Composite loss and return loss on coupling device using dummy load	Yes/ No
v	Measurement of AF frequency response (end to end) for the entire 4Khz bandwidth for speech and tele-protection channels	Yes/ No
vi	Measurement of Signal to Noise ratio with line energized condition.	Yes/ No
vii	Transmission time for tele-protection and other data channels	Yes/ No
viii	Observation of Tx/Rx levels (test tone) for each channel at both ends by sequential switching on/off parallel channels using dummy load and also with transmission line	Yes/ No
ix	Observation of end to end and trunk dialing performance	Yes/ No
x	Observation of unwarranted commands sent & received during switchyard operations	Yes/ No

2. Carrier SET Check List

a. Power Supply (Voltage as applicable)

i	48V POWER SUPPLY	Ok/ Not Ok
ii	60V POWER SUPPLY	Ok/ Not Ok
iii	+12V POWER SUPPLY	Ok/ Not Ok
iv	(-)12V POWER SUPPLY	Ok/ Not Ok
v	+5V POWER SUPPLY	Ok/ Not Ok

b. Ripple test

i	+12 V Ripplettes	Ok/ Not Ok
ii	(-) 12 V Ripple test	Ok/ Not Ok
iii	+5V Ripple test	Ok/ Not Ok

c. Freq generation check

i	System clock checked	Ok/ Not Ok
ii	Tx carrier Hz checked	Ok/ Not Ok
iii	Rx carrier Hz checked	Ok/ Not Ok
iv	Pilot freq. checked	Ok/ Not Ok

3. Transmitter

a.	**AF signal level**		
	i	Pilot	Ok/ Not Ok
	ii	Check Pressing test button	Ok/ Not Ok
	iii	Test tone checked	Ok/ Not Ok
b.		**Tx RF setting done**	Yes/ No
c.		Output Power/ Boosting checked	Ok/ Not Ok
d.		Tx alarm threshold checked	Ok/ Not Ok
e.		Tx alarm indication checked	Ok/ Not Ok

4. Receiver

i	Standard AGC setting done	Ok/ Not Ok
ii	Af rx level setting done	Ok/ Not Ok
iii	AGC test done	Ok/ Not Ok
iv	Remote Loop check done	Ok/ Not Ok
v	Rx alarm indication(interrupting RF Line)	Ok/ Not Ok

5. Telephony

i.	**TX Level Check**	Ok/ Not Ok
a.	4 wire IN Checked	Ok/ Not Ok
b.	2Wire in Checked	Ok/ Not Ok
ii.	**RX Level Check Feeding from Opposite Station**	Ok/ Not Ok
a.	4 wire Out Checked at 600Ohm	Ok/ Not Ok
b.	4 wire Out Checked at 600Ohm	Ok/ Not Ok
iii	Dialing Chanel Checked	Ok/ Not Ok
iv	Service Telephone checked	Ok/ Not Ok
v	Frequency Response across 600 Ohm (Attach separate sheet of results)	Ok/ Not Ok
vi	**Tele-operation:**	
a.	TX Level Check Done	Ok/ Not Ok
b.	Rx Level check done	Ok/ Not Ok

6. Digital Protection Coupler Check

i	Code-1 Transmit	Ok/ Not Ok
ii	Code-1 Receive	Ok/ Not Ok
iii	Code-2 Transmit	Ok/ Not Ok
iv	Code-2 Receive	Ok/ Not Ok
v	Code-3 Transmit	Ok/ Not Ok
vi	Code-3 Receive	Ok/ Not Ok
vii	Code-4 Transmit	Ok/ Not Ok
viii	Code-4 Receive	Ok/ Not Ok
ix	Visible Trip counter increment checked	Ok/Not Ok
x	Internal Event log enclosed	Yes/No

7. Analog Protection Coupler Check

a. Measurements

i	All LED Indications Checked	Ok/ Not Ok
ii	Transmit Level checked	Ok/ Not Ok
iii	Boost ratio Measured Boost ratio………………………	Ok/ Not Ok
iv	Muting of Speech Checked	Ok/ Not Ok

b. Command Transmission checking

i	RX Trip A	
	Command Transmission Time	……….ms
	Command Prolongation Time	……….ms
ii	Aux A Command Transmission Time	……….ms
iii	RX Trip B	
	Command Transmission Time	……….ms
	Command Prolongation Time	……….ms
iv	Aux B Command Transmission Time	……….ms
	Same for Trip C & D	
v	Trip Counters checked	Ok/ Not Ok
vi	All Alarms Checked	Ok/ Not Ok
vii	Loop test Done	Ok/ Not Ok
viii	End to End test Done	Ok/ Not Ok

8. Final Documentation Review

S.No.	Description	Status (Yes/ No)	Remarks(Record deficiencies, if any)
1.	Final document of Pre-commissioning checks reviewed and approved		
2.	Documents regarding spares, equipment, factory reports, O&M manuals etc. available at site for O&M purpose		
3.	After modification, if any, "As built drawing are available at site		

Signature:	**Signature:**	**Signature:**	**Signature:**
Name:	**Name:**	**Name:**	**Name:**
Desgn.:	**Desgn.:**	**Desgn.:**	**Desgn.:**
Organization: (Supplier Representative) (Wherever Applicable)	**(Erection Agency)**	**(POWERGRID Site I/C)**	**(POWERGRID Commg. Team) Members: 1. 2. 3. 4.**

Appendix-H
SUBSTATION AUTOMATION SYSTEM

Region:	**Sub-Station:**
Feeder Name:	**LOA No. :**
Date of testing:	**Make:**
Direction:	**Frequency:**
Cabinet No.	**Eqpt Sr. No.**

1. Availability of Items

i.	Check availability of all the IEDs, GPS Clock, Gateway, Computers & Servers, Peripherals, Network Switches, Modems and various communication hardware etc. as per Scheme	Ok/ Not Ok
ii.	Check availability of all the original softwares for PC/ Servers (OS + Application Softwares), IEDs, Switches, Gateway etc. as per the scheme	Ok/ Not Ok
iii.	Check the originality/ authenticity of all the hardware & software items for POWERGRID approval.	Ok/ Not Ok
iv.	Check the validity of license of softwares/ hardware keys.	Ok/ Not Ok

2. Communication Setup

i	Check laying & termination of optical fiber as per approved	Ok/ Not Ok
ii	Check the proper tagging of optical fiber cable for identifying the origin and termination.	Ok/ Not Ok
iii	Check the LAN switches for proper installation & configuration as per scheme e.g. IP address is entered correctly, ports of Network switches are correctly configured as per requirement, satisfactory working of all the ports etc. Keep the records of all IP addresses.	Ok/ Not Ok
iv	Check dual DC power supply to all Network switches.	Ok/ Not Ok
v	Check all the PCs & printers are connected over Ethernet LAN and functioning properly.	Ok/ Not Ok
vi	Check the satisfactory working of dual LAN as per scheme	Ok/ Not Ok
vii	Check for the alarm if any link failure(fiber cut)	Ok/ Not Ok
viii	Check communication of all IEDs through Network switches as per the allocated IP address.	Ok/ Not Ok
ix	Check the functionality & running of original NMS software.	Ok/ Not Ok
x	Check the NMS software is monitoring the healthiness of Network switches/ IEDs.	Ok/ Not Ok
xi	Check communication between GATEWAY & SAS PC.	Ok/ Not Ok

xii	Check the communication between GATEWAY and PLCC data channel.	Ok/ Not Ok
xiii	Check the communication of each IED with Both SAS PCs individually.	Ok/ Not Ok
xiv	Check communication of each IED with DR PC.	Ok/ Not Ok
xv	Check the availability of spare cores in the armoured fiber optic cable as per specifications.	Ok/ Not Ok

3. Time Synchronization

i	Check proper installation and configuration of GPS and associated hardware like antenna etc	Ok/ Not Ok
ii	Check the availability of Time Synchronization Signal in the LAN through SNTP	Ok/ Not Ok
iii	Check the synchronizing of each IED /Server with GPS.	Ok/ Not Ok
iv	Check for alarm in case of failure of time synchronizing	Ok/ Not Ok

4. IED Setup

i	Check the availability of list of names of IEDs and their front/rear port address	Ok/
ii	Check IP address of all IEDs correctly entered.	Ok/
iii	Check the proper installation and configuration of all IEDs (as per their proprietary softwares) and Preparation of their ICD files for integration in the S/S SCD file.	Ok/ Not
iv	Check the GOOSE function (Analog/Binary) for each IEDs and correctness of the same.	Ok/
v	Check SLD in IED HMI for correctness of same as per approved drawing.	Ok/
vi	Check each IED (for line/transformer/reactor/Bus-Bar/BCU) are correctly tested for every protection requirement of scheme.	Ok/
vii	Check loading of setting through local as well as remote.	Ok/
viii	Check availability of all setting address as per the relay setting received from CC-engg.	Ok/
ix	Check the operation of protection system and subsequent alarm at remote Local/HMI.	Ok/
x	Check the availability of alarms/events as per the POWERGRID requirement.	Ok/
xi	Check the Auto-downloading of DR Fault file in case of disturbance.	Ok/

5. Interlocking & Logic Setup (Through concerned BCUs)

i	Check configuration & working of all soft interlocks for CBs, Isolators, Earth Switches including Bus Isolators as per protection schemes.	Ok/ Not Ok

ii	Check configuration & working of all soft logics for Synchronization (DLDB, LLDB, LLLB, DLLB), Voltage Selection, Protection Transfer for DMT, Auto-sequencing etc. as per protection schemes.	Ok/ Not Ok

6. SCADA Setup

i	Check the proper integration of all IEDs and their ICD files in the S/S SCD file.	Ok/ Not Ok
ii	Check the building up of database as per approved point list	Ok/ Not Ok
iii	Check the correctness of HMI SLD for all bays/ feeders in both SAS PCs.	Ok/ Not Ok
iv	Check the correctness of operation of CB, Isolators &Tap changing operation through HMI SLD of both SAS PCs.	Ok/ Not Ok
v	Check that the status of CB,Isolators should change immediately in HMI after performing operation.	Ok/ Not Ok
vi	Check raising of audio alarm with SCADA alarm state for each breaker opening operation at HMI.	Ok/ Not Ok
vii	Check the PLCC,CB operation counters are correctly changing with operation.	Ok/ Not Ok
viii	Check the blocking of operation of bay equipments in case of issue of PTW through both SAS HMIs.	Ok/ Not Ok
ix	Check the availability of SLD of LT switchgear and operation of the same through local/remote. Check separate Pages for the LT system(MSB, LVAC, DG) and associated alarm signals in the same Page.	Ok/ Not Ok
x	Check all measurement functions (Current,Voltage,MW,MVA) and their correctness in local/remote HMI.	Ok/ Not Ok
xi	Check the availability of OTI, WTI readings of ICTs on HMI & correctness of same.	Ok/ Not Ok
xii	Check the availability of voltage & current of both auxiliary DC systems sources .	Ok/ Not Ok
xiii	Check the DG alarm/trip & fire fightning signals are coming in SAS HMI. Fire Fighting system signals from each zone, Jockey pump 1 & 2 operation, HVW operation, DG alarms, Deluge operated, Running/Stop commands should be given in separate page and ensure all the operation done in remote	Ok/ Not Ok
xiv	Check the monitoring of Kiosk AC/ kiosk temperature through both SAS HMI.	Ok/ Not Ok
xv	Check the colour coding of measurement parameters (Voltage,current,MW,MVAr,f etc.) if the values increases above a pre-set value with generation of audio/visual alarm.	Ok/ Not Ok

xvi	Check colour coding of SLD i.e. energized section will be in one colour and un-energized section will be in different colour.	Ok/ Not Ok
xvii	Check supervision of each IED on HMI of SAS PCs.	Ok/ Not Ok
xviii	Check Hot-stand by function availability between the SAS PCs.	Ok/ Not Ok
xix	Check after restoring of Master server, all the data must be transferred to Master server from slave server in a quick time as per HOT STAND By feature.	Ok/ Not Ok
xx	Check there should not be missing of any events during transfer from both Main to STANDBY and STANDBY to Main.	Ok/ Not Ok
xxi	Check provision of auto data backup & storage of monthly data backup.	Ok/ Not Ok
xxii	Check the correctness of alarm list and event list and proper sequencing of alarms/events.	Ok/ Not Ok
xxiii	Check weather all the events in event list are timely punched with milli second data.	Ok/ Not Ok
xxiv	Check the alarm/events of Auxiliary system are included in alarm/event list.	Ok/ Not Ok
xxv	Check that the SAS configuration tool should be password protected.	Ok/ Not Ok
xxvi	Check for any error signal while operating/running any software or performing any operation on SAS PC.	Ok/ Not Ok
xxvii	Check that basic training has been given to local operation staff so that in case of emergency they will be able to start the SAS PC in case of shut-down.	Ok/ Not Ok
xxviii	Check there should be no interruption in availability test.	Ok/ Not Ok
xxix	Check the Acknowledged alarms should shift to acknowledge window & persisting alarms should be in red colour with blinking of the same.	Ok/ Not Ok
xxx	Check the colour code of the acknowledged but persisting alarm.	Ok/ Not Ok
xxxi	Check the nomenclature of events and alarms for user friendliness.	Ok/ Not Ok
xxxii	Check the availability of backup of latest version configuration for ICD, SCD files, IED basic configuration, HMI server database etc.	Ok/ Not Ok

xxxiii	Ensure creation of appropriate restore points for each workstation in the substation after completion of commissioning.	Ok/ Not Ok

7. Trends & Reports Setup

i	Check all the operation formats are as per POWERGRID formats.	Ok/ Not Ok
ii	Check the reports generated by SAS PC are as per the requirement like max. & min. readings of voltage, MW, MVAR, MVA, Frequency, current etc. for a 24 hour period.	Ok/ Not Ok
iii	Check the reports/trends can be selected/filtered for any time period (date wise) specified by user.	Ok/ Not Ok
iv	Check the availability of measurements reports at desired interval of (15, 30,45 & 60 minutes) & correctness of the same.	Ok/ Not Ok
v	Check the trend display for each parameter(MW, MVA, MVAr, f, V, I etc.) at any time and at a interval selected by user.	Ok/ Not Ok

8. Remote Operation & RLDC reporting

i	Check that Gateway has been installed and configured properly and is working satisfactorily.	Ok/ Not Ok
ii	Check the Gateway Configuration as per approved interoperability profile of RLDC.	Ok/ Not Ok
iii	Check the healthiness of communication between Gateway and RLDC for both channels	Ok/ Not Ok
iv	Verify the data transfer to RLDC by point to point checking as well as at local level through Protocol Analyser	Ok/ Not Ok
v	Check that the online parameters on local/remote SLD like current, voltage, MW, MVAr, frequency etc are getting updated.	Ok/ Not Ok
vi	Check the operation of equipments/alarms/events for remote controlled ss.	Ok/ Not Ok
vii	Check the status of CBs & Isolators should be available at RLDC and if any link fails then alarm should be generated.	Ok/ Not Ok

viii	If SAS S/S has to be remote controlled then check authenticity of operation from Local & remote end(i.e When control is in hand of RCC, all local operation should be blocked and vice versa)	Ok/ Not Ok
ix	Check that in case of failure of one channel, changeover at remote end happens automatically and no interruption in data flow to Remote end occurs.	Ok/ Not Ok
x	Check for availability of final approved signal list for 101 communication with all details.	Ok/ Not Ok

9. Final Documentation Review

S.No.	Description	Status (Yes/ No)	Remarks(Record deficiencies, if any)
1.	Final document of Pre-commissioning checks reviewed and approved		
2.	Documents regarding spares, equipment, factory reports, O&M manuals etc. available at site for O&M purpose		
3.	After modification, if any, "As built drawing are available at site		

Signature:	**Signature:**	**Signature:**	**Signature:**
Name:	**Name:**	**Name:**	**Name:**
Desgn.:	**Desgn.:**	**Desgn.:**	**Desgn.:**
Organization: (Supplier Representative) (Wherever Applicable)	**(Erection Agency)**	**(POWERGRID Site I/C)**	**(POWERGRID Commg. Team) Members:** **1.** **2.** **3.** **4.**

Annexure-I

i. CHECK LIST FOR TESTING OF DISTRIBUTED BB&LBB PROTECTION (ONE & HALF CB SCHEME)

Part- (a)

NAME OF THE STATION	…………………………………………
DETAILS OF BUS UNDER TEST	…………………………………………

1. Pre-Test Check List (To be done well in advance of the testing activity, signed checklist to be sent to RHQ for concurrence)

S.No.	Description	Status (Yes/ No)
I.	Identify the bus to be tested & give requisition for the S/D of the same.	Yes/ No
II.	Ensure that the commissioning team shall do the testing and Substation In-Charge shall be present in the station on the day of testing.	Yes/No
III.	Verify the wiring and input/output contact assignment of the Busbar/LBB relays as per the scheme.	Yes/ No
IV.	Check the bus bar relay settings as per approved relay settings.	Yes/ No
V.	Check for any pending alarms or annunciations in the bus bar/LBB relays.	Yes/ No
VI.	Check for the integrity of the current values in the bus bar relays. (Both in the PU or Bay unit HMI as well as the software by taking the relay online).	Yes/ No
VII.	Verify that the topology in the Busbar Central unit is correct. Ensure correct status of Isolator and Breakers in the Busbar protection	Yes/ No

2. Check the schematic for the bus bar protection and LBB protection and validate the configuration/programming of the Bus Bar Peripheral unit, LBB relays that the following logic exists. (**For Main CB + Tie CB i.e. Bus-Bar is connected to Main CB).**

I.	Bus Bar protection operation shall trip the connected Main CB only	Yes/ No

II.	Bus Bar protection operation MUST NOT trip the Tie CB and other main CB.	Yes/ No
III.	Bus Bar protection operation shall send DT to remote end ONLY if the Tie CB is open(In case of transmission line)	Yes/ No
IV.	Bus Bar protection operation shall send Inter-Trip to other end of ICT, ONLY if the Tie CB is open(In case of Transformer)	Yes/ No
V.	Main Bay CB LBB operation i. shall issue 3-pole trip to the main CB after re-trip delay(100ms) and ii. shall trip all the CBs of associated Bus after a back-trip delay(200ms) iii. Send DT to other end of the associated line/Send Inter-trip to other end of the ICT as applicable. iv. Extend the trip to Associated Tie CB	Yes/ No
VI.	LBB operation for Tie CB i. shall issue 3-pole trip to the Tie CB after re-trip delay(100ms) and ii. Shall trip Both the Main CBs in the dia after a back-trip delay(200ms). iii. Shall send DT/Inter-trip to both Line/ICT in the Dia.	Yes/ No
VII.	Ensure signal availability for busbar protection related alarms to SAS/NTAMC as per Signal list	Yes/ No

3. Check the schematic for the bus bar protection and LBB protection and validate the configuration/programming of the BusBar Peripheral unit, LBB relays that the following logic exists. **(Future Bay + TieCB i.e. Bus-Bar is connected to Tie Bay)**

I.	Bus Bar protection shall take Tie Bay CT current as input.	Yes/ No
II.	Busbar protection operation shall trip the Tie CB only	Yes/ No
III.	Bus Bar protection operation shall send DT to remote end ONLY if the Main CB is open(In case of transmission line) if Tie CB is connected to Busbar	Yes/ No
IV.	Bus Bar protection operation shall send Inter-Trip to other end of ICT, ONLY if the Main CB is open(In case of Transformer) if Tie CB is connected to Busbar	Yes/ No
V.	LBB operation for Tie CB i. Shall issue 3-pole trip to the Tie CB after retrip delay(100ms) and ii. Shall trip the other Main CB in the Dia and all the CBs connected to the bus (Bus connected to future bay) after Backtrip Delay (200ms). iii. Shall send DT/Intertrip to Line/ICT in the Dia.	Yes/ No

VI.	Check that in case of PU for "Future Bay", Tie LBB Trip signal is configured through "External LBB/CBF Trip" function and not through "PU->CU Signal". If PU->CU signal is used for LBB/CBF, suitable changes to be done during testing	Yes/ No
VII.	Ensure signal availability for busbar protection related alarms to SAS/NTAMC as per Signal list	Yes/ No

4. **Other logic**

I.	DT send circuit, associated with BB/LBB, checked(End to End)	Yes/ No
II.	Zone Tripping from GD (For GIS/AIS with SF6 CT) checked & verified. Ensure the Manual Trip Enable/Disable for GD Bus zone trip to Busbar logic implemented via SAS HMI & Busbar CUA/CUB relay for both Bus-1 & 2 as per the IOM.	Yes/ No

Part- (b)

NAME OF THE STATION	....
DETAILS OF BUS UNDER TEST	....

1. **<u>Checks to be done during BusBar/Main Bay LBB testing(If Main-1 Protection under Testing for Bus-1, Main-2 protection must be in service)</u>**

S.No.	**Description**	**Status (Yes/ No)**
I.	After taking the Bus Shutdown, Respective bays connected to the Bus has to be isolated.	Yes/ No
II.	Ensure that Main-2 protection is healthy and no alarm is persisting.	Yes/ No
III.	Put Bus-Bar Protection of Main-1 Protection Bus-I & II out of Service. Check the same through SCADA event and Central Unit relay HMI display.	Yes/ No
IV.	One of the fibres (Tx/Rx) of all the existing PUAs (Except PUA of Bus-1) needs to be removed and check for PU error/fibre comm. Error etc.	Yes/ No
V.	All the PUAs (except Bus-1) need to be taken out of service in configuration of CUA (Bus Bar Central Unit).	Yes/ No
VI.	Check for reset of all the communication alarms and selector switch of Bus-II to be put back into service.	Yes/ No

VII.	All the alarms should be reset. The same need to be verified through event log of relays/SAS	Yes/ No
VIII.	Make the setup for the said testing and ensure all the connections are properly connected especially the current wires and the feedback cable. In addition, the output contact where feedback cable is connected is masked in the PSL/configuration matrix for the required protection function.	Yes/ No
IX.	Ensure that for Re-trip and Bus-bar differential test, the fault duration in Testing Kit is configured as 150ms only	Yes/ No
X.	Do the necessary Busbar and LBB Testing.	Yes/ No
XI.	Ensure signal reporting for busbar protection related alarms to SAS/NTAMC as per Signal list	Yes/ No

2. Normalization

S.No.	Description	Status (Yes/ No)
I.	Check that no Peripheral Units/ Bus Bar Relay/LBB relay is having any alarm.	Yes/ No
II.	Put Main-I Bus-I & II, Bus Bar protection out of service using Selector Switch	Yes/ No
III.	Put all the PUAs “in service” in the configuration of Busbar relay.	Yes/ No
IV.	Connect all the removed Fibres of the PUAs.	Yes/ No
V.	Check that the Busbar protection/LBB relay does not have any alarm.	Yes/ No
VI.	Put Main-I Bus-II, Busbar protection in service using Selector Switch	Yes/ No
VII.	All the alarms should be reset. The same need to be verified through event log of relays/SAS	Yes/ No

Note: Testing to be carried out for both Main1 & Main-2 Bus bar protections of each bus

Signature:	**Signature:**	**Signature:**	**Signature:**
Name:	**Name:**	**Name:**	**Name:**
Desgn.:	**Desgn.:**	**Desgn.:**	**Desgn.:**
Organization: (Supplier Representative) (Wherever Applicable)	**(Erection Agency)**	**(POWERGRID Site I/C)**	**(POWERGRID Commg. Team) Members:** **1.** **2.**

ii. CHECK LIST FOR TESTING OF CENTRALIZED BB&LBB PROTECTION (ONE & HALF CB SCHEME)

Part – (a)

NAME OF THE STATION	....
DETAILS OF BUS UNDER TEST	....

1. **Pre-Test Check List (To be done well in advance of the testing activity, signed checklist to be sent to RHQ for concurrence)**

S.No.	Description	Status (Yes/ No)
I.	Identify the bus to be tested & give requisition for the S/D of the same.	Yes/ No
II.	Ensure that the commissioning team shall do the testing and Substation In-Charge shall be present in the station on the day of testing.	Yes/No
III.	Verify the wiring and input/output contact assignment of the Busbar/LBB relays as per the scheme.	Yes/ No
IV.	Check the bus bar relay settings as per approved relay settings.	Yes/ No
V.	Check for any pending alarms or annunciations in the bus bar/LBB relays.	Yes/ No
VI.	Check for the integrity of the current values in the bus bar relays. (Both in the relay HMI as well as the software by taking the relay online).	Yes/ No
VII.	Verify that the topology in the Busbar protection relay is correct. Ensure correct status of Isolator and Breakers in the Busbar protection	Yes/ No

2. Check the schematic for the bus bar protection and LBB protection and validate the configuration/programming of the Busbar protection relay, LBB relays that the following logic exists. (**For Main CB + Tie CB i.e. Bus-Bar is connected to Main CB).**

I.	Bus Bar protection operation shall trip the connected Main CB only	Yes/ No

II.	Bus Bar protection operation MUST NOT trip the Tie CB and other main CB.	Yes/ No
III.	Bus Bar protection operation shall send DT to remote end ONLY if the Tie CB is open(In case of transmission line)	Yes/ No
IV.	Bus Bar protection operation shall send Inter-Trip to other end of ICT, ONLY if the Tie CB is open(In case of Transformer)	Yes/ No
V.	Main Bay CB LBB operation i. shall trip the main CB after re-trip delay(100ms) and ii. shall trip all the CBs of associated Bus after a back-trip delay(200ms) iii. Send DT to other end of the associated line/Send Inter-trip to other end of the ICT as applicable. iv. Extend the trip to Associated Tie CB	Yes/ No
VI.	LBB operation for Tie CB i. shall trip the Tie CB after re-trip delay(100ms) and ii. Shall trip Both the Main CBs in the dia after a back-trip delay (200ms). iii. Shall send DT/Inter-trip to both Line/ICT in the Dia.	Yes/ No
VII.	Ensure signal availability for busbar protection related alarms to SAS/NTAMC as per Signal list	Yes/ No

3. Check the schematic for the bus bar protection and LBB protection and validate the configuration/programming of the Bus Bar Protection Unit, LBB relays that the following logic exists. **(Future Bay + Tie CB i.e. Bus-Bar is connected to Tie Bay)**

I.	Bus Bar protection shall take Tie Bay CT current as input.	Yes/ No
II.	Busbar protection operation shall trip the Tie CB only	Yes/ No
III.	Bus Bar protection operation shall send DT to remote end ONLY if the Main CB is open(In case of transmission line) if Tie CB is connected to Busbar	Yes/ No
IV.	Bus Bar protection operation shall send Inter-Trip to other end of ICT, ONLY if the Main CB is open(In case of Transformer) if Tie CB is connected to Busbar	Yes/ No
V.	LBB operation for Tie CB i. Shall trip the Tie CB after retrip delay(100ms) and ii. Shall trip the other Main CB in the Dia and all the CBs connected to the bus (Bus connected to future bay) after Backtrip Delay (200ms). iii. Shall send DT/Intertrip to Line/ICT in the Dia.	Yes/ No

VI.	Check that in case of "Future Bay", Tie LBB Trip signal is configured through "External LBB/CBF Trip" function and not through "External Logic". If External Logic is used for LBB/CBF, suitable changes to be done during testing	Yes/ No
VII.	Ensure signal availability for busbar protection related alarms to SAS/NTAMC as per Signal list	Yes/ No

4. **Other logic**

I.	DT send/Receive circuit, associated with BB/LBB, checked(End to End)	Yes/ No
II.	Zone Tripping from GD(For GIS/AIS with SF6 CT) checked & verified. Ensure the Manual Trip Enable/Disable for GD Bus zone trip to Busbar logic implemented via SAS HMI & Busbar CUA/CUB relay for both Bus-1 & 2 as per the IOM.	Yes/ No

Part – (b)

NAME OF THE STATION	....
DETAILS OF BUS UNDER TEST	....

1. **Checks to be done during BusBar/Main Bay LBB testing(If Main-1 Protection under Testing for Bus-1, Main-2 protection must be in service)**

S.No.	**Description**	**Status (Yes/ No)**
I.	After taking the Bus Shutdown, Respective bays connected to the Bus has to be isolated.	Yes/ No
II.	Ensure that Main-2 protection is healthy and no alarm is persisting.	Yes/ No
III.	Put Bus-Bar Protection of Main-1 Protection Bus-1 & 2 out of Service. Check the same through SCADA event and Central Unit relay HMI display.	Yes/ No
IV.	All the Bays (except Bus-1) need to be taken out of service in configuration of Main-1 Bus Bar Protection relay.	Yes/ No
V.	Check for reset of all the alarms in both Main-1 & 2 and selector switch of Bus-II to be put back into service.	Yes/ No

VI.	All the alarms should be reset. The same need to be verified through event log of relays/SAS	Yes/ No
VII.	Make the setup for the said testing and ensure all the connections are properly connected especially the current wires and the feedback cable. In addition, the output contact where feedback cable is connected is masked in the PSL/configuration matrix for the required protection function.	Yes/ No
VIII.	Ensure that for Re-trip and Bus-bar differential test, the fault duration in Testing Kit is configured as 150ms only	Yes/ No
IX.	Do the necessary Busbar and LBB Testing.	Yes/ No
X.	Ensure signal reporting for busbar protection related alarms to SAS/NTAMC as per Signal list	Yes/ No

2. **Normalization**

S.No.	**Description**	**Status (Yes/ No)**
VIII.	Check that no Bus Bar Relay/LBB relay is having any alarm.	Yes/ No
IX.	Put Main-I Bus-I & II, Bus Bar protection out of service using Selector Switch	Yes/ No
X.	Put all the bay “in service” in the configuration of Busbar relay.	Yes/ No
XI.	Check that the Busbar protection/LBB relay does not have any alarm.	Yes/ No
XII.	Put Main-I Bus-II, Busbar protection in service using Selector Switch	Yes/ No
XIII.	All the alarms should be reset. The same need to be verified through event log of relays/SAS	Yes/ No

Note: Testing to be carried out for both Main1 & Main-2 Bus bar protections of each bus

Signature:	**Signature:**	**Signature:**	**Signature:**
Name:	**Name:**	**Name:**	**Name:**
Desgn.:	**Desgn.:**	**Desgn.:**	**Desgn.:**
Organization: (Supplier Representative) (Wherever Applicable)	**(Erection Agency)**	**(POWERGRID Site I/C)**	**(POWERGRID Commg. Team) Members:** **1.** **2.** **3.** **4.**

iii. CHECK LIST FOR TESTING OF HIGH IMPEDANCE BB&LBB PROTECTION (ONE & HALF CB SCHEME)

Part – (a)

NAME OF THE STATION	…………………………………………
DETAILS OF BUS UNDER TEST	…………………………………………

1. **Pre-Test Check List (To be done well in advance of the testing activity, signed checklist to be sent to RHQ for concurrence)**

S.No.	Description	Status (Yes/ No)
I.	Identify the bus to be tested & give requisition for the S/D of the same.	Yes/ No
II.	Ensure that the commissioning team shall do the testing and Substation In-Charge shall be present in the station on the day of testing.	Yes/No
III.	Verify the wiring and input/output contact wiring of the Busbar/LBB relays as per the scheme.	Yes/ No
IV.	Check the bus bar relay settings as per approved relay settings**.**	Yes/ No
V.	Check for any pending alarms (CT Supervision etc.) or annunciations in the bus bar/LBB relays.	Yes/ No
VI.	Check for the "Spill Voltage" in the bus bar relays. It should be more than zero and lower than the setting of supervision relay.	Yes/ No

2. Check the schematic for the bus bar protection and LBB protection and validate the wiring of the Busbar protection relay, LBB relays that the following logic exists. (**For Main CB+TieCB i.e. Bus-Bar is connected to Main CB).**

I.	Bus Bar protection operation shall trip the connected Main CB only	Yes/ No
II.	Bus Bar protection operation MUST NOT trip the Tie CB and other main CB.	Yes/ No
III.	Bus Bar protection operation shall send DT to remote end ONLY if the Tie CB is open (In case of transmission line)	Yes/ No
IV.	Bus Bar protection operation shall send Inter-Trip to other end of ICT, ONLY if the Tie CB is open (In case of Transformer)	Yes/ No

V.	Main Bay CB LBB operation i. shall trip the main CB after re-trip delay(100ms) and ii. shall trip all the CBs of associated Bus after a back-trip delay(200ms) iii. Send DT to other end of the associated line/Send Inter-trip to other end of the ICT as applicable. iv. Extend the trip to Associated Tie CB	Yes/ No
VI.	LBB operation for Tie CB i. shall trip the Tie CB after re-trip delay(100ms) and ii. Shall trip Both the Main CBs in the dia after a back-trip delay (200ms). iii. Shall send DT/Inter-trip to both Line/ICT in the Dia.	Yes/ No
VII.	Ensure signal availability for busbar protection related alarms to SAS/NTAMC as per Signal list	Yes/ No

3. Check the schematic for the bus bar protection and LBB protection and validate the wiring of the Bus Bar Protection Unit, LBB relays that the following logic exists. **(Future Bay + Tie CB i.e. Bus-Bar is connected to Tie Bay)**

I.	Bus Bar protection shall take Tie Bay CT current as input.	Yes/ No
II.	Busbar protection operation shall trip the Tie CB only	Yes/ No
III.	Bus Bar protection operation shall send DT to remote end ONLY if the Main CB is open(In case of transmission line) if Tie CB is connected to Busbar	Yes/ No
IV.	Bus Bar protection operation shall send Inter-Trip to other end of ICT, ONLY if the Main CB is open(In case of Transformer) if Tie CB is connected to Busbar	Yes/ No
V.	LBB operation for Tie CB i. Shall trip the Tie CB after retrip delay(100ms) and ii. Shall trip the other Main CB in the Dia and all the CBs connected to the bus (Bus connected to future bay) after Backtrip Delay (200ms). iii. Shall send DT/Intertrip to Line/ICT in the Dia.	Yes/ No
VI.	Check that in case of “Future Bay”, Tie LBB Trip signal is wired as “Main LBB/CBF Trip” function.	Yes/ No
VII.	Ensure signal availability for busbar protection related alarms to SAS/NTAMC as per Signal list	Yes/ No

4. **Other logic**

I.	DT send/Receive circuit, associated with BB/LBB, checked (End to End)	Yes/ No
II.	Zone Tripping from GD (For GIS/AIS with SF6 CT) checked & verified. Ensure the Manual Trip Enable/Disable for GD Bus zone trip to Busbar logic implemented via SAS HMI & Busbar CUA/CUB relay for both Bus-1 & 2 as per the IOM.	Yes/ No

Part – (b)

NAME OF THE STATION	**…………………………………………..**
DETAILS OF BUS UNDER TEST	**…………………………………………..**

1. **<u>Checks to be done during BusBar/Main Bay LBB testing(If Protection under Testing for Bus-1, Bus-2 protection must be in service)</u>**

S.No.	Description	Status (Yes/ No)
I.	After taking the Bus Shutdown, Respective bays connected to the Bus has to be isolated.	Yes/ No
II.	Ensure that Main-2 protection is healthy and no alarm is persisting.	Yes/ No
III.	Check the healthiness of secondary CT circuit by DC earth fault locator. To be done alternatively for check zone/Bus-1/2 zones.	Yes/ No
IV.	Put Bus-Bar Protection of Main-1 Protection Zone-1 out of Service. Check the same through SCADA/event.	Yes/ No
V.	Selector switch to be put into service. Insert test handle to isolate trip of bus bar protection for Bus-I, only one bay trip can be extended for any future bay / bay with least importance.	Yes/ No
VI.	All the alarms should be reset. The same need to be verified through event log /SAS	Yes/ No
VII.	Make the setup for the said testing and ensure all the connections are properly connected especially the current wires and the feedback cable. In addition, the output contact where feedback cable is connected is designated for tested protection function.	Yes/ No

VIII.	Ensure that for Re-trip and Bus-bar differential test, the fault duration in Testing Kit is configured as 150ms only	Yes/ No
IX.	Do the necessary Busbar and LBB Testing.	Yes/ No
X.	Ensure signal reporting for busbar protection related alarms to SAS/NTAMC as per Signal list	Yes/ No

2. Normalization

S.No.	Description	Status (Yes/ No)
I.	Check that no Bus Bar Relay/LBB relay is having any alarm.	Yes/ No
II.	Put Main-I Bus-I, Bus Bar protection out of service using Selector Switch	Yes/ No
III.	Connect all the wirings, disconnected during testing/before testing.	Yes/ No
IV.	Check that the Busbar protection/LBB relay does not have any alarm.	Yes/ No
V.	Put Main-I Bus-I, Busbar protection in service using Selector Switch	Yes/ No
VI.	All the alarms should be reset. The same need to be verified through event log /SAS	Yes/ No

Note: Testing to be carried out for both Main1 & Main-2 Bus bar protections of each bus

Signature:	**Signature:**	**Signature:**	**Signature:**
Name:	**Name:**	**Name:**	**Name:**
Desgn.:	**Desgn.:**	**Desgn.:**	**Desgn.:**
Organization: (Supplier Representative) (Wherever Applicable)	**(Erection Agency)**	**(POWERGRID Site I/C)**	**(POWERGRID Commg. Team) Members:** **1.** **2.** **3.** **4.**

iv. CHECK LIST FOR TESTING OF DISTRIBUTED BB&LBB PROTECTION (DOUBLE MAIN OR TRANSFER BUS SCHEME)

Part- (a)

NAME OF THE STATION	………………………………………
DETAILS OF BUS UNDER TEST	………………………………………

1. Pre-Test Check List (To be done well in advance of the testing activity, signed checklist to be sent to RHQ for concurrence)

S.No.	Description	Status (Yes/ No)
I.	Identify the bus to be tested & give requisition for the S/D of the same.	Yes/ No
II.	Ensure that the commissioning team shall do the testing and Substation In-Charge shall be present in the station on the day of testing.	Yes/No
III.	Verify the wiring and input/output contact assignment of the Busbar/LBB relays as per the scheme.	Yes/ No
IV.	Check the bus bar relay settings as per approved relay settings.	Yes/ No
V.	Check for any pending alarms or annunciations in the bus bar/LBB relays.	Yes/ No
VI.	Check for the integrity of the current values in the bus bar relays. (Both in the relay HMI as well as the software by taking the relay online).	Yes/ No
VII.	Verify that the topology in the Busbar Central unit is correct. Ensure correct status of Isolator and Breakers in the Busbar protection & SCADA	Yes/ No
VIII.	Verify that there is no isolator discrepancy alarm in either relay or SCADA. Ensure configuration of this alarm in Bus bar relay for all isolators. Check that the bus bar relay takes isolator status as per protection setting.	Yes/ No
IX.	Verify that there is no bus zone Interconnected alarm (i.e. merging of both buses) in either relay or SCADA. Ensure configuration of this alarm in Bus bar relay for all bus zones.	Yes/ No

2. Check the schematic for the bus bar protection and LBB protection and validate the configuration/programming of the Bus Bar Peripheral unit, LBB relays that the following logic exists.

I.	Bus Bar protection operation shall trip the connected Main CB only	Yes/ No
II.	Bus Bar protection operation of Bus-I MUST NOT trip the main CB connected to Bus-II & vice versa.	Yes/ No
III.	Bus Bar protection operation shall send DT to remote end (In case of transmission line)	Yes/ No
IV.	Bus Bar protection operation shall send Inter-Trip to other end of ICT (In case of Transformer)	Yes/ No
V.	Main Bay CB LBB operation i. shall trip the main CB after re-trip delay(100ms) and ii. shall trip all the CBs of associated Bus after a back-trip delay(200ms) iii. Send DT to other end of the associated line/Send Inter-trip to other end of the ICT as applicable.	Yes/ No
VI.	LBB operation for Transfer Bus Coupler CB i. shall trip the Bus Coupler CB after re-trip delay(100ms) and ii. Shall trip Both both Buses after a back-trip delay(200ms). iii. Shall send DT/Inter-trip to both Line/ICT.	Yes/ No
VII.	Ensure signal availability for busbar protection related alarms to SAS/NTAMC as per Signal list	Yes/ No

3. **Other logic**

I.	DT send/Receive circuit, associated with BB/LBB, checked(End to End)	Yes/ No
II.	Zone Tripping from GD(For GIS/AIS with SF6 CT) checked & verified. Ensure the Manual Trip Enable/Disable for GD Bus zone trip to Busbar logic implemented via SAS HMI & Busbar CUA/CUB relay for both Bus-1 & 2 as per the IOM	Yes/ No

Part- (b)

NAME OF THE STATION	………………………………………………
DETAILS OF BUS UNDER TEST	………………………………………………

3. **Checks to be done during BusBar/Main Bay LBB testing(If Main-1 Protection under Testing for Bus-1, Main-2 protection must be in service if available)**

S.No.	Description	Status (Yes/ No)
I.	All the bays need to be transferred to Bus-I except the bay to be tested with Busbar protection & Buscoupler in open condition.	Yes/ No
II.	Ensure that Main-2 protection (if applicable) is healthy and no alarm is persisting.	Yes/ No
III.	Put Bus-Bar Protection of Main-1 Protection Bus-2 out of Service. Check the same through SCADA event and Central Unit relay HMI display.	Yes/ No
IV.	One of the fibres (Tx/Rx) of all the existing PUAs (Except PUA of Bus-1) needs to be removed and check for PU error/fibre comm. Error etc.	Yes/ No
V.	All the PUAs (except Bus-1) need to be taken out of service in configuration of CUA (Bus Bar Central Unit).	Yes/ No
VI.	Check for reset of all the communication alarms and selector switch of Bus-2 to be put back into service.	Yes/ No
VII.	All the alarms should be reset. The same need to be verified through event log of relays/SAS	Yes/ No
VIII.	Make the setup for the said testing and ensure all the connections are properly connected especially the current wires and the feedback cable. In addition, the output contact where feedback cable is connected is masked in the PSL/configuration matrix for the required protection function.	Yes/ No
IX.	Ensure that for Re-trip and Bus-bar differential test, the fault duration in Testing Kit is configured as 150ms only	Yes/ No
X.	Do the necessary Busbar and LBB Testing.	Yes/ No

Note: Testing to be carried out for both Main1 & Main-2 Bus bar protections.

4. Normalization(If Main-1 Protection under Testing for Bus-1, Main-2 protection must be in service if available)

S.No.	Description	Status (Yes/ No)
I.	Check that no Peripheral Units/ Bus Bar Relay/LBB relay is having any alarm.	Yes/ No
II.	Put Main-I Bus-2, Bus Bar protection out of service using Selector Switch	Yes/ No
III.	Put all the PUAs “in service” in the configuration of Busbar relay.	Yes/ No
IV.	Connect all the removed Fibres of the PUAs.	Yes/ No
V.	Check that the Busbar protection/LBB relay does not have any alarm.	Yes/ No
VI.	Put Main-I Bus-2, Busbar protection in service using Selector Switch	Yes/ No
VII.	All the alarms should be reset. The same need to be verified through event log of relays/SAS	Yes/ No

Signature:	**Signature:**	**Signature:**	**Signature:**
Name:	**Name:**	**Name:**	**Name:**
Desgn.:	**Desgn.:**	**Desgn.:**	**Desgn.:**
Organization: (Supplier Representative) (Wherever Applicable)	**(Erection Agency)**	**(POWERGRID Site I/C)**	**(POWERGRID Commg. Team) Members: 1. 2. 3. 4.**

v. **CHECK LIST FOR TESTING OF CENTRALIZED BB&LBB PROTECTION (DOUBLE MAIN OR TRANSFER BUS SCHEME)**

Part – (a)

NAME OF THE STATION	…………………………………………
DETAILS OF BUS UNDER TEST	…………………………………………

1. **Pre-Test Check List (To be done well in advance of the testing activity, signed checklist to be sent to RHQ for concurrence)**

S.No.	Description	Status (Yes/ No)
I.	Identify the bus to be tested & give requisition for the S/D of the same.	Yes/ No
II.	Ensure that the commissioning team shall do the testing and Substation In-Charge shall be present in the station on the day of testing.	Yes/No
III.	Verify the wiring and input/output contact assignment of the Busbar/LBB relays as per the scheme.	Yes/ No
IV.	Check the bus bar relay settings as per approved relay settings.	Yes/ No
V.	Check for any pending alarms or annunciations in the bus bar/LBB relays.	Yes/ No
VI.	Check for the integrity of the current values in the bus bar relays. (Both in the relay HMI as well as the software by taking the relay online).	Yes/ No
VII.	Verify that the topology in the Busbar protection relay is correct. Ensure correct status of Isolator and Breakers in the Busbar protection and SCADA	Yes/ No
VIII.	Verify that there is no isolator discrepancy alarm in either relay or SCADA. Ensure configuration of this alarm in Bus bar relay for all isolators. Check that the bus bar relay takes isolator status as per protection setting.	Yes/ No
IX.	Verify that there is no bus zone discrepancy alarm (i.e. merging of both buses) in either relay or SCADA . Ensure configuration of this alarm in Bus bar relay for all bus zones.	Yes/ No

2. Check the schematic for the bus bar protection and LBB protection and validate the configuration/programming of the Busbar protection relay, LBB relays that the following logic exists.

I.	All the bays need to be transferred to Bus-I except the bay to be tested with Busbar protection & Buscoupler in open condition.	Yes/ No
II.	Bus Bar protection operation shall trip the connected Main CB only	Yes/ No
III.	Bus Bar protection operation of Bus-I MUST NOT trip the main CB connected to Bus-II & vice versa.	Yes/ No
IV.	Bus Bar protection operation shall send DT to remote end (In case of transmission line)	Yes/ No
V.	Bus Bar protection operation shall send Inter-Trip to other end of ICT (In case of Transformer)	Yes/ No
VI.	Main Bay CB LBB operation i. shall trip the main CB after re-trip delay(100ms) and ii. shall trip all the CBs of associated Bus after a back-trip delay(200ms) iii. Send DT to other end of the associated line/Send Inter-trip to other end of the ICT as applicable.	Yes/ No
VII.	LBB operation for Bus Coupler CB i. shall trip the Bus Coupler CB after re-trip delay(100ms) and ii. Shall trip Both both Buses after a back-trip delay(200ms). iii. Shall send DT/Inter-trip to both Line/ICT.	Yes/ No

3. Other logic

III.	DT send/Receive circuit, associated with BB/LBB, checked(End to End)	Yes/ No
IV.	Zone Tripping from GD(For GIS/AIS with SF6 CT) checked & verified. Ensure the Manual Trip Enable/Disable logic implemented via SAS HMI & logic implemented in the Busbar relay	Yes/ No

Part – (b)

NAME OF THE STATION	…………………………………………
DETAILS OF BUS UNDER TEST	…………………………………………

3. **<u>Checks to be done during BusBar/Main Bay LBB testing(If Main-1 Protection under Testing for Bus-1, Main-2 protection must be in service if available)</u>**

S.No.	Description	Status (Yes/ No)
XI.	Ensure that Main-2 protection (if applicable) is healthy and no alarm is persisting.	Yes/ No
XII.	Put Bus-Bar Protection of Main-1 Protection Bus-2 out of Service. Check the same through SCADA event and Central Unit relay HMI display.	Yes/ No
XIII.	All the Bays (except Bus-1) need to be taken out of service in configuration of Bus Bar Protection relay	Yes/ No
XIV.	Check for reset of all the alarms and selector switch to be put into service.	Yes/ No
XV.	All the alarms should be reset. The same need to be verified through event log of relays/SAS	Yes/ No
XVI.	Make the setup for the said testing and ensure all the connections are properly connected especially the current wires and the feedback cable. In addition, the output contact where feedback cable is connected is masked in the PSL/configuration matrix for the required protection function.	Yes/ No
XVII.	Ensure that for Re-trip and Bus-bar differential test, the fault duration in Testing Kit is configured as 150ms only	Yes/ No
XVIII.	Do the necessary Busbar and LBB Testing.	Yes/ No

Note: Testing to be carried out for both Main1 & Main-2 Bus bar protections.

4. **Normalization(If Main-1 Protection under Testing for Bus-1, Main-2 protection must be in service if available)**

S.No.	Description	Status (Yes/ No)
VIII.	Check that no Bus Bar Relay/LBB relay is having any alarm.	Yes/ No
IX.	Put Main-I Bus-2, Bus Bar protection out of service using Selector Switch	Yes/ No
X.	Put all the bay “in service” in the configuration of Busbar relay.	Yes/ No
XI.	Check that the Busbar protection/LBB relay does not have any alarm.	Yes/ No
XII.	Put Main-I Bus-I, Busbar protection in service using Selector Switch	Yes/ No
XIII.	All the alarms should be reset. The same need to be verified through event log of relays/SAS	Yes/ No

Signature:	**Signature:**	**Signature:**	**Signature:**
Name:	**Name:**	**Name:**	**Name:**
Desgn.:	**Desgn.:**	**Desgn.:**	**Desgn.:**
Organization: (Supplier Representative) (Wherever Applicable)	**(Erection Agency)**	**(POWERGRID Site I/C)**	**(POWERGRID Commg. Team) Members:** **1.** **2.** **3.** **4.**

vi. CHECK LIST FOR TESTING OF HIGH IMPEDANCE BB&LBB PROTECTION (DOUBLE MAIN OR TRANSFER BUS SCHEME)

vii. Part – (a)

NAME OF THE STATION	…………………………………………
DETAILS OF BUS UNDER TEST	…………………………………………

5. **Pre-Test Check List (To be done well in advance of the testing activity, signed checklist to be sent to RHQ for concurrence)**

S.No.	Description	Status (Yes/ No)
VII.	Identify the bus to be tested & give requisition for the S/D of the same.	Yes/ No
VIII.	Ensure that the commissioning team shall do the testing and Substation In-Charge shall be present in the station on the day of testing.	Yes/No
IX.	Verify the wiring and input/output contact wiring of the Busbar/LBB relays as per the scheme.	Yes/ No
X.	Check the bus bar relay settings as per approved relay settings.	Yes/ No
XI.	Check for any pending alarms (CT Supervision etc.) or annunciations in the bus bar/LBB relays.	Yes/ No
XII.	Check for the "Spill Voltage" in the bus bar relays. It should be more than zero and lower than the setting of supervision relay.	Yes/ No
XIII.	Ensure the proper CT selection of the bays with actual position of isolators.	Yes/ No
XIV.	Verify that there is no bus zone discrepancy alarm (i.e. incomplete CT selection alarm) in either SCADA or Annunciation panel.	Yes/ No

6. Check the schematic for the bus bar protection and LBB protection and validate the wiring of the Busbar protection relay, LBB relays that the following logic exists.

VIII.	Bus Bar protection operation shall trip the connected Main CB only	Yes/ No
IX.	Bus Bar protection operation of Bus-I MUST NOT trip the main CB connected to Bus-II & vice versa.	Yes/ No

X.	Bus Bar protection operation shall send DT to remote end (In case of transmission line)	Yes/ No
XI.	Bus Bar protection operation shall send Inter-Trip to other end of ICT, ONLY if the Tie CB is open (In case of Transformer)	Yes/ No
XII.	Main Bay CB LBB operation iv. shall trip the main CB after re-trip delay(100ms) and v. shall trip all the CBs of associated Bus after a back-trip delay(200ms) vi. Send DT to other end of the associated line/Send Inter-trip to other end of the ICT as applicable.	Yes/ No
XIII.	LBB operation for Bus Coupler CB iv. shall trip the Bus Coupler CB after re-trip delay(100ms) and v. Shall trip Both both Buses after a back-trip delay(200ms). vi. Shall send DT/Inter-trip to both Line/ICT.	Yes/ No

7. Other logic

III.	DT send/Receive circuit, associated with BB/LBB, checked (End to End)	Yes/ No
IV.	Zone Tripping from GD (For GIS/AIS with SF6 CT) checked & verified	Yes/ No

Part – (b)

NAME OF THE STATION	…………………………………………
DETAILS OF BUS UNDER TEST	…………………………………………

3. Checks to be done during BusBar/Main Bay LBB testing(If Protection under Testing for Bus-1, Bus-2 protection must be in service if available)

S.No.	Description	Status (Yes/ No)
XI.	Ensure that Main-2 protection (if applicable) is healthy and no alarm is persisting.	Yes/ No
XII.	Check the healthiness of secondary CT circuit by DC earth fault locator. **To be done alternatively for check zone/Bus-1/2 zones.**	Yes/ No
XIII.	Put Bus-Bar Protection of Main-1 Protection Bus-2 out of Service. Check the same through SCADA/event.	Yes/ No
XIV.	Check for reset of all the communication alarms and selector switch to be put into service.	Yes/ No
XV.	All the alarms should be reset. The same need to be verified through event log /SAS	Yes/ No
XVI.	Make the setup for the said testing and ensure all the connections are properly connected especially the current wires and the feedback cable. In addition, the output contact where feedback cable is connected is designated for tested protection function.	Yes/ No
XVII.	Ensure that for Re-trip and Bus-bar differential test, the fault duration in Testing Kit is configured as 150ms only	Yes/ No
XVIII.	Do the necessary Busbar and LBB Testing.	Yes/ No

Note: 1.Testing to be carried out for both Bus bar main zones & check zones

4. Normalization

S.No.	Description	Status (Yes/ No)
VII.	Check that no Bus Bar Relay/LBB relay is having any alarm.	Yes/ No
VIII.	Put Main-I Bus-I, Bus Bar protection out of service using Selector Switch	Yes/ No
IX.	Connect all the wirings, disconnected during testing/before testing.	Yes/ No
X.	Check that the Busbar protection/LBB relay does not have any alarm.	Yes/ No
XI.	Put Main-I Bus-I, Busbar protection in service using Selector Switch	Yes/ No
XII.	All the alarms should be reset. The same need to be verified through event log /SAS	Yes/ No

Signature:	**Signature:**	**Signature:**	**Signature:**
Name:	**Name:**	**Name:**	**Name:**
Desgn.:	**Desgn.:**	**Desgn.:**	**Desgn.:**
Organization: (Supplier Representative) (Wherever Applicable)	**(Erection Agency)**	**(POWERGRID Site I/C)**	**(POWERGRID Commg. Team) Members:** **1.** **2.** **3.** **4.**

Annexure-II

Configuration & Commissioning Procedure of CSD (Controlling Switching Device)

1. Commissioning of Siemens PSD:

1.1. Configuration of CSD on PSD-Control Software

For configuration of CSD, install **PSD-Control** Software on PC/Laptop with the help of installation CD provided with CSD. After installation, The *PSD-Control* program can be started with a shortcut on the Desktop or the Start menu.

The main menu contains six sub-menus:

Figure-1: PSD-Control Menu

After installation of *PSD-Control* software, PC/Laptop is connected with CSD unit through serial PC interface under Setting>Global>Com-Port menu.

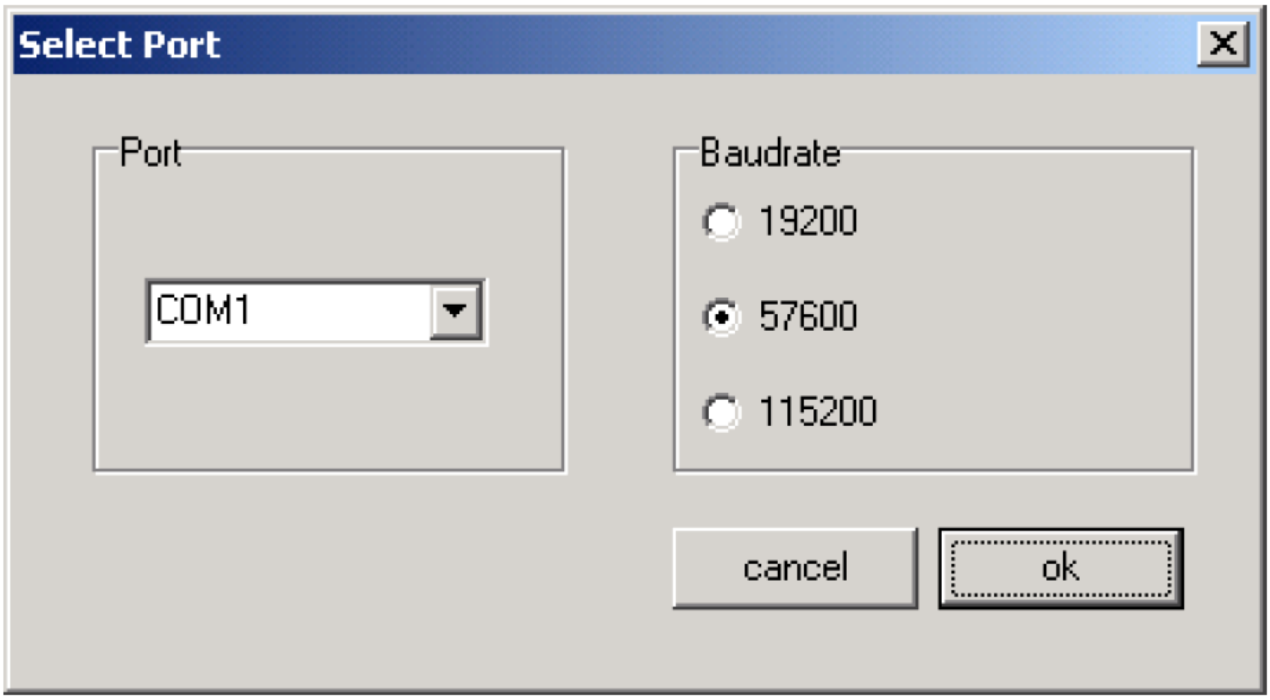


Figure-2: Com Port Selection

Preferably, RS232 interface with 57 baud rate should be used. If the PC or Laptop does not have as RS232 interface available, the included USD-RS232 converter can be used. After the USB driver has been installed, the virtual com interface can be detected in Windows device configuration under Ports. The COM interface on the PC to which the PSD Control unit is connected to the PC can be configured under *Interface.* **If the control unit is connected, the status bar shows online. If the connection is interrupted, or no device is connected, the status bar shows offline.**

If the connection was interrupted, the connection is automatically re-established and displayed at the next communication attempt. After connecting with device, a configuration file can be created for Rector/Transformer for their control switching.

a) Creating a New Configuration

An empty configuration is opened in 'default mode' under NEW. On the General tab enter the data, select the default and view values as well as signals which are independent of the switching operations.

b) Circuit-Breaker Identification Tab

On this tab enter the data for identifying the circuit breaker (serial number) with which the control unit should be operated. The time interval for saving the data should still be set by the control unit.

Enter the serial number of the circuit-breaker to provide a reference for the evaluations later.

The control unit configuration must specify whether a circuit-breaker which is equipped with a common operating mechanism for the three circuit-breaker poles or with one mechanism per pole (3 operating mechanisms) is to be controlled. Depending on the type of circuit-breaker enter:

- 1... for common operating mechanism
- 3... for one operating mechanism per pole

Approximately 500 events can be saved in the control unit in FIFO mode (first in - first out). Once the storage space is exceeded, the latest events will be saved, and the oldest data will be deleted accordingly. **Recommendation: Save once per day (1440 min.)**

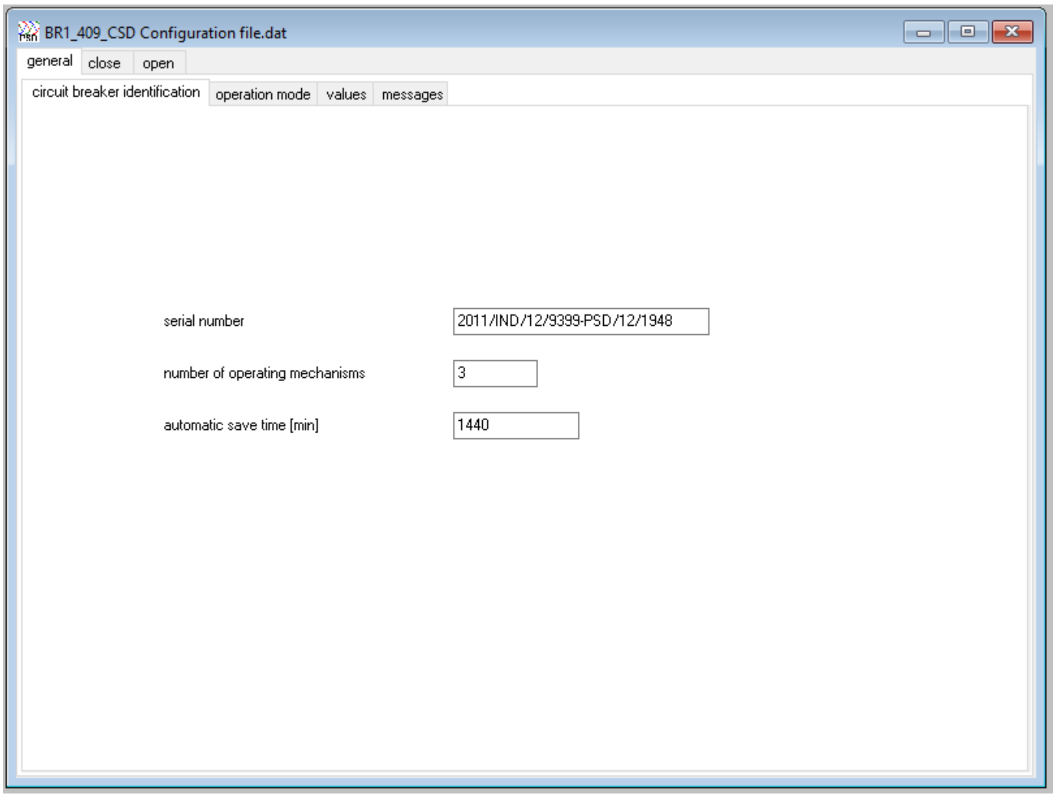


Figure- 3: CB Identification Page

c) Values Tab

Under this tab, enter the band of frequency, control voltage, close or trip operating voltage, hydraulic pressure (if applicable), temperature etc.

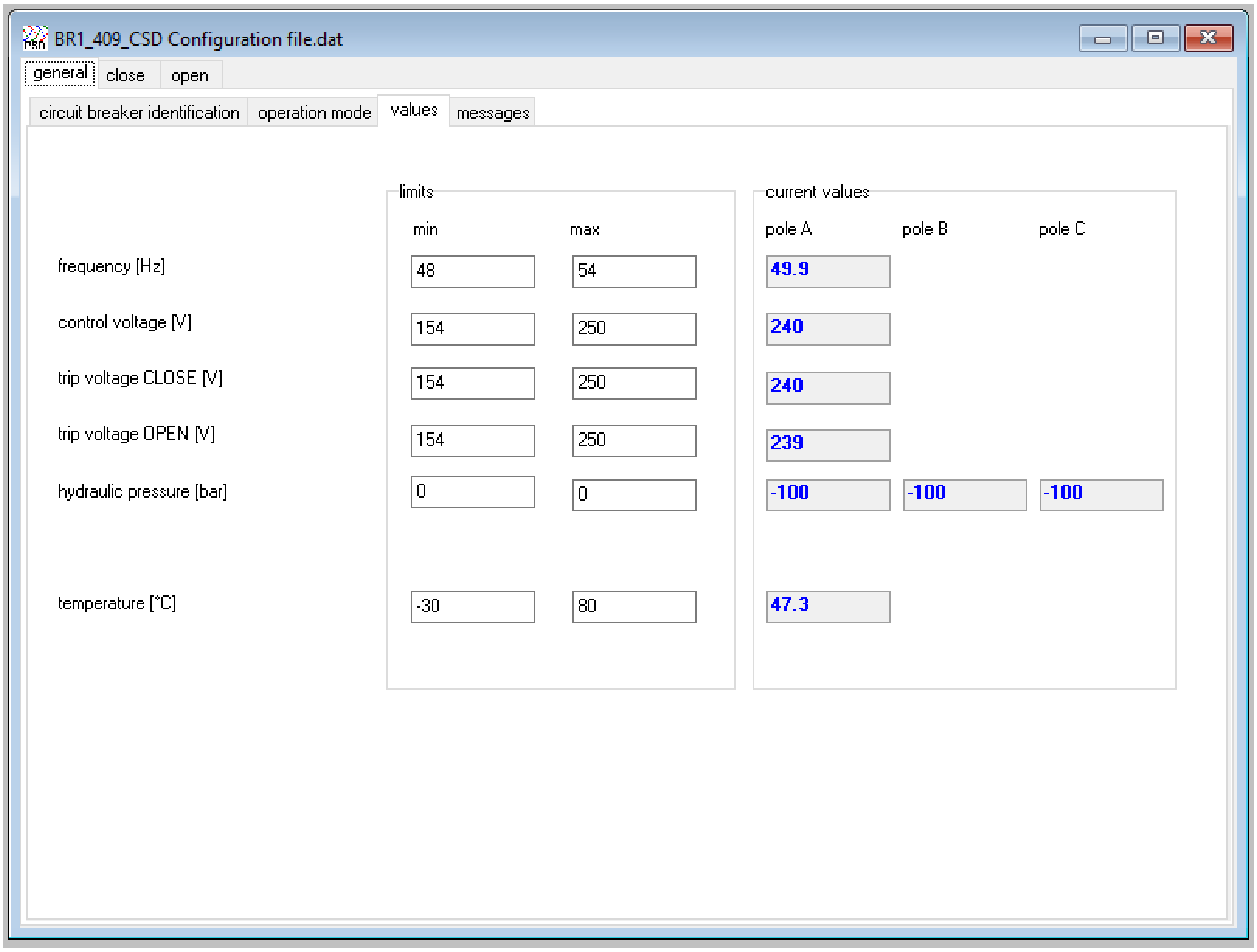


Figure-4: Values Tab

d) Message Tab

Status: Under this tab, Display the general function status of the device. If there are no functional defects, the field is highlighted and the green DEVICE OK LED illuminates. If there is an error in the switch module, these are displayed accordingly. The DEVICE OK LED switches off and the field is no longer highlighted.

Error: The boxes in this section indicate whether there are one or more errors. The checks in the boxes indicate which parameters are outside the set range. This only applies to the parameters which are set to be active.

The individual errors will be described in the following section:

Switching board/Booster: The module forwards the command to the circuit breaker. The function of the control unit module is checked. When idle, the switch transistors are checked for alloy consistency and when active for excessive release current (short circuit).

Control Voltage: The control voltage supplies the control unit. It is monitored separately from the release voltages because the voltages can be supplied from different sources. There is a constant check to see whether the control voltage is within the set limits.

U Close: The trip voltage U CLOSE is used to trigger the closing trip. There is a constant check to see whether the trip voltage CLOSE is within the set limits.

U Open: The trip voltage U OPEN is used to trigger the opening trips. There is a constant check to see whether the trip voltage OPEN is within the set limits.

No Zero Crossing: The zero crossings of the voltage on the busbar side serve as a reference for determining the switching instants. (When opening a phase of the current can also be selected as a reference.) There is a constant check to see whether the zero crossings of the selected reference can be detected.

Frequency & Temperature Sensor: There is a check to see whether the H.V. system frequency and Temperature Values are within the set limits.

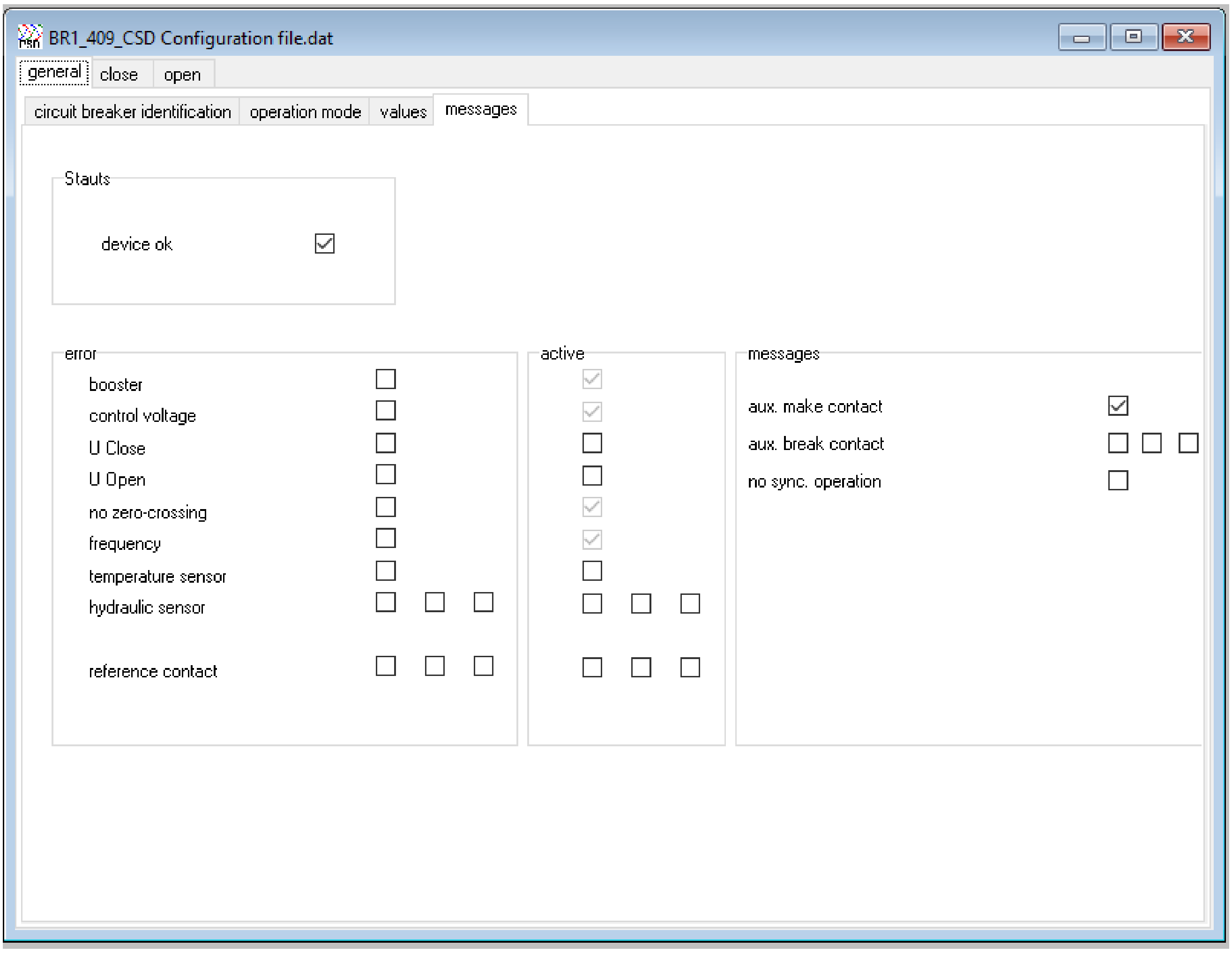


Figure-5: Message Tab

e) CLOSE/OPEN TAB

Initial Value: Parameters for the circuit breaker as delivered are entered under the Initial Values tab. These values are determined during routine testing at the factory or pre commissioning test at site and must be requested if necessary or recorded and entered when commissioning the control unit with the circuit breaker.

Closing time/Opening time: Enter value of the closing time or opening time of the high-voltage circuit-breaker in mSec.

Hydraulic pressure: Hydraulic pressure of the circuit-breaker in bar at which the closing time or opening time was recorded (as applicable).

Close/Open Operation Voltage: Switching voltage of the circuit-breaker in V at which the closing time or opening time was recorded.

Temperature: Ambient temperature of the circuit breaker in °C at which closing/opening time was recorded.

Reference contact delay: Time interval in mSec from the reference contact signal to opening or closing of the circuit-breaker contact system at which the closing time or opening time was recorded. The rising edge of the signal is evaluated when closing and the falling edge when opening.

Reference contact signal duration: Duration of the reference contact signal in mSec at which the closing time or opening time was recorded. Time between the rising and falling edge of the reference contact signal.

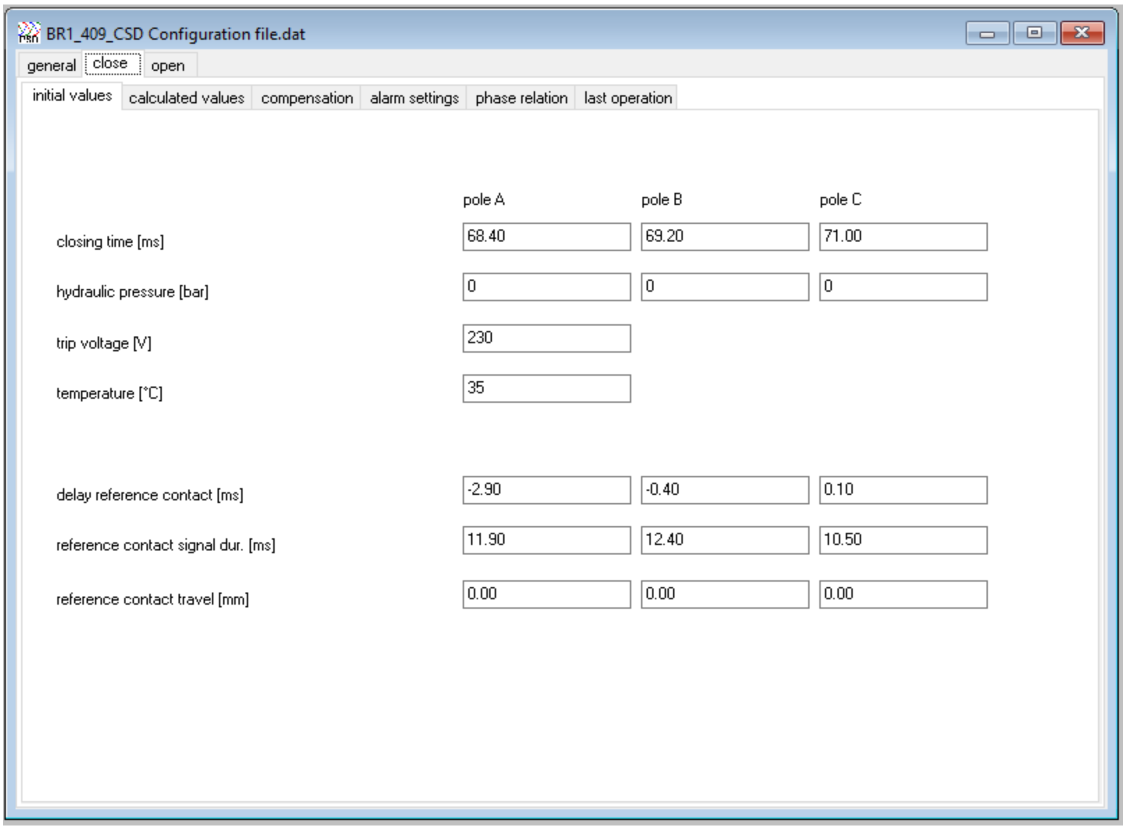


Figure-6: Parameter Setting for Close

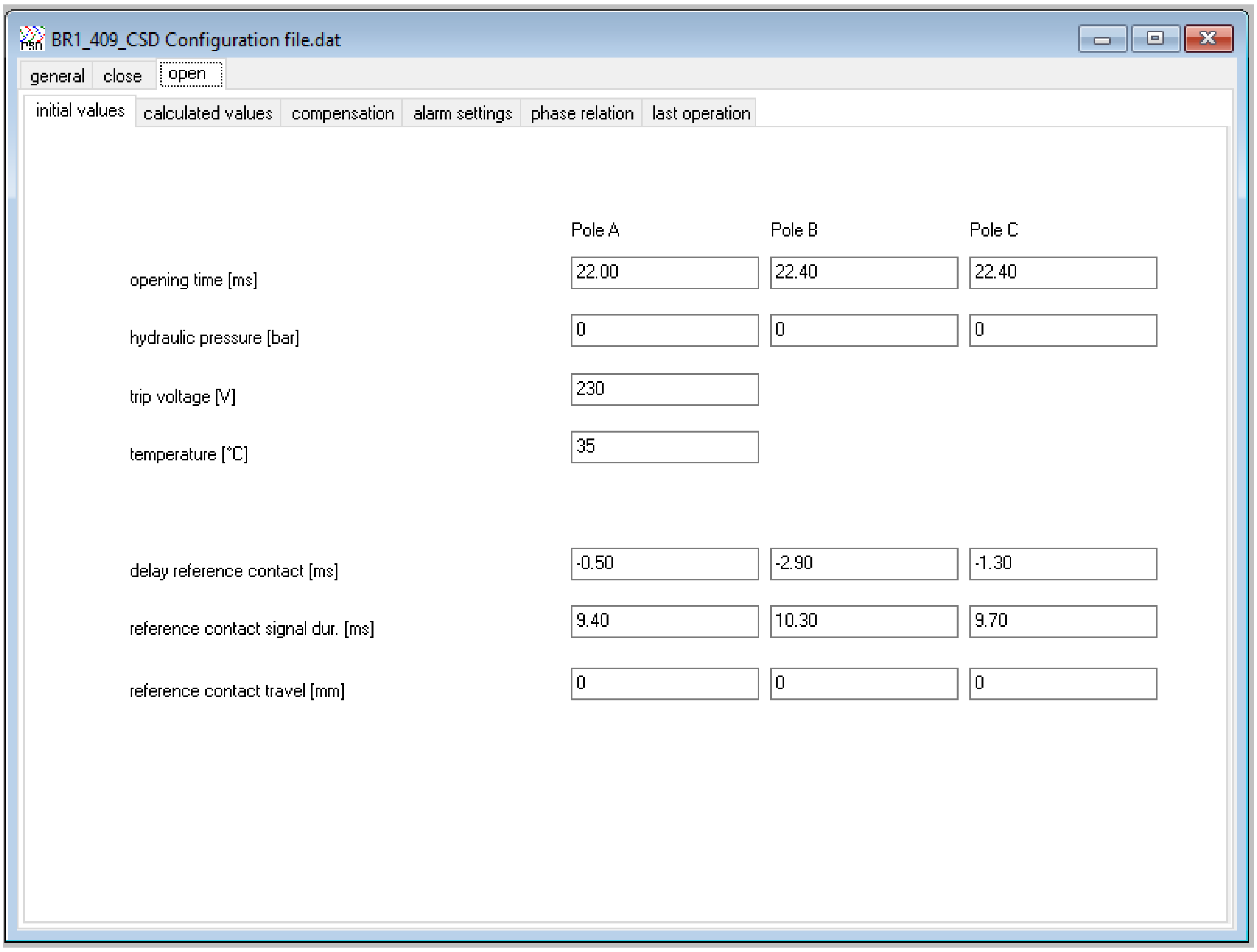


Figure-7: Parameter setting for Open

Phase Relation

Enter the defaults for the switching instant when the control unit should open or close the circuit-breaker for the set kind of load (mode) on this tab. The default for the switching sequence of the 3 circuit breaker poles is entered as a basis in the Phase shift/pole boxes. **It is not recommended for changing this basic setting even if the individual switching instants have to be adjusted further to obtain the best switching operation during commissioning.**

Further settings can then be made for all 3-pole circuit breaker poles together using the Phase shift/breaker box and/or for the individual circuit-breaker poles using the Adjusting time or Arcing time box.

Trigger source (Closing/Opening):

The following trigger sources can be selected for closing:

For Closing: The trigger source (L1>Up, L2>Up & L3>Up) can be selected for closing. If L1>Up is not selected, the trigger source is converted to L1>Up by the control unit. Recommended to set L1>Up.

For Opening: We can select the current or voltage in any phase on the load side or as same as closing voltage L1>Up as a trigger source.

Phase Shift/Pole: Here set the fixed interval between the switching instants of the individual circuit breaker poles. These defaults are fixed values which can be selected from Table 1-4.

Adjusting Time (Closing) or Arcing Time (Opening)

The switching instant for each of the 3-pole circuit breaker poles can be set individually under Adjusting Time/Arcing Time.

For closing operation negative values mean the switching instant will be brought forward. Entering positive values will delay the switching instant. **For opening operation** negative values mean the switching instant will be delayed. Entering positive value will bring the switching instant forward.

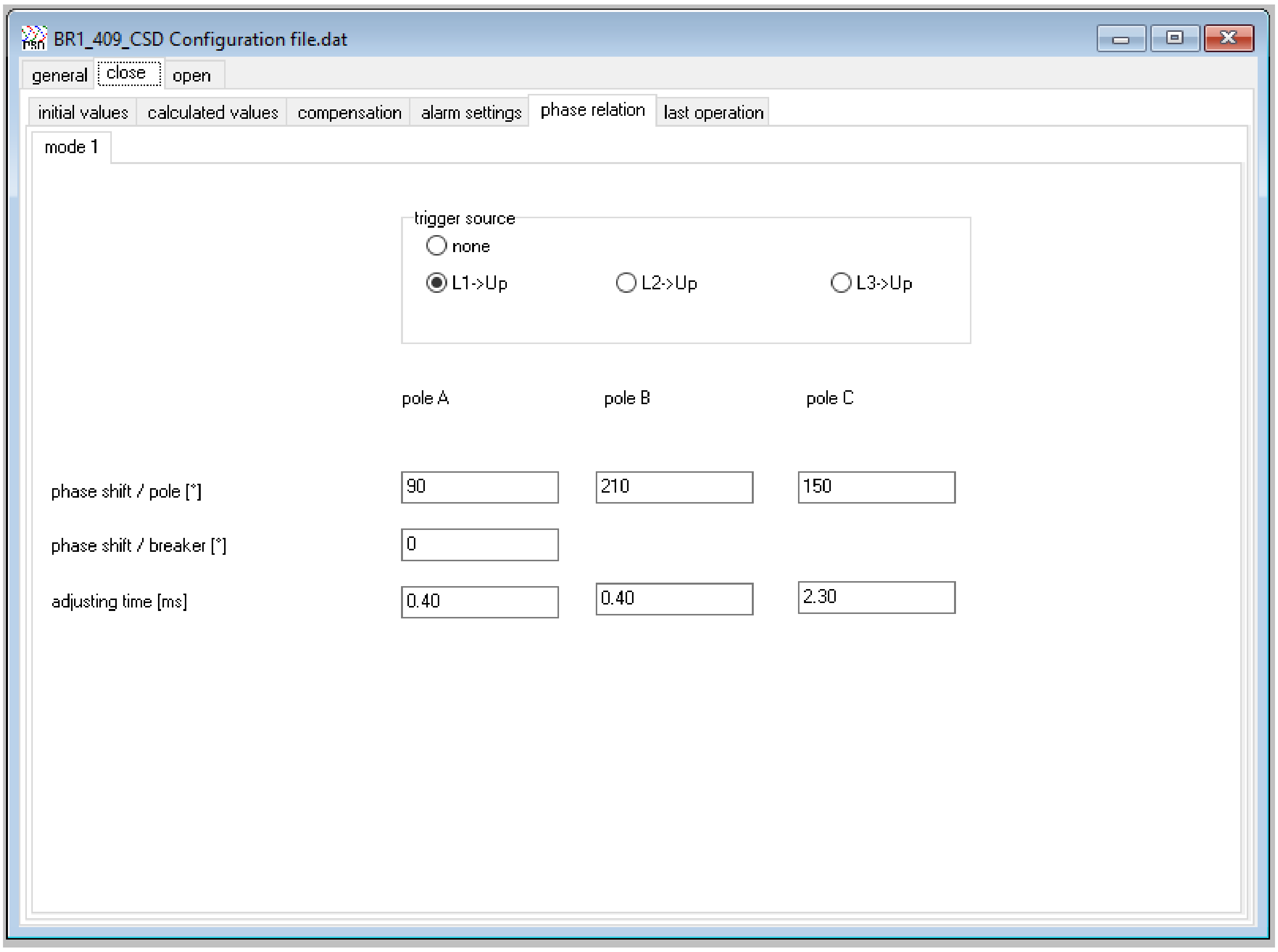


Figure-8: Phase relation windows for close operation.

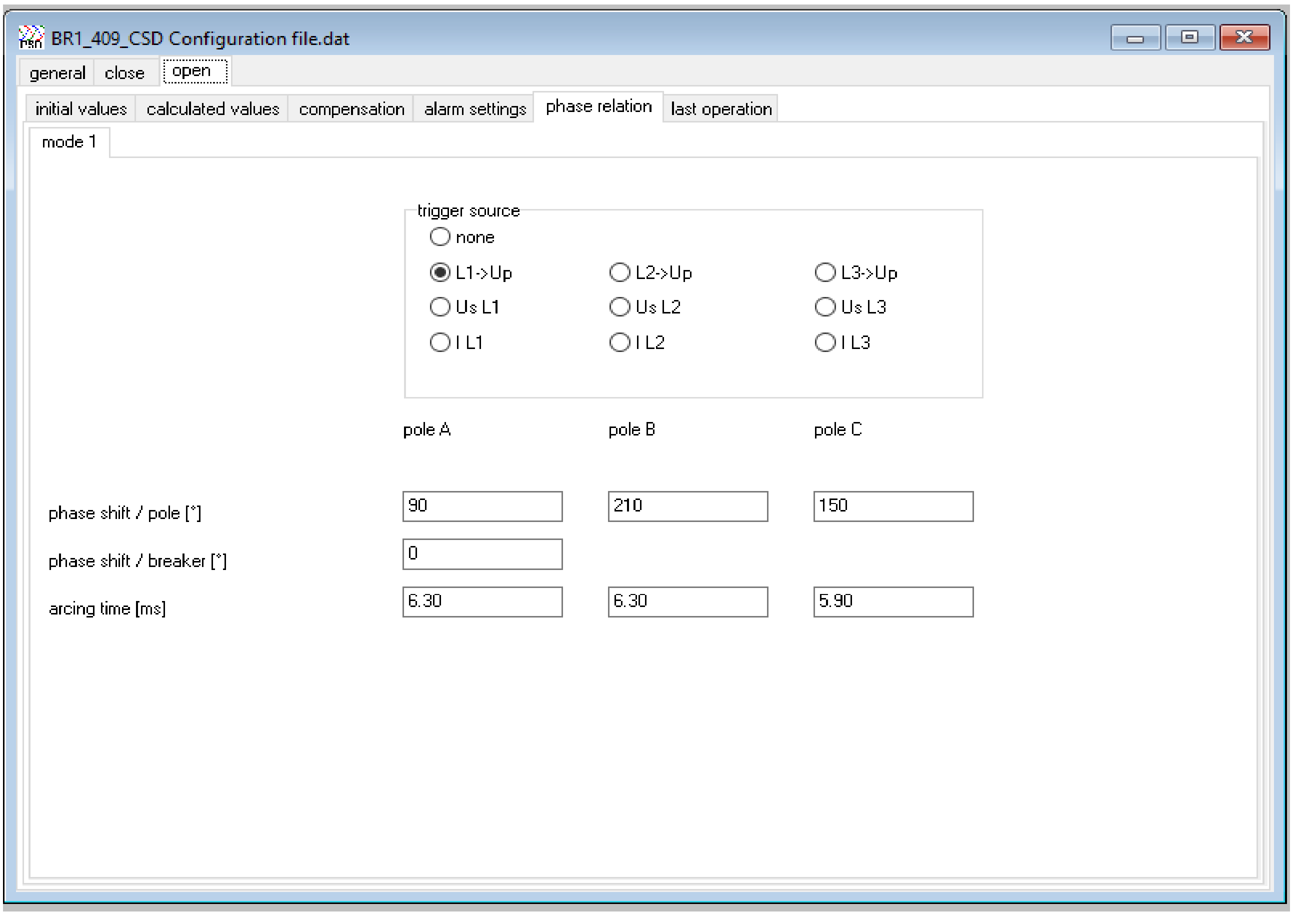


Figure- 9: Phase relation windows for open operation.

This entry is initially as a default for the adjusting time or arcing time. With closing the current flow stat is brought forward by the pre-arcing time before the contact touch. The adjusting time can be used to delay the contact touch until the desired switching instant is achieved.

With opening the current flow stop will be delayed by the arcing time after the contact separation. If the test switching operations for one or two phases do not provide the desired result correct this by making individual adjusting or arcing time settings for these circuit breaker poles.

The value to be entered depends on the circuit breaker time, voltage, and the kind of load. The same can be requested by the manufacturer.

f) Saving of Configuration file

After entering the parameters, configuration file can be saved by using the *Save As* in the active windows with a different location and file name.

g) Sending of Configuration file into Device

If a new configuration file is created or an existing configuration file is modified, it will have to be transferred to the control unit. *Send* sub-menu and File menu is used to transfer the configuration file to the control unit. A copy of the configuration file is stored in the project path at the same time. This provides a backup copy to allow unintentional changes to be undone.

Send function is generally not available for standard user level. To enable this use password “**union”** as a ‘superuser’ in menu *Settings>User Level.*

h) Controlled Switching of Circuit Breaker from CSD

After configuring the control unit performs close/open operation. After operation, oscillation graph will be stored in control unit. The oscillation from the last four switching operations in FIFO mode (first in first out) are stored using the set memory space in the control unit.

The control unit draws oscillograms for evaluating the switching operations which gives parameter for accessing the switching operations intervals.

The oscillograms have to be downloaded on the PC from the control unit. This is done with the *Receive* function. One or more oscillogram can be selected in this window and by using *Receive* or *View.* If view is selected, the oscillogram is saved and is also shown in a new window.

i) Evaluation of Oscillogram

A new application window will appear when we download or open an oscillogram. The application window is a default Windows box and consists of a title bar, work area and status bar. The title bar contains the file name of the oscillogram as well as date and time of its recording. Current and voltage curves are displayed in the oscillogram window along with the commands and reference contact signals. Codes for the analogous curves and digital representations are displayed on the left border of the oscillogram window.

Curve abbreviations:

EnaClose:	Booster enable signal for the opening command
EnaOpen	Booster enable signal for the closing command
CMD open	The opening command received by the control unit
CMD close	The closing command received by the control unit
Cmd-A, Cmd-B, Cmd-C	Output command at the respective circuit-breaker pole
Ref-A, Ref-B, Ref-C	Display of the reference contact signal from the respective circuit-breaker pole
Is-A, Is-B, Is-C	Analog or digital current transformer signal of respective circuit-breaker pole
Us-A, Us-B, Us-C	Analog or digital voltage transformer signal of respective circuit-breaker pole.
Up	Analog or digital voltage transformer signal - feed side
HSo-A, HSo-B, HSo-C	Representation of the auxiliary switch position of the break contact on the respective circuit-breaker pole
HSs-ABC	Representation of the auxiliary switch positions of the make contact of the 3 circuit-breaker poles

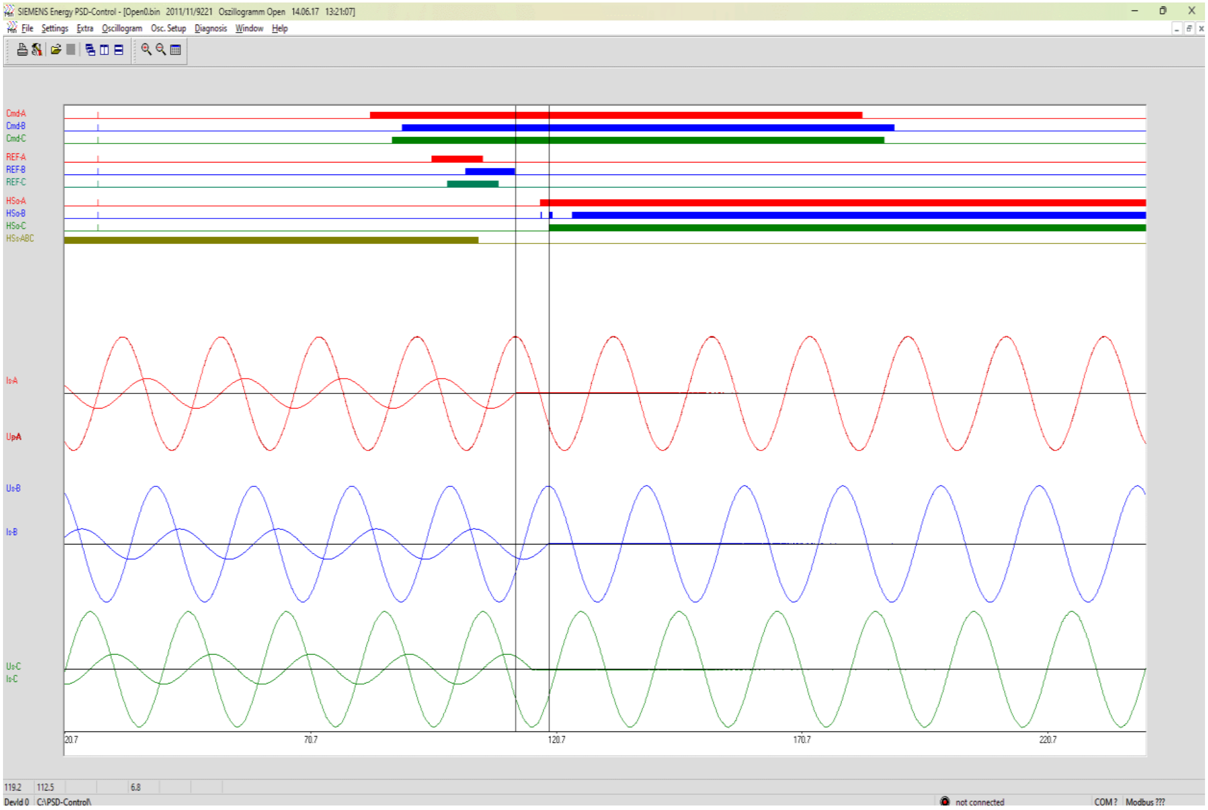


Figure- 10: Sample Open Oscillogram

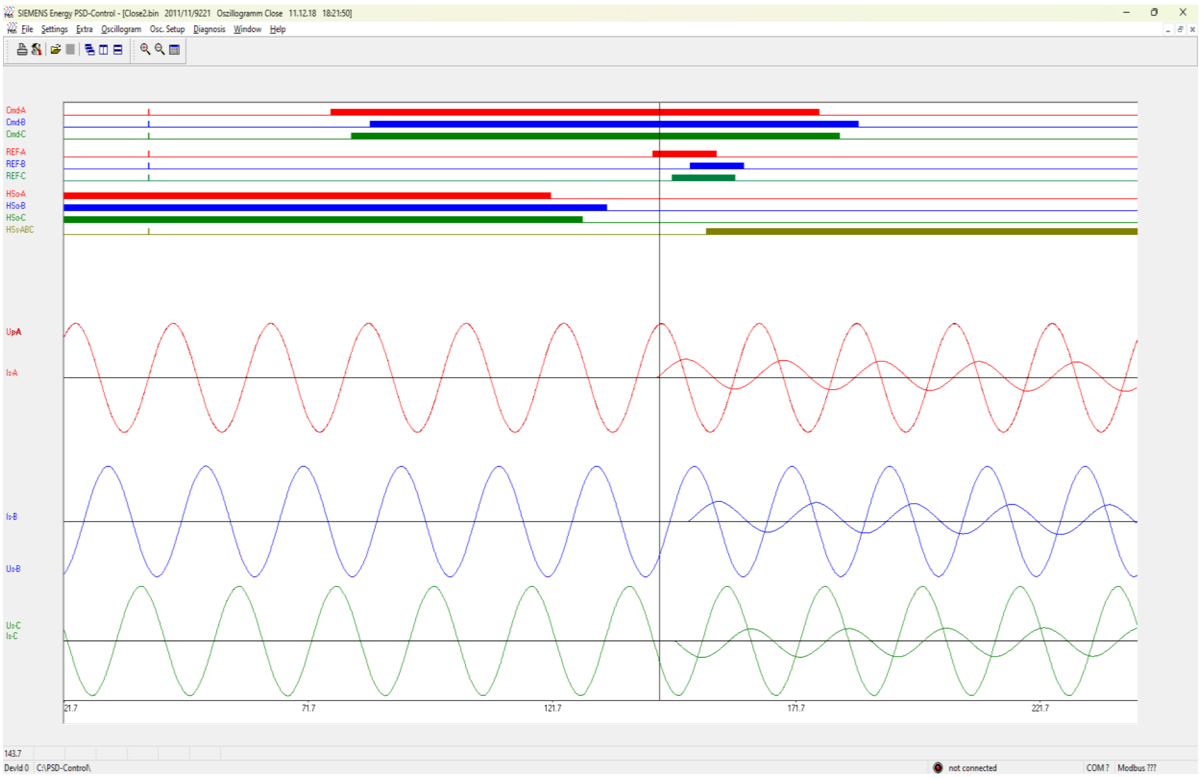


Figure-11: Sample Close Oscillogram.

1.2. Typical Connection Arrangement for Siemens PSD

Note: The connection arrangement presented below includes excerpts from the available OEM manual. During the commissioning process, it is imperative to adhere to the approved drawing connection arrangement and follow the instructions provided in the manual accompanying the Control Switching Device.

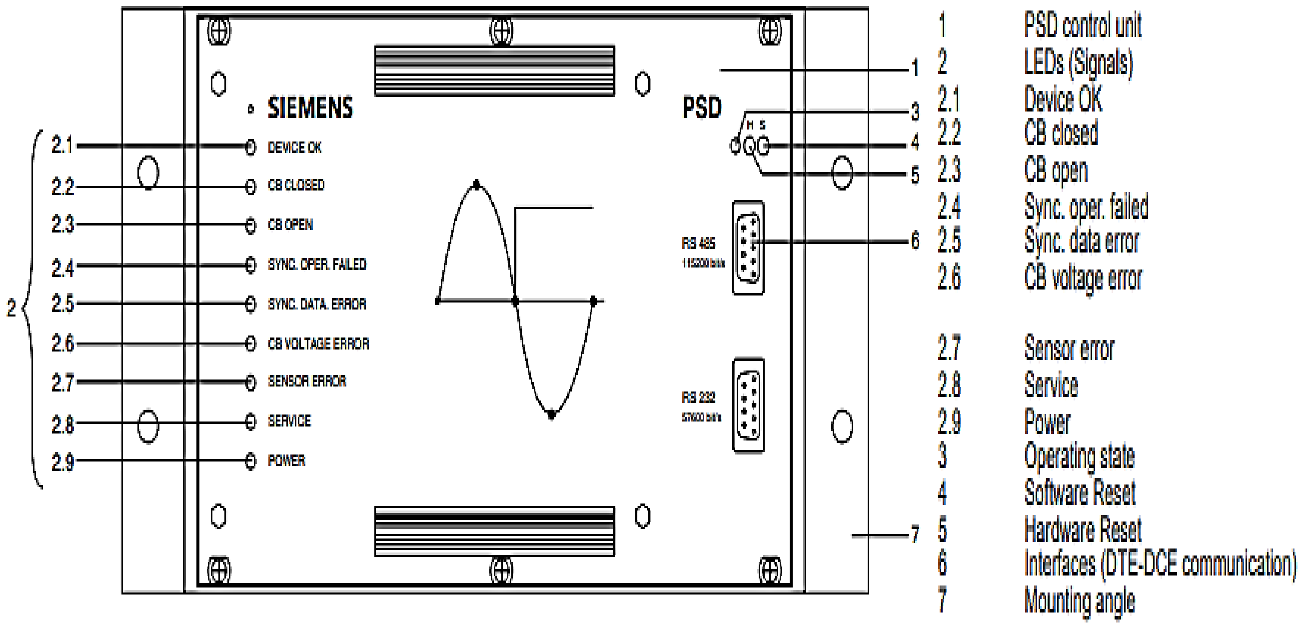


Figure-12: Front Layout of PSD 02

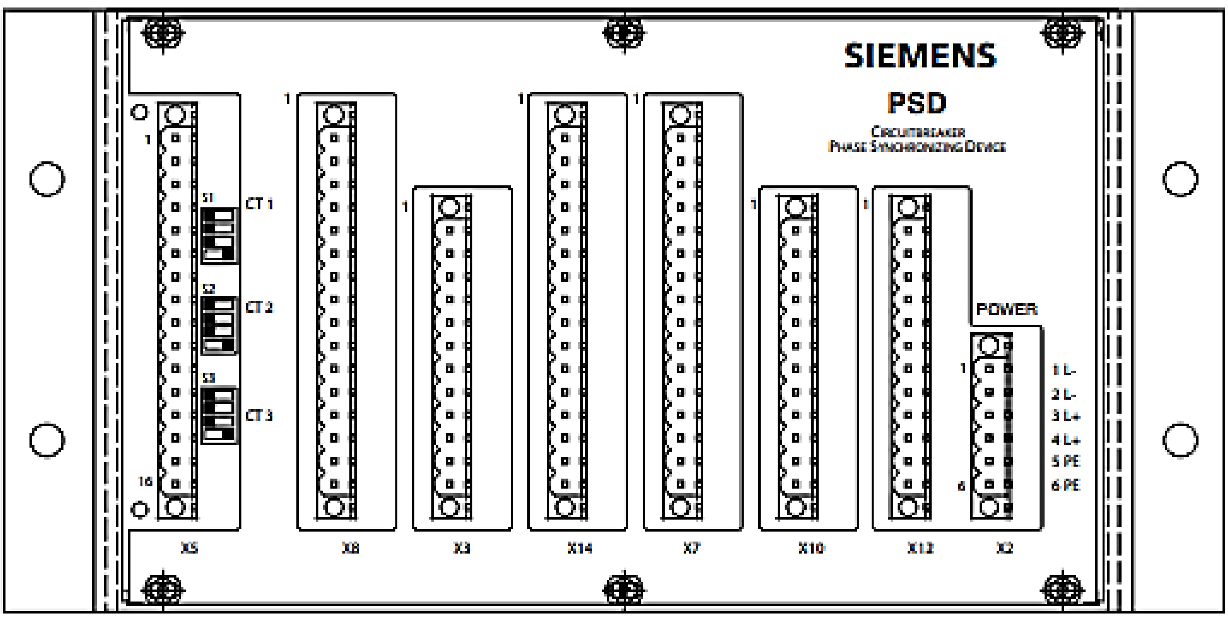
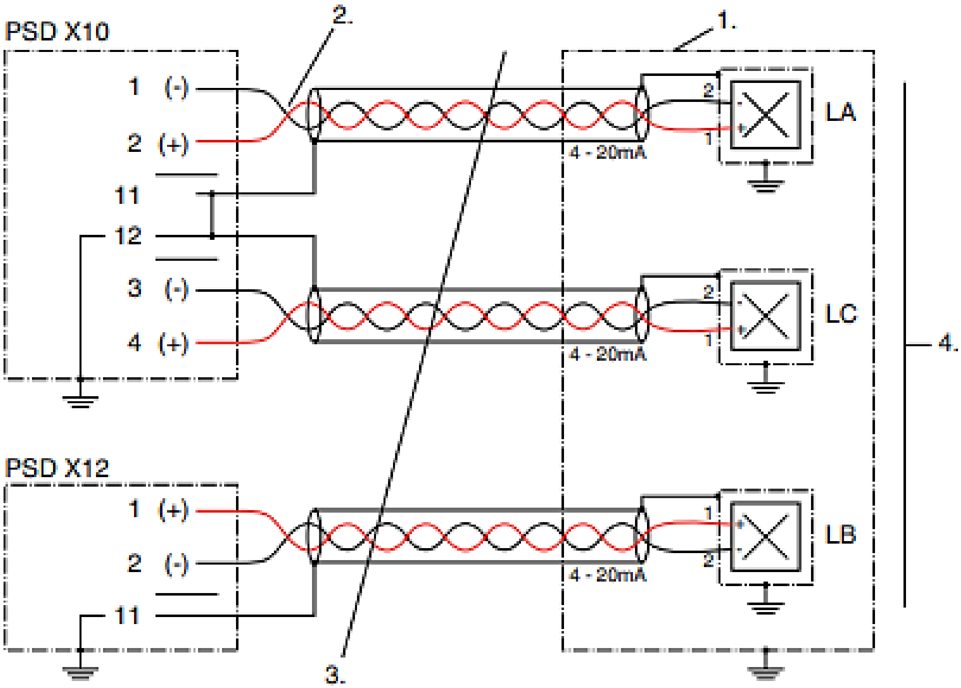
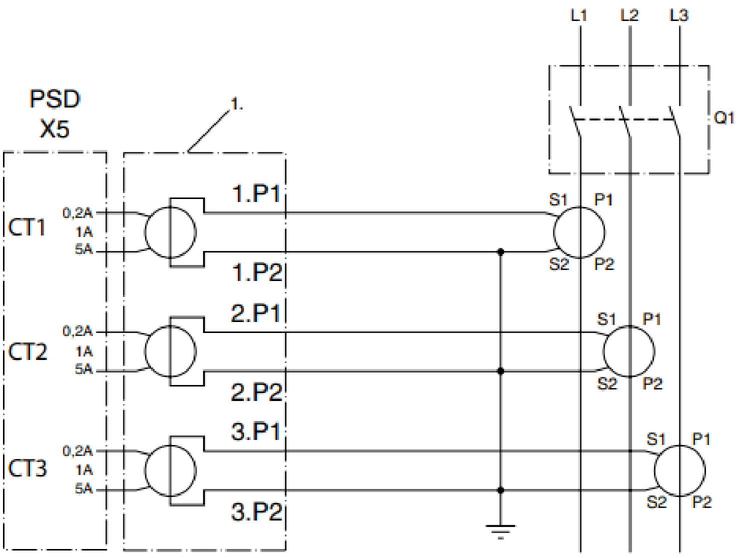


Figure-13: Back Layout of PSD 02



1	Circuit-breaker
2	The unshielded ends of the cables should be as short as possible. (≤.10 cm)
3	Twisted Pair 1P X AWG 22 C
4	Reference contacts

Figure-14: Reference Contact Connection diagram



Q1	Circuit-breaker
1	Push-through current transformer PSD-CTA

Figure-15: Connection of Current Transformer-through PSD-CTA

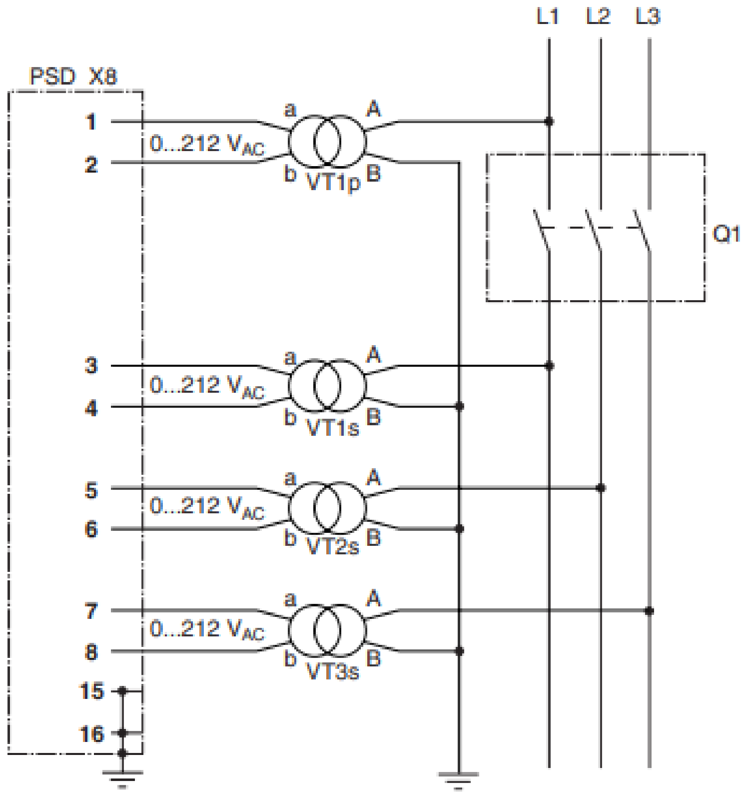


Figure-16: CVT Connection diagram

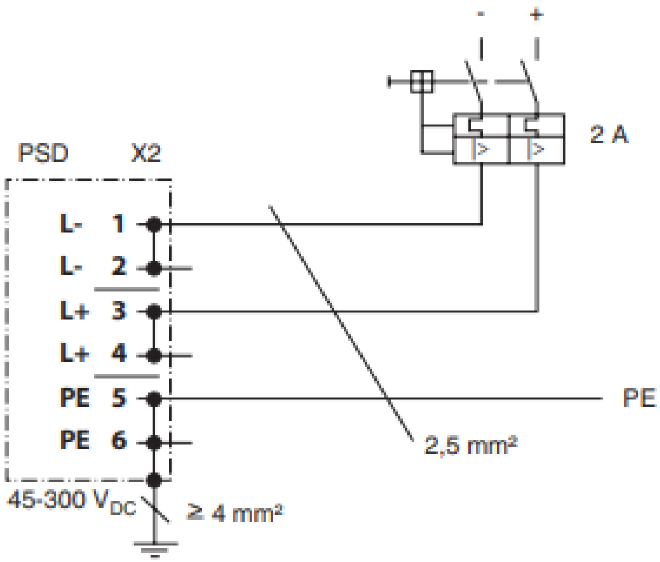


Figure-17: Power Supply Connection

Other Connection Assignment

Terminal	description
X7.1	+ OPEN coil C
X7.2	+ OPEN coil A
X7.3	+ OPEN coil B
X7.4	- OPEN trip voltage
X7.5	- OPEN trip voltage
X7.6	+ OPEN trip voltage
X7.7	+ OPEN trip voltage
X7.8	+ CLOSE trip voltage
X7.9	+ CLOSE trip voltage
X7.10	- CLOSE trip voltage
X7.11	- CLOSE trip voltage
X7.12	+ CLOSE coil C
X7.13	+ CLOSE coil A
X7.14	+ CLOSE coil B
X7.15	PE
X7.16	PE

Terminal	description
X3.1	NO contact signal 1 (Service)
X3.2	NO contact signal 2 (Sensor error)
X3.3	
X3.4	NO contact signal 3 (CB-Voltage error)
X3.5	NO contact signal 4 (Synch. data error)
X3.6	
X3.7	NO contact signal 5 (synchr. operation failed)
X3.8	NO contact signal 6 (CB OPENED)
X3.9	NO contact signal 7 (CB CLOSED)
X3.10	NO contact signal 8 (Device OK)
X3.11	Common terminal
X3.12	Common terminal

Terminal	description
X10.1	- Reference contact A (4..20 mA)
X10.2	+ Reference contact A (4..20 mA)
X10.3	- Reference contact C (4..20 mA)
X10.4	+ Reference contact C (4..20 mA)
X10.5	- OPEN operation command
X10.6	+ OPEN operation command
X10.7	- Auxiliary break contact A
X10.8	+ Auxiliary break contact A
X10.9	- Auxiliary break contact C
X10.10	+ Auxiliary break contact C
X10.11	PE
X10.12	PE

Terminal	description
X12.1	+ Reference contact B (4..20 mA)
X12.2	- Reference contact B (4..20 mA)
X12.3	+ CLOSE operation command
X12.4	- CLOSE operation command
X12.5	+ Auxiliary make contact ABC
X12.6	- Auxiliary make contact ABC
X12.7	+ Auxiliary break contact B
X12.8	- Auxiliary break contact B
X12.9	+ Mode input
X12.10	- Mode input
X12.11	PE
X12.12	PE

2.0. Commissioning of ALSTOM/GE CSD- RPH3

2.1. Configuration of RPH3- Interfacing from LAPTOP/PC TO RPH3

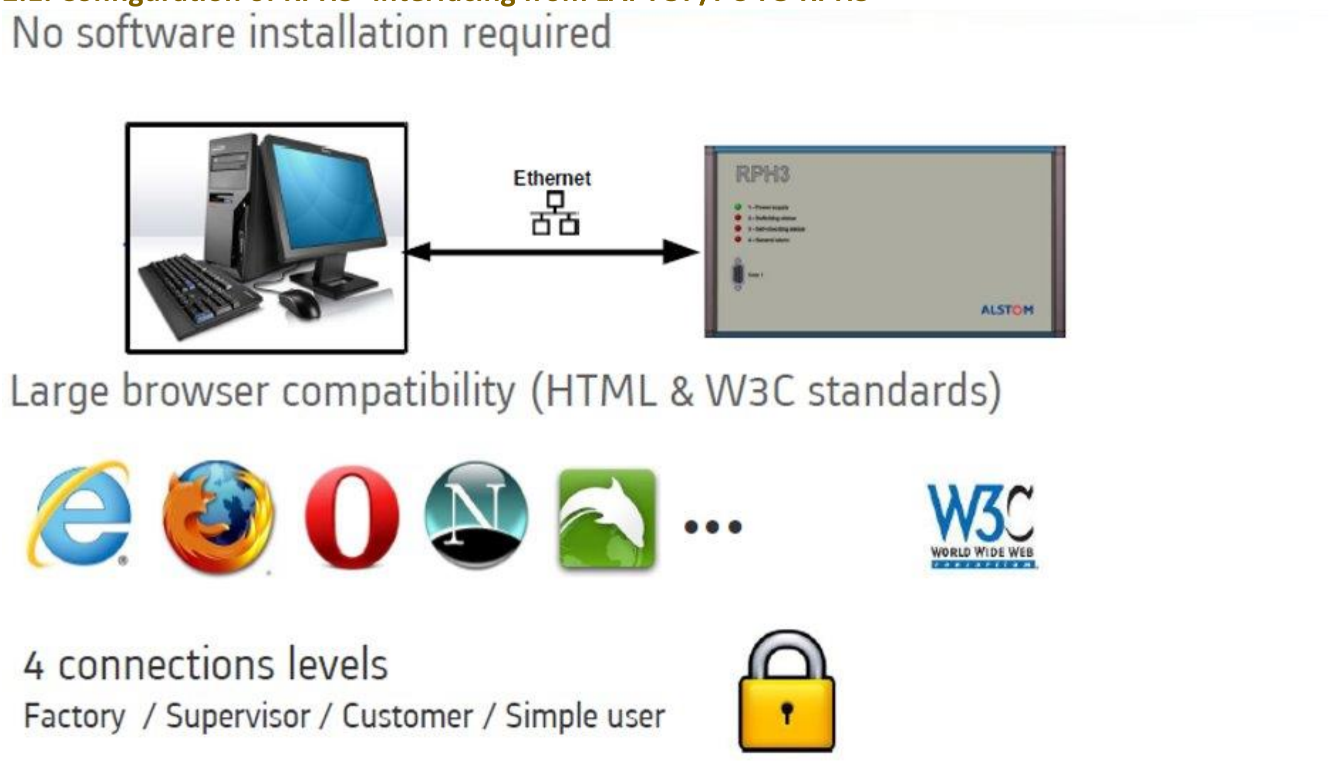


Figure-18: Interfacing from LAPTOP/PC TO RPH3

a) **Starting UP**

Default address (URL) of the RPH3: http://192.168.5.2/

User Id: **User**
Password: **Control**

HMI Section:

"Display" section shows real time information about the RPH3 device status & application status.

"Setting" section shows the various parameters needed for Controlled Switching Application.

"Downloads" section to download archives and logs from RPH3 device.

Figure-19: Control Interface

b) Settings Parameter Tab:

General: Common Parameters needed to execute properly the processing of control switching operations and focuses on six main items.

Figure-20: Display of Setting Interface

Main Options: Define the control switching program and conditions for application.

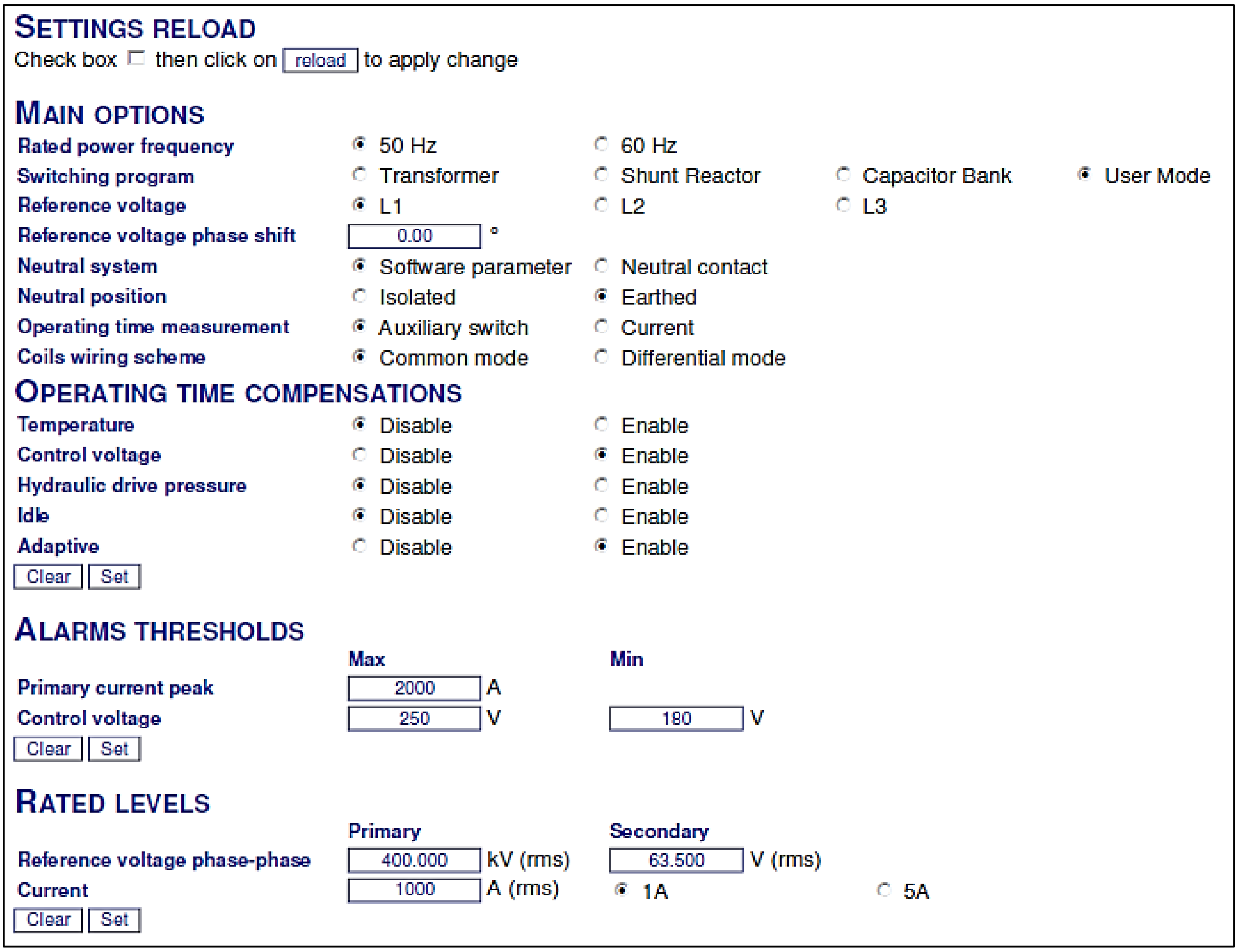


Figure-21: Display of General Setting Interface

Operating time compensations: It defines the ambient conditions to consider for circuit breaker operating time compensation features. It can be individually depending on type of circuit breaker and condition of use.

- **Temperature Compensation:** This feature is to integrate circuit breakers operating time modification linked to temperature compensation from -50°C to +50°C.
- **Control Voltage Compensation:** This feature is to integrate circuit breakers operating time modification linked to low voltage source tolerance.
- **Hydraulic drive Pressure:** This for hydraulic drive mechanism circuit breaker. It is to integrate circuit breakers operating time modification link to real hydraulic pressure.
- **Idle:** This is also mainly for hydraulic drive mechanism circuit breaker. When circuit breaker is not switched for a long time, it compensates for their operating time.
- **Adaptive:** This feature is to take consideration previous switching times to set next operating time calculations.

Alarm thresholds & rated levels: In this section we enter control voltage, primary current peak value & current transformer and voltage transformer ratio. **Note:** VT Secondary value is critical as, it have a direct influence on operating condition.

System & application alarms assignment: Under this section we configure alarms on output relays.

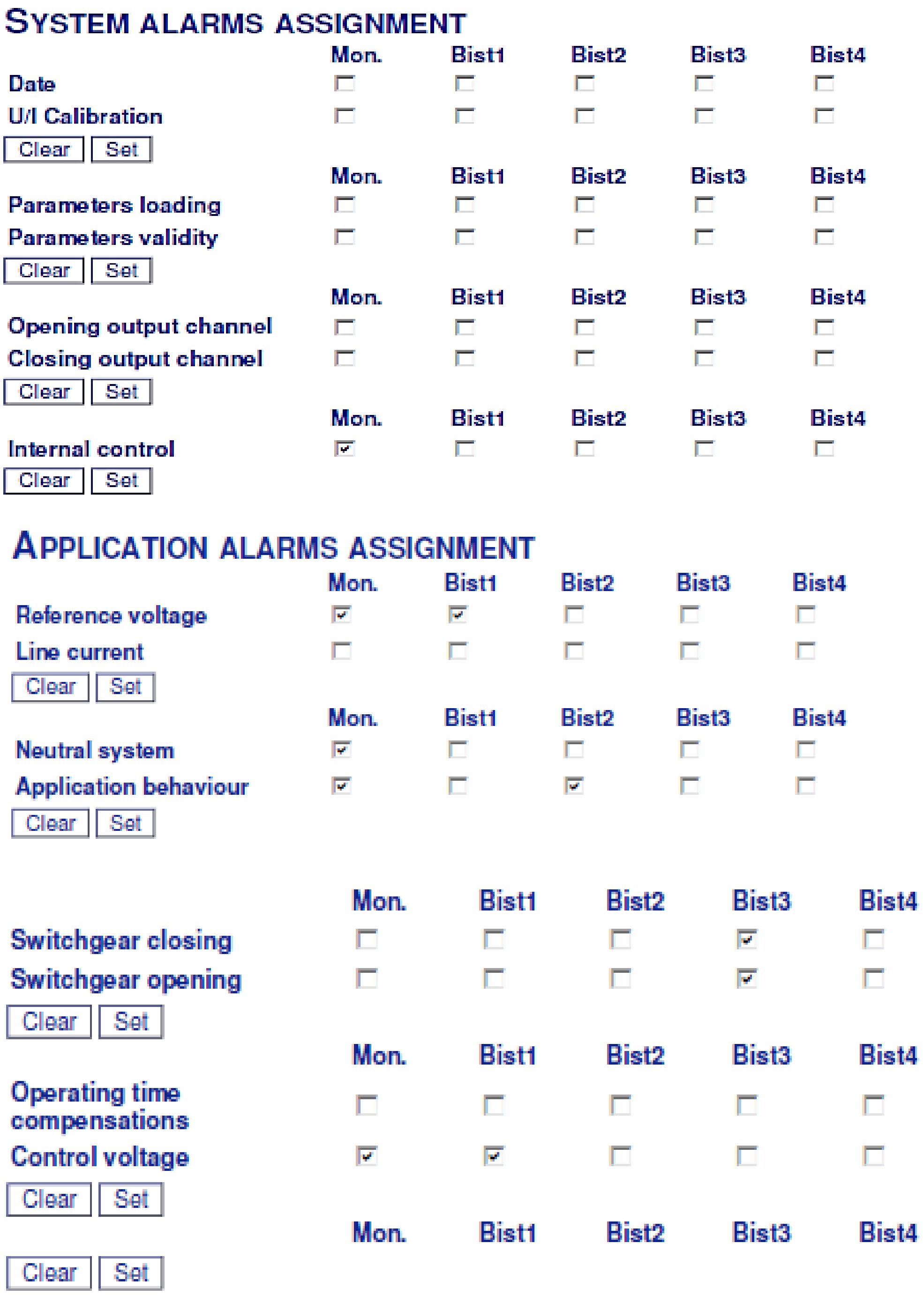


Figure-22: Display of Alarms Setting Interface

User and fallback programs Shift Angles: Here we enter the value of shift angle as per table 1 – 4. We can also select either equipment has earthed or isolated neutral or we can choose fall back mode.

USER AND FALL BACK PROGRAMS SHIFT ANGLES

	L1	L2	L3
Isolated neutral	0.00 °	0.00 °	0.00 °
Earthed neutral	0.00 °	0.00 °	0.00 °
Fall Back	0.00 °	0.00 °	0.00 °

Clear Set

Figure-23: Display of Shift Angles Setting Interface

Circuit breaker data: Here enter value of the closing time or opening time of the high-voltage circuit-breaker in mSec. Under this section, enter the value of the pre-arcing time for closing & arcing time for opening operation. Enter the value of closing/opening coil trigger duration.

Operating time measurement: Under this section, enter the value of auxiliary contact time shift during closing or opening operation. Enter the value of min and maximum of closing or opening time.

SETTINGS RELOAD

Check box ☐ then click on reload to apply change

USER AND FALL BACK PROGRAMS SHIFT ANGLES

	L1	L2	L3
Earthed neutral	90.00 °	210.00 °	150.00 °

Clear Set

CIRCUIT BREAKER DATA

	L1	L2	L3
Circuit breaker pole closing time	97.86 ms	100.70 ms	98.92 ms
Pre-arcing time User mode	2.20 ms	2.20 ms	2.20 ms
Output order duration	80 ms		

Clear Set

OPERATING TIME MEASUREMENT

	L1	L2	L3
Auxiliary contact time-shift	-10.63 ms	-10.50 ms	-11.32 ms
	Detection	Dating	
Current thresholds	217.0 A (rms)	115.0 A	
	Min	Max	Operating time tolerance
Closing measurement limits	94.00 ms	114.00 ms	4.00 ms

Clear Set

Figure-24: Display of CB Data Setting Closing

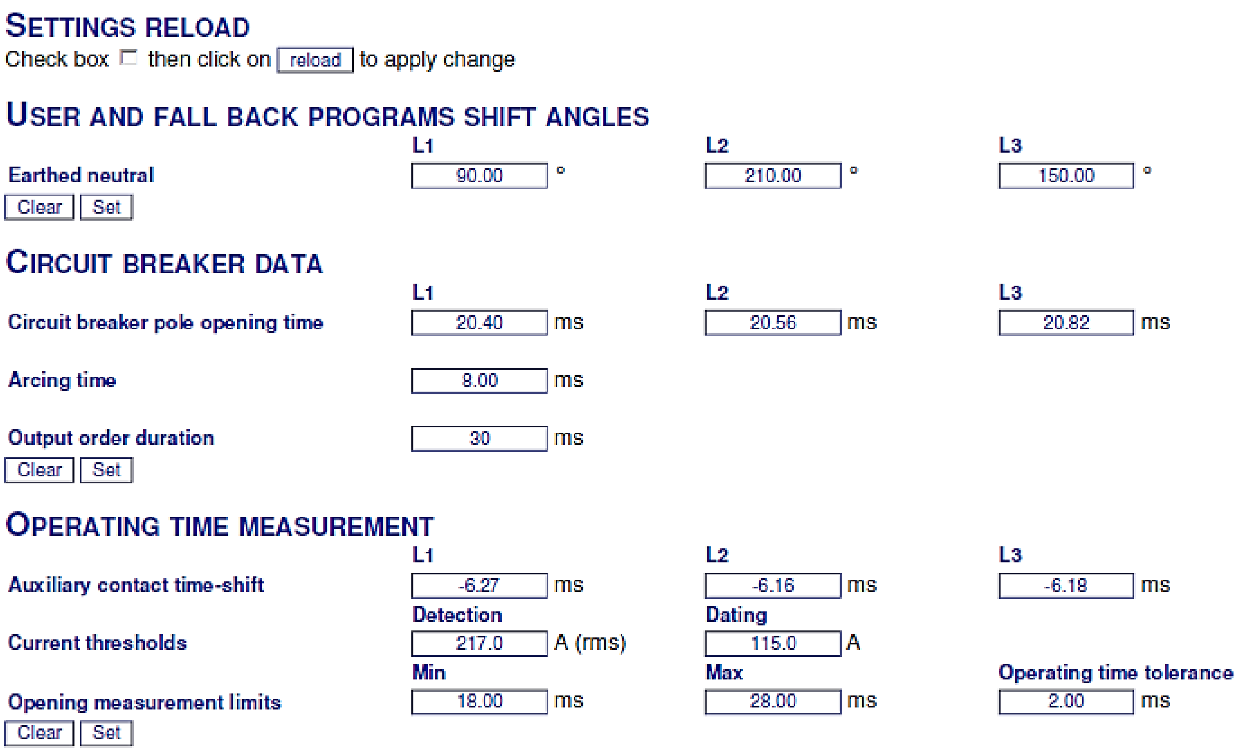


Figure-25: Display of CB Data Setting Opening

Operating time compensations: Here enter the value of control voltage of operation and compensation setting of close/open operation.

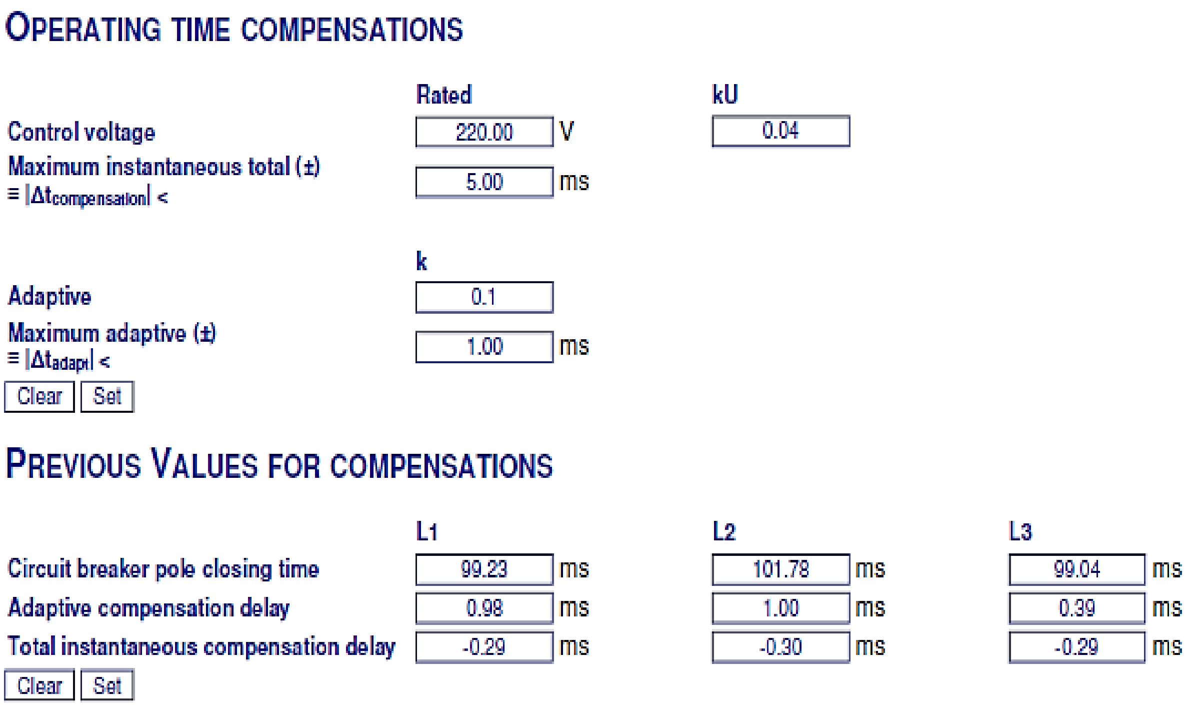


Figure-26: Compensating Setting Closing

Operating time compensations

	Rated		kU
Control voltage	220.00	V	0.20
Maximum instantaneous total (±) ≡ $\lvert\Delta t_{compensation}\rvert$ <	5.00	ms	

	k	
Adaptive	0.1	
Maximum adaptive (±) ≡ $\lvert\Delta t_{adapt}\rvert$ <	1.00	ms

Clear Set

Previous values for compensations

	L1		L2		L3	
Circuit breaker pole opening time	20.70	ms	20.45	ms	20.81	ms
Adaptive compensation delay	0.48	ms	0.23	ms	0.26	ms
Total instantaneous compensation delay	-0.30	ms	-0.31	ms	-0.31	ms

Clear Set

Figure-27: Compensating Setting Opening

Network setting: Here we can adjust the date and time. To change the date and time, click on the change date button and enter desired value and again click on change date button. We can also configure network parameters to access the RPH3 interface from Remote.

General Closing Opening Network & Time

Time

Date (m/d/y): 6 / 16 / 2023 UTC Time (24h): 16 : 07 . 33

Change date

Network configuration

Port 8.1: TX

IP address: 10 . 22 . 91 . 144

IP mask: 255 . 255 . 255 . 0

Change network configuration

SNTP configuration

Enable Disabled

Update rate 60 s

Server IP 10 . 22 . 91 . 100

Change SNTP configuration

Reset

Check box ☐ then click on Reset RPH3 to apply change

Figure-28: Network Setting

Display: It displays the alarms, last closing/opening results. Under *Status* tab of Display, We can view the current global status of controller, current system alarms, current application alarms and self-test alarms.

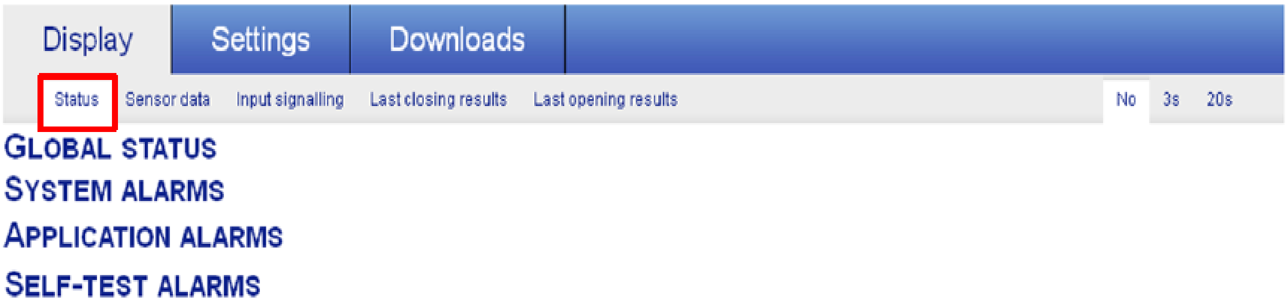


Figure-29: Display Status

Download: To download switching Archives.

Figure-30: Display of Archives

Full Archives contains detailed data (measurement, alarms etc.) and 4 seconds of signal sampled values (voltage, current, auxiliary contacts etc.) as collected by the RPH3 controller during associated switching operation. These detailed data might be useful for deep post operation analysis features. The RPH3 controller is able to store 1 "full" archive for each of the last 25 switching attempts.

Small Archives contains only data like measurements, alarms etc. as collected by the RPH3 controller during associated switching operation. Up to 1025 "small" archives can be recorded by RPH3 controller corresponding to the last 1025 operation attempts.

Checking of current/voltage waveforms: To check the waveform of switching operation, install **RPH3 Records Viewer** in PC or Laptop. Click on any full archive file in the download section, it offers to save them in local storage or open directly to view the records. The file saves with extension ".ARCH".

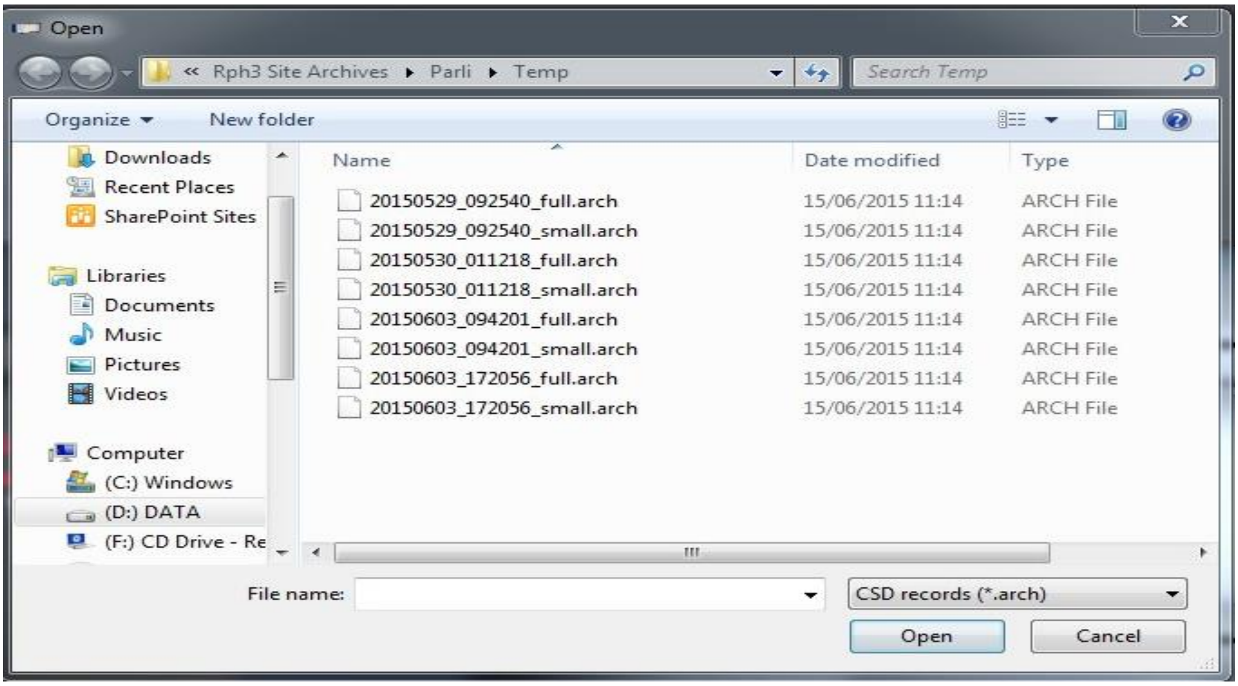


Figure-31: Saving of Archives

Once we select or open any archive file, we can see the following screenshot where the complete waveforms will be displayed: Top screen refers to voltage graph and bottom screen refers to current graph.

Figure-32: Sample RPH3 Waveform

On the below screen, on the right side we can see the Zoom button to zoom the archives for better clarity. At the same time, on the left side we can see the 3 buttons named L1, L2 & L3.

Suppose If we want to analyze only R phase waveforms, just simply tick the L1 and untick the L2 and L3 buttons.

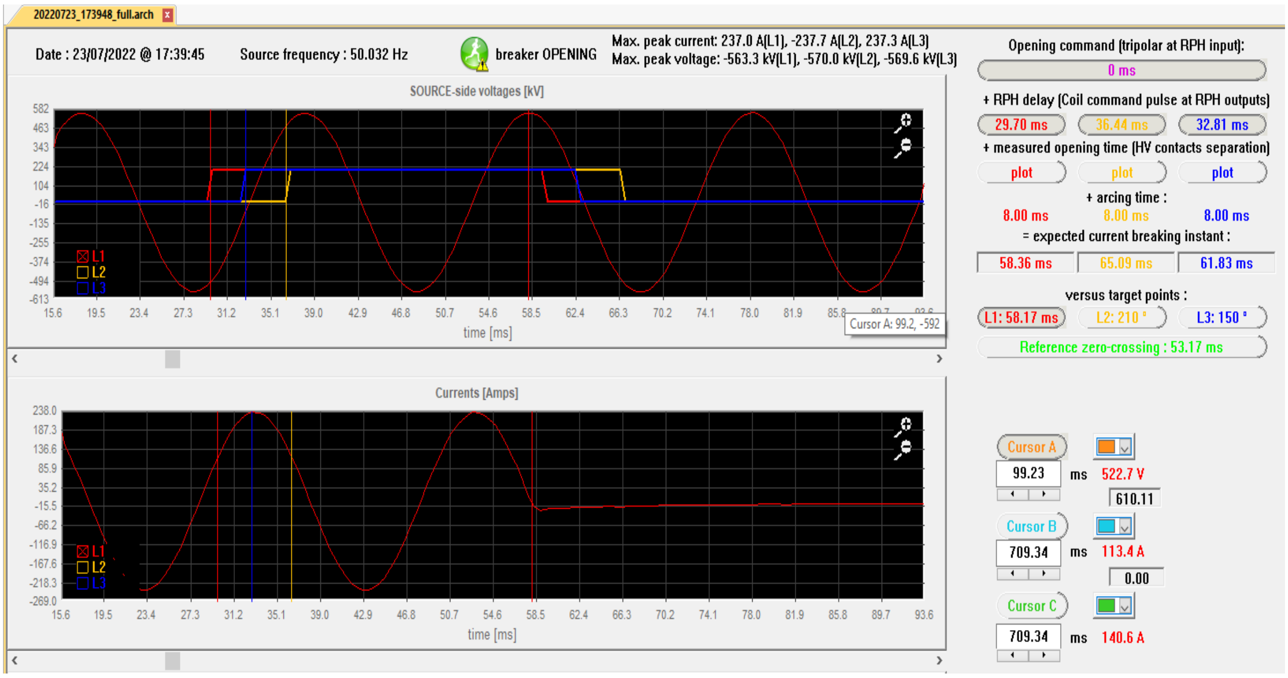


Figure- 33: Sample RPH3 R-PH Waveform

Similarly repeat the same procedure for L2 and untick the L1 and L3 buttons to view the "Y" phase waveforms.

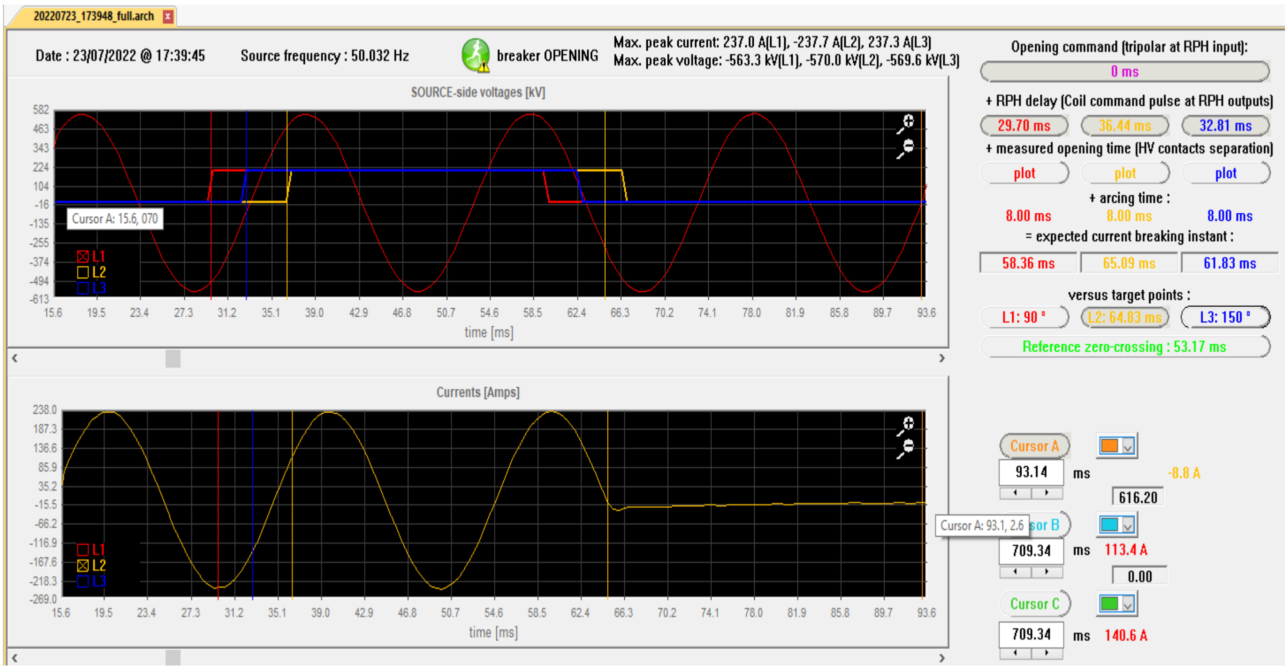


Figure-34: Sample RPH3 Y-PH Waveform

Similarly repeat the same procedure by simply tick the L3 and untick the L1 and L2 buttons to view the "B" phase waveforms.

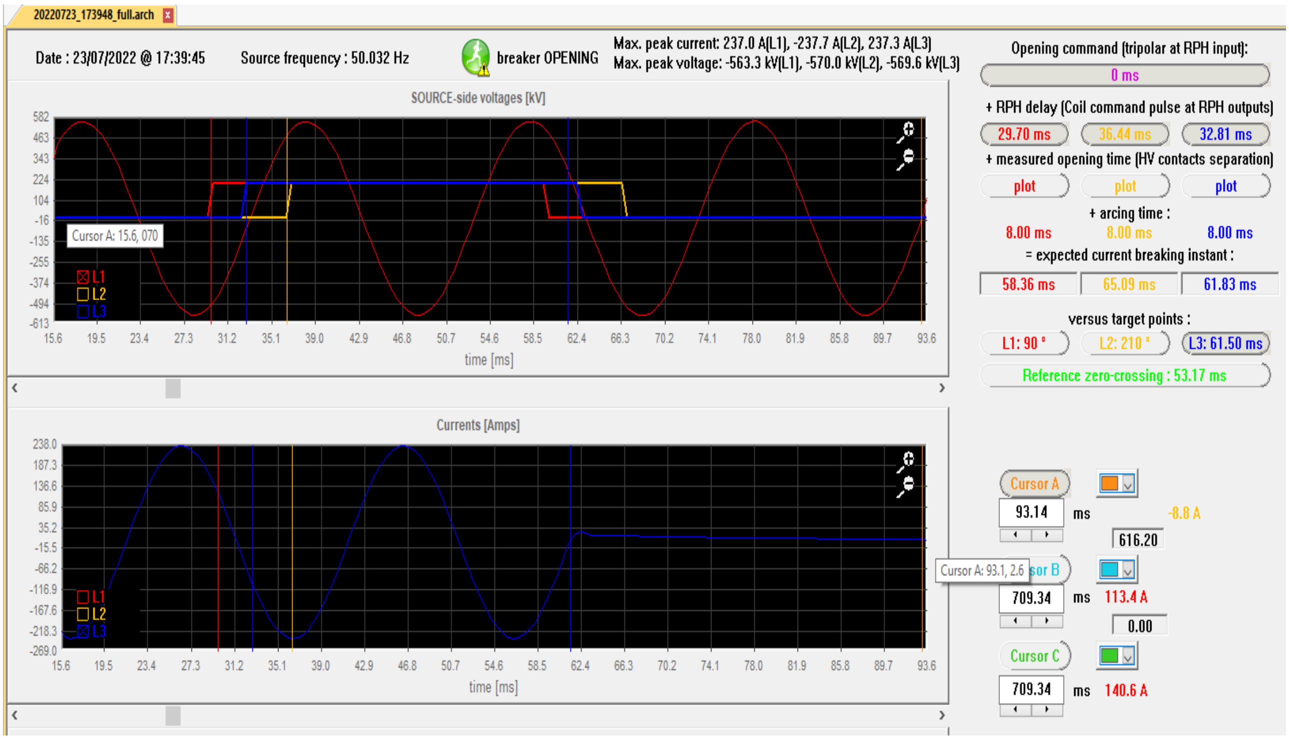


Figure-35: Sample RPH3 B-PH Waveform

Similarly, we can analyze the closing waveforms received from RPH3 Controller.

4.2 Typical Connection Arrangement for RPH3:

Note: The connection arrangement presented below includes excerpts from the available OEM manual. During the commissioning process, it is imperative to adhere to the approved drawing connection arrangement and follow the instructions provided in the manual accompanying the Control Switching Device.

Figure-36: Front Layout of RPH3

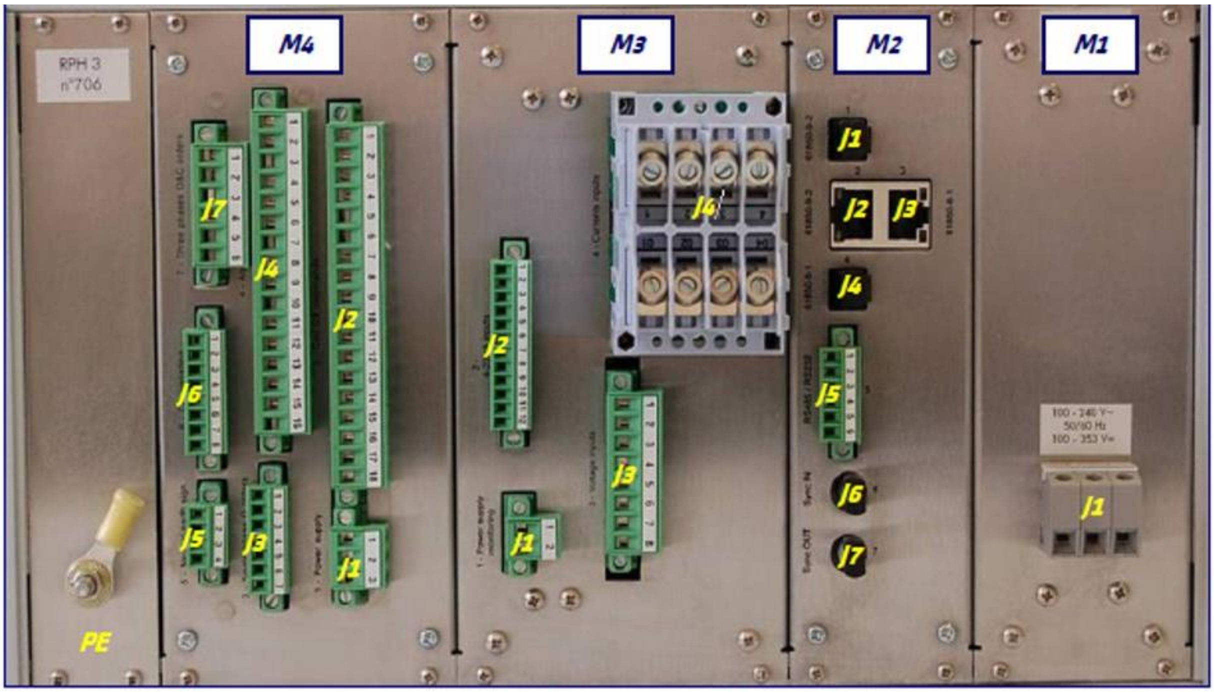


Figure-37: Back Layout of RPH3

The RPH3 Controller is designed as a global 19” rack integrating 5 single electronic modules connected through internal links and with removable terminal blocks at their back for external wiring.

The 5 Single Modules are:

M1 Module: Power Supply

M2 Module: Digital Signal Processing & Communication.

M3 Module: Acquisition & Digital Conversion

M4 Module: I/O, monitoring and CB coils driving commands.

M5 Module: Front panel signalization module

Each built RPH3 rack shall be customized depending on:

- Rated DC Voltage for CB coils supply (48V, 110-125V or 220-250V)
- Rated Current flowing through CT secondary windings (1A, 5A)

RPH3 Terminal assignment

M1 Module: Power Supply

M1J1 – RPH3 POWER SUPPLY		
Power supply	M1J1: 1	Ground
	M1J1: 2	Phase or Polarity +
	M1J1: 3	Neutral or Polarity -

M2 Module: Digital Signal Processing & Communication

M2 – COMMUNICATION PORT		
61850-9-2 optical link	M2J1	MT-RJ (AFBR 5903)
61850-9-2 copper link	M2J2	RJ45

61850-8-1 copper link	**M2J3**		**RJ45**
61850-8-1 optical link	M2J4		MT-RJ (AFBR 5903)
RS485 / RS232 serial link	M2J5: 1	RS232 TX iso	MC 1,5/6-STF-3.81
	M2J5: 2	GND iso	
	M2J5: 3	RS232 RX iso	
	M2J5: 4	RS485 A	
	M2J5: 5	RS485 TERM	
	M2J5: 6	RS485 B	
Sync IN optical link	M2J6		ST (HFBR 1414Z)
Sync OUT optical link	M2J7		ST (HFBR 2412Z)

M3 Module: Acquisition & Digital Conversion

M3J1 – OUTPUT COIL SUPPLY MONITORING		
DC Supply	M3J1: 1	Polarity -
	M3J1: 2	Polarity +
M3J3 – VOLTAGE INPUTS		
Line voltage L1 phase	M3J3: 1	S1
	M3J3: 2	S2
Line voltage L1 phase	M3J3: 3	S1
	M3J3: 4	S2
Line voltage L1 phase	M3J3: 5	S1
	M3J3: 6	S2
Source Voltage	M3J3: 7	S1
	M3J3: 8	S2
M3J4 – CURRENTS INPUTS		
Load current / Neutral	M3J4: 01	Not Used
	M3J4: 1	Not Used
Load current / L1 phase	M3J4: 02	S1
	M3J4: 2	S2
Load current / L2 phase	M3J4: 03	S1
	M3J4: 3	S2
Load current / L3 phase	M3J4: 04	S1
	M3J4: 4	S2

M4 Module: I/O, monitoring and CB coils driving commands.

M4J1 – CB COIL SUPPLY		
Circuit breaker coil command supply	M4J1: 1	Coil power supply / +
	M4J1: 2	Coil power supply / -
	M4J1: 3	Shield
M4J2 – CB COIL OUTPUT COMMAND		
Opening output / L1 phase	M4J2: 1	Coil + L1
	M4J2: 2	Coil – L1
	M4J2: 3	Shield
Opening output / L2 phase	M4J2: 4	Coil + L2
	M4J2: 5	Coil – L2
	M4J2: 6	Shield
Opening output / L3 phase	M4J2: 7	Coil + L3
	M4J2: 8	Coil – L3
	M4J2: 9	Shield
Closing output / L1 phase	M4J2: 10	Coil + L1
	M4J2: 11	Coil – L1
	M4J2: 12	Shield

Closing output / L2 phase	M4J2: 13	Coil + L2
	M4J2: 14	Coil – L2
	M4J2: 15	Shield
Closing output / L3 phase	M4J2: 16	Coil + L3
	M4J2: 17	Coil – L3
	M4J2: 18	Shield
M4J4 – OUTPUT ALARMS		
Shield	M4J4: 1	Shield
All-or-Nothing 4 pins relay "Mon"	M4J4: 2	Alarm b
	M4J4: 3	Alarm a
All-or-Nothing 7 pins relay #1 "Bist1"	M4J4: 4	Alarm 1b (NC)
	M4J4: 5	Common 1
	M4J4: 6	Alarm 1a (NO)
All-or-Nothing 7 pins relay #2 "Bist2"	M4J4: 7	Alarm 2b (NC)
	M4J4: 8	Common 2
	M4J4: 9	Alarm 2a (NO)
All-or-Nothing 7 pins relay #3 "Bist3"	M4J4: 10	Alarm 3b (NC)
	M4J4: 11	Common 3
	M4J4: 12	Alarm 3a (NO)
All-or-Nothing 7 pins relay #4 "Bist4"	M4J4: 13	Alarm 4b (NC)
	M4J4: 14	Common 4
	M4J4: 15	Alarm 4a (NO)
Shield	M4J4: 16	Shield
M4J5 – NEUTRAL EARTH SIGNALING		
Shield	M4J5: 1	Shield
Neutral / Ground signaling	M4J5: 2	+48V common
	M4J5: 3	N/G NO
	M4J5: 4	N/G NC
M4J6 – CB AUXILIARY SIGNALLING		
Shield	M4J6: 1	Shield
Auxiliary contact / L1 phase	M4J6: 2	CB position / L1 phase
	M4J6: 3	+48V common
Auxiliary contact / L2 phase	M4J6: 4	CB position / L2 phase
	M4J6: 5	+48V common
Auxiliary contact / L3 phase	M4J6: 6	CB position / L3 phase
	M4J6: 7	+48V common
Shield	M4J6: 8	Shield

3.0. Commissioning of Vizimax SynchroTeq Plus:

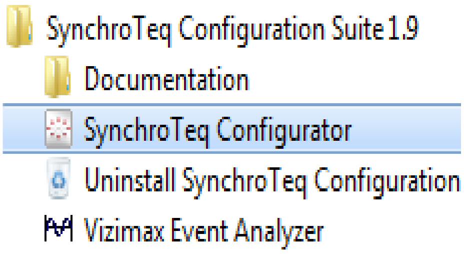
3.1. Configuration of CSD on SynchroTeq Control Software:

a) Installing the SynchroTeq configuration suite:

To install the SynchroTeq Configuration Suite Insert the media containing the SynchroTeq Configuration Suite installer in the PC or download the SynchroTeq Configuration Suite Setup.exe installation file to a temporary directory. Execute the SynchroTeq Configuration Suite Setup.exe file.

Once the installation of the SynchroTeq Configuration Suite is complete, you can open SynchroTeq Configurator using either of the following:

From the Windows task bar, click Start>Programs >SynchroTeq Configurator.



SynchroTeq requires two configuration files, as follows:

1. The **application configuration file** includes the parameters the SynchroTeq uses to manage C/B operations, such as:
    - C/B timing data, temperature, voltage, and pressure.
    - Parameters required for precise point-on-wave switching (opening and closing target angle, pre-arc time, nominal voltage and current).
    - Sensor calibration limits and alarm parameters.
    - Power transformer and high voltage bushing sensor information, if applicable.
2. The **system configuration file** includes parameters specific to the SynchroTeq system, such as system ID, communication information (IP address, DHCP address) and system services such as NTP synchronization.

b) Create a new configuration file

Create a new configuration file (*.stpcfg) by opening a configuration Template (*.stpcfgt):

1. Click File.
2. Click New.
3. Configure a system configuration file, select **SysConfig.stpcfgt** template.
4. Configure an application configuration file depending on your application type:

i. **AppConfig.stpcfgt:** Basic SynchroTeq applications with fixed settings, including:

- Discharged capacitor bank load (when a significant delay exist between de-energization and re-energization of the bank)
- Discharged harmonic filter (when a significant delay exist between de-energization and re-energization of the load)
- Unloaded power transformer without residual flux measurement (rapid closing strategy at peak voltage)

ii. **FastMSCFLT.stpcfgt**: For fast switched capacitor bank and harmonic filters applications. This template supports dynamic closing angle of the C/B according to the residual charges in the load capacitors.

iii. **FastMSR.stpcfgt**: For fast switching reactors.

iv. **STPRFC.stpcfgt**: For unloaded power transformer applications taking in account the residual flux (Dynamic settings).

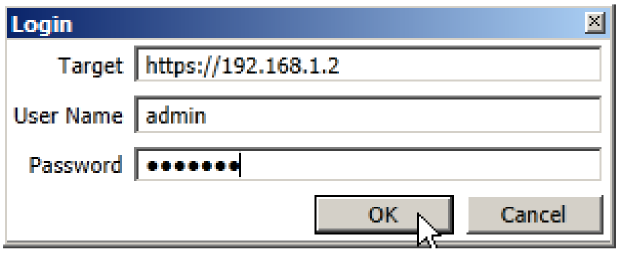
v. **STPTLComp.stpcfgt**: For compensated transmission line with reclosing and line side voltage measurement.

vi. **STPTLUncompNoTrap.stpcfgt**: For uncompensated transmission lines with no trapped charges.

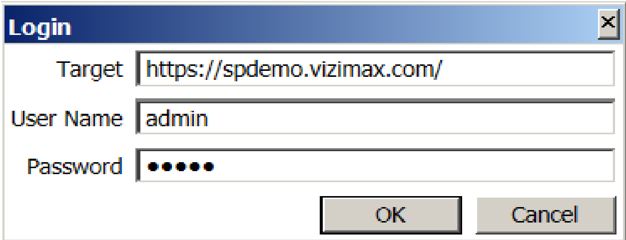
vii. **STPTLUncompTrap.stpcfgt**: For uncompensated transmission lines with trapped charges. This configuration supports single pole and 3 poles reclosing.

c) Connecting the configurator online

The “File/ Connect to Target…” command establishes an online secured connection between the computer and the SynchroTeq. Enter the Target IP address or the URL (preceded by https://), Username and Password. Then click OK to connect online with the unit.



or



User Group	User Name	Factory default Password
Administrator	admin	@1Admin
Maintenance	maint	@1Maint
Operation	oper	@1Oper
Viewer	view	@1View

Figure-38: SynchroTeq Login Page

Once the connection is established, the configurator home screen appears:

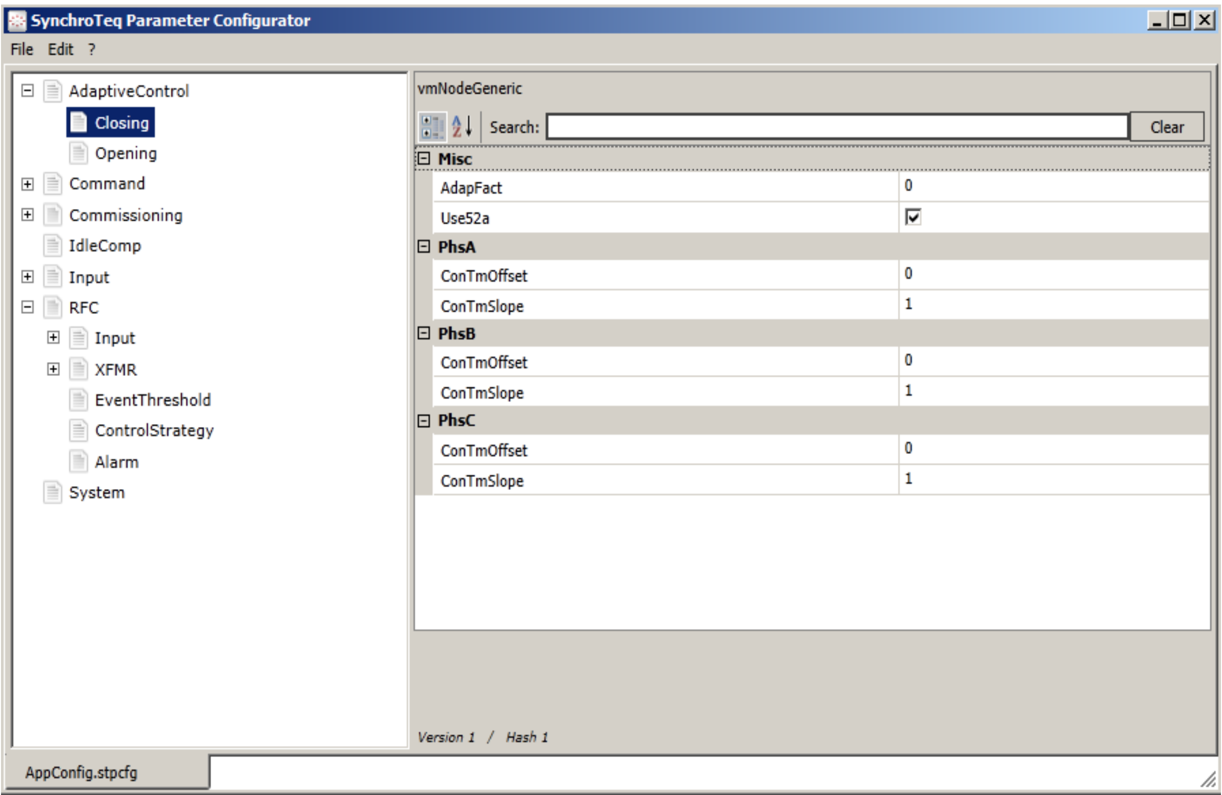


Figure-39: SynchroTeq Configuration Page

d) Circuit Breaker Adaptive Control

These sets of parameters are used for the adjustment of the adaptive control of the CB, which automatically optimize the calculation of the next operation based on the cumulated timing error measured from the previous operations. Adaptive control compensates for CB wear and for performance deviations from the standard compensation model used to describe the influence of the operating environment on the CB timing.

For example, if there is a 1 ms difference between the B predicted operating time calculated by SynchroTeq based on the operating conditions and the measured timing of the last operation, the next operation calculation will be corrected by a fraction of this error in order to have a more accurate timing prediction. The adaptive control correction is cumulative, meaning that it does not only compensates for the error of the last operation (which has the strongest impact), but also from the operation history of the C/B.

CB adaptive control for closing: This set of parameters is used for the adjustment of the adaptive control of the C/B for the closing operations.

CB adaptive control for Opening: This set of parameters is used for the adjustment of the adaptive control of the C/B for the opening operations.

Menu:Sub-menu:Category	Parameter	Range	Unit	Parameter description
AdaptiveControl: Closing:Misc	*AdapFact*	0.00 to 1.00	-	Feedback control for closing operations. Entering a *0* value disable the adaptive control correction and entering a *1* value force a full feedback from the last operation. (Default: *0*) A *0.250* value applies 25% of the relative error (measured Vs. predicted) to correct the next operation. A value between 0.25 and 0.5 is recommended to achieve a good stability.
	Use52a	Enable/Disable		Selection of the technique used for the corrected measurement of the C/B operating time (time from command up to the main contact closure): • *Enable* to calculate the corrected measurement of C/B closing time from the 52a auxiliary contacts. • *Disable* to calculate the corrected measurement of C/B closing time from the load current flow detection. (Default: *Enable*) When energizing an unloaded power transformer, no current will flow. In this case, timing from 52a contacts should be selected.
AdaptiveControl: Closing:PhsA *AdaptiveControl: Closing:PhsB* *AdaptiveControl: Closing:PhsC*	*ConTmOffset*	-1.0000 to +1.0000	Second	Offset involved in the calculation of the corrected measurement of C/B closing (TM, C/B main contacts closure) from the 52a auxiliary contacts timing (Tom) using the following equation: TM = Tom x *ConTmSlope* + *ConTmOffset* When the main and auxiliary contacts have the same timings, the offset is 0. A negative value indicates that the C/B main contacts are faster than the auxiliary contacts. (Default: *0*, Ex: -0.00045: the main contact is ahead of the 52a contact by 4.5 ms when *ConTmSlope* = 1)
	ConTmSlope	-10.0 to +10.0	-	Gain involved in the calculation of the corrected measurement of C/B closing (TM, C/B main contacts) from the 52a auxiliary contacts timing (Tom) using the following equation: TM = Tom x *ConTmSlope* + *ConTmOffset* The slope is equal to 1 when there is a constant or no offset between the main and auxiliary contacts. (Default: *1*)

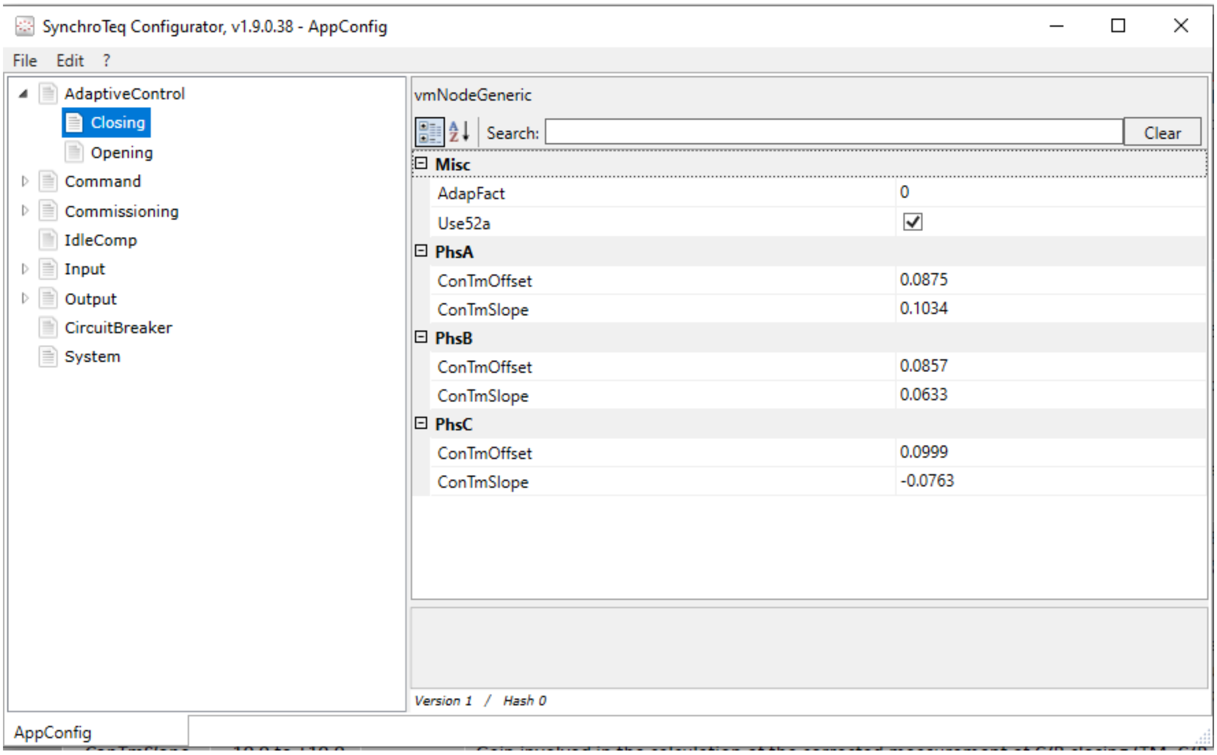


Figure-40: CB Adaptive Control for Closing

Menu:Sub-menu:Category	Parameter	Range	Unit	Parameter description
AdaptiveControl: Opening:Misc	*AdapFact*	0.00 to 1.00	-	Feedback control for opening operations. Entering a *0* value disable the adaptive control correction and entering a *1* value force a full feedback from the last operation. (Default: *0*) A *0.250* value applies 25% of the relative error (measured Vs. predicted) to correct the next operation. A value between 0.25 and 0.5 is recommended to achieve a good stability.
	Use52a	Enable/Disable	-	*Enable* to calculate the corrected measurement of C/B opening time from the 52a auxiliary contacts. Cannot be changed (Default: *Enable*, cannot be changed).
AdaptiveControl: Opening:PhsA *AdaptiveControl: Opening:PhsB* *AdaptiveControl: Opening:PhsC*	*ConTmOffset*	1.0000 to +1.0000	Second	Offset involved in the calculation of the corrected measurement of C/B opening (TM, C/B main contacts) from the 52a auxiliary contacts timing (Tom) using the following equation: TM = Tom x *ConTmSlope* + *ConTmOffset* When the main and auxiliary contacts have the same timings, the offset is 0. A negative value indicates that the C/B main contacts are faster than the auxiliary contacts. (Default: *0*, Ex: -0.00045: the main contact is ahead of the 52a contact by 4.5 ms when *ConTmSlope* = 1)
	ConTmSlope	-10.0 to +10.0	-	Gain involved in the calculation of the corrected measurement of C/B opening (TM, C/B main contacts) from the 52a auxiliary contacts timing (Tom) using the following equation: TM = Tom x *ConTmSlope* + *ConTmOffset* The slope is equal to 1 when there is a constant or no offset between the main and auxiliary contacts. (Default: *1*)

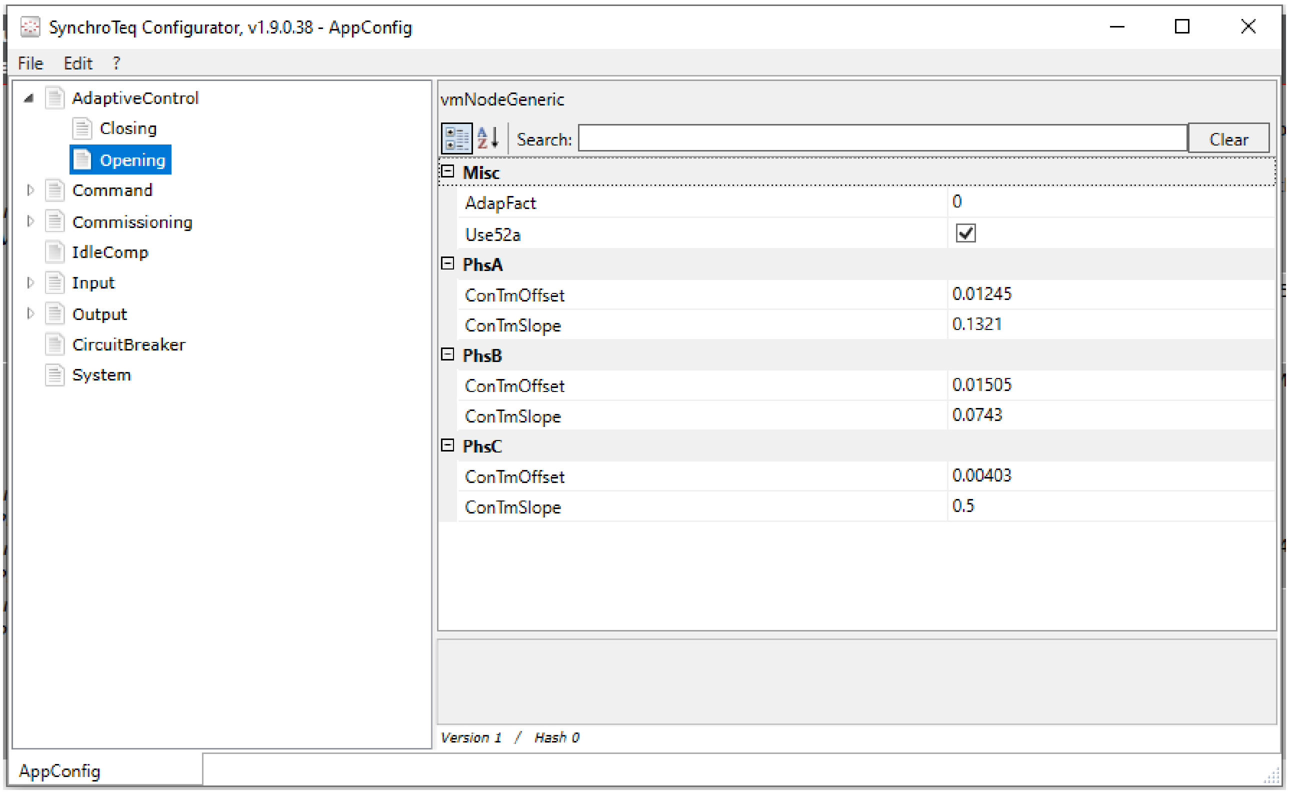


Figure-41: CB Adaptive Control for Opening

e) **Command: Circuit Breaker Control and Alarms:** The *ActPulseInc* parameter is applicable for both the closing and opening operations. It defines the C/B coil command pulse increment (10 or 100ms).

Menu:Sub-menu:Category	Parameter	Range	Parameter description
Command:System	*ActPulseInc*	From list: 10 or 100ms	Duration of the C/B coil opening/closing pulses command increment: 10 ms or 100 ms. See Closing: C/B Closing commands and Opening: Opening command. (Default: 100 ms).

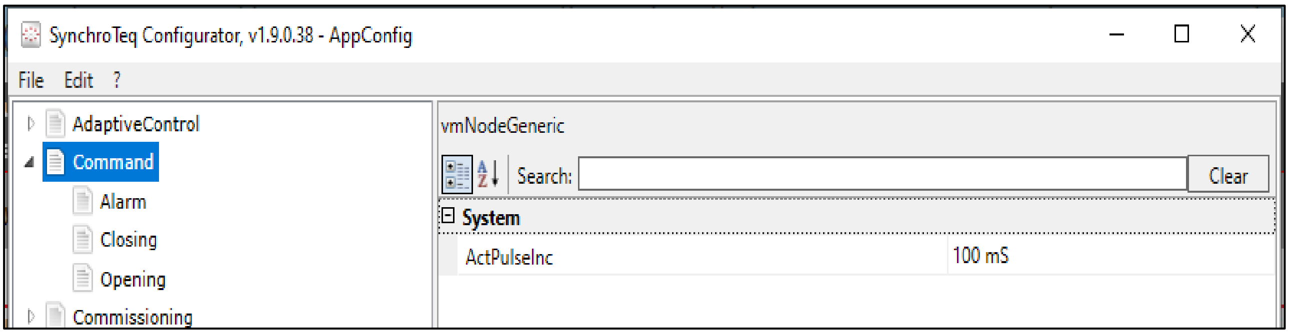


Figure-42: CB Control and Alarms

CB Closing Inrush Current Detection: Excessive inrush current alarm is detected by computing the average current over 10 samples sliding window. The average of the sliding window must be above the inrush current threshold for 10 consecutive times. This means that a short glitch will be eliminated, but sustained current will be detected. SynchroTeq supports two detection thresholds: the normal limit (less sensitive) and the degraded/low limit (more sensitive). The active threshold is selected by the **Inrush.Threshold.Mode** parameter.

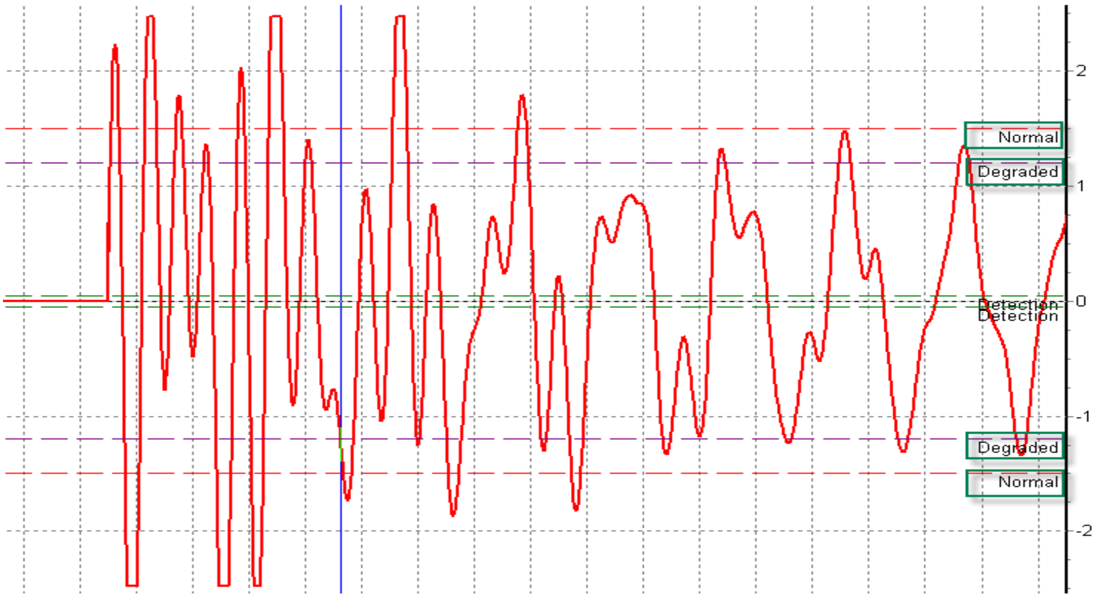


Figure-43: Inrush Current Detection

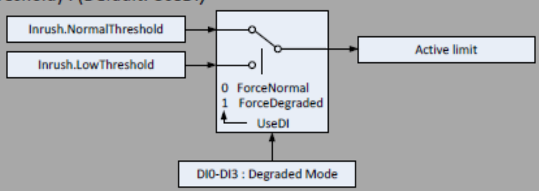
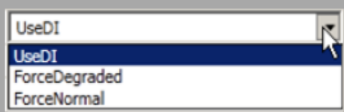
Menu:Sub-menu:Category	Parameter	Range	Unit	Parameter description
Command:Alarm: Closing	*Inrush.Enable*	Enable/Disable	-	*Enable/disable* the excessive inrush current alarm when closing the C/B. (Default: *Enable*)
	Inrush. LowThreshold	0.00 to 5.00	PU	Lowest limit of inrush current detection (most sensitive). (Default: *2*). This limit is selected by the *Inrush.Threshold.Mode* parameter.
	Inrush. NormalThreshold	0.00 to 5.00	PU	Normal limit of inrush current detection (less sensitive). (Default: *2*). This limit is selected by the *Inrush.Threshold.Mode* parameter.
Command:Alarm: Closing	*Inrush. Threshold.Mode*	From list		Determine which inrush current detection threshold is active (*Inrush.LowThreshold* or *Inrush.NormalThreshold*) : (Default: *UseDI)*  • ***UseDI***: Use one of the DI0:DI3 programmable digital inputs to select the active threshold. The low threshold (most sensitive) is selected when the input is active, and the normal threshold is selected when the input is inactive. The programmable digital input used for the threshold selection must be assigned to the "Degraded mode" function (see DI0/DI1/DI2/DI3: User general purpose digital inputs). Please aslo refer to the SynchroTeq installation guide, section "Connect the SPSEQ module (digital inputs)". • ***ForceDegraded***: Use the Inrush.LowThreshold. • ***ForceNormal***: Use the Inrush.NormalThreshold. 

Figure-44: CB Alarm Configuration

CB Timing Alarm Detection on Closing (operation limit): Each time the C/B is closed, SynchroTeq has the capability to verify if it has operated as expected and otherwise generate an "operation limit" alarm. This timing alarm is detected using limits defining 3 operation zones:

- The normal zone (green), defined by the ***Overflow.Minor*** limits is the normal and expected zone in which the closing of the C/B should occur.
- The minor deviation zones (orange), defined between the ***Overflow.Minor*** and ***Overflow.Severe*** limits. An "operation limit" alarm will be notified if the closing of the C/B occurs from 1 to 10 consecutive times within these zones ***(Overflow.Minor.Consecutive)***.

- The severe deviation zones (red), defined by the ***Overflow.Severe*** limits. An "operation limit" alarm will be notified on the first occurrence of C/B closing in these red zones.

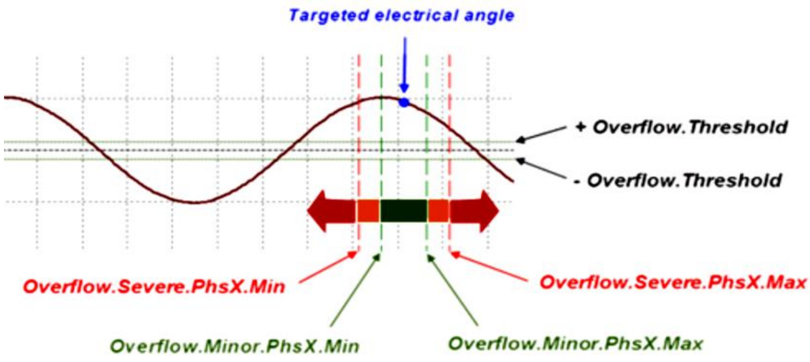
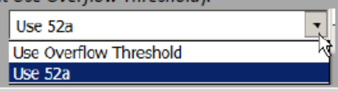


Figure-45: Overflow Detection

Menu:Sub-menu: Category	Parameter	Range	Unit	Parameter description
Command:Alarm: Closing	*OpLimitDetection*	From list	-	Operation limit alarm detection technique: • ***Use52a***: Use the mechanical closing moment: the Corrected mechanical operating time (see Measurement of the C/B operating time) derived from the 52a auxiliary contact is compared with the Predicted operating time. • ***Use Overflow Threshold***: Use the load current detection and verify the match with the target angle. (Default *Use Overflow Threshold*). 
	Overflow.Minor. Consecutive	1 to 10	-	Number of consecutive minor close overflow timing error on a phase-by-phase basis before an operation limit alarm occurs if enabled. (Default: *1*) The reference point is the electrical target point (current flow detection) or the predicted operating time (52a detection). For each phase: • The closing operation is considered successful if the switching moment is within the green zone defined by the two *Overflow.Minor* green limits. • An operation limit alarm is immediately signaled if the switching moment is outside the red zone defined by the two *Overflow.Severe* red limits. • An operation limit alarm is signaled after "*Overflow.Minor.Consecutive*" consecutive times when the switching moment is outside the green zone defined by the two *Overflow.Minor* green limits by inside the two *Overflow.Severe* red limits.
	Overflow.Minor. PhsA.Max *Overflow.Minor. PhsB.Max* *Overflow.Minor. PhsC.Max*	-10.0 to +10.0	ms	Phase A/B/C upper limit used to define the normal zone C/B timing for the operation limit alarm detection. (Default: 1) *Overflow.Minor .Min* should be smaller than *Overflow.Minor .Max.* *Overflow.Minor .Min* and *Overflow.Minor .Max* should be adjusted according to the C/B mechanical scatter time.

Menu:Sub-menu:Category	Parameter	Range	Unit	Parameter description
	Overflow.Minor. PhsA.Min *Overflow.Minor. PhsB.Min* *Overflow.Minor. PhsC.Min*	-10.0 to +10.0	ms	Phase A/B/C lower limits are used to define the normal C/B timing zone for the operation limit alarm detection. (Default: -1) *Overflow.Minor .Min* should be smaller than *Overflow.Minor .Max.* *Overflow.Minor .Min* and *Overflow.Minor .Max* should be adjusted to the C/B mechanical scatter time.
	Overflow.PhsA. Enabled *Overflow.PhsB. Enabled* *Overflow.PhsC. Enabled*	Enable/ Disable	-	*Enable/disable* the Operation limit alarms detection for closing operations on phase A/B/C. (Default: *Enable*)
Command: Alarm:Closing	*Overflow.Severe. PhsA.Max* *Overflow.Severe. PhsB.Max* *Overflow.Severe. PhsC.Max*	-10.0 to +10.0	ms	Phase A/B/C upper limit used to define the abnormal C/B timing zone for the operation limit alarm detection. An operation limit alarm is immediately signaled if the switching moment occurs after the red limit defined by the *Overflow.Severe...Max* parameter. (Default: *2*) *Overflow.Severe .Min* should be smaller than *Overflow.Minor .Max.* *Overflow. Severe .Min* and *Overflow.Minor .Max* should be adjusted according t the C/B mechanical scatter time.
	Overflow.Severe. PhsA.Min *Overflow.Severe. PhsB.Min* *Overflow.Severe. PhsC.Min*	-10.0 to +10.0	ms	Phase A/B/C lower limit are used to define the abnormal C/B timing zone for the operation limit alarm detection. An operation limit alarm is immediately signaled if the switching moment occurs before the red limit defined by the *Overflow.Severe Min* parameter. (Default: *-2*) *Overflow.Severe .Min* should be smaller than *Overflow.Minor .Max.* *Overflow. Severe .Min* and *Overflow.Minor .Max* should be adjusted according the C/B mechanical scatter time.
	Overflow. Threshold	0.00 to 2.00	PU	Threshold for the detection to determine the electrical closing moment based the load current flow. This parameter is only applicable when the ***Use Overflow Threshold*** is selected for the operation limit alarm detection.(Default: *0.05*)
	RandomCmd. Enabled	Enable/ Disable	-	*Enable/disable* an alarm if a random closing operation is generated by SynchroTeq due to the absence of a synchronization signal or to an invalid compensation input signal replaced by a default value. (Default: *Enable*)

Figure-46 CB Timing Alarm Detection on Closing (Operation Limit)

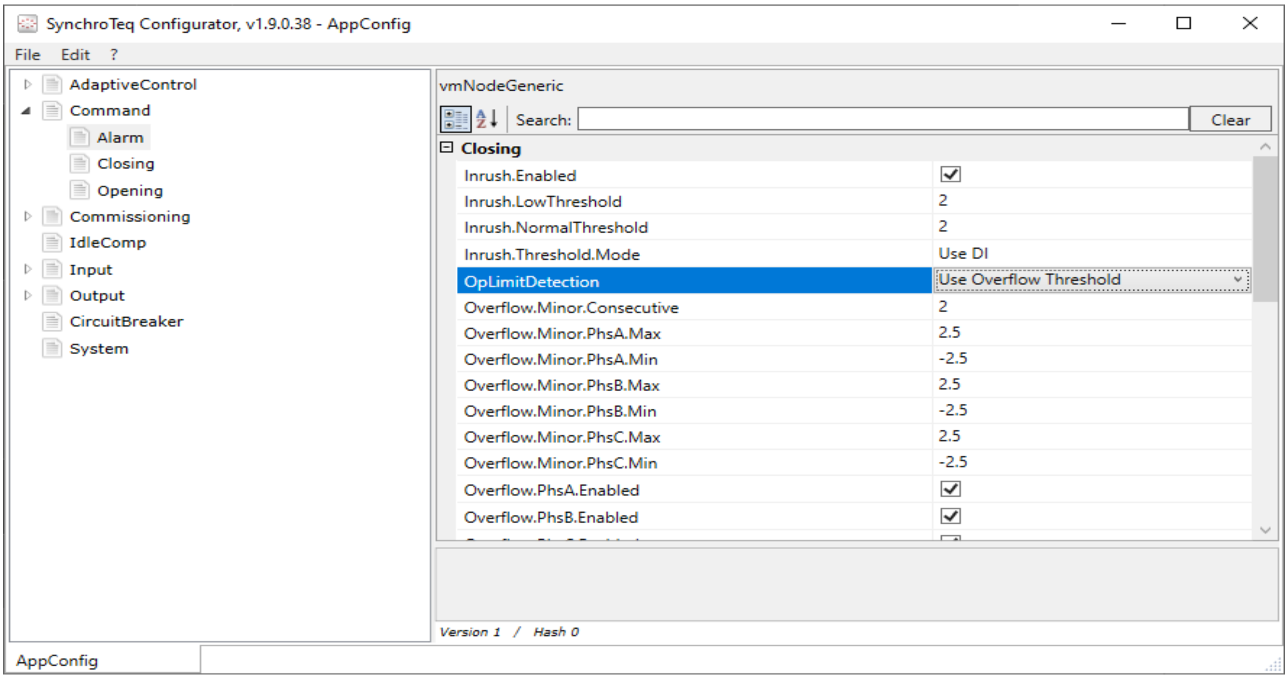


Figure-47: CB Timing Alarm Detection on Closing (Operation Limit Default Settings)

Menu:Sub-menu:Category	Parameter	Range	Unit	Parameter description
Command:Alarm: Opening	*Overflow. Consecutive*	1 to 10	-	Number of consecutive opening timing overflows required before setting the Operation limit alarm. An opening timing overflow is detected when the current is still flowing (electrical operating time) after the desired electrical target time. (Default: *1*)
	Overflow.PhsA. Enabled *Overflow.PhsB. Enabled* *Overflow.PhsC. Enabled*	Enable/ Disable	-	*Enable/disable* the Operation limit alarm detection on phase A/B/C. (Default: *Enable*)
	Overflow. Threshold	0.00 to 0.20	PU	Out of limit/Re-ignition/re-strike/ current threshold detection. The current detection is active after the desired electrical target angle. (Default: *0.2*)
	RandomCmd. Enabled	Enable/ Disable	-	*Enable/disable* an alarm if a random opening operation is generated by SynchroTeq due to the absence of an adequate synchronization signal or to an invalid compensation input signal replaced by a default value. (Default: *Enable*)
Command:Alarm: Sequence	*CoilOverCurr. AbortCmd*	Enable/Disable		*Enable/disable* the interruption and abortion of the open or close command in progress if there is an instantaneous C/B coil control output current exceeding 45A to prevent damaging the SynchroTeq. (Default: *Disable*)
	CoilOverCurr. Enabled	Enable/Disable		*Enable/disable* the coil overcurrent alarm detection. (Default: *Enable*)
	OperSpecific	Enable/Disable		*Enable/disable* the validation of the C/B coil control output sequence to the current operation (open or close, Enable) or to all of the 6 open/close control outputs (disable). (Default: *Enable*) For example when the *OperSpecific* is enabled, a disturbance signal appearing on one of the "CLOSE" coil driver output during an opening operation won't generate any sequence alarm.
	PhsA.Enabled *PhsB.Enabled* *PhsC.Enabled*	Enable/Disable		*Enable/disable* the detection of the *coil sequence alarm* on phase A/B/C during the execution of a command. The alarm indicates that the read back of the C/B coil control outputs during the command execution does not correspond to the state expected by the processor. (Default: *Enable*)

Figure-48: CB Timing Alarm Detection on Opening (Operation Limit)

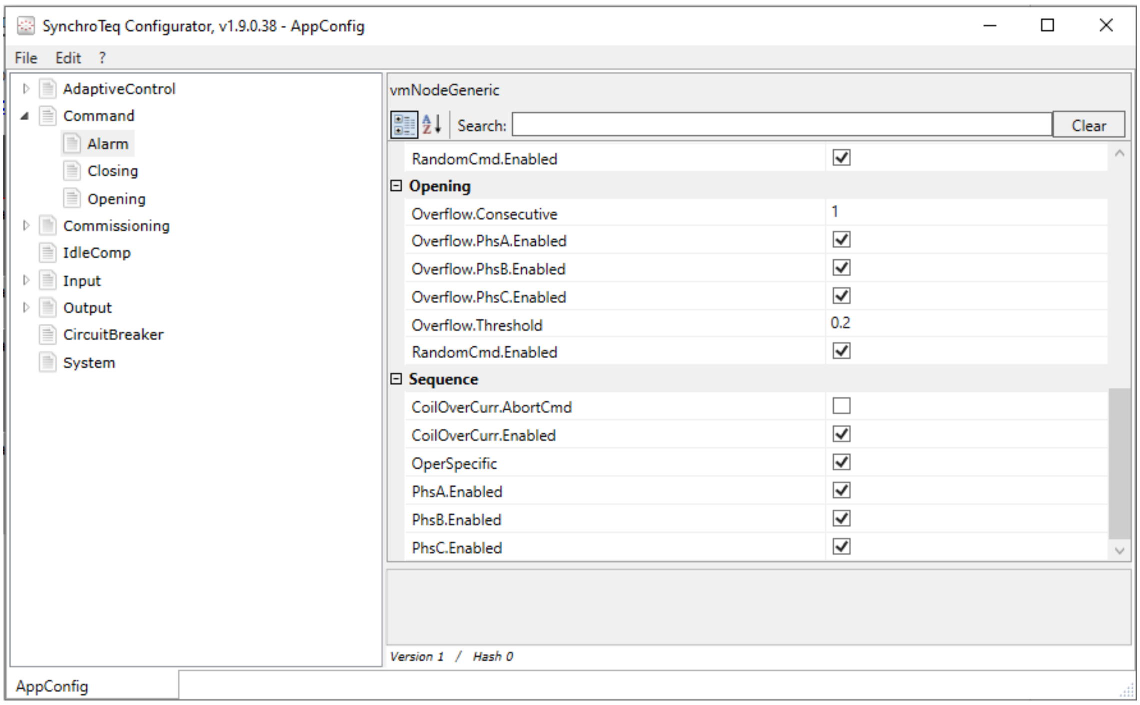


Figure-49: CB Timing Alarm Detection on Opening (Operation Limit Default Setting)

Closing: CB closing command:

Menu:Sub-menu: Category	Parameter	Range	Unit	Parameter description
Command:Closing: Application	*PhsA.PreArcTm* *PhsB.PreArcTm* *PhsC.PreArcTm*	0.00 to 10.00	ms	Phase A/B/C closing arcing time (prestrike delay). Arcing occurs when closing at other than null voltage across the C/B contacts. The arc extinguishes when the C/B contacts are making. (Default: *0*)
	PhsA.TgtAng	0 to 2160	°	Phase A electrical closing target angle (load energization) in reference to phase A voltage. (Default: *0*) (Max : 6 cycles = 2160°)
	PhsB.TgtAng	0 to 2160	°	Phase B electrical closing target angle (load energization) in reference to phase A voltage. (Default: *120*) (Max : 6 cycles = 2160°).
	PhsC.TgtAng	0 to 2160	°	Phase C electrical closing target angle (load energization) in reference to phase A voltage. (Default: *240*) (Max : 6 cycles = 2160°).
Command:Closing: Misc	*CoilSupervision*	Enable/ Disable	-	Supervision of the close C/B coils circuits using a 3mA DC current to detect if they are connected to the SynchroTeq outputs. Coil supervision can be *Disabled* (no supervision current), *Always* enabled or active only when the CB is *Ready to Operate* (C/B is open and ready to be closed). A Coil supervision alarm is set if there a discontinuity in the C/B coil loop. (Default: *Disabled*)
	FrontPanelEnabled	Enable/ Disable	-	Enable/disable the operation of the C/B Close command from the front panel. (Default: Enabled)
	SyncEdge	From list	-	Phase A zero-crossing synchronization edge used to establish the target angle: (Default: *Falling*) • *Rising*: 0° at positive going edge (when dV/dt is positive). In this case, 90° is the peak positive voltage. • *Falling*: 0° at negative going edge (when dV/dt is negative). In this case, 90° is the peak negative voltage. Must be selected for smallest command latency (fast switching and power transformers applications) • *AlternateEdge*: Each successive closing operation synchronization will alternate between Rising and Falling edges. Recommended for saturable reactors
Command:Closing: System	*ActPulseTm*	1 to 100	-	Close command output pulse activation time, by increments of *Command:System: ActPulseInc*. (Default: *5*, multiplied by 10ms or 100ms)
	AllowRandomCmd	Enable/ Disable	-	*Enable/disable* random (unsynchronized) operation of the C/B when: • phase A synchronization reference signal is not available within the *MaxSyncWaitTm* delay • when using a default voltage/temperature/pressure compensation input. (Default: *Enable*)
	MaxSyncWaitTm	1 to 10	100ms	Maximum waiting time to detect the phase A synchronization reference signal when executing a Close command. At the delay expiration, an unsynchronized command results if *AllowRandomCmd* is enabled. (Default: *5*, which is 500ms)

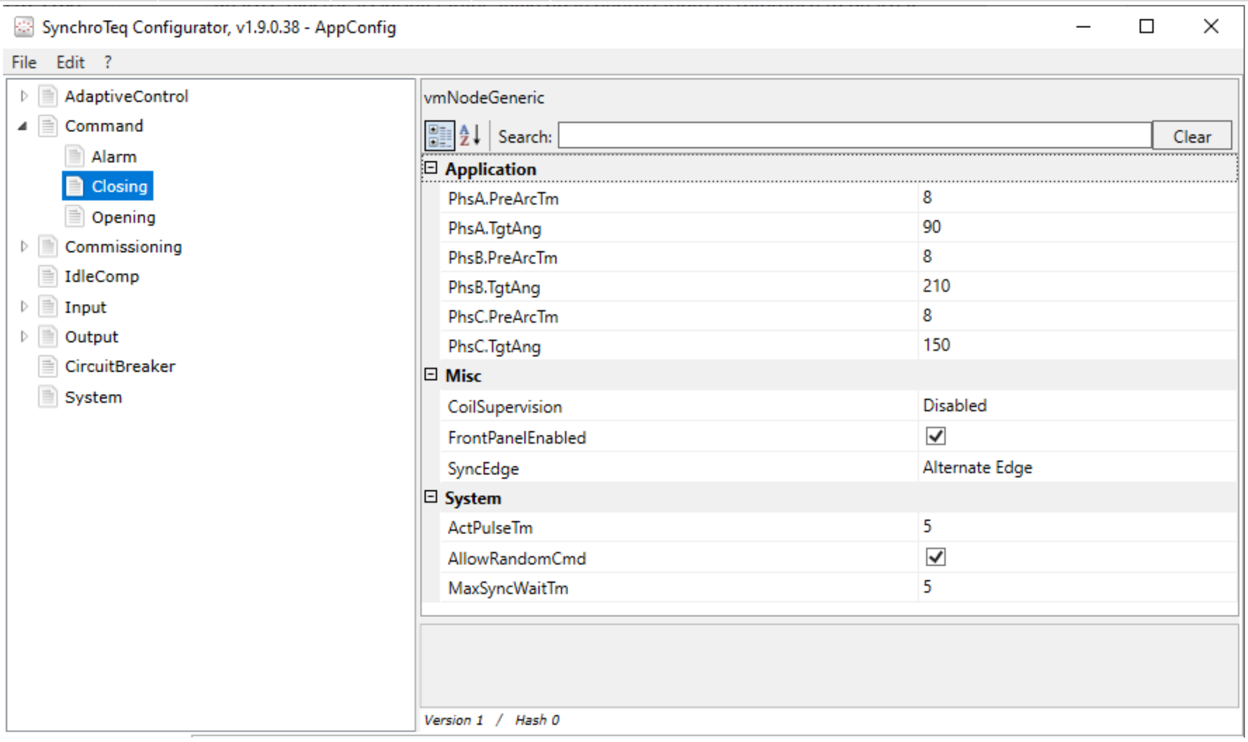


Figure-50: CB Closing Command Configuration

Opening: CB opening command

Menu:Sub-menu:Category	Parameter	Range	Unit	Parameter description
Command: Opening: Application	*PhsA.ArcTm PhsB.ArcTm PhsC.ArcTm*	0 to 180	°	Phase A/B/C expected arcing time duration after contact separation to ensure that the dielectric strength of the C/B is sufficient to maintain AC load current interruption after it has reached zero crossing. (Default: *30*)
	PhsA.TgtAng	0 to 2160	°	Phase A electrical opening target angle (load de energization) in reference to phase A voltage or current (see *SyncOnVA*). (Default: *0*)
	PhsB.TgtAng	0 to 2160	°	Phase B electrical opening target angle (load de energization) in reference to phase A voltage or current (see *SyncOnVA*). (Default: *120*)
	PhsC.TgtAng	0 to 2160	°	Phase C electrical opening target angle (load de energization) in reference to phase A voltage or current (see *SyncOnVA*). (Default: *240*)
Command: Opening:Misc	*CoilSupervision*	Enable/Disable	-	Supervision of the Open C/B coils circuits using a 3mA DC current to detect if they are connected to the SynchroTeq outputs. Coil supervision can be ***Disabled*** (no supervision current), ***Always*** enabled or active only when the CB is ***Ready to Operate*** (C/B is closed and ready to be open). A Coil supervision alarm is set if there a discontinuity in the C/B coil loop. (Default: *Disabled*) (Default: *Disabled*)
	FrontPanel Enabled	Enable/Disable	-	Enable/disable the operation of the C/B Open command from the front panel. (Default: Enabled)
	SyncEdge	SyncEdge	-	Phase A zero-crossing synchronization edge used to establish the target angle: (Default: *Falling*) • ***Rising***: 0° at positive going edge (when dV/dt is positive). In this case, 90° is the peak positive voltage or current. • ***Falling***: 0° at negative going edge (when dV/dt is negative). In this case, 90° is the peak negative voltage or current. Must be selected for smallest command latency (fast switching and power transformers applications) • ***AlternateEdge:*** Each successive closing operation synchronization will alternate between *Rising* and *Falling* edges. Recommended for saturable reactors.
	SyncOnVA	Enable/Disable	-	*Enable* to use phase A voltage as synchronization reference instead of using phase A current (*Disable* to use phase A current). (Default: *Disable*) This parameter must be disabled in applications where load current is variable (Po Transformer and Transmission Line applications). In these cases, load current zero crossing synchronization signal (ZX IA) may not be properly detected.

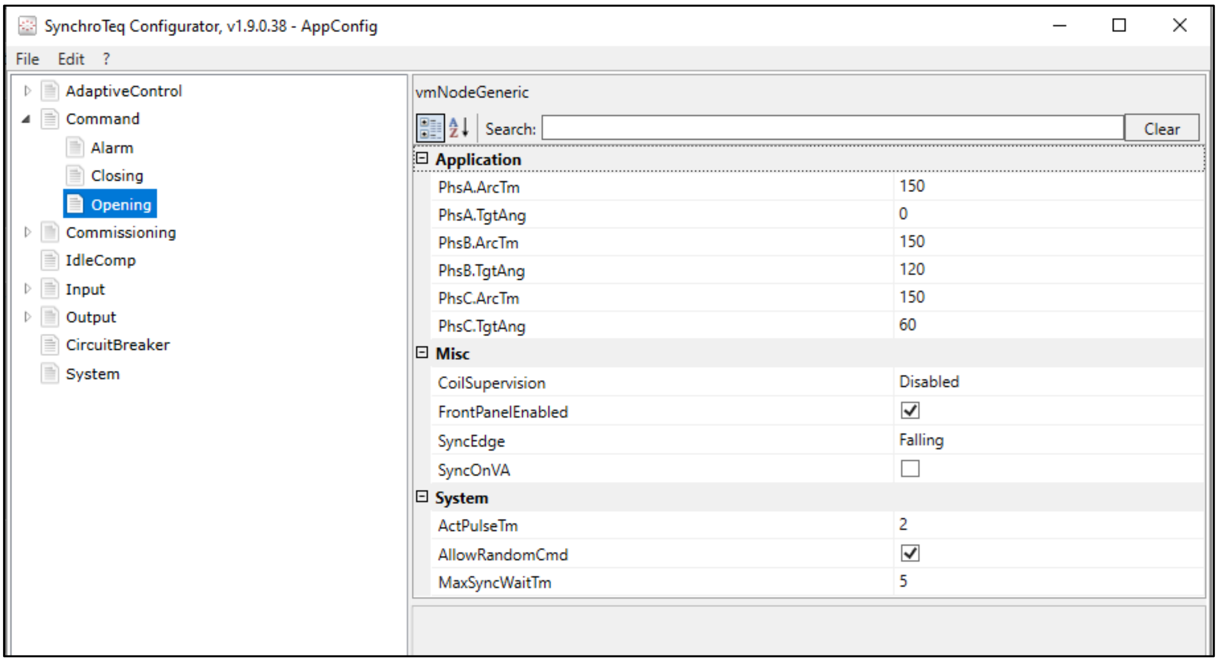


Figure-51: CB Opening Command Configuration

f) **Commissioning: Reference measurements for opening and closing operations-** These parameters describe the C/B operating conditions during the timing tests: they are valid for both the opening and closing operations.

Menu:Sub-menu:Category	Parameter	Range	Unit	Parameter description
Commissioning:Ref	*CBVol*	0 to 300.0	V	C/B coils supply voltage measured during the C/B timing tests at commissioning. (Default: *125*)
	GlobalComp	See description	Sensor unit	C/B global compensation measurement during the C/B timing tests at commissioning. For example, enter -5.5 if the C/B timing tests were done when the average C/B temperature measured with a sensor connected to the Global Compensation input (AGC) was -5.5°C. The valid range for this input is the defined by *the Input:GlobalComp:Alarm:Limits.Min* and *Limits.Max* parameters which defines the operating range of the C/B (see GlobalComp: Sensor for the global compensation of the C/B operating time). The Global compensation input can be used for the measurement of the temperature, the hydraulic pressure or any other factor that affects the timing of all the C/B poles. (Default: *25*)

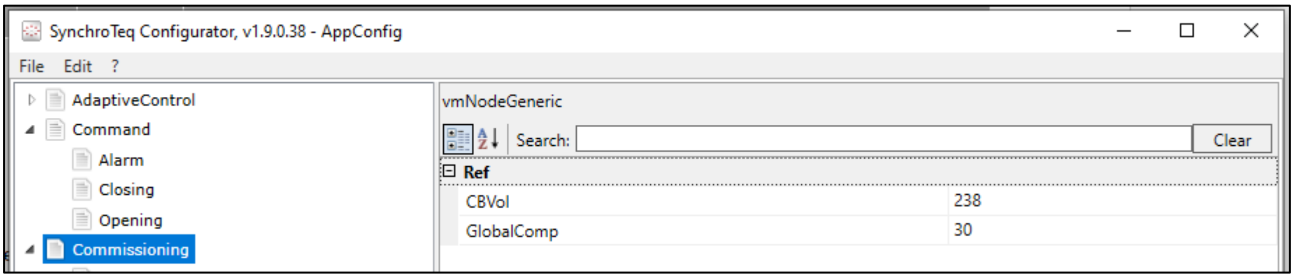


Figure-52: Commissioning_Ref

Closing: CB closing commissioning- These parameters describe the C/B closing times measured on each phase at the PhaseComp pressure reading (if applicable) during the C/B timing tests at commissioning.

Menu:Sub-menu:Category	Parameter	Range	Unit	Parameter description
Commissioning: Closing:Ref	*ClsTm.PhsA* *ClsTm.PhsB* *ClsTm.PhsC*	0.0 to 262.0	ms	Phase A/B/C closing time measured during the C/B tests at commissioning, which is the elapsed time from the coil command up to the main contact closure. This time is used to calculate the predicted C/B operating time of each phase using the compensation multipliers. (Default: 100)
	PhaseComp. PhsA *PhaseComp. PhsB* *PhaseComp. PhsC*	See description	Sensor unit	Phase-by-phase compensation measurement during the C/B timing tests at commissioning. Usually, the phase-by-phase compensation inputs are used to compensate the C/B timing calculation for pneumatic/hydraulic/isolating gas pressure variation. It can also be used for the auxiliary voltage measurement when the dual SPSBO option is used. (Default: 0) For example, enter 115 if the C/B timing tests were done when the average C/B hydraulic pressure measured with a sensor connected to the corresponding Phase Compensation input (AP_x) was 115 Bars. The range for these parameters are defined by the operating range of the C/B (Input:PhaseComp:Phsx:Alarm:Limits.Min and Limits.Max parameters, seePhaseComp: Circuit Breaker phase-by-phase compensation inputs). When not using the phase-by-phase compensation, enter 0. When using only one sensor shared between the 3 C/B poles (common pressure pipes): 1- Connect the sensor to A_PA Phase A compensation input 2- Enter the sensor value measured during the C/B test in *PhaseComp.PhsA* 3- Set PhaseComp.PhsB and PhaseComp.PhsC to 0.

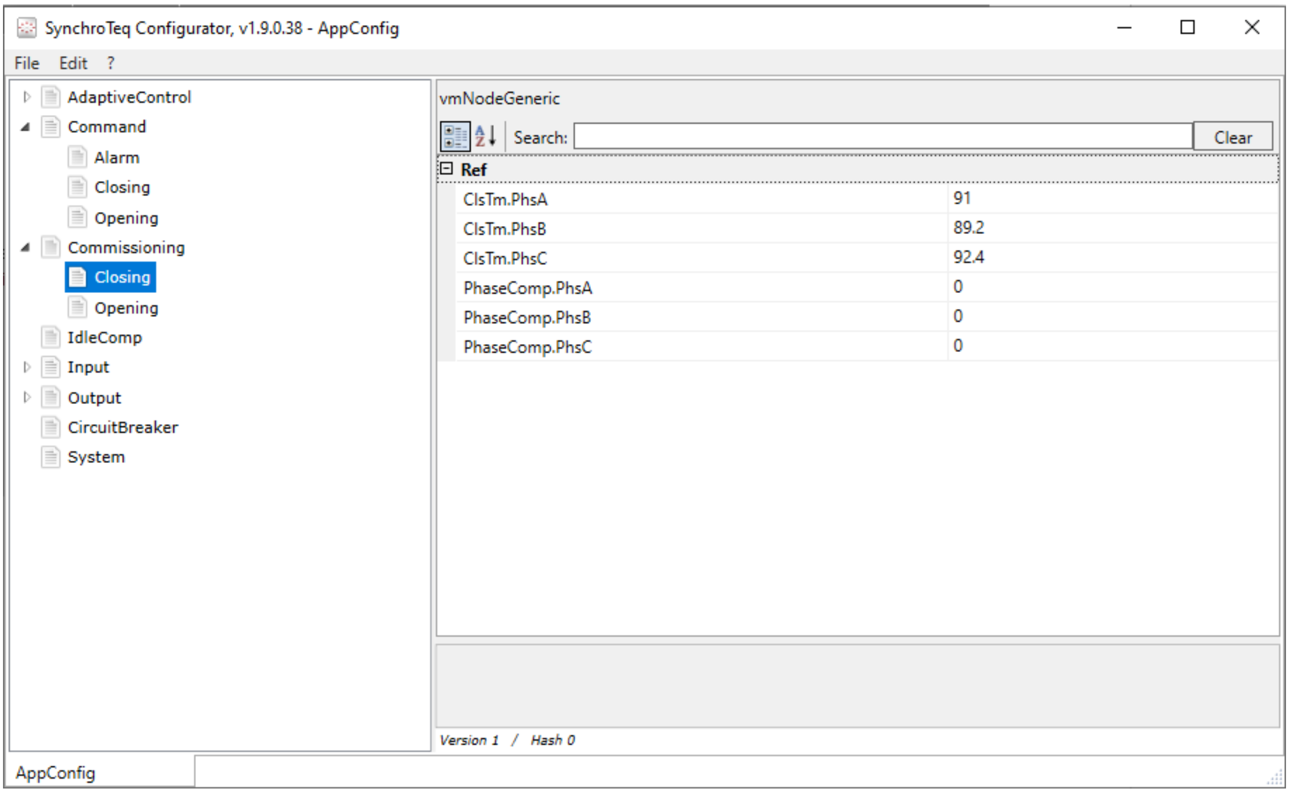


Figure-53: Closing Commissioning_Ref

Opening: CB opening commissioning- These parameters describe the C/B opening times measured on each phase at the PhaseComp pressure reading (if applicable) during the C/B timing tests at commissioning.

Menu:Sub-menu:Category	Parameter	Range	Unit	Parameter description
Commissioning: Opening:Ref	*OpnTm.PhsA* *OpnTm.PhsB* *OpnTm.PhsC*	0.0 to 262.0	ms	Phase A/B/C opening time measured during the C/B tests at commissioning, which is the elapsed time from the coil command up to the main contact opening. This time is used to calculate the predicted C/B operating time of each phase using the compensation multipliers. (Default: *40*)
	PhaseComp.PhsA *PhaseComp.PhsB* *PhaseComp.PhsC*	See description	Sensor unit	Phase-by-phase compensation measurement during the C/B timing tests at commissioning. Usually, the phase-by-phase compensation inputs are used to compensate the C/B timing calculation for pneumatic/hydraulic/isolating gas pressure variation. (Default: 0) For example, enter 525 if the C/B timing tests were done when the average C/B pneumatic pressure measured with a sensor connected to the corresponding Phase Compensation input (AP_x) was 525 psi. The range for these parameters are defined by the operating range of the C/B (Input:PhaseComp:Phsx:Alarm:Limits.Min and Limits.Max parameters, see PhaseComp: Circuit Breaker phase-by-phase compensation inputs). When not using the phase-by-phase compensation, enter 0. When using only one sensor shared between the 3 C/B poles (common pressure pipes): 1- Connect the sensor to A_PA Phase A compensation input 2- Enter the sensor value measured during the C/B test in *PhaseComp.PhsA* 3- Set PhaseComp.PhsB and PhaseComp.PhsC to 0. When using the dual SPSBO control output option, the *PhaseComp.PhsA* input can be used for dc control voltage compensation for C/B close operations independently of the open operation. In this case, the *PhaseComp.PhsA* parameter should be set to the closing control voltage measurement at the time of commissioning and *PhaseComp.PhsB* and *PhaseComp.PhsC* should be set to 0.

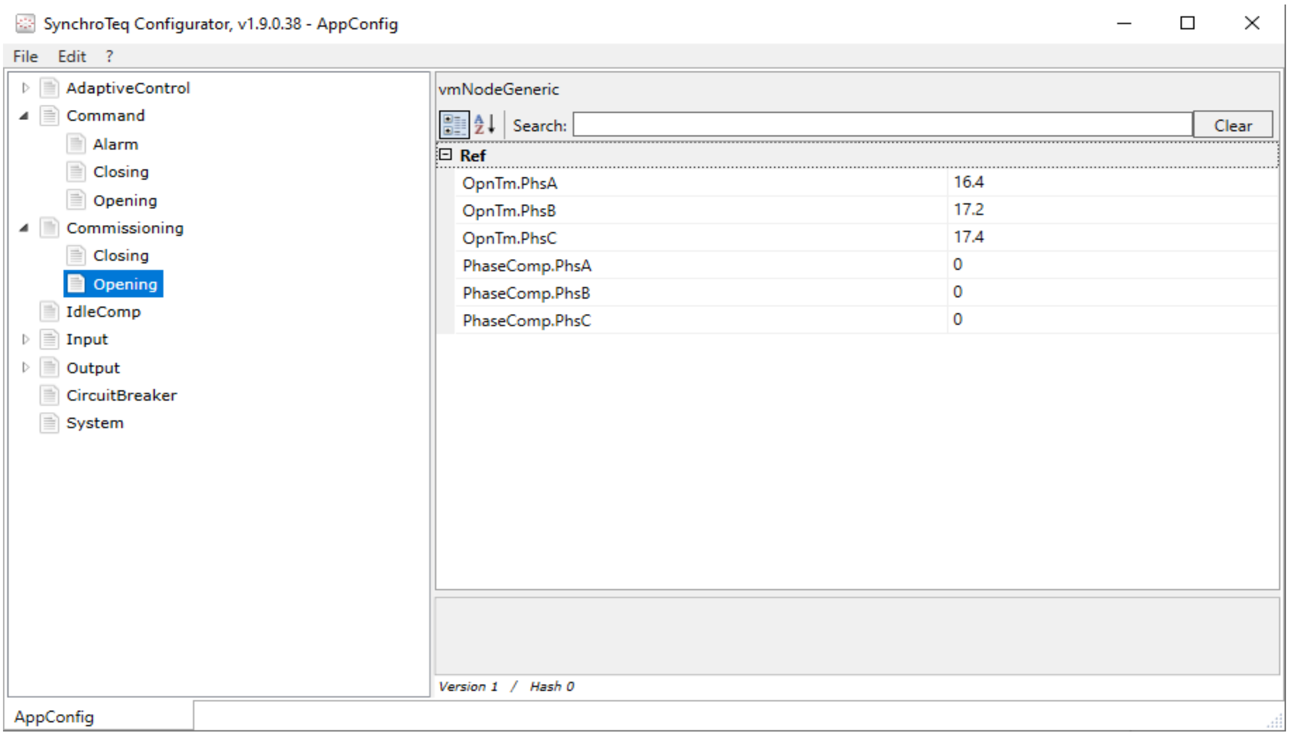


Figure-54: Opening Commissioning_Ref

g) Idle Time compensation

SynchroTeq integrates a CB idle time compensation algorithm that changes the predicted operating time according to the time elapsed since the last CB operation. For example, if the CB remained closed for a 3-month period, it will probably be slower in the next operation than if it would have been operated 5 minutes ago, due to lubricants property changes, friction coefficient changes, etc. The idle time compensation is applicable to the Open and Close operations using 2 different compensation tables.

In the following example, the CB closing time is stable if the opening operation occurred within a period less than 48 hours. It then increases almost linearly up to 1.0072 times its initial timing after 80 hours after which it is stable again. This would lead to the construction of the following compensation table which has a maximum of 6 data point entries. It should be noted that a linear interpolation is used between the data points. For example, if an operation occurred at 78 hours, the operating time would be multiplied by 1.0058, halfway between the 72- and 84-hours values.

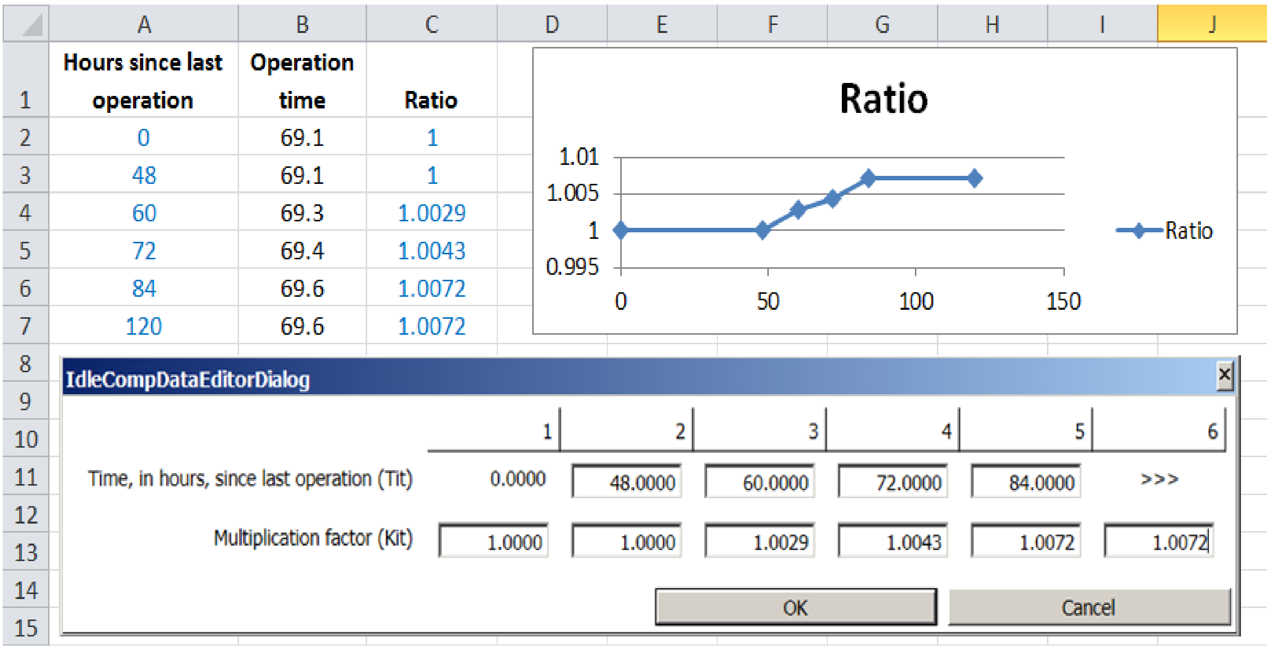


Figure-55: Idle Time Compensation Setting

h) Input: SynchroTeq Analog and Digital inputs management

A: Load current measurement from CT inputs- These parameters define the configuration of the load current input connected to the current transformers (CT). The load current is mainly used to determine if the CB operation occurred as expected. The load current inputs are recorded when the CB is operated or when a snapshot of the inputs is performed. A measurement CT source is preferred over a protection CT.

Menu:Sub-menu:Category	Parameter	Range	Unit	Parameter description
Input:A:Calibration	*PhsA.MultFactor* *PhsB.MultFactor* *PhsC.MultFactor*	50.0 to 150.0	%	Calibration factors used for the AC load current measurement. (Default: 100) This is affecting both the load current values displayed on the web interface and the magnitude of the captured waveforms. Use 100% for a measurement corresponding exactly to the CT calibration ratio. For example, if the displayed value of a current input is 18A instead of being 18.33A, the MultFactor for that input should be adjusted to 18.33/18 = 101.83%.
Input:A:Misc	*A_PU*	1.0 to 1 000 000.0	A	Load RMS current amplitude corresponding to 1 per unit (PU). (Default: 4000) For example, the rated current for a 10MVA 3-phase transformer operated at rated line-to line voltage of 315kV is: $Irated = A\_PU = \frac{10MVA}{\sqrt{3} \times 315kV} = 18.33\ Amps$ Therefore, A_PU = 18.33
	CTRatio	1.0 to 10 000.0	-	Current Transformer (CT) primary to secondary ratio used for the AC current measurement input. (Default: 4000) For example: - If a primary to secondary ratio is 600:5, use CTRatio =600/5=120 (5A input). - If a primary to secondary ratio is 1200:1, use CTRatio =1200/=1200 (1A input).
	DecimalCount	0 to 6	-	Number of decimals of the load current measurement displayed on the SynchroTeq WEB interface. For example, a load current of 18.33A will be rounded to 18.3A when using 1 decimal count, or to 18A when using 0 decimal count. (Default: 1)

Menu:Sub-menu:Category	Parameter	Range	Unit	Parameter description
Input:A:Misc	*Label*	Text, 2 char. max	-	Label used to designate the load current in the Web interface and waveform viewer applications, for example I, IL, etc. (Default: I) ⚠ In order to keep the waveforms files compatible with the COMTRADE format, only use ASCII characters. In order to display the information correctly on the Vizimax Event Analyzer application (waveform viewer) and on the front panel display (SynchroTeq), the label should be limited to 2 characters.
	Units	Text, 2 char. max	-	Label used to designate the load current units in the Web interface and waveform viewer applications, for example A, kA, etc. (Default:A) ⚠ In order to keep the waveforms files compatible with the COMTRADE format, only use ASCII characters. In order to display the information correctly on the Vizimax Event Analyzer application (waveform viewer) and on the front panel display (SynchroTeq), the label should be limited to 2 characters.

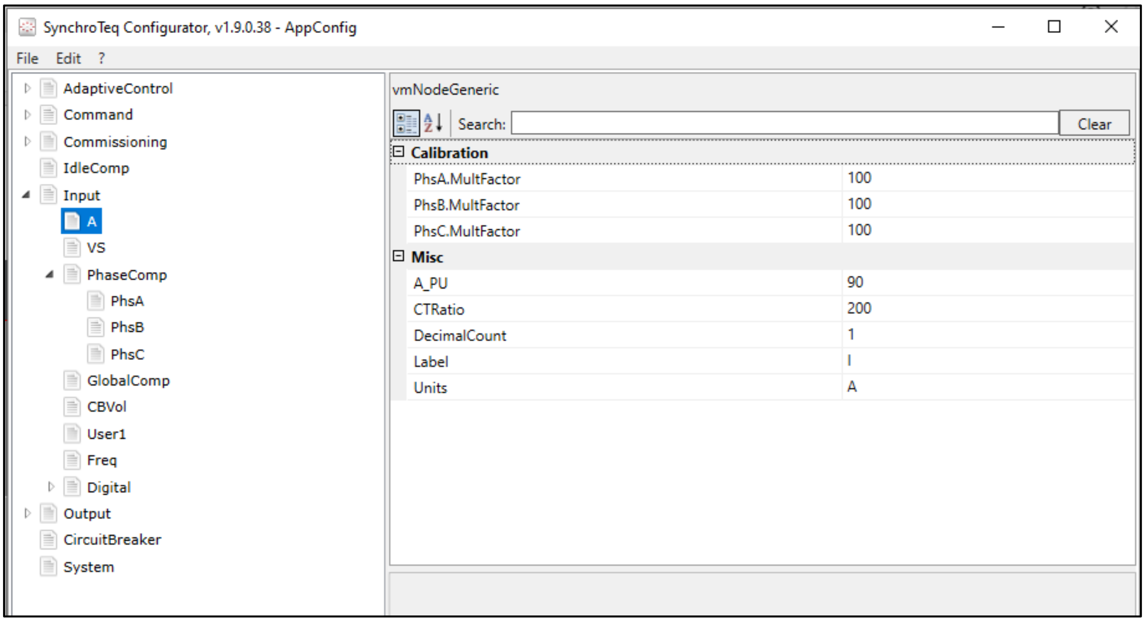
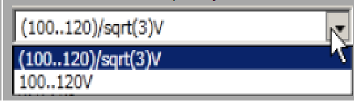


Figure-56: Load current measurement from CT Input

VS: Source Voltage Measurement from PT inputs- These parameters define the configuration of the source voltage input connected to the potential transformers (PT). The source voltage must be measured on the un-switched side of the CB (upstream). Phase A voltage is used as a reference for the synchronization of the controlled switching of the /B. The 2 other phases are used in power transformer and transmission line applications to determine the optimum switching moment. The voltage inputs are recorded when the CB is operated or when a snapshot of the inputs is performed.

Menu:Sub-menu:Category	Parameter	Range	Unit	Parameter description
Input:VS: Calibration	*PhsA.MultFactor* *PhsB.MultFactor* *PhsC.MultFactor*	50.0 to 150.0	%	Calibration factors used for the AC voltage measurement. (Default: *100*) This is affecting both the source voltage values displayed on the web interface and the magnitude of the captured waveforms. Use 100% for a measurement corresponding exactly to the PT calibration ratio. For example, if the displayed value of a voltage input is 185kV instead of being 181.9kV, the *MultFactor* for that input should be adjusted to181.9/185 = 98.32%.
Input:VS:Misc	*DecimalCount*	0 to 6	-	Number of least significant digits of the source voltage measurement displayed on the SynchroTeq WEB interface. For example, a load voltage of 181.93kV will be rounded to 181.9kV when using 1 decimal count, or to 182kV when using 0 decimal count. (Default: 1)
	InputRange	From list	-	Select the programmable input range for the PT measurement: (Default: *(100…120)/sqrt(3)*) **(100…120)/sqrt(3)V:** For 100/√3V, 110/√3V or 120/√3V secondary PTs. **100…120V:** For 100, 110, or 120V secondary PTs. 

Menu:Sub-menu:Category	Parameter	Range	Unit	Parameter description
Input:VS:Misc	*Label*	Text, 2 char. max	-	Label used to designate the source voltage in the Web interface and waveform viewer applications, for example V, Vs, etc. (Default: VS) In order to keep the waveforms files compatible with the COMTRADE format, only use ASCII characters. In order to display the information correctly on the Vizimax Event Analyzer application (waveform viewer) and on the front panel display (SynchroTeq), the label should be limited to 2 characters.
	PTRatio	1.0 to 10 000.0	-	Potential transformer primary to secondary ratio. (Default: *4000*) For example, for a primary to secondary ratio of 480kV/√3:120V/√3, use: $\frac{480kV / \sqrt{3}}{120V / \sqrt{3}} = 4000$ (e.g.: *PTRatio = 4000*).
Input:VS:Misc	*Units*	Text, 2 char. max	-	Label used to designate the source voltage in the Web interface and waveform viewer applications, for example V, kV, etc. (Default: kV) In order to keep the waveforms files compatible with the COMTRADE format, only use ASCII characters. In order to display the information correctly on the Vizimax Event Analyzer application (waveform viewer) and on the front panel display (SynchroTeq), the label should be limited to 2 characters.
Input:VS:VLL	*Rating*	0.0 to 10 000.0	kV	Line to line voltage rating of the voltage measured by the PT connected to the SynchroTeq voltage input. (Default: *315*) It should be noted that the voltage displayed on the web interface is the RMS Phase to ground voltage (V_{LG}): $V_{LG} = V_{LL}/\sqrt{3} = V_{LL}/1.73$

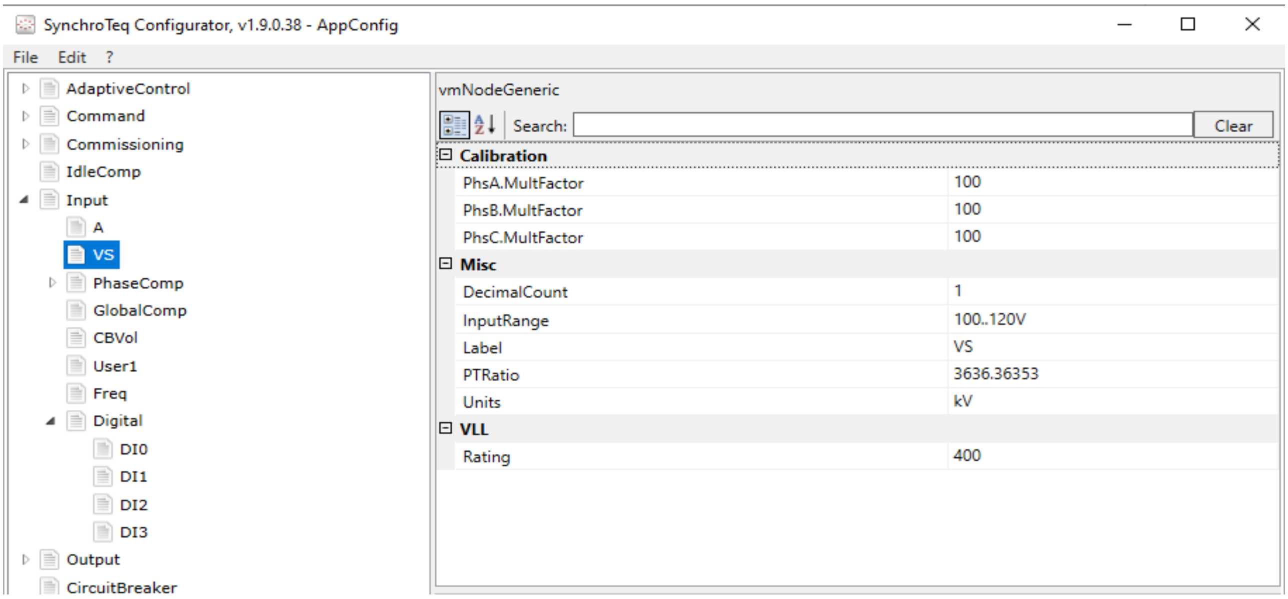


Figure-57: CVT Input Setting Configuration

CBVol: Circuit Breaker Voltage Compensation- The CBVol compensation parameters are used to calculate the predicted operating time of the CB according to the influence of the dc control voltage which is applicable to all the CB poles simultaneously. The input has a measurement range of 0-300Vdc.

Menu:Sub-menu:Category	Parameter	Range	Unit	Parameter description
Input:CBVol: Alarm	*Action*	List of actions	-	Select the automatic action taken by SynchroTeq when the CBVol measurement is out of the C/B normal operating range (Default: Force Out SVC) • **Force Out SVC:** Force SynchroTeq out of service, in which case the C/B commands will not be processed. If SynchroTeq Plus is equipped with the optional bypass module, the unit will be bypassed (automatic mode) or the bypass module will be locked (timer mode). • **Use Default Value:** Use the *DefaultValue* parameter as a substitution for an out of range sensor measurement. In this case: o *DefaultValue* is used for the C/B timing compensation calculation o C/B commands are executed if the corresponding ***Command:Alarm:…:AllowRandomCmd*** parameter is enabled (see Closing: C/B Closing command and Opening: C/B Opening command) o Out of range alarm is signalled in the event list if the alarm is enabled. o Front panel Sensor alarm indicator is turned ON o R9 Sensor alarm output is activated if this alarm is enabled (see note). If enabled, the C/B operation is counted as a Random Switching operation
	DefaultValue	As per C/B operating range	V	Default substitution value of the dc control voltage input if the measurement is out of C/B rated operating range. The alarm is produced if enabled, but the default value is used for the circuit breaker timing compensation. The default value is memorized and should be adjusted when commissioning the unit to the measured average voltage. (Default: 136)
	Limits.Delay	0 to 86400	Sec	ON and OFF alarm signalization delay used when the dc control voltage is out of the normal C/B operating range. For example, if a C/B is designed to operate from 105Vdc to 140Vdc, an alarm will be signaled when the measured dc control voltage is out of the range for the minimum specified delay. (Default: *10*).
	Limits.Enabled	Enable/ Disable	-	*Enable/disable* the "out of range" alarm for the dc control voltage. (Default: *Enable*)
	Limits.Max	As per C/B operating range	V	Upper limit of the C/B dc control voltage operating range. For example, if a C/B is designed to operate from 105Vdc to 140Vdc, Limits.Max should be set to 140. (Default: 140).
	Limits.Min	As per C/B operating range	V	Lower limit of the C/B dc control voltage operating range. For example, if a C/B is designed to operate from 105Vdc to 140Vdc, Limits.Min should be set to 105. (Default: *105*)

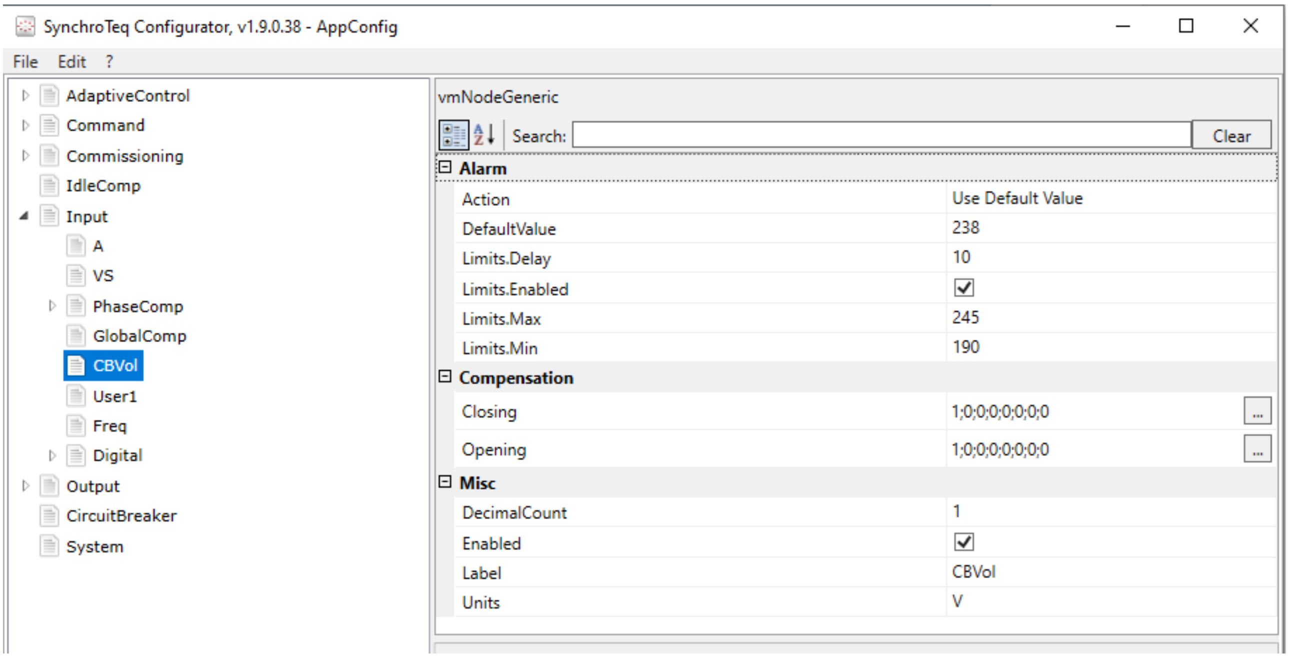


Figure-58: CB Voltage Compensation Configuration

Freq: Frequency Measurement- The network frequency is computed from Phase A source/network voltage input. The network frequency is used to compute the opening and closing moments of the CB in order to reach the desired electrical target angle whatever is the frequency. Parameters are as follow:

Menu:Sub-menu:Category	Parameter	Range	Unit	Parameter description
Input:Freq:Alarm	*Limits.Delay*	0 to 86400	Sec	ON and OFF alarm signalization delay used when the input frequency measured from Phase A voltage is out of the normal operating range. For example, if the application requires a 45 to 55Hz operation, an alarm will be signaled when the measured frequency is out of the range for the minimum specified delay. (Default: *10*).
	Limits.Enabled	Enable/Disable	-	*Enable/disable* the "out of range" alarm for the network frequency. - R9 Sensor alarm output is activated if this alarm is enabled (see note). (Default: *Enable*)
	Limits.Max	40.0 to 80.0	Hz	Upper limit of the operating frequency range. (Default: *65*)
	Limits.Min	40.0 to 80.0	Hz	Lower limit of the operating frequency range (Default: *55*)
Input:Freq:Misc	*DecimalCount*	0 to 6	-	Number of decimals of the frequency measurement displayed in the SynchroTeq Web interface. Refer to Figure 71. (Default: *2*)
	Label	Text, 10 char. max	-	Frequency label used in the SynchroTeq Web interface (e.g.: Freq, F, etc.). Refer to Figure 71. (Default: *Freq*)
	NomLineFrequency	50 or 60	Hz	Nominal network frequency, required for the adjustment of the waveform capture sampling rate frequency. The sampling rate is 167 samples/cycle, which is 10 020 samples/s at 60Hz and 8 350 samples/s at 50Hz. This parameter is of a great importance for the Power Transformer application where the residual flux is calculated. (Default: *60*).
	Units	Text, 4 char. max	-	Frequency unit label used in the SynchroTeq Web interface. (e.g.: Hz). (Default: *Hz*)

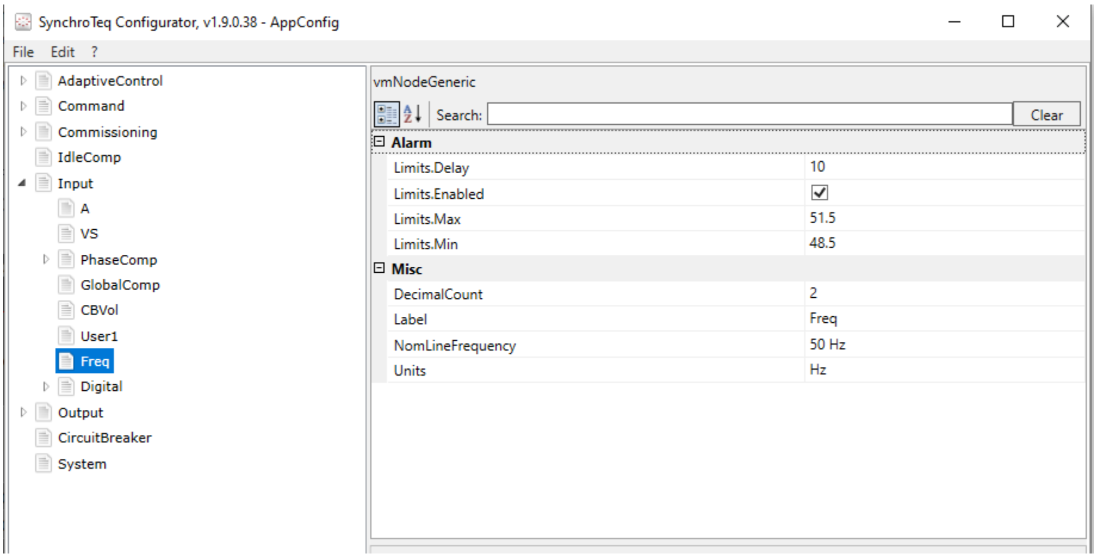
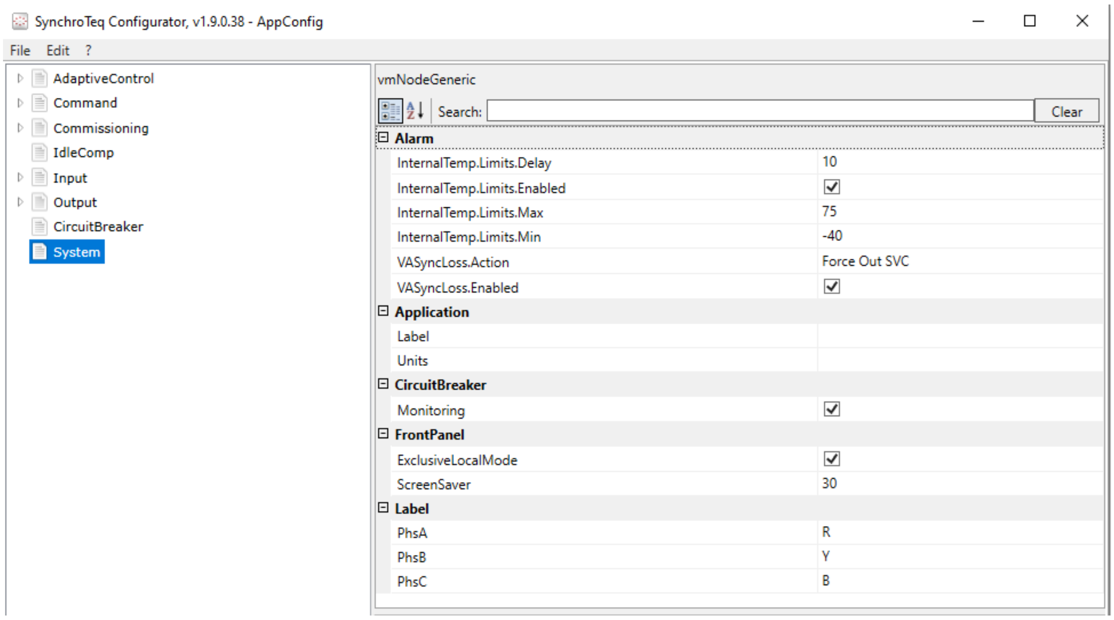


Figure-59: Frequency Measurement Configuration

i) **System: SynchroTeq system configuration-** This parameter group defines the SynchroTeq system related parameters:

- **SynchroTeq unit internal operating temperature monitoring,** measured using a calibrated digital sensor. The SynchroTeq internal temperature is normally 15°C to 20°C higher than the ambient temperature. A larger temperature rise indicates an improper convection cooling of the enclosure (excessive heat dissipated by the other devices installed in the same enclosure or air flow blocking).
- **Synchronization alarm management**
- **Dynamic closing target angle condition measurement:** label and units of the condition that is dynamically modifying the closing target angle for power transformers and fast switching applications. Circuit breaker monitoring and RDDS characteristics
- **Front panel management**.

- **Phase naming convention** (“A, B, C”, “R, Y, B”, “0, 4, 8”, etc.)



Menu:Category	Parameter	Range	Unit	Parameter description
System: Alarm	*InternalTemp. Limits.Delay*	0 to 86400	Sec.	ON and OFF alarm signalization delay used when the internal SynchroTeq temperature is out of the normal operating range of -40 to +75°C. An alarm will be signaled when the measured temperature is out of the range for the minimum specified delay. (Default: *10*).
	InternalTemp. Limits.Enabled	Enable /Disable	-	*Enable/disable* the “out of range” alarm for the SynchroTeq internal temperature. - R9 Sensor alarm output is activated if this alarm is enabled (see note). (Default: *Enable*)
	InternalTemp. Limits.Max	0 to 75	ºC	Upper limit of the SynchroTeq enclosure internal temperature.(Default: 75) The internal temperature measurement is factory calibrated. The *Limits.Max* parameter should never be increased to a value higher than 75°C.
	InternalTemp. Limits.Min	-40 to 75	ºC	Lower limit of the SynchroTeq enclosure internal temperature (Default: -40) The internal temperature measurement is factory calibrated. The *Limits.Min* parameter should never be changed to a value lower than -40°C.

Figure-60: Internal Temperature Limits

Menu:Category	Parameter	Range	Unit	Parameter description
System: Alarm	*VASyncLoss. Action*	List of actions	-	Select the automatic action taken by SynchroTeq when the synchronization alarm is active: • **No action:** The alarm has no effect on the SynchroTeq operation • **Ignore Close:** The alarm blocks the processing of C/B closing requests. • **Ignore Open:** The alarm blocks the processing of C/B opening requests. • **Ignore All Commands:** The alarm blocks the processing of both C/B opening and closing requests but the unit remains in Service. If SynchroTeq Plus is equipped with the optional bypass module, the unit will not be bypassed. • **Force Out SVC:** The alarm forces SynchroTeq out of service, in which case the C/B commands will not be processed. If SynchroTeq Plus is equipped with the optional bypass module, the unit will be bypassed (automatic mode) or the bypass module will be locked (timed mode). (Default: Force Out SVC)
	VASyncLoss. Enabled	Enable/Disable	-	Enable/disable the synchronization loss alarm upon detection of phase A reference voltage (Va). (Default: Enable)

Figure-61: VA Sync Loss

Menu:Category	Parameter	Range	Unit	Parameter description
System: Application	*Label*	Text, max. 20 char.	-	Application specific label in the WEB interface for the condition that is dynamically modifying the closing target angle. It should be assigned to: • "Residual flux" for power transformer applications (Default for *STPRFC* template) • "Residual charge" for fast switching applications of capacitor banks and filters and for transmission lines with trapped charges (Default for *FASTMSCFLT and STPTLUncompTrap* templates). Default is "blank" for the other applications.
	Units	String	-	Residual flux or residual charge unit label used in the SynchroTeq Web interface application. Should be assigned to "PU" for power transformer and for fast switching applications (default for these applications) or "blank" for the other applications.

Figure-62: Dynamic Closing Target Angle Condition Measurement

Menu:Category	Parameter	Range	Unit	Parameter description
System: CircuitBreaker	*Monitoring*	Enable/ Disable	-	**Enable** to create an "External open" or "External close" event based on the C/B position change detected from the 52a_A input. It should be noted that the external events are counted and displayed in the Web interface. The elapsed time since last CB operation is also updated for the idle time compensation. **Disable** externals do not cause external events. (Default: Enabled) : Note: A DI configured as an external trip will created an event when a trip is detected and no event will be created by the monitoring of 52a (no duplicate event).
	RDDS.PhsA *RDDS.PhsB* *RDDS.PhsC*	0.0 to 1000.0	PU	Phase A/B/C Circuit Breaker Rate of Decrease of Dielectric Strength, in PU. This parameter is only taken into consideration for power transformer applications for the automatic calculation of the pre arc time. (Default: 200) Please refer to Prestrike delay section for the measurement of the CB RDDS

Figure-63: Circuit Breaker Monitoring and RDDS Characteristics

Menu:Sub-menu:Category	Parameter	Range	Unit	Parameter description
System:FrontPanel	*ExclusiveLocal Mode*	Enable/ Disable	-	This parameter defines how the front panel is managed in local and remote mode. (Default: *Enable*) • **Enabled:** When the exclusive mode is enabled, the front panel commands are accepted only in Local mode. In Remote mode, front panel operations are inhibited and the commands are only accepted from the Ethernet port (SCADA system or Configurator) and the Digital Inputs. • **Disable:** When the exclusive mode is disabled, the front panel commands are accepted in both Local and Remote modes. In Local mode, the commands from the Ethernet port (SCADA system or Configurator) and the digital inputs are not accepted.
	ScreenSaver	0 to 120	Min	Inactivity timeout period before turning off the front panel display. The time-out period is extended each time F1 is pressed. A zero value disables the screen saver mode (the display never turns off) (Default: 30)

Figure-64: Front Panel Management

Menu:Sub-menu:Category	Parameter	Range	Unit	Parameter description
System:Label	*PhsA*	Text, 2 char. max.	-	Phase "A" label used in the SynchroTeq Web interface and Vizimax Event Analyzer application. See Figure 78. (Default: *A*).
	PhsB	Text, 2 char. max.	-	Phase "B" label used in the SynchroTeq Web interface and Vizimax Event Analyzer application. See Figure 78. (Default: *B*)
	PhsC	Text, 2 char. max.	-	Phase "C" label used in the SynchroTeq Web interface and Vizimax Event Analyzer application. See Figure 78. (Default: *C*)
System: WaveformCapture	*PostTrigger*	1000 to 2000	ms	When the control is processed by the SynchroTeq, the trigger is either the Close or Open request input. When the control is processed by a third-party (protection trip for example), the trigger is the phase A 52a input. The monitoring must be enabled to get a capture in this case (*System:CircuitBreaker:Monitoring*).
	PreTrigger	250 to 1000	ms	

Figure-65: Phase Naming Convention

j) Send a configuration file to SynchroTeq

To update the configuration files from your PC to the SynchroTeq:

1. Before sending a configuration file to the SynchroTeq unit, put the unit Out of Service.
2. Save the configuration file on the computer using File->Save or File->Save as command.
3. Click File->Send configuration to Target menu.
4. Enter the Target IP address or the URL (preceded by https://), the Username and Password.
5. Click OK to initiate the upload.

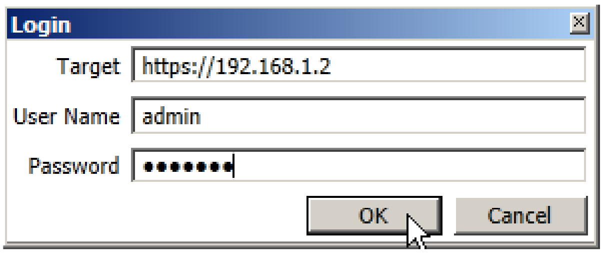


Figure-66: SynchroTeq Login Screen

k) Switching through SynchroTeq unit and analyze waveform

After completing the procedure of configuring the SynchroTeq unit, perform CB closing/opening operations through CSD unit and see the waveform received by the control unit. Once again, we have to connect to the SynchroTeq unit. Once the connection is established, the configurator home screen appears.

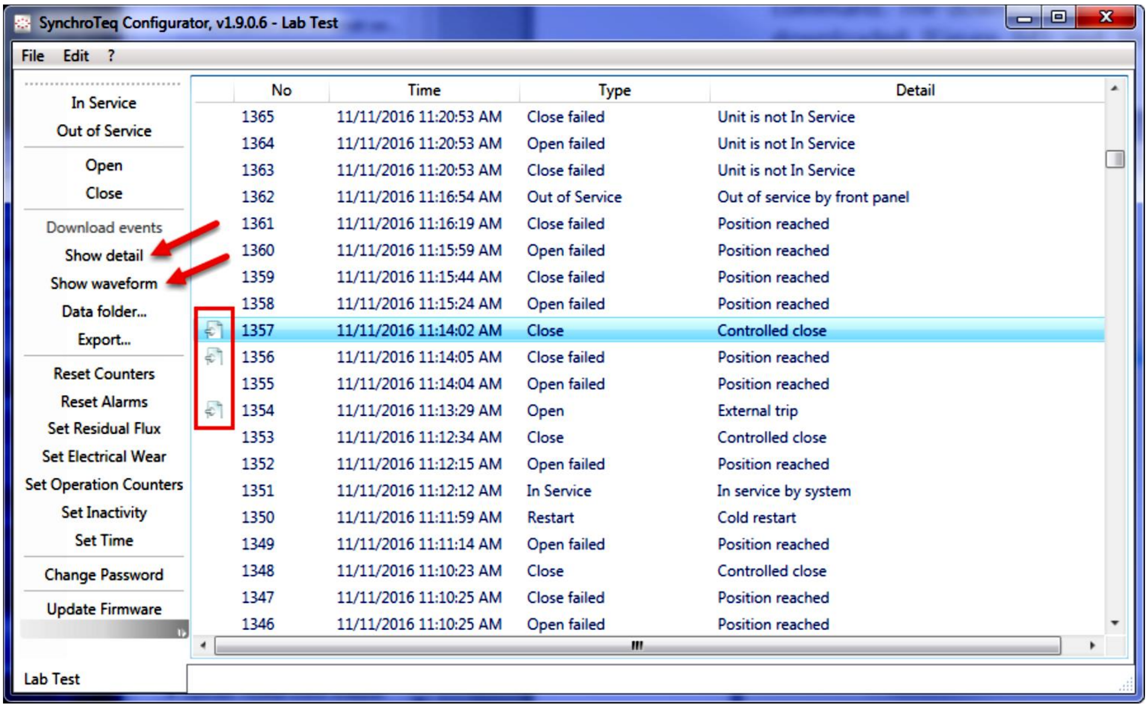
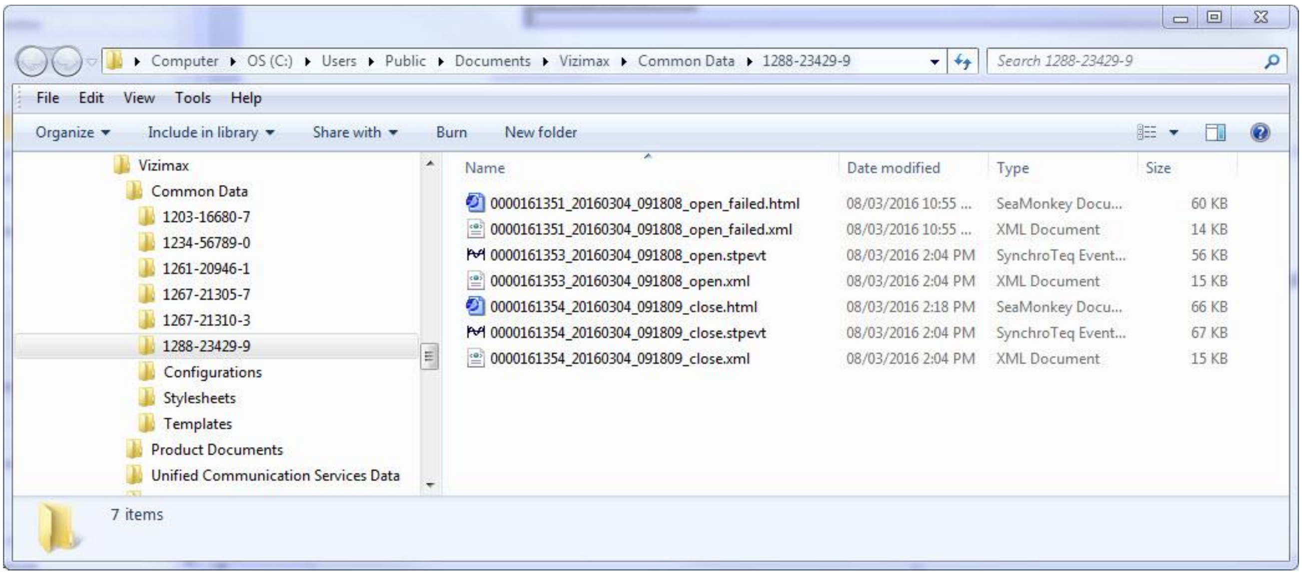


Figure-67: SynchroTeq Configurator Home Screen

l) **Download Events:** This command downloads a selected event (and the associated files if any) from the SynchroTeq unit memory to a specific 'Data folder' on your computer. The specific data folder is: C:\Users\Public\Documents\Vizimax\Common Data\xxxx-xxxxx-x. where xxxx-xxxxx-x is the SynchroTeq serial number.

In the Events list, select the event to be downloaded and click on the Download event command. The downloaded icon will appear on the left when the associated event is downloaded and the 'show details' and 'Show waveform' commands become available.



Once the files have been downloaded on your server or workstation, display and analysis can be done with the following tools:

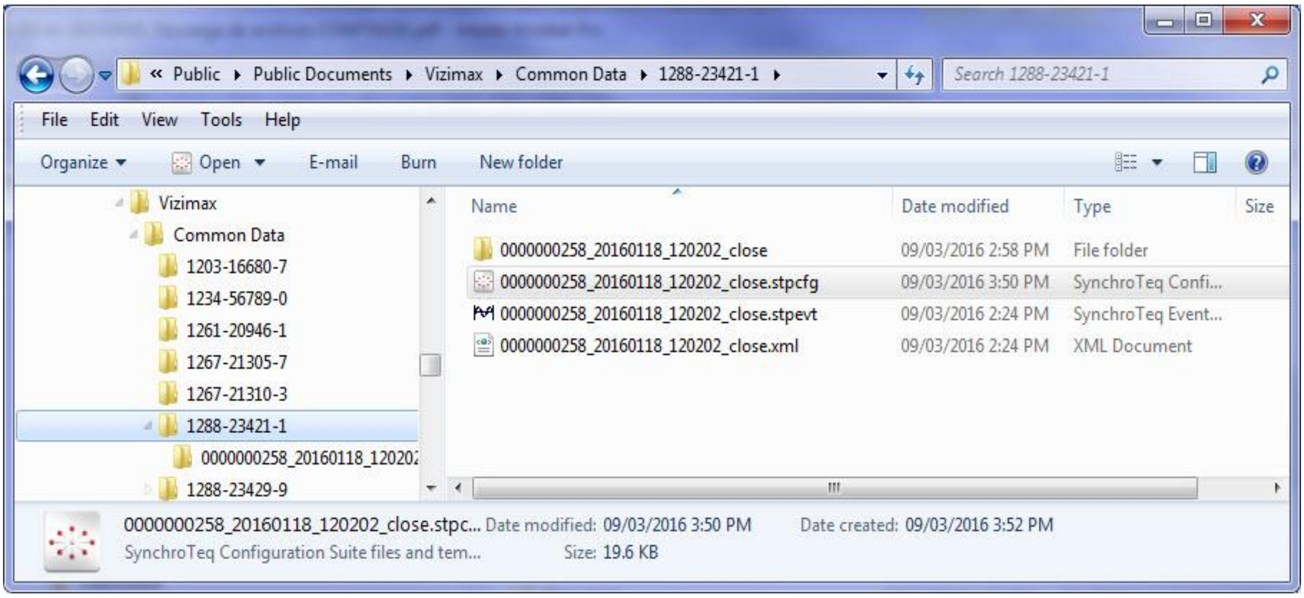


Figure-68: Event Saving Window

By double clicking of the *.stpcfg file, the SynchroTeq Configurator opens and displays the application configuration file.

By double clicking of the *.stpevt file, the 'Vizimax Event Analyzer' opens and displays the waveform file.

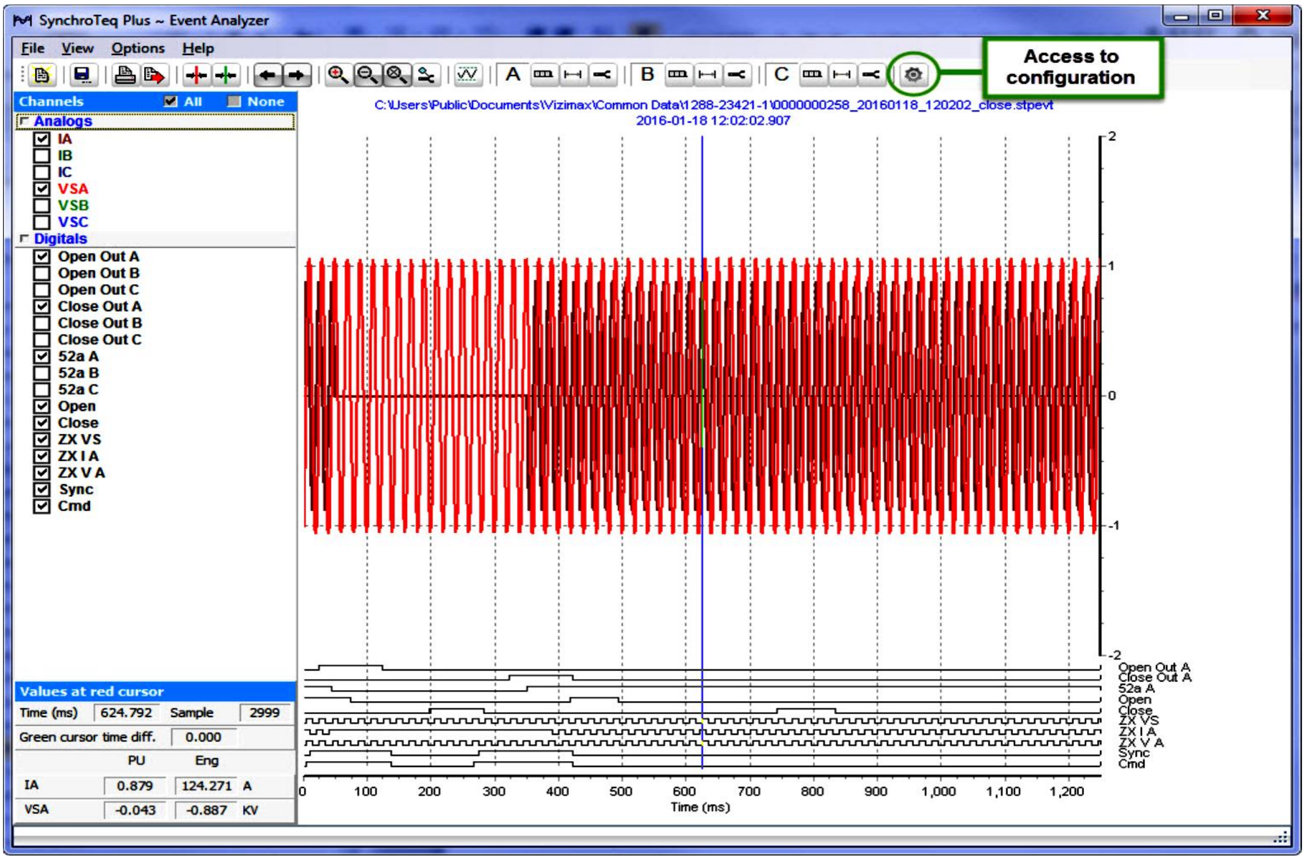


Figure-69: Sample Waveform

m) Functions offered by Vizimax event analyzer

The Vizimax Event Analyzer main window is divided into five sections:

- The menu bar provides access to sub-menu generic functions.

- The Tool function bar provides direct access to different tool functions.
- The Signals display control is used to select and control signals to be displayed.
- The Waveform display area is used to view and analyze selected signals.
- The Amplitude and time measurement area which displays the measured values at the red cursor position (signals amplitude and time difference vs the green cursor).

The 'channel display control' box located on the left top side of the screen allows to select the signals (analog and digital) to be displayed.

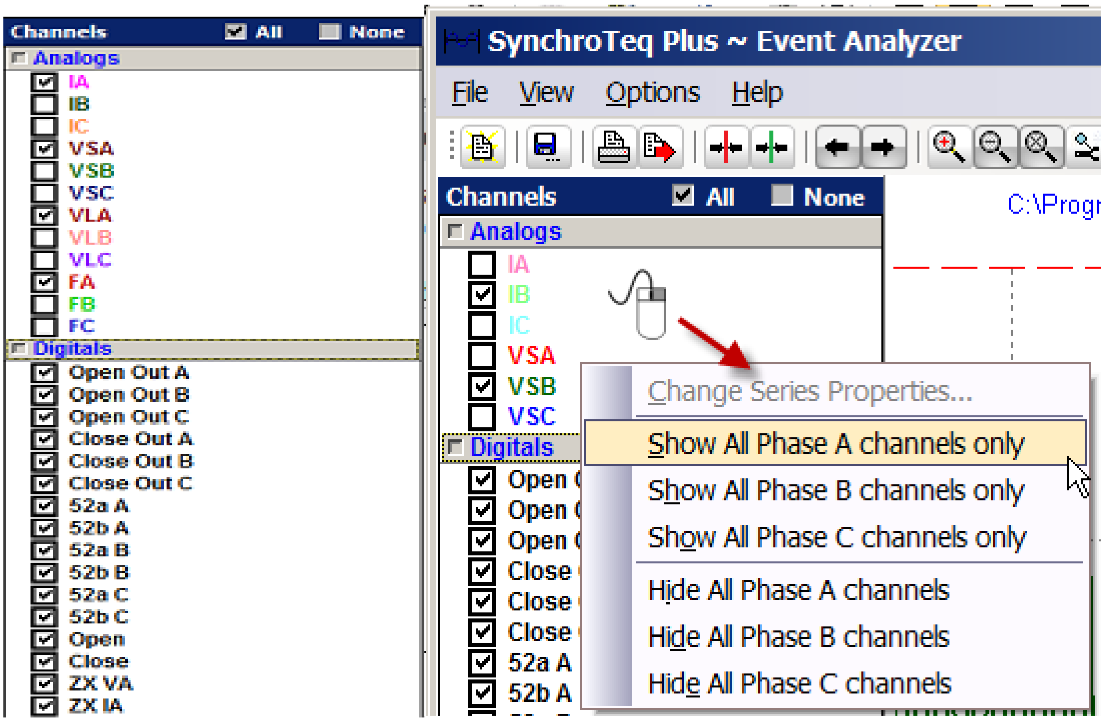


Figure-70: Channel Display

It should be noted that phase labels are programmable (using the SynchroTeq Configurator). Phase designation "A, B, C" is the default label but it can be configured to "R, Y, B", "0, 4, 8" etc.

To select all analog and digital channels for display, select Channels All and to clear the display select Channels None. Click on the Analogs button to hide/unhide the selected analog signals and Digitals to hide/unhide the selected digital signals.

Each signal can be individually selected, but right-clicking in the 'channel display control area' allows to select/unselect all the signals associated with each phase:

- Show Phase X channels only: Displays only the signals from this phase. The two (2) other phases signals are hidden.
- Hide Phase X channels: Hide the signals of this phase. The other phase signals are still displayed if they were previously visible.
- **IA, IB, IC** are the phase A, B or C load current measurements (measured on either side of the CB).
- **VS (or VSA, VSB, VSC**) are the phase A, B or C source voltage measurements measured on the unswitched side of the circuit breaker (source on the upstream side of the CB).
- **VLA, VLB, VLC** are the phase A, B or C load voltage measurements measured on the downstream side of the CB (switched side).
- **FA, FB, FC** are phase A, B or C calculated residual flux values. They are only available for Power Transformer de-energized RFC type events in power transformer applications.

- **Open Out A, Open Out B, Open Out C:** SynchroTeq output commands the CB OPEN coils of phases A, B and C.

- **Close Out A, Close Out B, Close Out C:** SynchroTeq output commands to the CB CLOSE coils of phases A, B and C. 52a A, 52a B, 52a C: SynchroTeq inputs of CB 52a position contacts of phase A, B and C.
- The 52a contact mirrors the position of the CB main contact (52a is ON when the CB is closed).
- **Open, Close:** SynchroTeq OPEN and CLOSE digital input commands. When both OPEN and CLOSE signals are activated at the same time, means the command is received from a communication link or the front or rear SynchroTeq panel.
- **ZX VS:** Zero crossing of the source voltage from phase A (unswitched side of the CB, VSA), which is the synchronization reference of the system.
- **ZX IA:** Zero crossing of the current from phase A (IA), which can be used as a synchronization source for CB OPEN commands in shunt reactor and capacitor bank applications.
- **ZX VA:** Zero crossing of the voltage from phase A (unswitched side of the CB, VSA), which is the synchronization reference of the system (when VS is not used).

Use time bars, alarm thresholds and limits to analyze a waveform:

A unique feature of the Vizimax Event Analyzer compared to the other COMTRADE file viewers is its ability to superimpose the CB timing information on the display.

- The time bars icon associated with each phase provides information on the CB operating time. These values are computed or measured by SynchroTeq unit.
- The targeted CB operating zone associated with each phase is represented by vertical green dashed lines (limits of targeted operating zone) and red dashed lines (severe alarm zone limits).
- The threshold limits icon displays the current detection threshold (detection) and the inrush current threshold limits (normal and degraded), representing the horizontal dashed lines. These limits are defined in the configuration file and are the same for all phases.

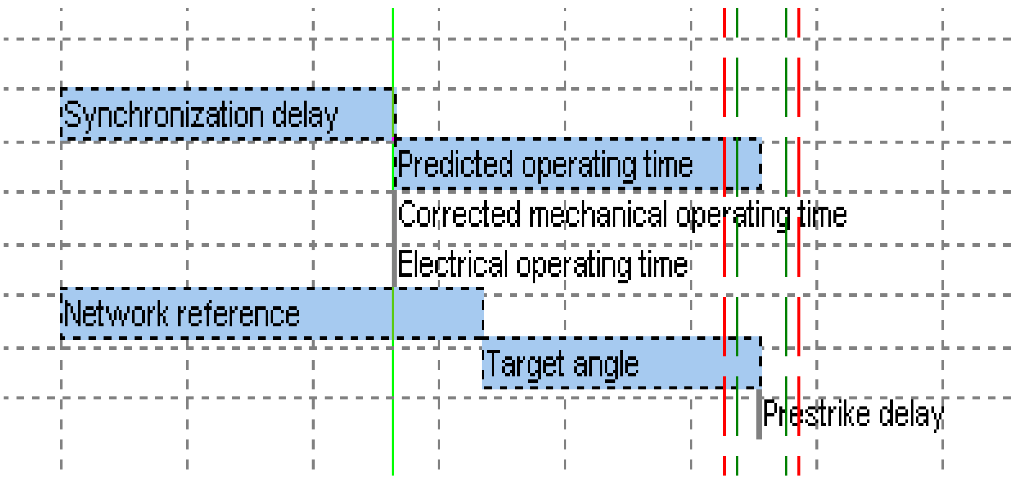


Figure-71: Time Bars

The time bars and limits for a CB CLOSING operation can be illustrated as follows:

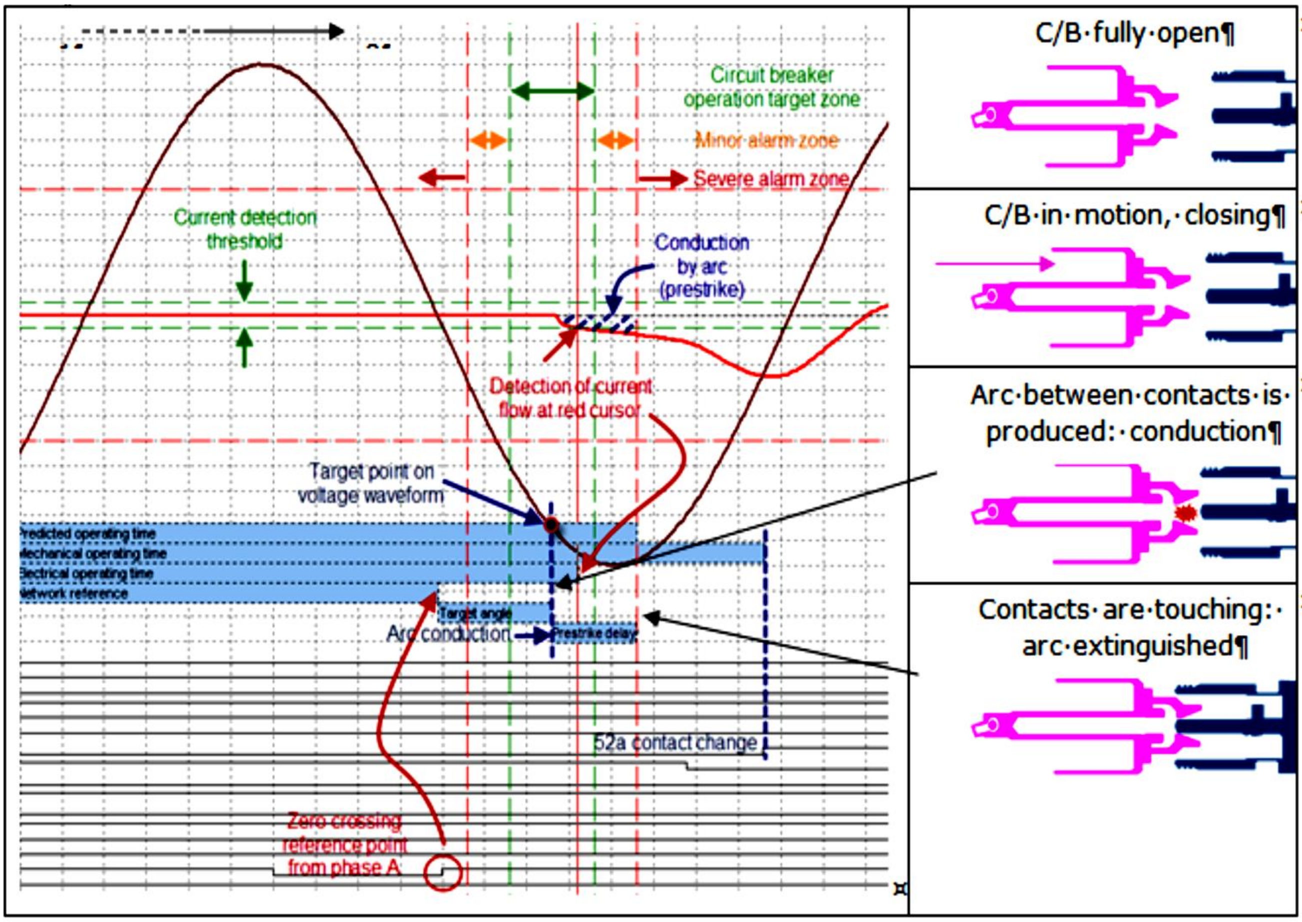


Figure-72: Time bar & Limits for CB Closing

Step 1: the CB main contacts are fully separated (maximum distance), offering the maximum dielectric strength between the contacts.

Step 2: A CLOSE command is executed, the CB coils are activated, and the mobile contact starts moving toward the CB fixed contact.

Step 3: When the CB contacts are close to each other, the CB will start conducting before the contacts are engaged mechanically: this is the prestrike, and the current is arcing. The prestrike occurs when the voltage across the CB contacts is higher than the dielectric strength (RDDS) of the CB. Generally, the prestrike duration is very low or non-existent when the electrical target point is close to zero crossing and highest when closing the CB at peak voltage (shunt inductors).

Step 4: The arc is extinguished when mechanical closure of the contacts occurs and the current flows by metallic conduction.

The time bars and limits for a CB OPENING operation can be illustrated as follows:

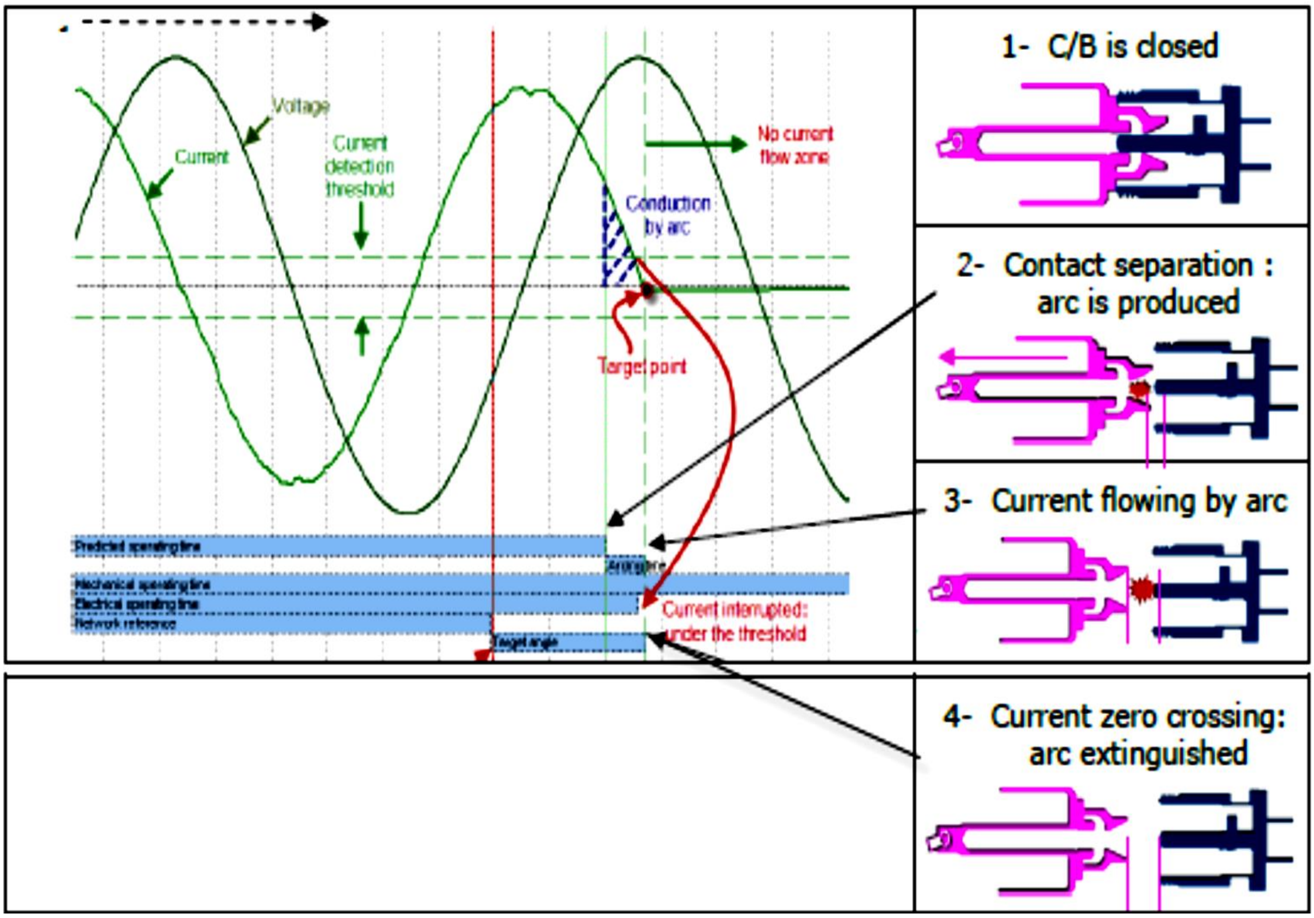


Figure-73: Time bar & Limits for CB Opening

Step 1: the CB main contacts are fully engaged, establishing metallic current conduction.

Step 2: an OPEN command is received, the CB coils are activated after the synchronization delay, and the mobile contacts start to separate. When there is a contact separation the current will continue flowing by arcing, since in most of the cases, the dielectric strength (RDDS) of the CB will not be sufficient to interrupt the arcing. Note that when the current is extremely low (for example, the magnetization current of a power transformer), the current can be interrupted at the moment of contact separation. In the other cases, SynchroTeq is used to control the arcing time of the CB, minimizing the energy dissipated in the CB.

Step 3: The current will continue flowing in the CB by arcing until it is extinguished by the zero crossing of the current.

Step 4: At the time of zero crossing of the current, if the contacts are mechanically separated enough, the dielectric strength (RDDS) of the CB will be sufficient to maintain current interruption. Therefore, there will be no current after the target point.

3.2. Typical Connection Arrangement for SynchroTeq Plus

Note: The connection arrangement presented below includes excerpts from the available OEM manual. During the commissioning process, it is imperative to adhere to the approved drawing connection arrangement and follow the instructions provided in the manual accompanying the Control Switching Device.

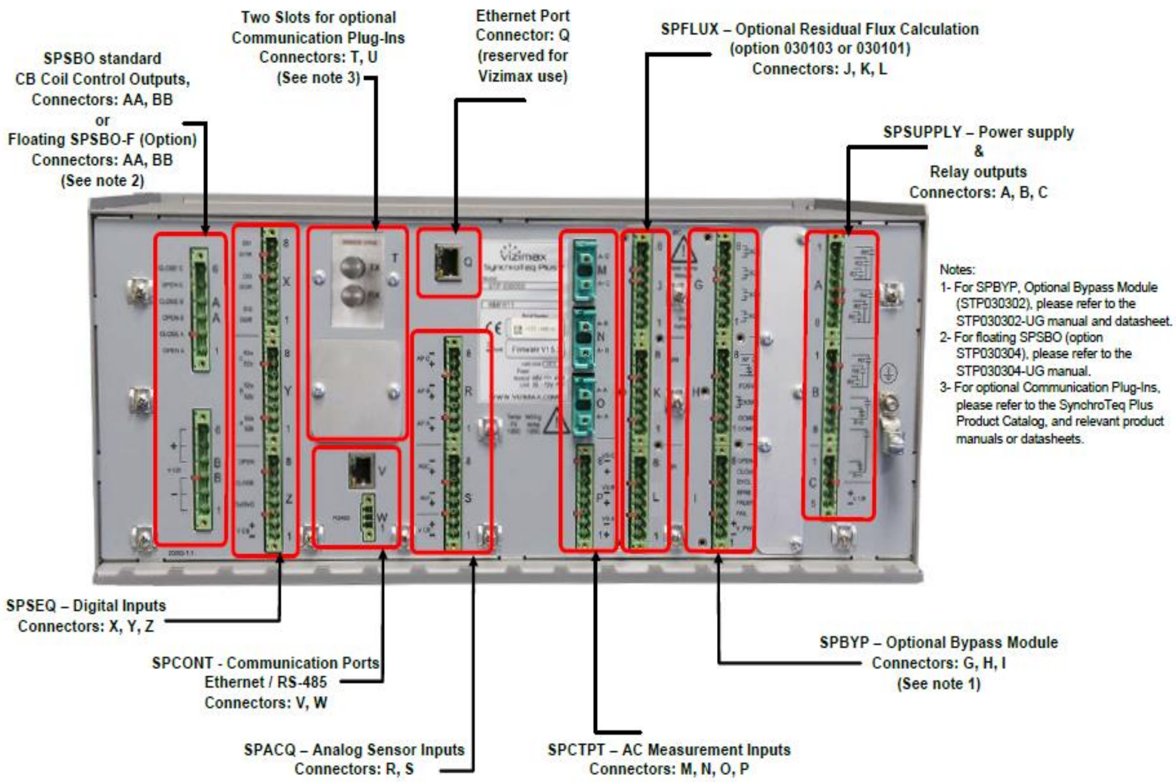


Figure-74: Front & Back View of SynchroTeq Unit

ABOUT VIZIMAX SYNCHROTEQ PLUS

The SynchroTeq Plus is a controlled switching device (CSD) platform for high voltage circuit breakers (C/Bs). The SynchroTeq Plus unit automatically adjusts C/B operations according to the supply voltage, air temperature, pressure of the drive mechanism and so on. In addition, the unit intelligently adjusts the next operation based on calculations from previous C/B timing performance.

Power Up of Vizimax SynchroTeq Plus

Terminal	Label	Description	Function
C4	V_C/B+	SynchroTeq Plus power supply input (positive), connected to V2P on the supply distribution panel	SynchroTeq Plus power
C5	V_C/B–	SynchroTeq Plus power supply input (negative), connected to V2N on the supply distribution panel	SynchroTeq Plus power

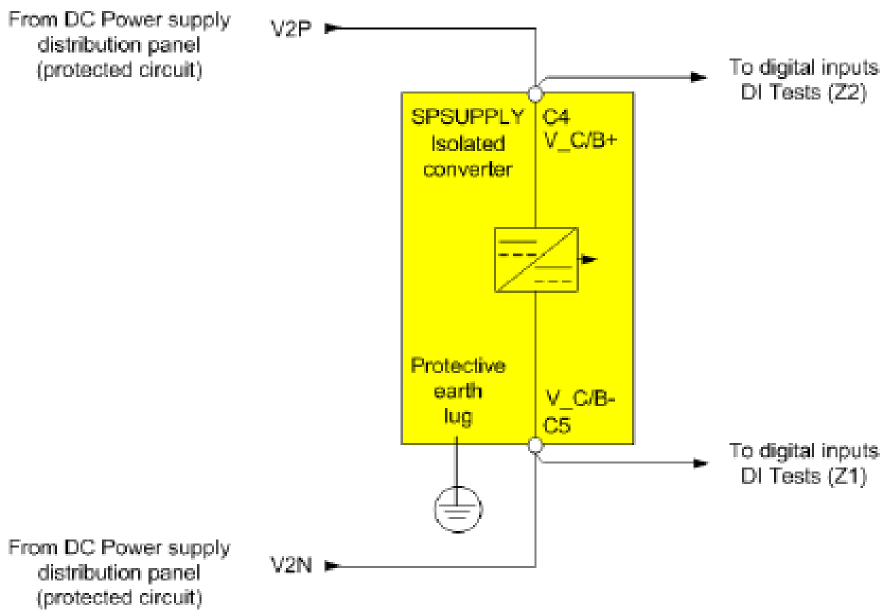


Figure-75: DC Supply to SynchroTeq Unit

SIGNALIZATION RELAY OUTPUTS (CONNECTORS A-B-C)

On the SPSUPPLY module, SynchroTeq Plus provides 11 dry contacts relays to signal alarm conditions to external devices such as remote terminal units (RTUs) and annunciators:

- A specific alarm/status is assigned to each output. The indicated function is active when the contact to common is closed.
- The contacts are grouped (1 common for a group of relays). The common can be connected to a positive or a negative supply rail.
- Each contact is protected by an overvoltage device to minimize contacts wear when opening inductive devices.
- The status of the outputs is summarized on the front panel.
- An event is generated in the event list when an output is activated/deactivated.

Connector A-B-C

Terminal	Label	Description	Function
A1	R1NO	NO relay contact output – Grouped Alarm Grouped alarm contact: will be activated if any abnormal condition occurs.	Open : No Alarm Closed : Alarm Occurred
A2	R2NO	NO relay contact output – C/B opening limit alarm	Open : C/B opening limit OK Closed : C/B opening limit alarm
A3	R3NO	NO relay contact output – C/B closing limit alarm	Open : C/B closing limit OK Closed : C/B closing limit alarm
A4	R123C	Common contact output for relays R1, R2 and R3	R1-2-3 common return
A5	R4NO	NO relay contact output – Reserved for future use	Open : Not used Closed : Not used
A6	R5NO	NO relay contact output – Controlled opening problem	Open : Controlled opening OK Closed : Controlled opening problem occurred
A7	R6NO	NO relay contact output – Controlled closing problem	Open : Controlled closing OK Closed : Controlled closing problem occurred
A8	R456C	Common contact output for relays R4, R5 and R6	R4-5-6 common return

Terminal	Label	Description	Function
B1	R7NO	NO relay contact output – SynchroTeq in local mode	Open : Unit in remote mode Closed : Unit in local mode
B2	R8NO	NO relay contact output – C/B interface alarm	Open : No Alarm Closed : Alarm occurred on C/B interface
B3	R9NO	NO relay contact output – Sensors alarm	Open : No alarm Closed : alarm occurred on at least on one sensor
B4	R789C	Common contact output for relays R7, R8 and R9	R7-8-9 common return
B5	R10NO	NO relay contact output – Out of Service	Open : In Service Closed : Out of Service
B6	R10NC	NC relay contact output – In Service	Open : Out of Service Closed : In Service
B7	R10C	Common contact output for R10 relay	R10 common return
B8	R11NO	NO relay contact output – System OK	Open : System Failure Closed : System OK

Terminal	Label	Description	Function
C1	R11NC	NC relay contact output – System failure This contact is interconnected to the optional integrated bypass module (STP030302). Otherwise, it can be used to activate an external bypass system.	Open : System OK Closed : System Failure
C2	R11C	Common contact output for relays R11	R11 common return
C3	-	Not Connected	N/A

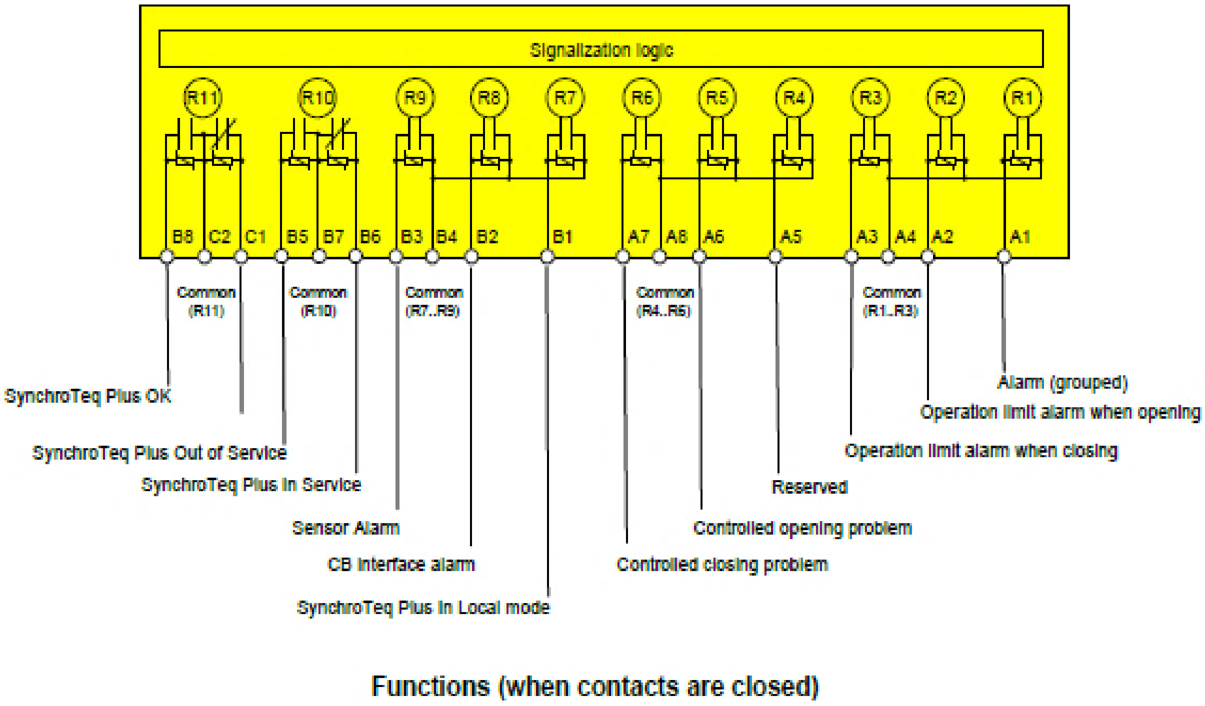


Figure-76: Connector A-B-C of SynchroTeq Unit

C/B COIL CONTROL OUTPUTS (CONNECTORS AA-BB)

The SynchroTeq Plus unit allows controlling up to three OPEN and three CLOSE C/B coils using one of the following configurations:

- Standard SPSBO module (default factory configuration). The outputs are designed to “push” current from the positive bus into the C/B coils that are connected to the negative bus (‘source’ configuration).
- Optional floating SPSBO-F module (STP030304) provides 6 potential free isolated solid-state outputs (must be specified at ordering). These outputs are designed to ‘’push” the current or to “pull” the current from the C/B coils connected to the positive bus or to drive a C/B electronic controller that has floating inputs.

Connector AA-BB

Pin no.	Name	Description
AA6	CLOSE_C	Phase C C/B CLOSE coil control output
AA5	OPEN_C	Phase C C/B OPEN coil control output
AA4	CLOSE_B	Phase B C/B CLOSE coil control output
AA3	OPEN_B	Phase B C/B OPEN coil control output
AA2	CLOSE_A	Phase A C/B CLOSE coil control output
AA1	OPEN_A	Phase A C/B OPEN coil control output

Pin no.	Name	Description
BB6	V_C/B +	C/B power supply, positive (V1P, see Figure 8)
BB5		
BB4		
BB3	V_C/B –	C/B power supply, negative (V1N, see Figure 8)
BB2		
BB1		

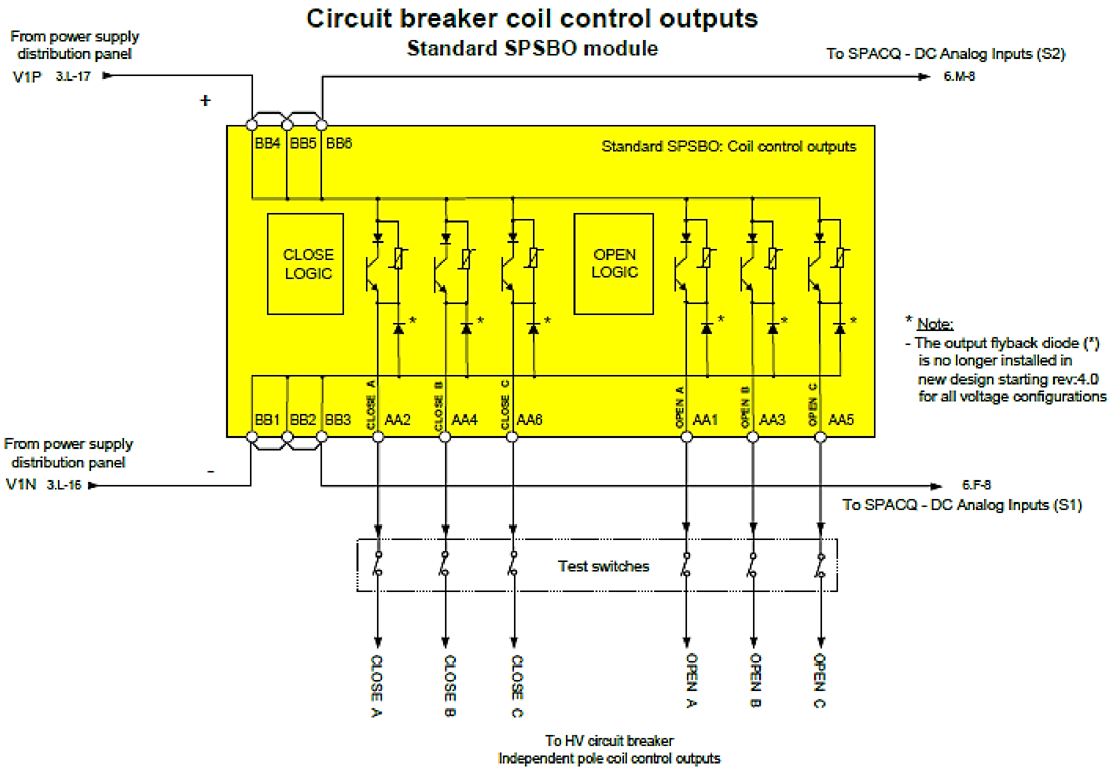


Figure-77: Connector AA-BB of SynchroTeq Unit

DIGITAL INPUTS (CONNECTORS X-Y-Z)

The SynchroTeq Plus SPSEQ module is a processor circuit board with 12 opto-isolated digital inputs as follows:

- X connector: Three isolated general purpose contact inputs (for example, SF6 lockout contact, heater indicator and low-pressure alarm). These inputs can also be used as alternate trip/close commands.
- Y connector: Six inputs for C/B position (3x 52a, 3x 52b contacts) or (3x 52a, 3x phase fault trip detection for transmission line application).
- Z connector: Two inputs for remote C/B OPEN and CLOSE commands; and one general purpose contact input.

X-Connector:

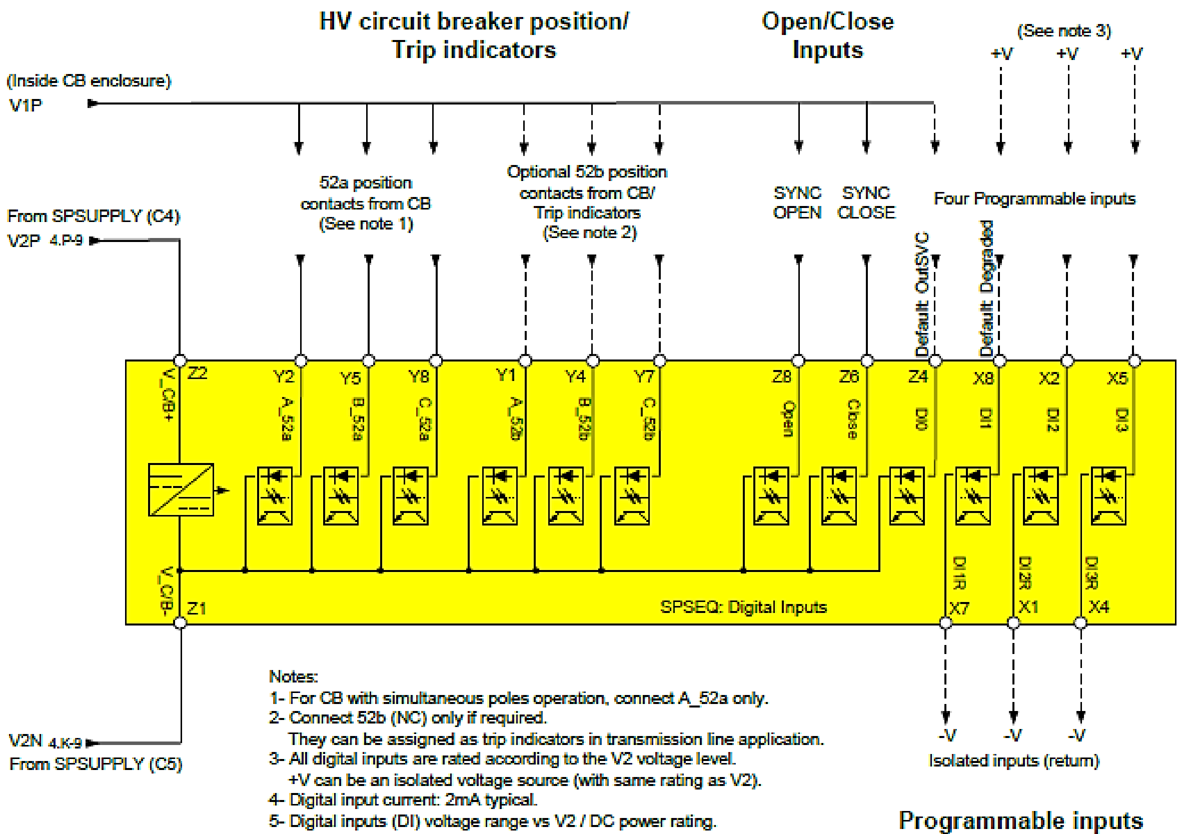
Pin no.	Name	Description
X8	DI1 (Default = Degraded)	Digital input 1 (source), see note above.
X7	DI1R	Digital input 1 return (sink)
X6	--	Not connected
X5	DI3	Digital input 3 (source), see note above.
X4	DI3R	Digital input 3 return (sink)
X3	--	Not connected
X2	DI2	Digital input 2 (source), see note above.
X1	DI2R	Digital input 2 return (sink)

Y-Connector:

Pin no.	Name	Description
Y8	52a_C	Circuit breaker phase C 52a contact (timing)
Y7	52b_C	Circuit breaker phase C 52b contact (position discrepancy detection) or phase trip detect (transmission line application)
Y6	--	Not connected
Y5	52a_B	Circuit breaker phase B 52a contact (timing)
Y4	52b_B	Circuit breaker phase B 52b contact (position discrepancy detection) or phase trip detect (transmission line application)
Y3	--	Not connected
Y2	52a_A	Circuit breaker phase A 52a contact (timing and command validation)
Y1	52b_A	Circuit breaker phase A 52b contact (position discrepancy detection) or phase trip detect (transmission line application)

Z-Connector:

Pin no.	Name	Description
Z8	OPEN	OPEN command input, remote mode.
Z7	--	Not connected.
Z6	CLOSE	CLOSE command input, remote mode.
Z5	--	Not connected
Z4	DI0 (Default = OutSVC)	Digital Input 0 (source), see note above.
Z3	--	Not connected
Z2	V_C/B+	Positive supply voltage of Open, Close, 52a/b and DI0 digital inputs (V2P)
Z1	V_C/B–	Common negative supply voltage of Open, Close, 52a/b and DI0 digital inputs (V2N)



DC power - V2	48 Vdc	110 Vdc	125 Vdc	220-250 Vdc
DI idle state	24 Vdc	69 Vdc	69 Vdc	150 Vdc
DI active state	31 Vdc	87 Vdc	87 Vdc	173 Vdc
DI max voltage	72 Vdc	150 Vdc	150 Vdc	280 Vdc

Figure-78: Connector X-Y-Z of SynchroTeq Unit

ANALOG SENSOR INPUTS (CONNECTORS R-S)

The SynchroTeq Plus acquisition (SPACQ) module is a processor circuit board that performs the following functions:

- Monitor C/B control voltage and operating conditions using 2-wire 4-20mA loop powered sensors (such as the ambient temperature, isolation gas or drive mechanism pressure).
- Predict the C/B operating time according to its operating conditions (sensor information). SynchroTeq Plus automatically adjusts the OPEN/CLOSE coil commands timing to operate the C/B at the optimal point on the wave. Compensation can be fine-tuned and activated through the SynchroTeq Plus configuration.

The SynchroTeq Plus acquisition (SPACQ) module provides:

- Isolated analog inputs for up to 5 sensors (2-wire 4-20mA loop powered sensors operated at 24Vdc) for C/B monitoring and timing compensation (AP_A, AP_B, AP_C, AGC and AU1inputs).
- An isolated 24 V dc power supply for each 4-20mA sensor.
- C/B control voltage monitoring (Inputs S1-S2) allowing C/B timing compensation for power supply variation.
- The function of each analog input is programmable: measurement label (ex: Hydraulic pressure) and units (ex: psi, BAR, etc.), measurement range (ex: 320 to 350 BAR), sensor calibration (ex: 500 BAR full range), alarming (enabled/disabled) and action (out of service, use default value, etc).
- The SPACQ module is equipped with a 100Base-T Ethernet port (Reserved for Vizimax internal tests).

To connect the analog sensor inputs, proceed as follow:

- (Optional, recommended): Install a set of terminal blocks equipped with test switches near the SynchroTeq Plus analog inputs.
- Connect shielded cables for Phase A, B, and C (pressure compensation sensors) to the R connector (AP_A, AP_B, AP_C).

R-Connector

Pin no.	Name	Description
R8	AP_C–	Phase C analog sensor input, 4 to 20 mA return
R7	AP_C+	Phase C analog sensor input, 4 to 20 mA positive source (ex: Pressure)
R6	--	Not connected
R5	AP_B–	Phase B analog sensor input, 4 to 20 mA return
R4	AP_B+	Phase B analog sensor input, 4 to 20 mA positive source (ex: Pressure)
R3	--	Not connected
R2	AP_A–	Phase A analog sensor input, 4 to 20 mA return
R1	AP_A+	Phase A analog sensor input, 4 to 20 mA positive source (ex: Pressure)

- Using shielded twisted pair cables connect the global compensation sensor AGC (usually ambient temperature or drive mechanism pressure) and the general-purpose user sensor AU1.
- Connect the C/B power supply to the V_C/B monitoring inputs according to below Table.
- Connect the sensor cable shields/drain wire under the pressure plate of the grounding lugs.

S-Connector

Pin no.	Name	Description
S8	AGC–	All-phase analog sensor input, 4 to 20 mA return
S7	AGC+	All-phase analog sensor input, 4 to 20 mA positive source (ex, C/B temperature)
S6	--	Not connected
S5	AU1–	General purpose analog user 1 (AU1) input, 4 to 20 mA return
S4	AU1+	General purpose analog user 1 input, 4 to 20 mA positive source
S3	--	Not connected
S2	V_CB+	C/B dc coil voltage measurement input (positive)
S1	V_CB–	C/B dc coil voltage measurement input (negative)

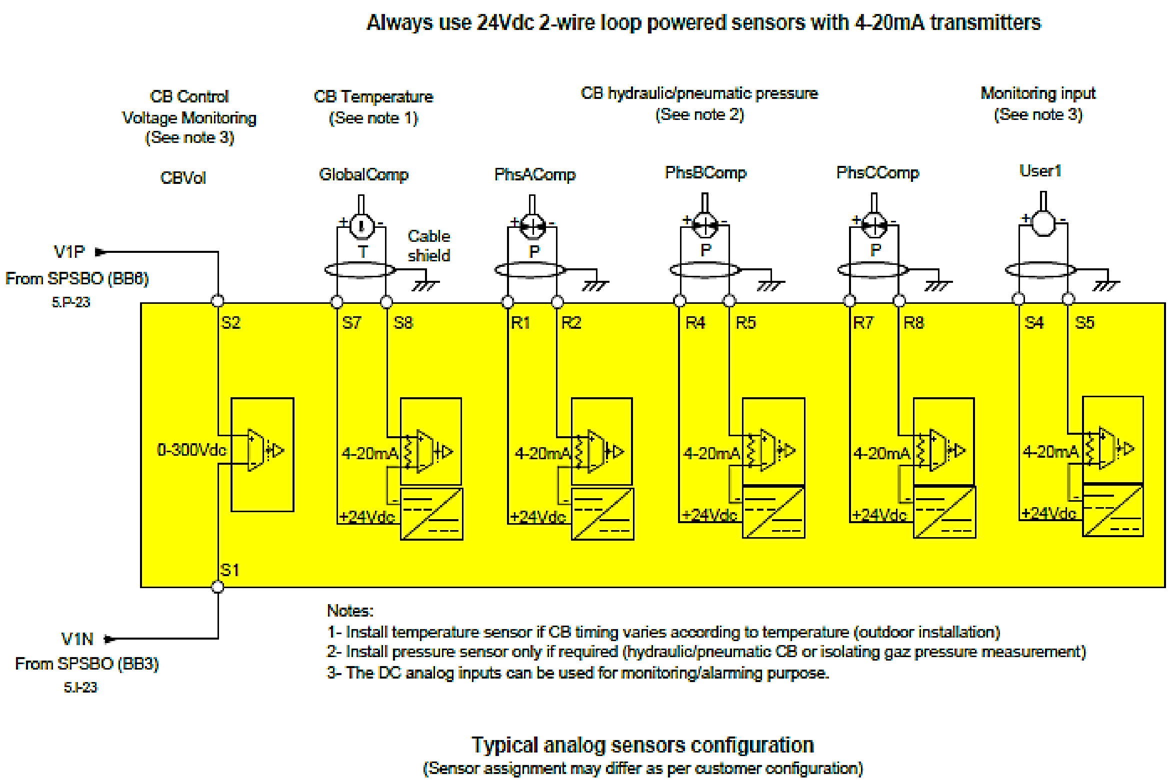


Figure-79: Connector R-S of SynchroTeq Unit

AC MEASUREMENT INPUTS (CONNECTORS M-N-O-P)

The SynchroTeq Plus current transformer and potential transformer (SPCTPT) module measures C/B current from CTs and the source (line or bus) voltage from PTs.

To connect the AC measurement inputs, proceed as follow:

- Install test switches for the PTs and CTs, one switch per circuit.
- Connect the test switches and the CTs with reference to CT and PT connections.
- Crimp the provided lugs on the wires connected on the test switches and connect them to the provided M, N and O input plugs.

- Insert the M, N and O input plugs in their respective connectors with reference to below mentioned Table.

M-N-O-Connector

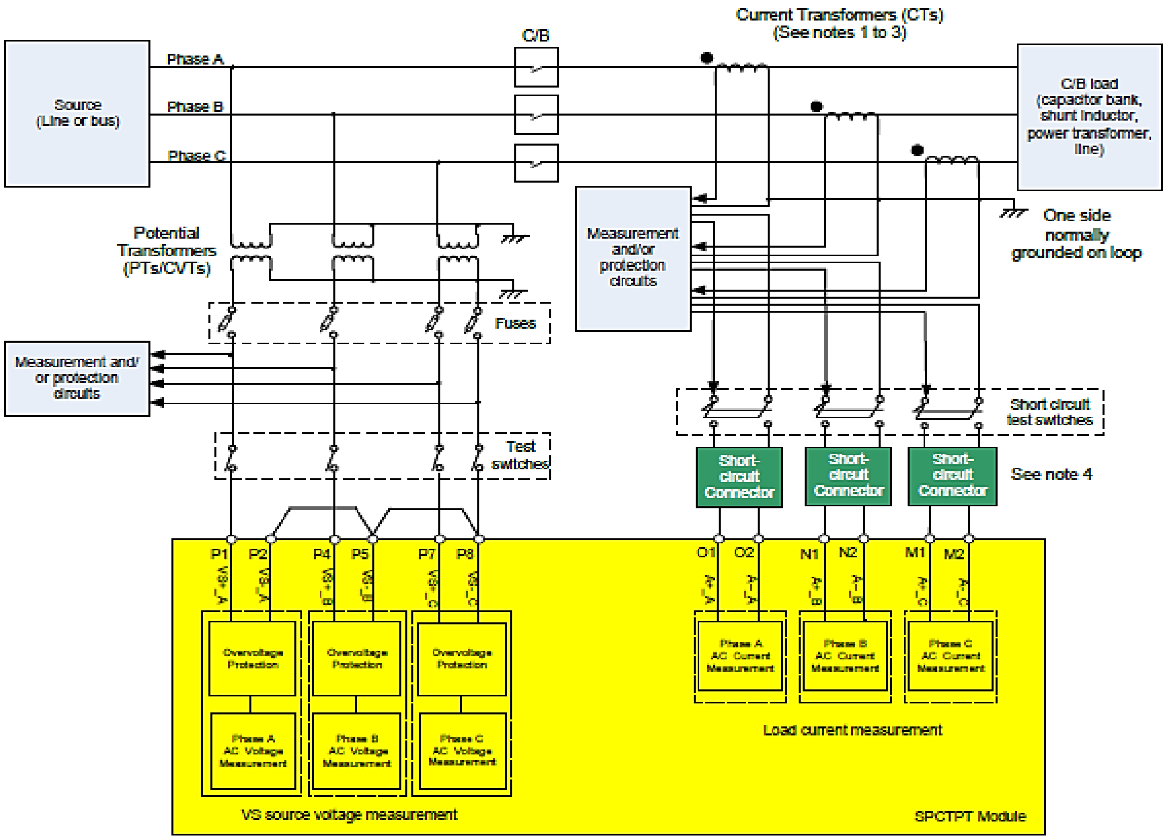
Pin no.	Name	Description
M2	A–_C	CT input, phase C (negative polarity)
M1	A+_C	CT input, phase C (positive polarity), 1A or 5A
N2	A–_B	CT input, phase B (negative polarity)
N1	A+_B	CT input, phase B (positive polarity), 1A or 5A
O2	A–_A	CT input, phase A (negative polarity)
O1	A+_A	CT input, phase A (positive polarity), 1A or 5A

Figure-80: CT input of SynchroTeq Unit

- Ensure that the PTs are properly fused, and that one side of each PT is properly grounded.
- Using 1.29 mm (16 AWG) stranded copper wire, connect the AC voltage measurement inputs and the PTs (via the test switches), with reference to below mentioned

P-Connector

Pin no.	Name	Description
P8	VS−_C	PT input, phase C (negative polarity)
P7	VS+_C	PT input, phase C (positive polarity)
P6	--	Not connected
P5	VS−_B	PT input, phase B (negative polarity)
P4	VS+_B	PT input, phase B (positive polarity)
P3	--	Not connected
P2	VS−_A	PT input, phase A (negative polarity)
P1	VS+_A	PT input, phase A (positive polarity)



Notes:
1- Current transformers (CT) can be located upstream or downstream side of CB.
2- Measurement or Protection CT can be used.
3- Positive current is measured by SynchroTeq Plus when it is entering on the dot side (●)
4- The current cable connector is automatically short-circuited when disconnected from SynchroTeq Plus.

Figure-81: Connector M-N-O-P of SynchroTeq Unit

CONNECT THE SYNCHROTEQ PLUS CONTROLLER (SPCONT) MODULE

The SynchroTeq Plus controller module (SPCONT) offers several communications ports depending on the options you selected when you ordered your SynchroTeq Plus.

- Ethernet 100Base-T / RJ45 (port V): standard delivery
- Serial link RS485 (port W): standard delivery

- 2 additional Plug-in (Port T and U): optional order (refer to SynchroTeq Plus catalog for available options)

PC COMMUNICATION SOFTWARE (SCADA, DSC) – OPC UA SERVER

Software tools for PC or Server platforms (MS Windows), VIZIMAX Unified Communication Service make it easier to retrieve real-time status information, events and data records from VIZIMAX SynchroTeq Plus and SynchroTeq MV units. Real-time status information is published and shared using the OPC UA protocol and is made available for easy integration in SCADA or DCS environment.

This software tools leverages non-proprietary yet secure HTTPS communication protocols thus enabling two-way transfer and store operations between computers/servers and SynchroTeq units over a variety of communication infrastructure and are run and controlled as background services.

SynchroTeq Unified Communication Services in Central Sites allows:

- Transfer and store statuses, events/alarms, waveform recordings and COMTRADE files from a limited (RWS055000) or an unlimited (RWS065000) number of remote SynchroTeq Plus and SynchroTeq MV units over IP-based communication networks.
- Automatically retrieve and archive SynchroTeq Plus and SynchroTeq MV content. Data content from limited (RWS055000) or unlimited (RWS065000) numbers of switching events (SynchroTeq Plus and SynchroTeq MV) will be collected and stored. Data volume will be capped according to the available storage capacity in central site.
- Seamless integration of SynchroTeq Plus and SynchroTeq MV data models in central SCADA or HMI solutions in control rooms through OPC UA Server interface and rich data management features allowing for real-time exchange, visualization and event generation from statuses, commands, parameters, set points, calculated data.
- The most appropriate communication and data refresh rate with respect to the available network infrastructure and performances (on-demand/manual, timed, scheduled).

Integration of CSD alarms with Local SCADA/NTAMC /RTAMC

Technical Specifications for Circuit Breaker defines communication requirement of CSD as below-

"The CSD shall be provided with a communication port to facilitate online communication of the CSD with Substation Automation System directly on IEC 61850 protocols. If the CSD does not meet the protocols of IEC 61850, suitable gateway shall be provided to enable the communication of CSD as per IEC 61850".

IEC-68150 compliant devices can be directly integrated to SCADA and relevant alarms can be configured for monitoring.

For IEC-61850 non-compliant CSDs, output contact for these alarms are available in O/P cards. To integrate these alarms with SCADA, wiring needs to be done to spare input contacts of any IED (BCU/Relay) reporting to SCADA in the station network.

Further, different manufacturers offer various alarm types and respective alarm labels/nomenclature for CSDs. For proper monitoring of CSDs, following standard signals are required to be configured for reporting in Local SCADA/NTAMC/RTAMC to ensure uniformity across all makes-

1. **CSD Unhealthy**
2. **Sync Operation Failed**
3. **CSD Bypassed**
4. **CSD Bypass (IN/OUT) Switch**

Signal integration for IEC-61850 non-compliant CSD:

The integration process is detailed below:

a) Siemens PSD02: Output contact for various Alarms is available in "X3" card as below-

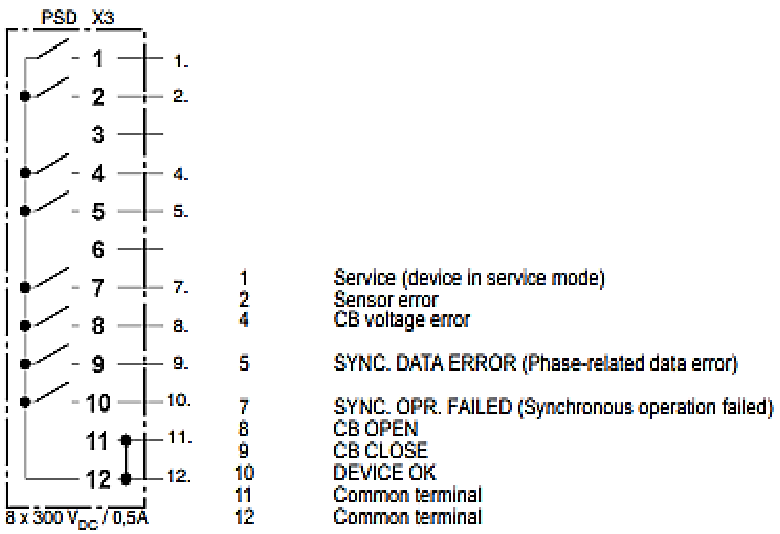


Figure-82: Output Contact diagram of PSD02.

Alarm Signal	Wiring Terminals
CSD Unhealthy	X3-11 or 12: +ve DC Wiring X3-10: Relay output for Device OK (
Sync Operation Failed	X3-11 or 12: +ve DC Wiring X3-07: Relay output for Sync Operation Failed
CSD Bypassed	An external bypass arrangement to be implemented for bypassing CSD through SCADA or by Bypass Switch or bypassed on CSD unhealthy or any other scheme. A signal for the same must be configured in SCADA/NTAMC/RTAMC.
CSD Bypass (IN/OUT) Switch	One spare NO contact of Bypass Switch to be configured for alarm when it will be used for bypassing the CSD. State 'NO': CSD will be in service. State 'NC': CSD bypassed.

b) GE/Alstom RPH3: 05 Nos. programmable output contacts are available of which 01 nos is Monostable & 04 Nos. are bistable programmable output contacts as below-

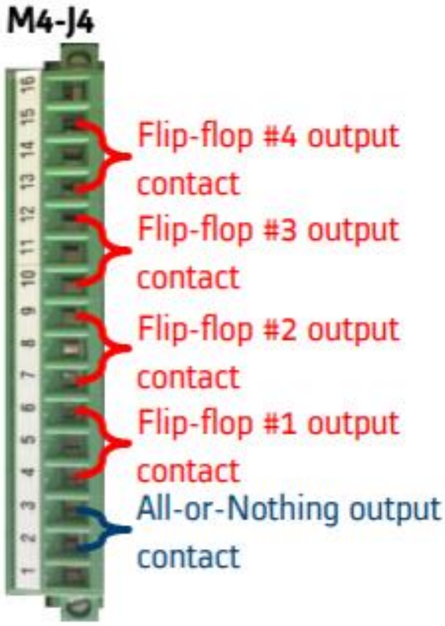


Figure-82: Output Contact diagram of RPH3.

Relay contact (M4-J4)	Monostable ("All-or-nothing")	Bistable #1 ("flip-flop")		Bistable #2 ("flip-flop")		Bistable #3 ("flip-flop")		Bistable #4 ("flip-flop")	
terminals / status	2-3 NO	4-5 NC	5-6 NO	7-8 NC	8-9 NO	10-11 NC	11-12 NO	13-14 NC	14-15 NO
power OFF	open	keep current state		keep current state		keep current state		keep current state	
alarm ON	open	open	closed	open	closed	open	closed	open	closed
alarm OFF	closed	closed	open	closed	open	closed	open	closed	open

Figure-84 **Relay-driven alarm output contacts status**

Alarm Signal	Wiring Terminals
CSD Unhealthy	**Flip-flop#1 output contact (Bist#1)** M4-J4-5: +ve DC Wiring M4-J4-6: Relay output for CSD Unhealthy

In Web MMI Software*, select following for Bist#1:

U/I Calibration:	Problem detected in internal current & voltage calibration
Parameters loading	Problem detected during software setting loading
Parameters validity:	Problem detected during setting parameter validation
Opening output channel:	A problem detected by the continuous monitoring feature of the switchgear opening control channel; either a discontinuity in the external CB opening circuit or an RPH3 internal issue with MOSFET switching transistors

Closing output channel: A problem detected by the continuous monitoring feature of the switchgear closing control channel: either a discontinuity in the external CB closing circuit or an RPH3 internal issue with MOSFET switching transistors

Internal control: An internal failure has been detected

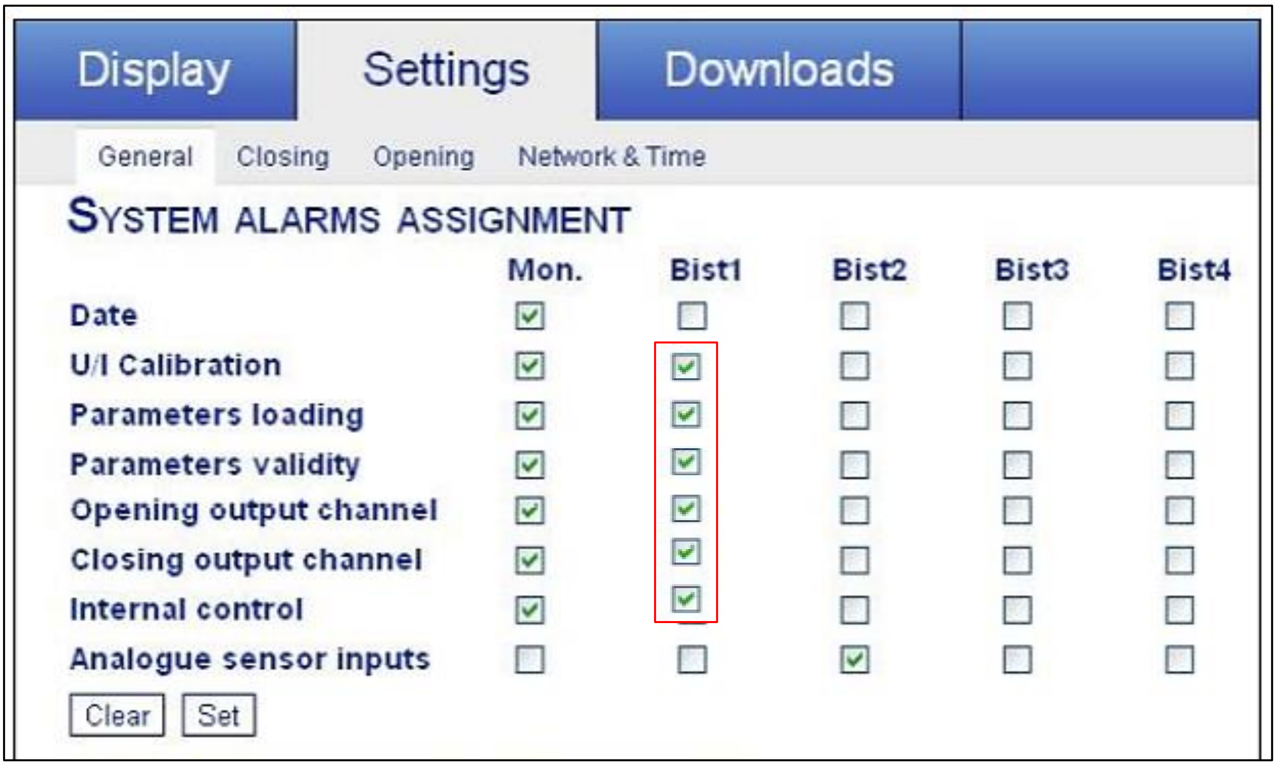


Figure-85: Assignment of "CSD Unhealthy Signal" in Flip-flop#1 output contact

Alarm Signal (Signal type: SPS)	Wiring Terminals
Sync Operation Failed	**Flip-flop#2 output contact. (Bist#2)** M4-J4-8: +Ve DC Wiring M4-J4-9: Relay output for Sync Operation Failed

In Web MMI Software*, select following for Bist#2-

Switchgear Closing: The switchgear closing time has been measured out of range on ≥1 CB Pole (s) during the last closing operation.

Switchgear Opening: The switchgear opening time has been measured out of range on ≥1 CB Pole (s) during the last opening operation.

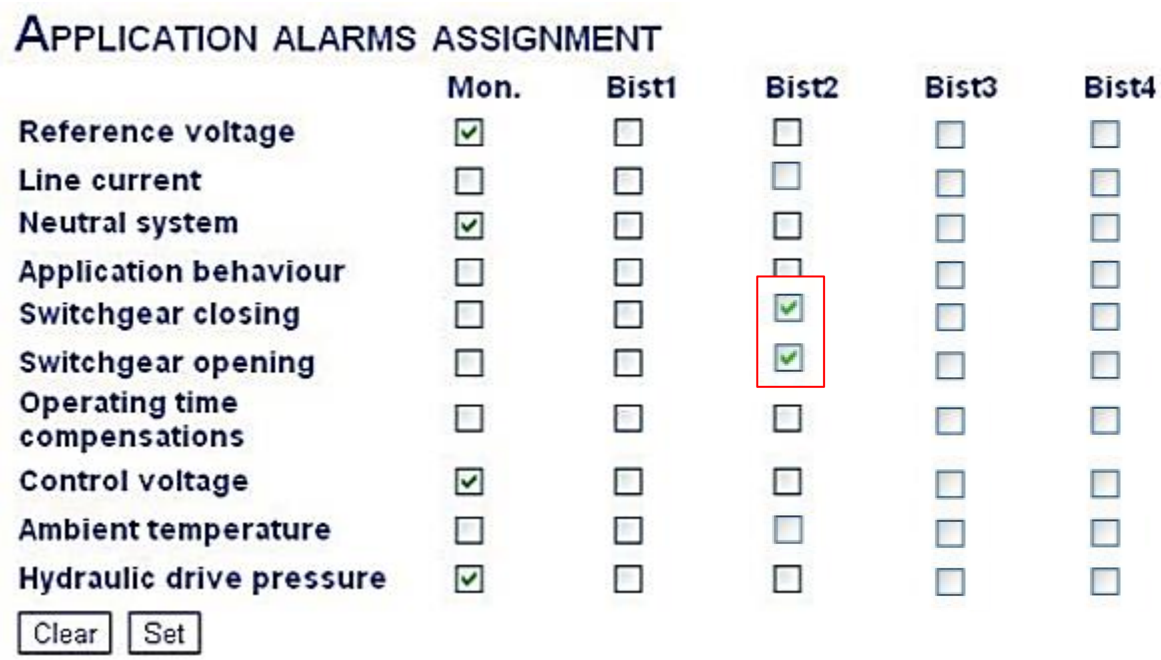
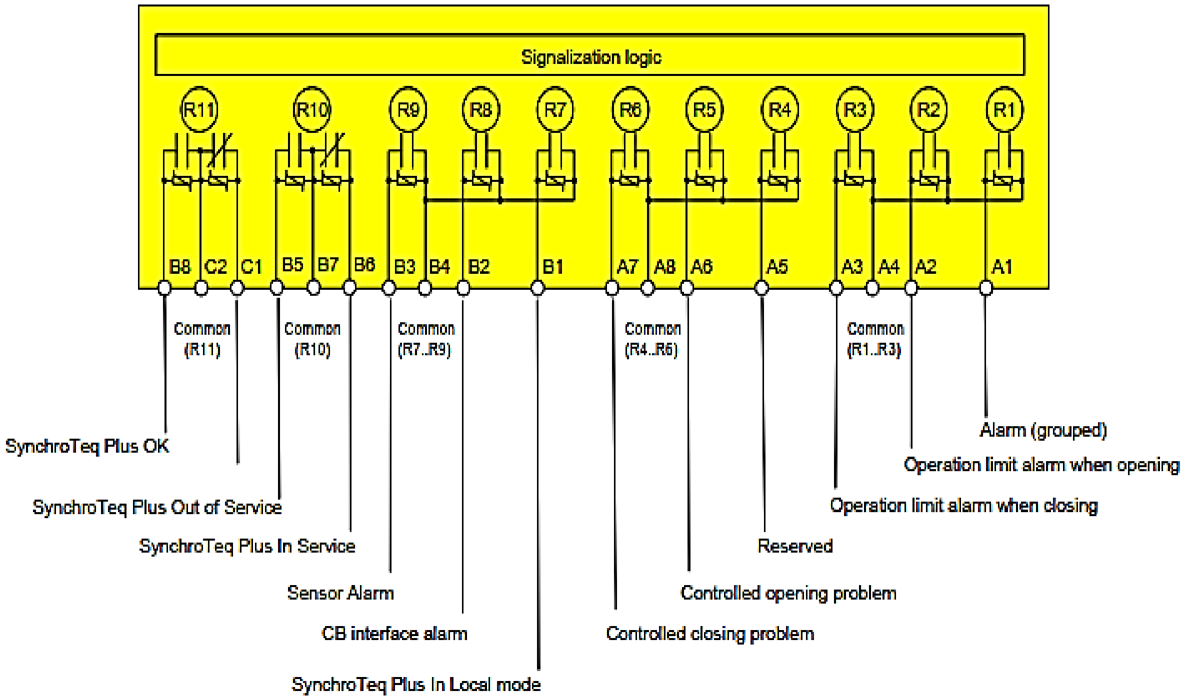


Figure-86: Assignment of "Sync. Operation Failed Signal" in Flip-flop#2 output contact

Alarm Signal (Signal type: SPS)	Wiring Terminals
CSD Bypassed	An external bypass arrangement to be implemented for bypassing CSD through SCADA or by Bypass Switch or bypassed on CSD unhealthy or any other scheme. A signal for the same must be configured in SCADA/NTAMC/RTAMC.
CSD Bypass (IN/OUT) Switch	One spare NO contact of Bypass Switch to be configured for alarm when it will be used for bypassing the CSD. State 'NO': CSD will be in service. State 'NC': CSD bypassed.

c) Vizimax: Alarms are available in A-B-C Connectors as shown below:

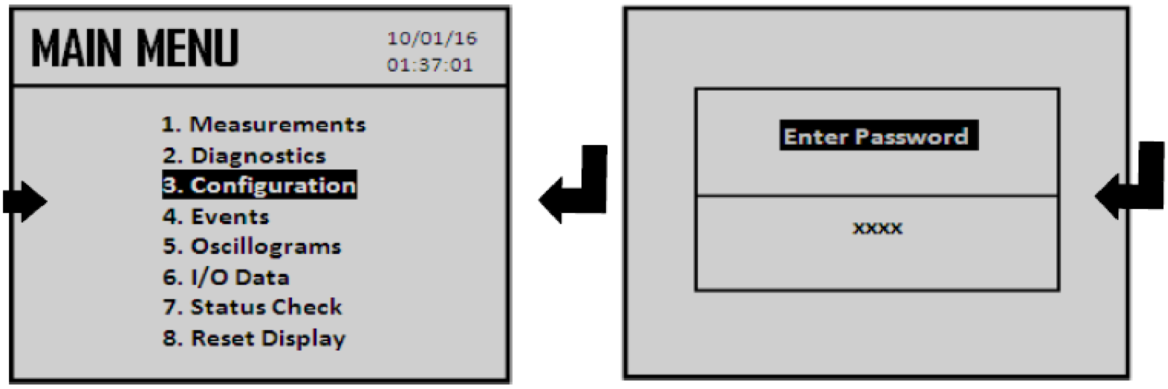


SIGNALIZATION RELAY OUTPUTS: SPSUPLY MODULE (CONNECTORS A-B-C)

Figure-87: Relay O/P contacts in Vizimax CSD

Alarm Signal (Signal type: SPS)	**Wiring Terminals**
CSD Unhealthy	C2-B7: +Ve DC Wiring (C2 & B7 looped) C1-B5: Relay output for Device Unhealthy (C1 & B5 looped)
Sync Operation Failed	A4-A8: +Ve DC Wiring (A4 & A8 looped) A2-A3-A6-A7: (looped for single output signal "Relay output for Sync Operation Failed".
CSD Bypassed	An external bypass arrangement to be implemented for bypassing CSD through SCADA or by Bypass Switch or bypassed on CSD unhealthy or any other scheme. A signal for the same must be configured in SCADA/NTAMC/RTAMC.
CSD Bypass (IN/OUT) Switch	One spare NO contact of Bypass Switch to be configured for alarm when it will be used for bypassing the CSD. State 'NO': CSD will be in service. State 'NC': CSD bypassed.

d) CGL: Manufacturer has defined alarms output at X5 Connectors. Configuration of Alarms can be performed directly from its menu display as well as with Sync Intellect Software.



Default device password is **2001**. Now go to DO NO/NC Configuration

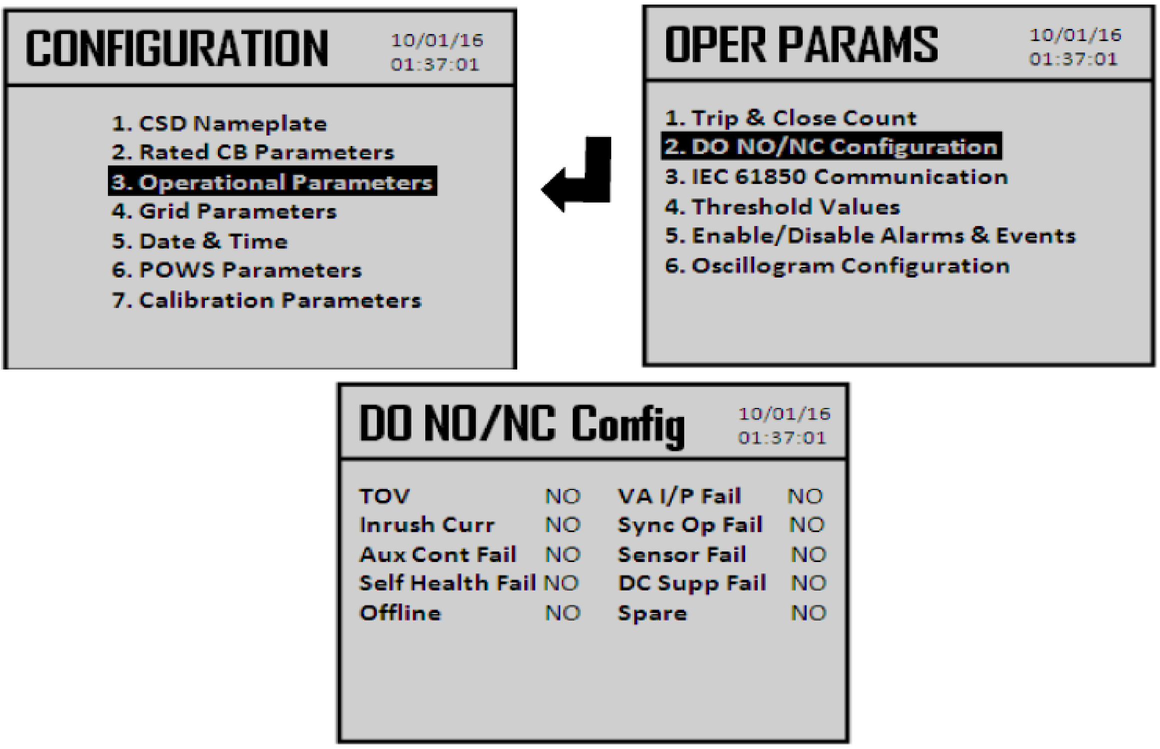


Figure-88: Alarm O/P contact configuration process in CGL CSD

Generally, all output contacts are default set as NO contact. The same may be changed as per our requirements.

Enable / Disable Alarms & Events menu under Configuration allows the user to enable/disable the issuing of alarms & generation of events for various possibilities of unhealthy operating conditions. The following figure shows navigation of the Enable/Disable Alarms & Events menu.

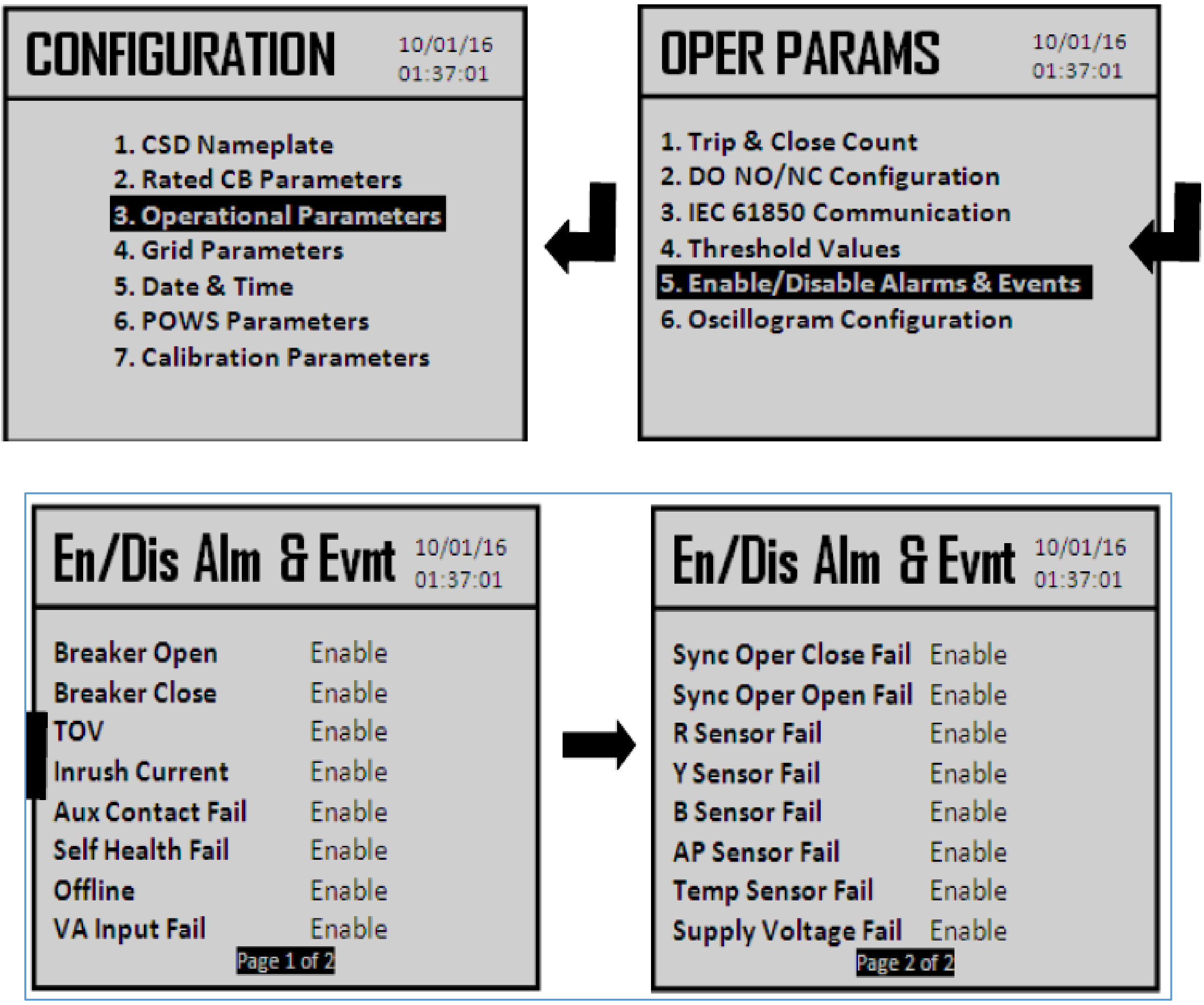
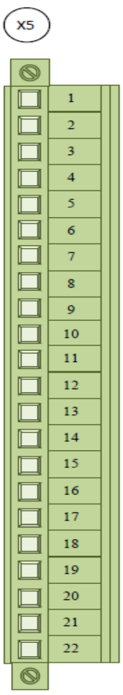


Figure-89: Alarm/Event configuration process in CGL CSD

Terminal Details (X5)



NO.	SYMBOL	DESCRIPTION
1	P (BO1)	Temporary Over Voltage
2	NO (BO1)	
3	P (BO2)	Inrush Current
4	NO (BO2)	
5	P (BO3)	Auxiliary Contact Fail
6	NO (BO3)	
7	P (BO4)	Controller Fail
8	NO (BO4)	
9	P (BO5)	Controller Offline
10	NO (BO5)	
11	P (BO6)	VA Input Fail
12	NO (BO6)	
13	P (BO7)	Sync Operation Fail
14	NO (BO7)	
15	P (BO8)	Sensor Fail
16	NO (BO8)	
17	P (BO9)	DC Supply Fail
18	NO (BO9)	
19	P (BO10)	Spare
20	NO (BO10)	
21	NC	No Connection
22	NC	

Figure-90: Terminal Details

Alarm Signal	Wiring Terminals
CSD Unhealthy	X5: 07-09: +ve DC Wiring (07 & 09 looped) X5: 08-10: Relay output for Device Unhealthy (08 & 10 looped)
Sync Operation Failed	X5: 13: +ve DC Wiring X5: 14: Relay output for Sync Operation Failed
CSD Bypassed	An external bypass arrangement to be implemented for bypassing CSD through SCADA or by Bypass Switch or bypassed on CSD unhealthy or any other scheme. A signal for the same must be configured in SCADA/NTAMC/RTAMC.
CSD Bypass (IN/OUT) Switch	One spare NO contact of Bypass Switch to be configured for alarm when it will be used for bypassing the CSD. State 'NO': CSD will be in service. State 'NC': CSD bypassed.

e) **RPH2:** Only one output contact is available X6 (-X6:12/13) connector for assigning "Device Not Ready" or "CSD Unhealthy" alarm. No switching operation is possible during this alarm. The Contact -X6:12-13 will be closed at following conditions: -

- Key switch is "OFF".
- Relay starting up.
- Reference voltage is missing.
- Frequency not in permitted range
- Neutral earthing switch in intermediate position

Alarm Signal (Signal type: SPS)	Wiring Terminals
CSD Unhealthy	X6:12: +Ve DC Wiring X6-13: Relay output for Device Unhealthy
CSD Bypassed	An external bypass arrangement to be implemented for bypassing CSD through SCADA or by Bypass Switch or bypassed on CSD unhealthy or any other scheme. A signal for the same must be configured in SCADA/NTAMC/RTAMC.
CSD Bypass (IN/OUT) Switch	One spare NO contact of Bypass Switch to be configured for alarm when it will be used for bypassing the CSD. State 'NO': CSD will be in service. State 'NC': CSD bypassed.

f) **ABB SWITCHSYNC:** Only one output contact (NC contact) is available for Alarm. This output relay is normally high and the time of alarm (also at the time of loss of power supply), it becomes low (NO)

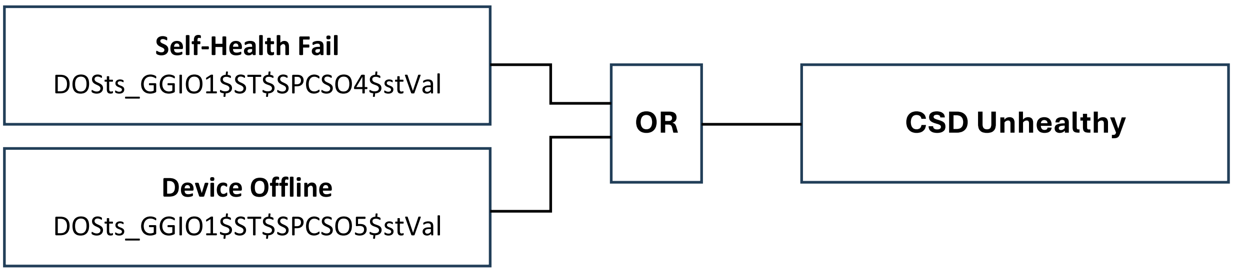
Alarm Signal (Signal type: SPS)	Wiring Terminals
CSD Unhealthy	D:01: +Ve DC Wiring D:02: Relay output for Device Unhealthy (Inverted)
CSD Bypassed	An external bypass arrangement to be implemented for bypassing CSD through SCADA or by Bypass Switch or bypassed on CSD unhealthy or any other scheme. A signal for the same must be configured in SCADA/NTAMC/RTAMC.
CSD Bypass (IN/OUT) Switch	One spare NO contact of Bypass Switch to be configured for alarm when it will be used for bypassing the CSD. State 'NO': CSD will be in service. State 'NC': CSD bypassed.

Signal integration for IEC-61850 compliant CSD:

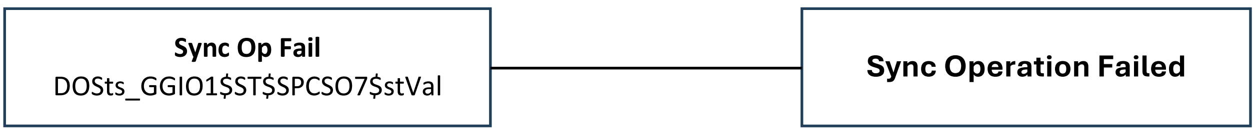
a) **CGL SYNC INTELLECT CSD** has provision to integrate directly with SCADA and relevant alarms can be configured for monitoring. "**Sync Intellect**" software provides graphical interface for making various configurations in the device. IEC 61850 Communication Settings submenu allows the user to configure the network settings of the device required for IEC 61850 protocol.

CGL 61850 IED Configuration Tool can be used to configure CGL IEC 61850 based devices for substation automation. The tool helps the user to map data from remote Goose into CGL IED data. CGL also provides predefined IEC 61850 Logical Nodes which can be used for mapping of alarms.

Configuration of CSD Unhealthy:



Configuration of Sync Operation Failed:



b) **VIZIMAX SYNCHROTEQ PLUS:** VIZIMAX SynchroTeq Communication Module (RWK000016 /RWK000016F) allows master device to communicate with or operate SynchroTeq units using IEC 61850, Modbus or DNP3 protocols on an Ethernet LAN (or Modbus/RTU on a serial link). The STCM is compatible with the following SynchroTeq products:

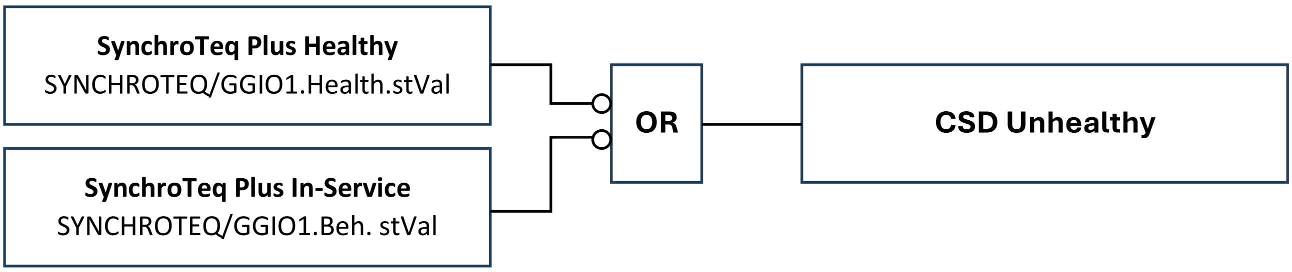
- STU0x5000: SynchroTeq rackmount (RM) or standalone (SA)
- STM0x0000: SynchroTeq MV (MVR and MVX)
- STP030000: SynchroTeq Plus

Vizimax provides an XML configuration template (RWK000016_Template.xml or RWK000016F_Template.xml) with the RWK000016 package which can be modified to indicate the parameters needed for the STCM to communicate within LAN, using the relevant protocols.

IEC 61850 protocol, the status, alarms and measurements are reported using three logical nodes as declared in the SynchroTeq IED Capability Description (ICD) file:

- XCBR is used for the position and control of the C/B
- MMXU is used to report the network frequency.
- GGIO is used to report the SynchroTeq alarms and analog measurements.

Configuration of CSD Unhealthy:



Configuration of Sync Operation Failed: