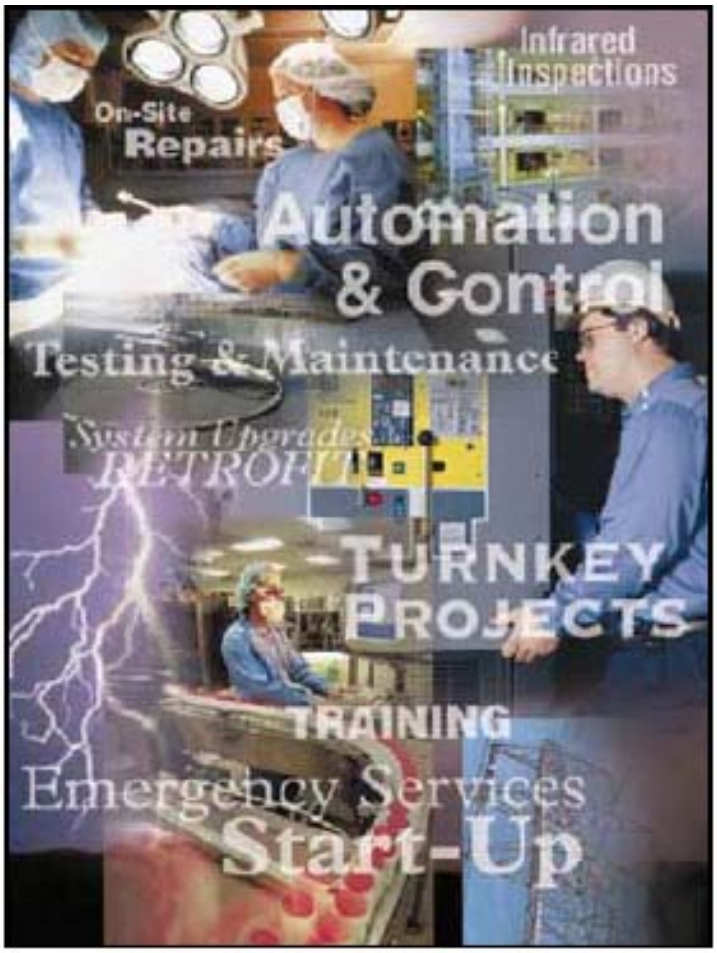
Instruction Bulletin

Procedures for Testing and Commissioning of Electrical Equipment



Schneider Electric

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SECTION-1 INTRODUCTION

The purpose of these specifications is to assure that all tested electrical equipment and systems supplied by either contractor or owner are operational and within applicable standards and manufacturer's tolerances and that equipment and systems are installed in accordance with design specifications.

The need for acceptance testing of electrical power systems is very clear to those with extensive start-up and/or operating experience. Shipping and installation damage, field and factory wiring errors, manufacturing defects, and systems and components not in accordance with drawings and specifications are some of the many problems that can be detected by appropriate testing. When these defects are found before start-up they can be corrected under warranty and without the safety hazards and possible equipment and consequential damages of loss of use/production that can occur if discovered after startup or energizing. In addition, test results obtained during acceptance testing are invaluable as base reference data for the periodic testing that is an essential element of an effective maintenance program.

This document lists a majority of the field test available for assessing the suitability for service and reliability of the power distribution system. Certain tests have been assigned an "**optional**" classification. The following considerations were used in determining the use of the "**optional**" classification:

1. Did another test listed provide similar information?
2. How did the cost of the test compare to the cost of other tests providing similar information?
3. How commonplace was the test procedure? Is it new technology?

While acknowledging the above, it is still necessary to make an informed judgment for each particular system regarding how extensive the testing should be. The approach taken in these specifications is to present a comprehensive series of tests that is applicable to most industrial and larger commercial systems. The guidance of an experienced testing professional should be sought when making decisions such as how extensive testing should be. In smaller systems some of the tests can be deleted. In other cases, a number of the tests indicated as optional should be performed.

As a further note, it is important to follow the recommendations contained in the manufacturer's instruction manuals. Many of the details of a complete and effective acceptance testing procedure can only be obtained from that source.

This document details the Field inspection, testing and commissioning procedures that must be followed during commissioning and startup of electrical equipment. These inspections and tests are performed on new equipment, after installation and prior to energizing, in order to confirm that:
1. The equipment has not been damaged during shipment or installation.
2. The equipment is in compliance with the purchase specification and design intent.
3. Documented test records that can serve as benchmarks for future tests.
For testing of equipment detailed in this document, Schneider Services will refer to the InterNational Electrical Testing Association's (NETA) guidelines in Acceptance Testing Specifications for Electrical Power Distribution Equipment and Systems (NETA ATS 1999).

SECTION-2 SAFETY

Proper safety procedures shall be reviewed and followed before each activity listed in this procedure. Job Safety Analysis followed by a toolbox/pre-job meeting shall be conducted prior to any activity listed in this procedure.
Proper safety procedures as detailed in the Square D/Schneider Electric "Field Services Safety, Health and Environmental Handbook", employee training, and customers requirements shall be implemented as dictated by each sites requirements.
Services Employees are NOT authorized to work on live equipment. There may be occasions in which you are taking measurements or checking voltages within an energized enclosure, but you are NOT authorized to "do Hands on Live" repairs!
Company representative does not typically perform shutdown and/or switching operations, because these operations may result in damage to property or persons downstream of the equipment as a result of conduct, errors, or omissions made by others. If a customer requests Company representative to perform such services, technicians must contact their Manager for approval and proper procedures.

SECTION-3 MECHANICAL CHECKS AND VISUAL INSPECTION

3.1. OBJECTIVE:

Mechanical checks and visual inspection to be done on all electrical installation to confirm that there is no physical damage, and all electrical connections and specification of equipments matching with the required one.

3.2. PROCEDURE:

The following points to be checked in mechanical checks and visual inspection.

Visual inspection:

- Nameplate details
- Physical condition (damage/ defect)
- Installation checks
- Equipment verification against rating and matching with requirement.

Mechanical checks:

- Power circuit connection tightness by torque method.
- Control wiring tightness.
- Interlock checks between equipment.
- Mechanical operations like rack in/ rack out.

The mechanical checks and visual inspection for equipments has been listed in detail under respective section.

SECTION-4 INSULATION RESISTANCE TEST

4.1. OBJECTIVE:

To determine the equipment is in proper condition to put in service for which it was designed and to give some basis for predicting whether or not that a healthy condition will remain or if deterioration is underway which can result in abnormally short life. These results can be kept as a record to compare in future and to understand the trend of insulation during maintenance.

4.2. TEST INSTRUMENTS REQUIRED:

- Insulation tester up to 5000V DC.

4.3. TEST PROCEDURE:

The following precautions should be taken care, before starting the testing.

- A visual inspection to be made to ensure the surface dust and moisture has been removed from the component under test.
- Ensure the component is isolated from other connected system, which may feed back to other components or circuits not under test.
- A check shall be made to verify the ground for the component under test and test equipment being connected to system ground and equipment like Lightning arrestor, capacitor and VT/ control transformer to be isolated.

Insulation test:

Insulation tester leads shall be connected between one phase conductor and earth. Test voltage shall be selected according to table 4.1. The duration could be 1min to 10min, and the reading shall be taken after this duration. Before disconnecting the test leads test object shall be discharged through ground. The same procedure shall be followed for other phases.

Influencing factors:

Insulation resistance value is influenced by various factors like temperature, humidity, and moisture. The ambient temperature value shall be noted during test. The relation between temperature and insulation resistance is inversely proportional.

Test methods:

- Short time or spot reading:

In this method the megger instrument is connected insulation to be tested and is applied for 60sec. The reading is recorded at the end of that time.

- Time resistance method:

In this method the testing is fairly independent of temperature provides considerably more information about the condition of insulation than the spot measurement. The test voltage shall be applied for 10minutes and readings are taken every 15sec for the first minute and every minute for 10 minutes. Dielectric absorption factor, polarization index could be calculated as below,

Dielectric absorption factor = 60sec reading/ 30sec reading.

Polarization index = 10min reading / 1min reading.

The insulation condition could be categorized as shown in the table 4.2.

- Step or multi- voltage method:

This method requires a multi voltage megger instrument, preferably with 1:5 voltage ratio ranges. Any reduction of insulation resistance at higher voltage is a sign of an insulation weakness.

The procedure of insulation test for equipments has been explained in respective section.

Rated voltage	Test voltage
100-1000V AC/DC	1000V DC
>1000 to <5000V AC	2500V DC
> 5000V AC	5000V DC

TABLE 4.1
TEST VOLTAGE LIMITS

Insulation condition	10min/1min Ratio (Polarisation Index)
Dangerous	<1
Poor	>1 to <1.5
Questionable	>1.5 to <2
Good	>2 to <4
Excellent	>4

TABLE 4.2
POLARISATION INDEX

4.4. ACCEPTABLE LIMITS:

Value of insulation resistance should meet the manufacturer minimum. If this value is not available, the component tested should have at least one Meg Ohm for every 1000 volts of rated voltage plus an additional one Meg ohm.

4.5. APPLICABLE STANDARDS:

SECTION-5 HIGH VOLTAGE TEST

5.1. OBJECTIVE:

To determine the equipment is in proper condition to put in service, after installation for which it was designed and to give some basis for predicting whether or not that a healthy condition will remain or if deterioration is underway which can result in abnormally short life.

5.2. TEST INSTRUMENTS REQUIRED:

Calibrated AC hi-pot test set for switchgear with leakage current indicator and overload protection.
Calibrated DC hi-pot test set for cables with leakage current indicator and overload protection.

5.3. TEST PROCEDURE:

5.3.1. SWITCHGEAR:

It includes panel enclosure, bus bar, CT & breaker / contactor. The following precautions should be taken care, before starting the test:

- A visual inspection will be made to ensure the surface dust and moisture has been removed from the component under test.
- Ensure the component is isolated from other connected system, which may feed back to other components or circuits not under test.
- A check shall be made to verify the ground for the component under test and test equipment being connected to system ground.
- CT's secondary terminals shall be shorted.
- VT's & Surge arresters shall be isolated from the equipment under test.
- Mark out test area and assure nobody can enter during test.
- Circuit breakers/contactors should be inserted and closed.
- Busbars should be fully mounted tightened and shields between phases & between phases and earth should be in place. Moreover, busbar covers should be in place.
- All earthing switches related to equipment under test should be open.
- Busbar conductivity test shall be performed.
- Insulation resistance test should be performed before and after commencing the test.
- Instructions of test equipment being used should be followed.
- After each test subject under test should be discharged to ground.
- The test connection shall be made as shown in the fig. 5.1.

Required test voltage shall be raised slowly and maintained for one minute between one phase and other phases connected to ground and than reduced slowly to zero, testing shall be repeated for other phases as mentioned above. During each test leakage current shall be recorded.

After the above test, another test shall be repeated after opening all circuit breakers / contactors and applying test voltage across opening distance between poles with three poles shorted on both sides and grounded on one side only as shown in the fig.5.2. Test voltage limits are mentioned in table 5.1.

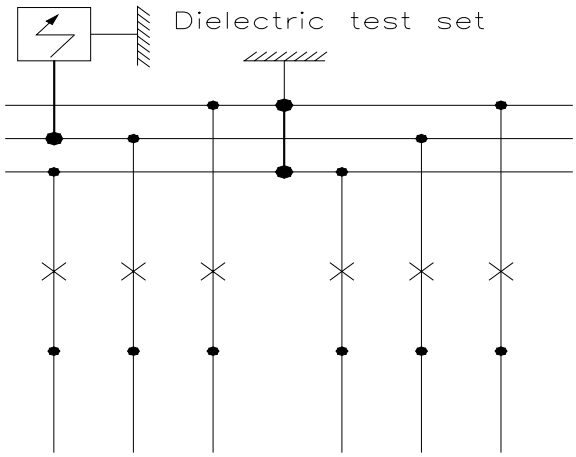


Fig 5.1
HV test for switchgear

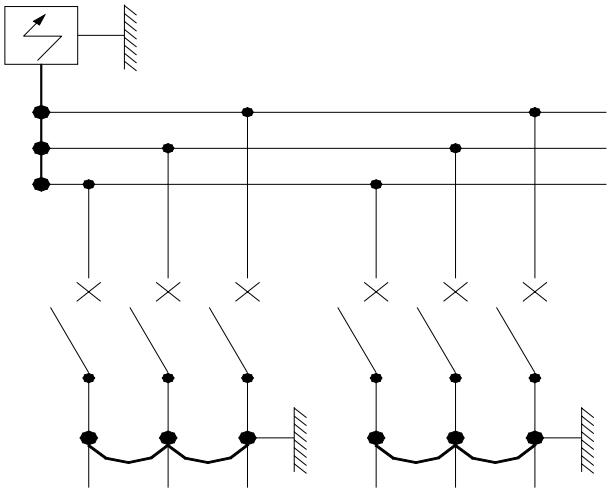


Fig 5.2
HV test for opening distance

5.3.2. POWER CABLES:

Following precautions shall be made before conducting test.

- Cable under test should be clean and free of dust especially at insulators and stress cones.
- Shields of all cables should be grounded and tied together at the near end of the cable and at far end bare conductor should be taped with some insulation.
- Cable under test should be disconnected at both ends. This will assure that the cable under test will not feed back to circuits / components not under test.

- Personnel should be stationed at both ends and / or the end opposite where the test is performed should be barricaded with warning tapes & signboards.
- Instructions of test equipment being used should be followed.

DC Voltage Test:

Dc voltage shall be raised slowly up to 4 x Uo (rated power frequency voltage between conductor and earth or metallic screen) and maintained for 15 minutes between one phase and other phases and metallic screen of all phases connected with ground. After elapse of test time, voltage shall be reduced slowly to zero and the cable shall be discharged. Testing shall be repeated for other phases as mentioned above. Test voltage limits are mentioned in table 5.2 as per IEC 60502-2(1997-04):

AC Voltage Test (Alternate method):

As per IEC 60502-2(1997-04), as an alternate method after agreement between the contractor and purchaser, an a.c voltage may be applied as a) or b) below:

a) Test for 5min with phase-to-phase voltage of the system applied between the conductor and the metallic screen
b) Test for 24 hours with the normal operating voltage Uo of the system.
Note: Normally cables have three voltages specified: i.e. Uo\U\Um
Where Uo=rated Phase to earth/screen voltage
U= rated Phase to phase voltage
Um=rated maximum Phase to phase voltage

-For cables used for solidly earthed system screen current for the earth fault will be high but cable Uo rating is low i.e. Uo=U/1.732

-For cables used for resistance earthed system screen current will be low for earth fault but cable Uo rating is high i.e. Uo=U

Note:
A VLF (Very Low Frequency) high voltage of 3xUo shall be applied between conductor and screen. Some utility customers are accepting this.

5.4. ACCEPTANCE LIMITS:

For Switchgear:
No flashover or disruptive discharge should occur during test. Corona discharge noise may be heard during this test.

For Power cables:
No flashover or disruptive discharge should occur during test.

Rated voltage (KV)	Rated I min. power frequency withstand voltage (KV)	Test voltage at field =80%KV
7.2	20	16
17.5	38	30.4
36	70	56

Note: For old switchgear the test voltage shall be reduced according to the age.

TABLE 5.1
SWGR TEST VOLTAGE

Rated Cable voltage (KV) Uo (Phase to earth)	Test voltage for 15min DC voltage (KV)
3.6	14.4
6.0	24
8.7	34.8
12	48
18	72

TABLE 5.2
CABLE TEST VOLTAGE

5.5. APPLICABLE STANDARD:

IEC 60298: - AC metal-enclosed switchgear and control gear for rated voltage above 1KV to 52KV.
IEC 60694: - Common specifications for HV switchgear.
IEC 60502: - Power cables with extruded insulation and their accessaries from 1KV up to 30KV.

SECTION-6 CURRENT TRANSFORMER TEST

6.1. OBJECTIVE:

To confirm the physical condition and electrical characteristics of current transformer installed in the installation. Ensure the CT is connected to system properly in all respect (primary and secondary).

6.2. TEST EQUIPMENTS REQUIRED:

Insulation tester
Polarity tester
Digital low ohmmeter
Current source, multimeter
Variac, step-up transformer (0-2kv)
Primary current injection set

6.3. TEST PROCEDURE:

6.3.1. MECHANICAL CHECK AND VISUAL INSPECTION:

- Verify nameplate ratings are in accordance with the approved drawings and specifications.
- Inspect for physical damage/ defects and mechanical condition.
- Verify correct connection of transformers with system requirements.
- Verify that adequate clearances exist between primary and secondary circuit wiring.
- Verify tightness of accessible bolted electrical connections by calibrated torque-wrench method.
- Verify that all required grounding and shorting connection provided.
- Verify all shorting blocks are in correct position, either grounding or open as required.
- Verify single point grounding of each core done properly. Grounding point shall be nearer to the CT location. However grounding shall be at relay point in case of several CT secondaries connected together like differential protection.

6.3.2. INSULATION RESISTANCE TEST:

The voltage shall be applied between

- Primary to secondary plus ground (covered during switchgear test).
- Secondary to primary plus ground.
- Secondary core to core.

Test voltage limits mentioned in table 4.1. The ambient temperature shall be noted down during test.

6.3.3. POLARITY TEST:

Polarity test is to confirm the polarity marking on the CT primary and secondary and verify it is matching with drawing. More ever it is giving an idea, how to connect the secondaries to make the protection (like directional, differential) and metering function properly.
Isolate CT secondary from the load and make circuit connection as shown in Fig. 6.1.
Close and open the battery switch connected on the primary. Observe the pointer is moving +ve direction, while closing and –ve direction while opening for correct polarity.

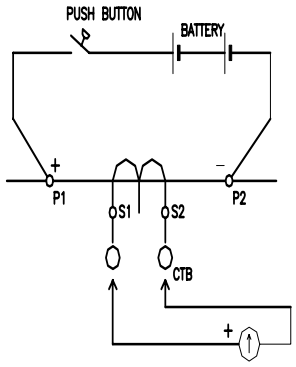


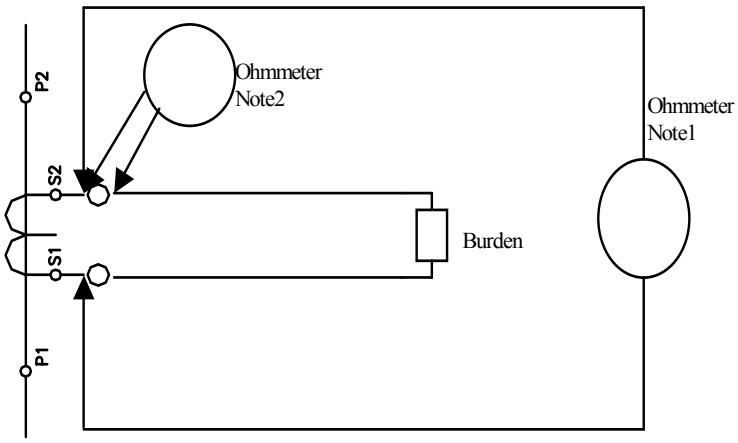
Fig 6.1
Polarity test

6.3.4. SECONDARY/ LOOP RESISTANCE TEST: (OPTIONAL TEST)

Secondary resistance test is to verify the CT secondary winding resistance with specified one and no discontinuity in the winding. This value can be used in other calculations. Loop resistance to ensure load is connected properly and circuits not left open.

- The circuit connection shall be made as shown Fig 6.2 for secondary resistance. Measure the dc resistance value and record. The same shall be done for all taps and cores. These values are influenced by temperature, so ambient temperature must be recorded during this test.
- The circuit connection shall be made as shown Fig 6.2 for loop resistance. Measure the dc resistance including CT and load, phase by phase and values can be compared between them.

Limits:
The value must be with in specified on nameplate after the effect of temperature taken in to account. If not factory test results shall be taken as reference.



Note1: ohmmeter connection for CT resistance excluding burden.
Note2: ohmmeter connection for CT loop resistance including burden.

Fig 6.2
CT resistance / loop resistance test

6.3.5. BURDEN TEST: (OPTIONAL TEST)

Burden test is to ensure the connected burden to CT is with in the rated burden, identified on the nameplate.
Injected the rated secondary current of the CT, from CT terminals towards load side by isolating the CT secondary with all connected load and observe the voltage drop across the injection points. The burden VA can be calculated as,
Burden VA = Voltage drop x rated CT sec. Current.

Limits:
The calculated burden should be less than rates CT burden.

Note:
Ammeter selector switch should be at respective phase during test.
High impedance relays shall be shorted during the test.

6.3.6. MAGNETIZATION CURVE TEST: (OPTIONAL TEST)

Mag. Curve test is to confirm the magnetisation characteristics of CT with nameplate specification.
This test shall be conducted before ratio test and after secondary resistance and polarity test, since residual magnetism left in the core due to DC test (polarity, resistance), which leads additional error in ratio test. The meters used for this test shall be having true RMS measurement.
The circuit connection shall be made as shown Fig 6.3. The primary should be open during test.

Demagnetisation:
Before start the test demagnetise the core by Inject voltage on secondary terminals and increase up to where considerable increment in current with small voltage increment. Now start decreasing the voltage to zero, the rate at which increased.

Magnetisation test:
Now increase the voltage and monitor the excitation current up to the CT reaching near to saturation point. Record the reading of voltage and current at several points. Plot the curve and evaluate the Vk and Img from the graph.

Limits:
Class X CT:
The obtained Vk should be greater than specified one; mag current should be less than specified one.
Protection class CT:
The secondary limiting voltage can be calculated as follow
Vslv = Is * ALF (Rct + (VA/Is*Is))
Is – rated secondary current
Rct- CT secondary resistance
VA- rated CT burden
ALF – Accuracy limit factor
The mag current (Img) drawn at Vslv can be obtained from graph. The following criteria should be satisfied.
Img < accuracy class * ALF * Is
Metering Class CT:
Accuracy can be ensured as follow,

Img at Vs (= 1.2 * VA / Is) should be less than (accuracy class * Is)
And instrument security factor to be verified.

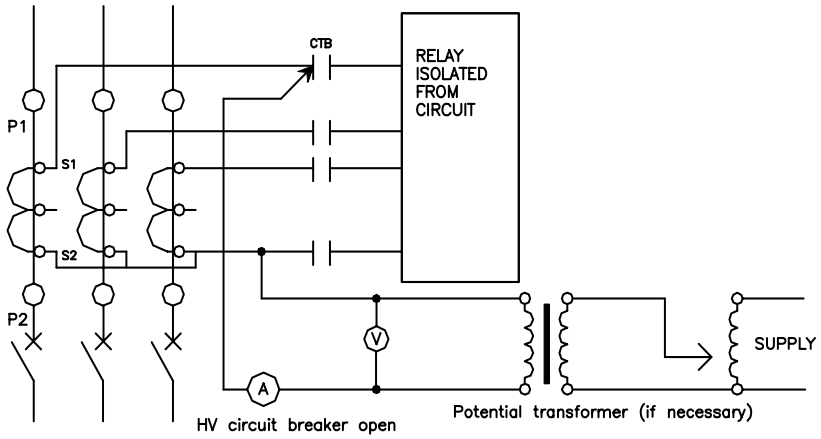


Fig 6.3
Magnetisation test

6.3.7. TURNS RATIO TEST: (OPTIONAL)

This test is to ensure the turn's ratio of CT at all taps.
The circuit connection shall be made as shown Fig 6.4. The primary current of minimum of 25%rated primary current to be injected on primary side of CT with secondaries shorted and the secondary current can be measured & recorded for all cores.
Limits:
The obtained turn's ratio should match with rated nameplate ratio.

6.3.8. PRIMARY INJECTION TEST:

This test is to ensure the CT circuits are properly connected with respected cores and there is no mix up in the circuit (phase identification).The circuit connections shall be made as shown in Fig 6.4. Single point grounding shall be verified for CT circuits, before starting this test.
Inject 25% of rated primary current between one phase and earth with all connected burden. Measure secondary current at all points of CT circuits. It shall be done for other phases.

Core identification:
When one CT is having several cores used for different purposes. The cores can be identified during primary injection test by shorting the one of the core at CT terminal itself and check there is no current only at relevant load. The same can be verified for other cores.
Inject 25% of rated primary current between phase to phase with all connected burden. Measure secondary current at all points of CT circuits. It shall be done for other phases.

Limits:
- Secondary current should only be observed at respective phase and neutral leads during Phase to earth injection.
- Secondary current should only be observed at respective phases and no current on neutral during Phase to phase injection.

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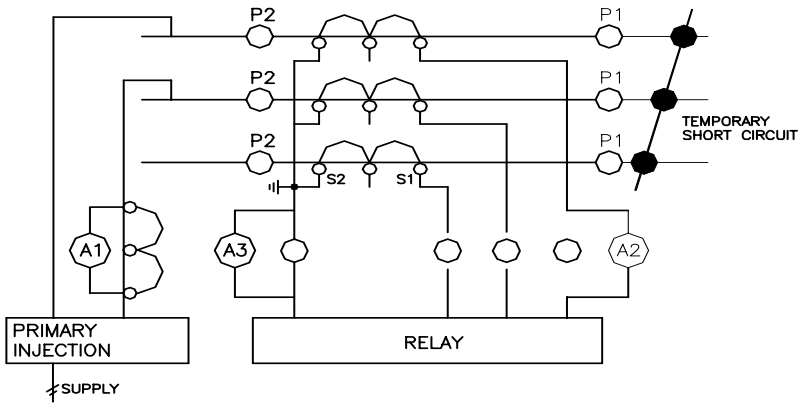


Fig 6.4
Primary injection /Ratio test

6.3.9. HIGH VOLTAGE TEST:

This test is included with switchgear high voltage and performed as per section 5.3.1.

6.3.10. COMMISSIONING TEST:

After commissioning, secondary current measurement shall be carried out in CT circuits. Phase angle check shall be done for correct direction. This test is discussed under section 'commissioning test'.

6.4. APPLICABLE STANDARD:

IEC 60044-1: Instrument transformers – current transformer.
IEC 60694: common specifications for HV switchgear.

SECTION-7 VOLTAGE TRANSFORMER TEST

7.1. OBJECTIVE:

To confirm the physical condition and electrical characteristics of voltage transformer installed in the installation. Ensure the VT is connected to system properly in all respect (primary and secondary).

7.2. TEST EQUIPMENTS REQUIRED:

Insulation tester
Polarity tester
Digital low ohmmeter
Voltage source, multimeter

7.3. TEST PROCEDURE:

7.3.1. MECHANICAL CHECK AND VISUAL INSPECTION:

- Verify nameplate ratings are in accordance with the approved drawings and specifications.
- Inspect for physical damage/ defects and mechanical condition.
- Verify correct connection of transformers with system requirements.
- Verify that adequate clearances exist between primary and secondary circuit wiring.
- Verify tightness of accessible bolted electrical connections by calibrated torque-wrench method.
- Verify that all required grounding and shorting connection provided.
- Verify correct operation of VT draw out mechanism and grounding operation.
- Verify correct primary and secondary fuse rating / healthiness for Voltage transformer.

7.3.2. INSULATION RESISTANCE TEST:

Above-mentioned precautions at section 4.3 shall be made for this also and primary / secondary winding ground connection to be isolated. The voltage shall be applied between

- Primary to secondary plus ground.
- Secondary to primary plus ground.
- Secondary winding to winding.

Test voltage limits mentioned in table 4.1.

7.3.3. POLARITY TEST:

Polarity test is to confirm the polarity marking on the VT primary and secondary and verify it is matching with drawing. More ever it is giving an idea, how to connect the secondaries to make the protection (like directional) and metering function properly.
Isolate VT secondary from the load and make circuit connection as shown in Fig 7.1.
Close and open the battery switch connected on the primary. Observe the pointer is moving +ve direction, while closing and –ve direction while opening for correct polarity.

7.3.4. WINDING RESISTANCE TEST: (OPTIONAL TEST)

Winding resistance test is to verify the VT primary & secondary have no discontinuity or abnormal in the winding.

Primary winding resistance can be measured by multimeter, as it will be a higher resistance. The secondary winding resistance can be measured with low ohmmeter for each winding.
Limits:
The value must be with in specified on nameplate after the effect of temperature taken in to account. If not factory test results shall be taken as reference.

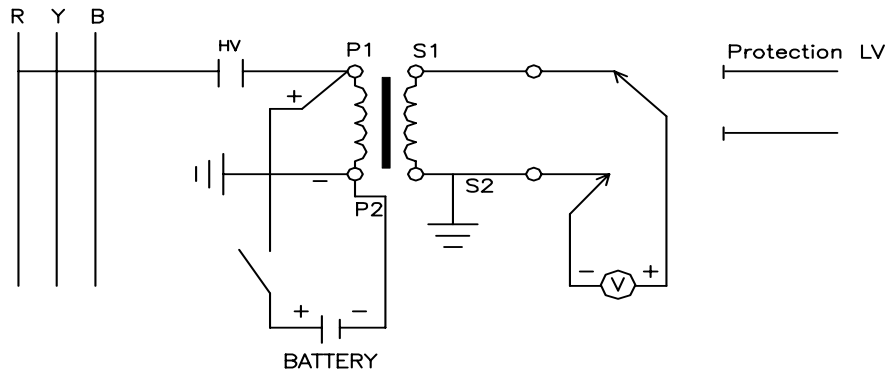


Fig 7.1
Polarity test

7.3.5. BURDEN TEST: (OPTIONAL TEST)

Burden test is to ensure the connected burden to VT is with in the rated burden, identified on the nameplate.
Injected the rated secondary voltage of the VT, from VT terminals towards load side by isolating the VT secondary with all connected load and observe the current drawn by the load. The burden VA can be calculated as,
Burden VA = Secondary Voltage * drawn load Current.

Limits:
The calculated burden should be less than rates VT burden.

Note:
Voltmeter selector switch should be at respective phase during test.

7.3.6. RATIO TEST:

This test is to ensure the turn's ratio of VT.
The circuit connection shall be made as shown Fig 6.2. The primary voltage of 220 V applied on primary terminals and secondary voltage measured from secondary terminals.
Limits:
The obtained turn's ratio should match with rated nameplate ratio.

7.3.7. HIGH VOLTAGE TEST: (OPTIONAL TEST)

This test is included with switchgear high voltage and performed as per SEC 5.3.1.

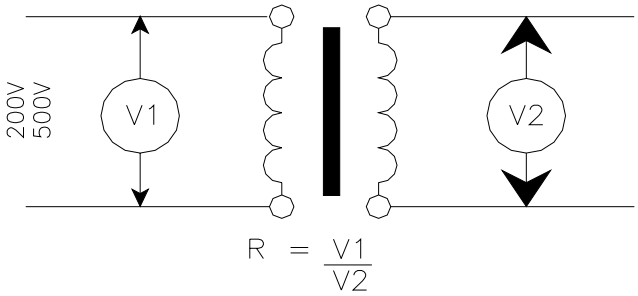


Fig 7.2
Ratio test

7.3.9. VT CIRCUIT CHECK:

This test is to confirm all the loads of VT are connected properly and no mix-up between phases.

Inject three-phase voltage with different magnitude at each phase, on the secondary circuit (VT side isolated), and measure voltage at all points. Verify that there is no mix-up between phases.

7.3.10. COMMISSIONING TEST:

After commissioning secondary voltage measurement shall be carried out in VT circuits. Phase sequence check to be done for correct rotation. This test is discussed under section 'commissioning test'.

7.4. APPLICABLE STANDARD:

IEC 60044-2: Instrument transformers -Voltage transformer
IEC 60694: Common specification for HV switchgear.

SECTION-8 POWER TRANSFORMER TEST

8.1. OBJECTIVE:

To confirm the physical condition and electrical characteristics of Power transformer installed in the installation. Ensure the power transformer is connected to system properly in all respect (primary and secondary).

8.2. TEST EQUIPMENTS REQUIRED:

Insulation tester
3-phase voltage source, multimeter
Digital low ohmmeter/ double bridge
BDV tester

8.3. TEST PROCEDURE:

8.3.1 MECHANICAL CHECKS AND VISUAL INSPECTION:

- Inspect for physical damage/ defects and oil leakage.
- Verify transformer nameplate ratings in accordance with customer drawings and specifications.
- Check the impact recorder records for any abnormal impacts during transit, if applicable.
- Verify that positive pressure is maintained on nitrogen-blanketed transformers, if applicable.
- Check tightness of all bolted connections (torque-wrench method).
- Check that all grounding is securely connected (including neutral grounding).
- Check that piping to Buchholz relay has proper slope.
- Check the transformer wheel stoppers installed.
- Top up the oil to the tank if required and drying out oil.
- Check oil in the tank, conservator and bushing for proper level.
- Release trapped air at the bushing turrets and tank top.
- Check that valves between the tank and the radiators are open.
- Check condition (colour and quantity) of silica gel in breather and oil in bath level.
- Check the OTI and WTI thermal probes are fixed in the oil pockets and the oil pockets are filled with oil.

8.3.2 INSULATION RESISTANCE TEST:

Above-mentioned precautions section4.3 shall be made for this also and primary/ secondary winding ground connection to be isolated. The voltage shall be applied between
- Primary to secondary plus ground.
- Secondary to primary plus ground.
- Primary winding to secondary winding.

Test voltage limits mentioned in table4.1. Test shall be conducted for 10min. The reading for 1 min and 10min will be noted and PI value can be calculated as PI= reading at 10min/1min. Condition of insulation indicated by PI values are listed in table 4.2.

8.3.3. VOLTAGE RATIO TEST:

This test is to verify the voltage ratio of the transformer with its nameplate values.
Test circuit connection shall be made as shown in fig 8.1.
The test voltage single-phase 220V shall be applied across one of the phase primary winding (in case of star connected RN, YN, BN or in case of delta

connected RY, YB, BR or RB, YR, BY) and voltage shall be measure at respective secondary winding. This test shall be done phase-by-phase for all taps.
Limits:
Compare the trend of voltage ratio with reference to nameplate or previous factory test results.

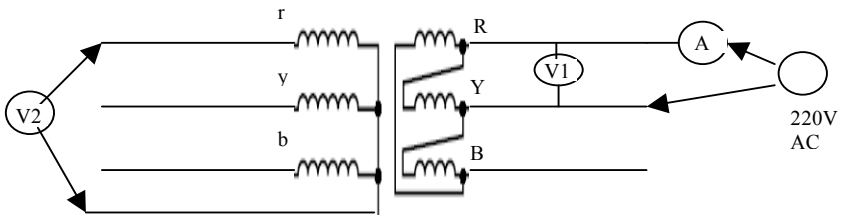


Fig 8.1
Ratio / Excitation test

8.3.4. MAGNETISATION CURRENT TEST:

This test is to verify there is no abnormality in no load magnetising current and there is no internal fault on transformer.
Test circuit connection shall be made as shown in Fig 8.1.
This test shall be done phase-by-phase. Apply test voltage across one of the phase of primary or secondary (preferably at secondary side) and other side kept open circuited. Measure the magnetising current drawn by the winding. This can be done during ratio test for each tap.
Limits:
Comparison shall be done with previous test results.

8.3.5. VECTOR GROUP TEST:

This test is to confirm the vector relation between primary and secondary as shown in the nameplate. This will ensure the polarity and terminal marking on the transformer.
The test connection shall be made as shown in Fig 8.2.
Apply 3-phase test voltage on transformer primary with secondary open circuited.
Short 'R' phase primary and 'r' phase secondary. Measure voltage on several points and record.
Check the criteria for specified vector group with recorded results.

Limits:
The result should match with nameplate specification.

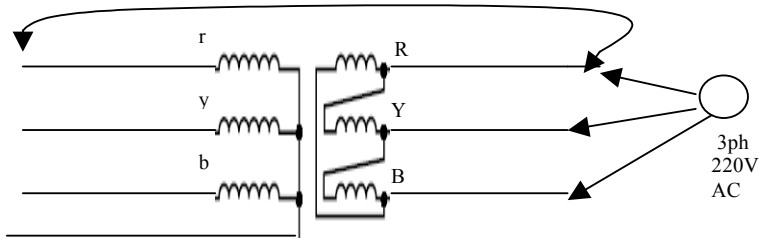


Fig 8.2
Vector Group test

8.3.6. WINDING RESISTANCE TEST: (OPTIONAL TEST)

This test is to measure the both primary and secondary winding dc resistance and to confirm there is no winding discontinuity, abnormality at all taps.
The test connection shall be made as shown in Fig 8.3.
The test shall be conducted at all taps by four-wire method or double bridge method.
Test to be done for primary and secondary winding phase by phase.
This test shall be the last test to avoid DC flux remaining in core and giving erroneous values to the other tests.
Limits:
The test values shall be compared with factory test reports after temperature correction.
Note:
The test values are influenced by temperature, so the oil temperature should be noted during test.

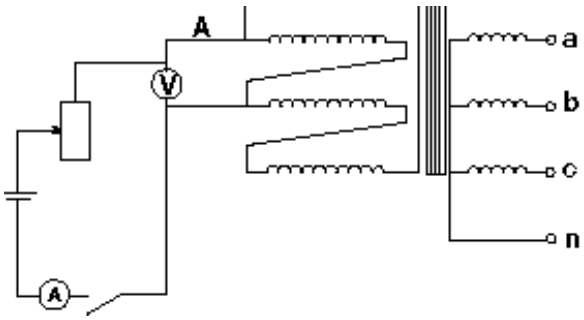


Fig 8.3
Winding resistance test

8.3.7. BUSHING CT TEST:

This test is to confirm the CT electrical characteristics and connectivity of CT circuits.
The following tests to be performed.
Insulation test as per SEC 4.2.3
Polarity test as per SEC
Winding /loop resistance as per SEC
Ratio test:
This shall be done by primary injection at test terminal (if provided) otherwise the primary current can be driven through BCT by injecting 3 phase test voltage at primary with short circuited secondary or vice versa.

Limits:
Test results should match with nameplate specification or factory test results shall be taken as reference.

8.3.8. TRANSFORMER OIL TEST:

This is to confirm the dielectric medium electrical characteristics and condition.
Oil samples shall be taken from top and bottom in both tank and OLTC (if applicable).
BDV test shall be performed for all the samples and recorded.
One more set of samples shall be sent for Dissolved gas analysis to laboratory.
Limits:
BDV value for oil should match with the manufacturer instruction manual.

8.3.9. TRANSFORMER AUXILIARIES:

Buchholz relay:
Operation verification shall be done gas injection as per supplier's instruction manual.
Alarm and trip contacts wiring shall be checked for proper operation.
Oil / Winding temperature indicator:

- OTI and WTI shall be calibrated with standard thermometer as per supplier's instruction manual.
- For WTI shall be tested for thermal image by injecting current at current terminals as per supplier's instruction manual.
- Check alarm / trip contacts for proper function.

Cooler fans:

- Insulation resistance of fan motor to be checked.
- Fan starting current and running current shall be noted and direction of rotation to be checked.
- The overload relays should be properly adjusted.

OLTC mechanism:

- Operation test shall be carried out for OLTC.
- Check Operation interlock.

8.4. APPLICABLE STANDARD:

IEC-60076 Power Transformer
IEC-60726 dry type power transformer

SECTION-9 METAL CLAD SWITCHGEAR

9.1. OBJECTIVE:

To verify the physical condition and proper connections of bus bar.

9.2. TEST EQUIPMENTS REQUIRED:

Insulation test
Micro ohmmeter
High voltage tester
Torque wrench

9.3. TEST PROCEDURE:

9.3.1. MECHANICAL CHECKS AND VISUAL INSPECTION:

- Inspect switchgear and all components for any physical damage / defects.
- Check nameplate information for correctness.
- Inspect enclosures for proper alignment, foundation fixing, and grounding and vermin entry.
- Inspect all covers, panels' section and doors for paintwork and proper fit.
- Check all the transport locks are removed.
- Check for smooth and proper movement of racking mechanisms, shutter, rollers, rails and guides.
- Check proper alignment of the primary and secondary contacts.
- Check operation of all mechanical interlocks.
- Check tightness of all bolted connections.
- Check for correct phasing connection of bus bar.
- Perform mechanical check and visual inspection for breaker/ Contactor as per section.
- Perform mechanical check and visual inspection for instrument transformers as per section
- Perform mechanical check and visual inspection on all disconnect and grounding switches as per section.

9.3.2. INSULATION RESISTANCE TEST:

It includes panel enclosure, busbar, CT & breaker. The following precautions should be taken care, before starting the testing.

- A visual inspection will be made to ensure the surface dust and moisture has been removed from the component under test.
- Ensure the component is isolated from other connected system, which may feed back to other components or circuits not under test.

On testing, voltage shall be applied between one phase and other phases connected with ground, testing shall be repeated for other phases as mentioned above. Test voltage limits mentioned in table 4.1.

9.3.3. CONTACT RESISTANCE TEST:

This test is to confirm the busbar joints are connected properly and verify the tightness.
The test connection diagram is as shown in Fig.
The test shall be done with CBs inserted and closed. Measure the contact dc resistance between panels by injecting 100ADC. This will include busbar joint, CB contact resistance, CB cluster resistance, and CT primary resistance (if applicable).

Limits:
The obtained results should be similar for all phases for each set of measurement.
Other influencing factors to be considered, like length of the measured path, rating of the busbar, rating of CB, rating of CT and temperature.

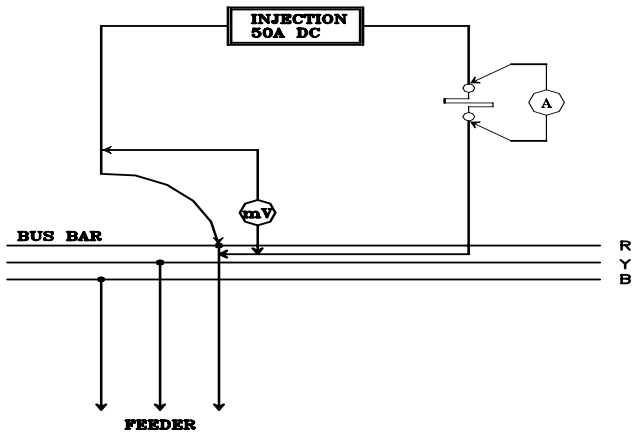


Fig 9.1
Contact resistance test

9.3.4 HIGH VOLTAGE TEST:

This shall be performed as per section 5.3.1

9.4. APPLICABLE STANDARD:

IEC60298: – AC metal enclosed switchgear and control gear for rated voltage above 1KV to 52KV.

SECTION-10 CIRCUIT BREAKER / CONTACTOR

10.1. OBJECTIVE:

To verify the physical condition and electrical characteristics of CB/ contactors.

10.2. TEST INSTRUMENTS REQUIRED:

Insulation tester
Micro ohmmeter
CB timing test kit
HV test kit

10.3. TEST PROCEDURE:

10.3.1. MECHANICAL CHECKS AND VISUAL INSPECTION:

- Inspect for physical damage/ defects.
- Check nameplate information for correctness.
- Check tightness for all bolted connections.
- Check the transport lock is removed for breaker/ contactor.
- Check racking mechanism for alignment and smoothness operation.
- Check operation of all mechanical interlocks.
- Check correct breaker/contactor position indication.
- Check for correct spring status indication.
- For SF6 breakers check the correct gas pressure.
- Check the manual operation of breaker/contactor.

10.3.2. INSULATION RESISTANCE TEST:

The test voltage shall be between phase to earth and across the poles.

- Each phase to earth (or body).
- Across the pole for each phase.

The applied test voltage limits shall be as per table 4.1.

10.3.3. CONTACT RESISTANCE TEST:

This test is to confirm the resistance of the main contacts.
Inject 100A DC current through the main contact by keeping CB closed. The voltage drop across the contact is measured and resistance is calculated. In many instruments resistance will be a direct reading.
Limits:
The obtained values shall be compared with factory test reports or manufacturer claimed values could be taken as reference.

10.3.4. CB TIMING TEST:

This test is to verify the open and closing time of CB contacts.
The test connection circuit is shown in Fig. Measure the closing time and tripping time with timing test kit that will measure and record the time and timing diagram.
Limits:
The obtained close/ open time shall be compared with manufacturer reference values or factory test results.

10.3.5. REDUCED VOLTAGE TEST:

This test is to confirm the operation of closing coil and opening coil at reduced voltage applied.
Apply reduce voltage of 80% of rated voltage for closing coil and 60% of rated voltage for trip coil and operation shall be noticed.

Limits:
Operation shall be observed without fail.

10.3.6. HIGH VOLTAGE TEST:

This test shall be performed as per section 5.3.1.

10.3.7. APPLICABLE STANDARD:

IEC 60056: High voltage AC circuit breakers.

SECTION-11 DISCONNECTOR / GROUND SWITCH

11.1. OBJECTIVE:

To verify the physical condition and electrical characteristics of disconnector / ground switch.

11.2. TEST INSTRUMENTS REQUIRED:

Insulation tester
Micro ohmmeter
HV test kit

11.3. TEST PROCEDURE:

11.3.1. MECHANICAL CHECKS AND VISUAL INSPECTION:

- Inspect for physical damage/ defects.
- Check nameplate information for correctness.
- Check the tightness of all the bolted connections.
- Check for smoothness operation.
- Check that ground switch is connected to earth bar.
- Check the mechanical interlocks.

11.3.2. INSULATION RESISTANCE TEST:

The test voltage shall be between phase to earth and across the poles.

- Each phase to earth (or body).
- Across the pole for each phase.

The applied test voltage limits shall be as per table 4.1.

11.3.3. CONTACT RESISTANCE TEST:

This test is to confirm the resistance of the main contacts.
Inject 100A DC current through the main contact by keeping disconnector/ earth switch closed. The voltage drop across the contact is measured and resistance is calculated. In many instruments resistance will be a direct reading.
Limits:
The obtained values shall be compared with factory test reports or manufacturer claimed values could be taken as reference.

11.3.4. HIGH VOLTAGE TEST:

This test shall be performed as per section 5.3.1.

11.4. APPLICABLE STANDARD:

IEC 60265: HV switches 1-52KV

SECTION-12 PROTECTIVE RELAY

12.1. OBJECTIVE:

To verify the physical condition and electrical characteristics of protective relays.

12.2. TEST EQUIPMENTS REQUIRED:

Relay test unit 3phase/ 1phase

12.3. TEST PROCEDURE:

12.3.1. MECHNICAL CHECKS AND VISUAL INSPECTION:

- Inspect for physical damage / defects.
- Check for nameplate information for correctness.
- Carryout visual check as per manufacturer recommendation.
- Check the wiring connections are as per approved drawing and verify tightness.

12.3.2. SECONDARY INJECTION TEST:

This test is to confirm the electrical characteristics of protective or control relay and the healthiness of the same. This will be carried out with relay alone (without external interfacing).

The secondary injection test shall be performed as per manufacturer pre-commissioning instructions and the forms shall be followed for record. The relay shall be set for final approved setting.

12.3.3. PROTECTION / CONTROL FUNCTIONAL TEST:

This test is to confirm the above tested relay is properly connected / interfaced with system, that required. This will verify all inputs to relay and outputs from the relay are properly connected, as it required. An injection (current/ voltage) shall be made and checked the functions outputs (trip, alarm, indication, control). Inputs shall be initiated from the source and monitored the proper outputs from the relay.

12.4. APPLICABLE STANDARDS:

IEC 60255: Electrical Relays.

SECTION-13 MEASURING INSTRUMENTS

13.1. OBJECTIVE:

To confirm physical condition and accuracy of the measuring instruments.

13.2. TEST INSTRUMENTS REQUIRED:

Secondary injection test unit

13.3. TEST PROCEDURE:

13.3.1. MECHANICAL CHECKS AND VISUAL INSPECTION:

- Inspect for physical damage / defects.
- Verify that indication range of meter is as specified.
- Verify that meter/ instrument connections are according to approved drawings.
- Check that all mounting bolts and wiring terminations are tight and secured.

13.3.2. ACCURACY TEST:

The secondary injection accuracy test shall be done by injecting the input quantities (voltage or current or both) from test block. Injection kit shall be a calibrated, stable source (ex. Computerised test kit like omicron CMC). Other wise another standard/calibrated measuring instrument shall be used as reference. The following steps shall be followed.
Before starting the test, zero adjustment to be done for pointer in case of analogue meter.
Injection shall be made to fix several points on the meter scale 0, 25%, 50%, 75%, 100% of rated primary reading and full scale.
Each measuring point shall be fixed at meter scale and injected secondary input recorded.
Meter accuracy shall be calculated based on full-scale deflection for analogue meters.

Limits:
The observed accuracy of meter at various points shall be compared with meter accuracy class.
Note:
Meter accuracy is influenced by ambient temperature at which the test is conducted. The temperature shall be noted during test and manufacturer instruction shall be followed for temperature effects on accuracy.

13.4. APPLICABLE STANDARDS:

IEC – 60059-9: Analogue electrical measuring instrument- recommended test methods.

SECTION-14 PROTECTION FUNCTION TEST

14.1. OBJECTIVE:

To confirm the some of specific protection systems (like differential, distance) are working properly as it required manner. These tests required to be performed before and after commissioning.

14.2. TEST INSTRUMENTS REQUIRED:

Primary injection test kit
Clamp meter
Multimeter
Secondary injection test kit

14.3. TEST PROCEDURE:

14.3.1. STABILITY TEST:

The stability and sensitivity test shall be performed for unit protection to prove the stability for through fault and sensitivity for the internal faults. The principle of the test is as followed.
The protected zone of unit protection is restricted by location of the CTs. For stability test the primary current shall be injected through one set of two CTs such a way one of current inwards and other outwards. At relay terminal no operating current shall be observed for proper connection. Sensitivity test shall be conducted with same set-up with either reversed CT polarity or injecting primary current on only one CT of the set. At relay terminal, operating current shall be observed for proper function.

Busbar Differential Protection:
Sensitivity Test:
The test connection shall be made as shown in Fig 14.1. This is applicable for high impedance differential relay. It is required measure the minimum primary operating current with all CTs are connected to the zone. Inject primary current and increase slowly until the relay operates. All the measurements shall be done as per test form. In case of bias differential protection this shall be done with one set of CTs injected and one of CT secondary reversed.

Stability Test:
The test connection shall be made as shown in Fig 14.2. Inject primary current of minimum 50 % primary operating current. The CTs secondary current and differential current at relay shall be measured. A zero differential current measurement shall be satisfactory results.

Transformer Differential Protection:
Stability Test:
The test connection shall be done as shown Fig 14.3 , 14.4. The test voltage shall be injected to a winding with another winding shall be shorted after the CT with nominal tap. Note that the test voltage is injected before the diff CT. The CTs secondary current shall be measured. At relay only relay through current will be observed and differential current will not be observed for proper connection. The above test shall be done for minimum and maximum tap. During this test a small differential current will be observed.
A sensitivity test shall be performed with same set-up and by reversing one of the side CT secondary in all phases.

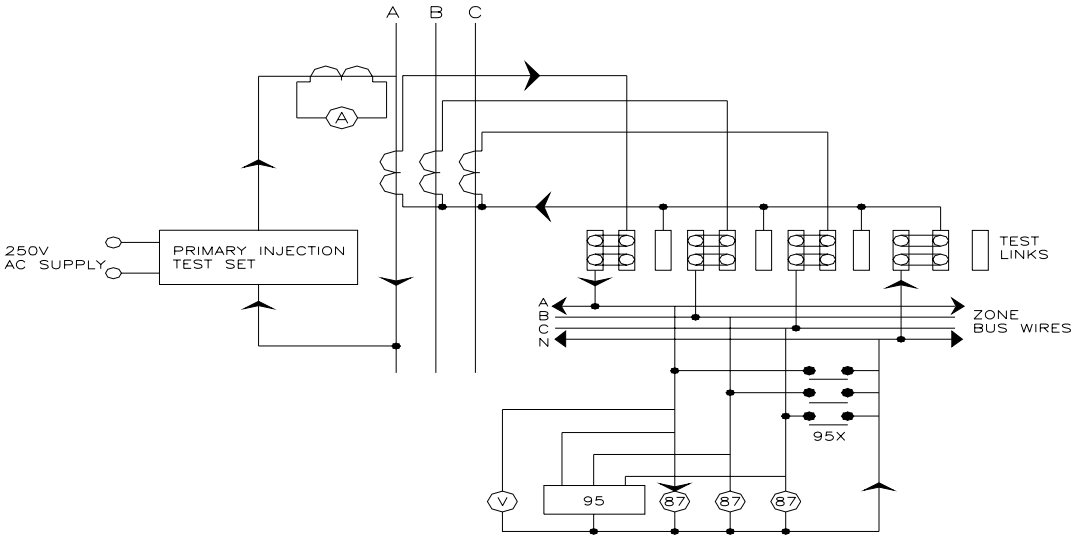


Fig 14.1
Busbar protection sensitivity test

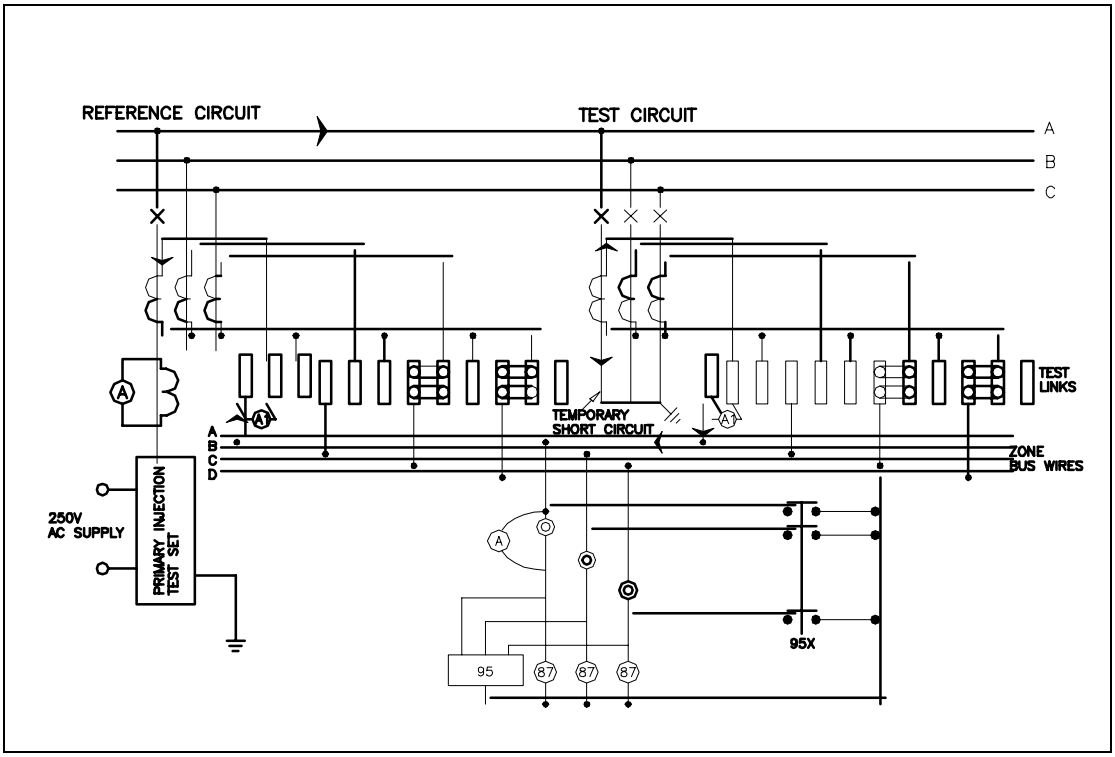


Fig 14.2
Busbar protection stability test

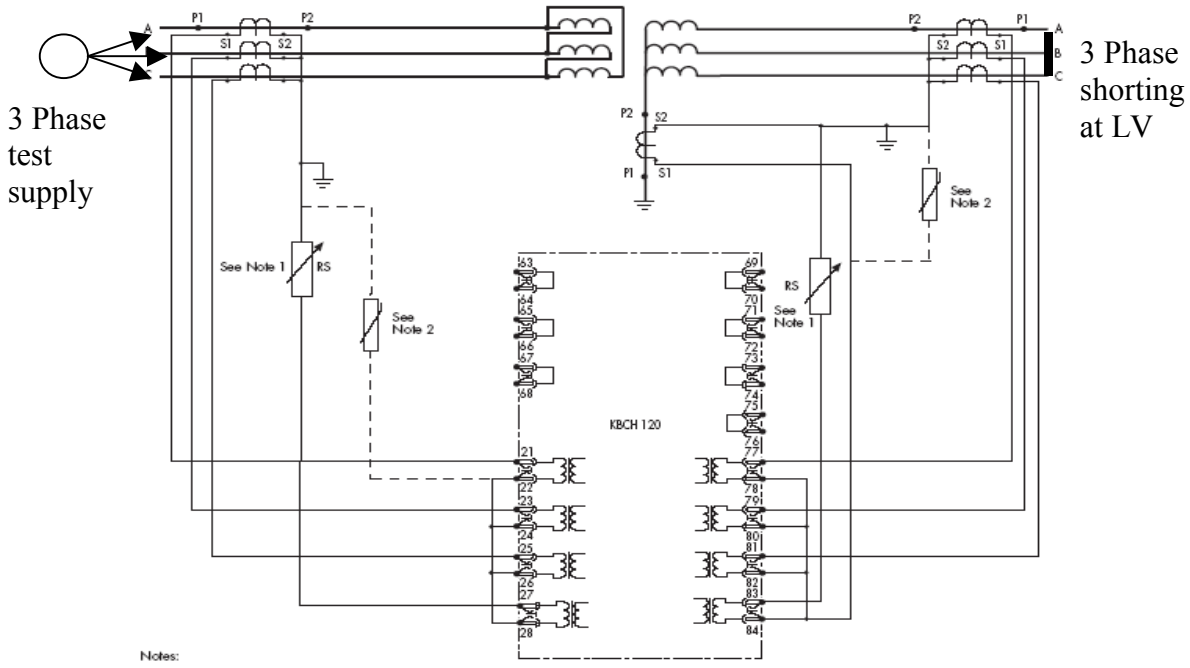


Fig 14.3
Transformer diff. Protection stability test

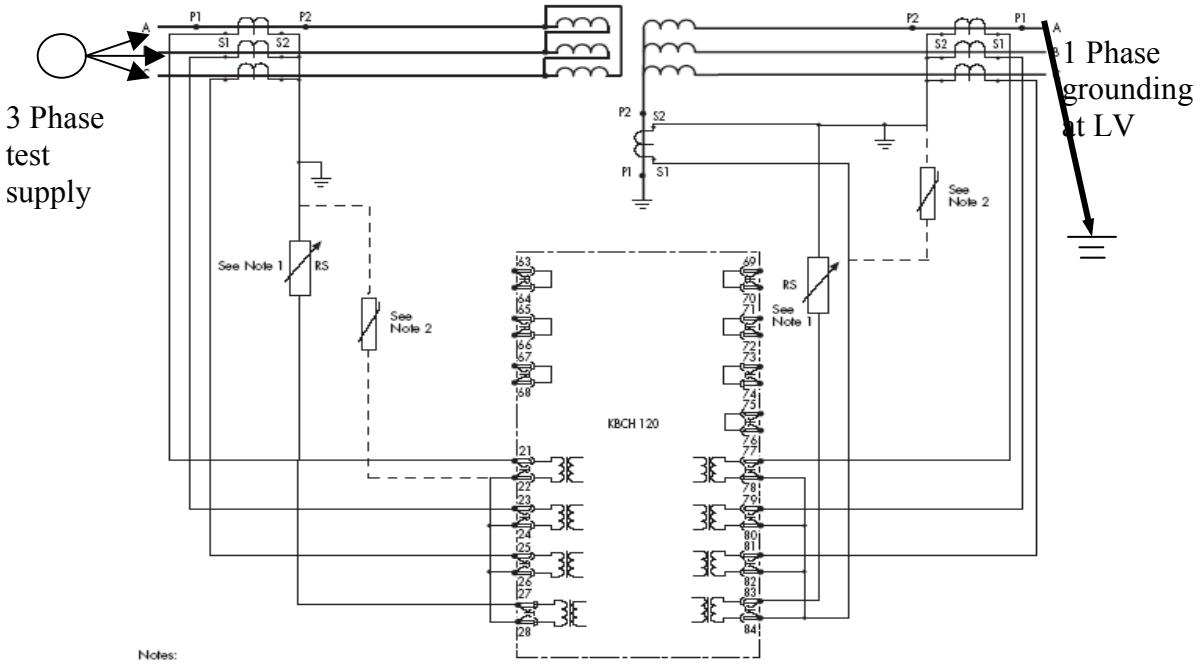


Fig 14.4
Transformer REF protection stability test

14.3.2. PILOT WIRE PROTECTION END-TO-END TEST:

This is the test to confirm the pilot wire protection is connected properly with remote end and ensure the operation with single end feed.
This test shall be performed as manufacturer recommendation and the limits are followed.

SECTION-15 POWER CABLE TEST

15.1. OBJECTIVE:

To confirm the healthiness of the power cable before putting into service.

15.2. TEST INSTRUMENTS REQUIRED:

- Insulation tester.
- Calibrated high voltage test kit.

15.3. TEST PROCEDURE:

15.3.1. MECHANICAL CHECKS AND VISUAL INSPECTION:

- Inspect for physical damage/ defects.
- Verify all cable connections as per drawing.
- Check for proper cable support, clamping and blocking.
- Check cable bends to ensure that the bending radius is equal to or greater than the specified one.
- Verify shield grounding as per design (single point, both ends, via voltage limiters).
- Check the tightness of the termination.
- Check that phases are identified and colour coded.

15.3.2. INSULATION TEST:

The test voltage shall be applied between conductor and shield or screen connected to ground. The reading shall be taken for each phase as below.

- Phase to ground + other phases.

The test voltage shall be applied for 1 min and the test voltage limits has been listed in table 4.1.

15.3.3. PHASE IDENTIFICATION TEST:

This is very important test for cable. Continuity check shall be done with both ends isolated and individually for each phase. The phase marking shall be done at both the ends. If there are many runs of cable, phasing check shall be done for each run.

15.3.4. HIGH VOLTAGE TEST:

This test shall be done as per section 5.3.2.

15.4. APPLICABLE STANDAREDS:

IEC 60502-2: Power cables with extruded insulation and their accessaries from 1 KV to 30KV.

SECTION-16 STATION DC SYSYTEM

16.1.OBJECTIVE:

Station Dc system consists of battery charger and battery. This is to verify the condition of battery and battery charger and commissioning of them.

16.2. TEST INSTRUMENTS REQUIRED:

- Multimeter.
- Battery loading unit (Torkel-720 (Programma Make) or equivalent. The Torkel-720 is capable of providing a constant current load to the battery under test.

16.3. COMMISSIONING TEST PROCEDURE:

16.3.1. BATTERY CHARGER:

- Visual Inspection: The battery charger cleanliness to be verified. Proper cable termination of incoming AC cable and the outgoing DC cable and the cable connection between battery and charger to be ensured. A stable incoming AC supply to the battery charger is also to be ensured.
- Voltage levels in the Float charge mode and the Boost charge mode to be set according to specifications using potentiometer provided.
- Battery low voltage, Mains 'Off", charger 'Off' etc., conditions are simulated and checked for proper alarm / indication. Thus functional correctness of the battery charger is ensued.
- Charger put in Commissioning mode for duration specified only one time during initial commissioning of the batteries. (By means of enabling switch.)
- Battery charger put in fast charging boost mode and battery set boost charged for the duration specified by the battery manufacturer.
- After the boost charging duration, the battery charger is to be put in float charging (trickle charge) mode for continuous operation. Some chargers automatically switch to float charge mode after the charging current reduces below a certain value.
- Voltage and current values are recorded during the boost charging and float-charging mode.

This test establishes the correct operation of the battery charger within the specified voltage and current levels in various operational modes.

13.3.2. BATTERY UNIT:

- Mandatory Condition: The battery set should have been properly charged as per the commissioning instructions of the battery manufacturer for the duration specified.
- Visual Inspection: Cleanliness of battery is checked and the electrolyte level checked as specified on the individual cells. The tightness of cell connections on individual terminals should be ensured.
- The load current, minimum voltage of battery system, ampere-hour, duration etc., is preset in the test equipment using the keypad. For (e.g.) a 58 AH battery set, 5 Hr. duration specification 11.6 A and 5 Hr. duration are set. Minimum voltage setting is = No. of cells x end cell voltage of cells as per manufacturer specification.

- It is to be ensured that the set value of the current and duration is within the discharge capacity of the type of cell used. Also the total power to be dissipated in the load unit should be within the power rating of the battery load kit.
- Individual cell voltages to be recorded before the start of the test.
- Battery charger to be switched off/load MCB in charger to be switched off.
- Loading of the battery to be started at the specified current value. Individual cell voltages of the battery set are to be recorded every half an hour.
- It is to be ensured that all the cell voltages are above the end-cell voltage specified by the manufacturer. If any of the cell voltages falls below the threshold level specified by the manufacturer, this cell number is to be noted and the cell needs to be replaced.
- Test set automatically stops loading after set duration (or) when minimum voltage reached for the battery set.
- Test to be continued until the battery delivers the total AH capacity it is designed for. Value of AH and individual cell voltages to be recorded every half an hour.

Acceptance Limits:

This test establishes the AH capacity of battery set at required voltage. The acceptance limit for the test is to ensure the battery set is capable of supplying the required current at specified DC voltage without breakdown for the required duration.

SECTION-17 TRANSFORMER OIL TEST

17.1. OBJECTIVE:

To verify dielectric strength of transformer oil from both tank and OLTC.

17.2. TEST INSTRUMENTS REQUIRED:

- Oil sample bottle
- BDV tester

17.3. TEST PROCEDURE:

17.3.1. OIL SAMPLING:

- A clean, dry GLASS container is to be used. The size of the container should be at least three times the size of the test cell. (A container of approximately 1 litre is sufficient)
- During sampling, rinse the glass container with little quantity of oil and drain.
- Fill the container with oil until the container over flows.
- Do not allow free air space inside the container.
- Do not allow air bubbles inside the container.
- Sampled Container should be closed airtight with cork or any other non-reactive material.
- (Optional). In case the oil is to be transported to a larger distances, ensure that oil is stored in a clean and dry place and transported with utmost care.
- Before filling the oil in the test cell, gently agitate the container without creating air bubbles.
- Rinse the walls of the test cells with little of oil and drain it.
- Ensure that the electrodes of the test cell are clean.
- Fill the oil sample until overflow, into the test cell without formation of air bubbles.
- Do not start the test for at least for 5 min. after filling the test sample (oil).

17.3.2. BREAK DOWN VOLTAGE TEST:

- The oil sampling to be carried out as per the procedure explained in the sampling instructions.
- The BDV test to be started after at least 5 minutes from the filling of the sample oil in the test cell.
- Ensure that the gap between the electrodes is maintained at 2.5mm.
- Ensure that the electrodes are clean.
- The rate of rise of the test voltage to be adjusted at 2kV per second.
- Conduct the BDV test for 5 to 6 times for the same sample with a time interval of at least 3 - 4 minutes between tests.
- Ensure that between tests, stirring of the test sample is carried out.
- Record the test results and obtain the average of the test results to obtain the Breakdown voltage of the test sample. (Ignore the odd values)

SECTION-18 SCHEME VERIFICATION TEST:

18.1. OBJECTIVE:

To conduct functional verification of scheme of the protection, control and monitoring system as per the schematic drawing.

18.2. TEST INSTRUMENTS REQUIRED:

- Multimeter
- Others (if required any).

18.3. PROCEDURE:

Following precautions / status conformation should be taken before starting the testing.

- Ensure that items and installation conform to the specified requirements and applicable drawings.
- Items are free from damage, have been tested and adjusted as per manufacturer instructions individually.
- Available drawings are the as-manufactured status.
- All labels and markings are correct.
- Ensure free movement of mobile parts.
- Correct polarities and continuities of electric circuits.
- Auxiliary control voltages are available in correct magnitude and polarities.
- Ensure the unit under test is not functionally connected with other live system (i.e.) isolation of trip links, CT isolation of Bus bar protection & etc.

Start checking the scheme of each assembly/unit as per schematic diagrams. During this test each device shall be tested for its function verification as a part of overall scheme. Any non-conformity found shall be rectified and recorded.

Following shall be verified:

- Operation sequence and interlock verification.
- Opening and closing operations of switching devices from local and remote.
- Tripping of switching devices from protection.
- Status of switching devices to local and remote.
- Alarms/indications availability to local and remote.

Functionality of each unit match / with in the customer stipulated specifications / procedure.

SECTION-19 COMMISSIONING TEST

19.1. OBJECTIVE:

To verify system condition after has been energized with rated system (service) voltage for which it is designed. Also to ensure the protection, metering system for correct directionality.

19.2. TEST INSTRUMENTS REQUIRED:

- Multimeter
- Phase angle meter
- Phase sequence meter
- Communication software (if required)

19.3. TEST PROCEDURE:

19.3.1. PRE – ENERGISATION CHECKS:

The following items shall be check without fail prior to energise the system.

- All pre commissioning tests are conducted for all equipments
- A visual check at CT circuits, not to be kept open.
- A visual check at VT circuits, all the links to be closed.
- VT primary is connected to line.
- Restoration of all isolation links and connections.
- Restoration of remote alarm and indication links.
- Adaptation of relay settings.
- CB trip test at test position from protection relay by shoring contacts to ensure protection trip.
- Power cable / conductor terminated with proper tightness.
- Visual check at power transformer for power cable termination, cable box cover, oil level and cooler fan setting.
- Visual check for insulation medium level SF6 if applicable.
- Cancellation of PTW (permit to work), other authorised documents for relevant system prior to energization.
- No admission for unauthorised personnel in the concern vicinity.
- A study of switching programme or the sequence to be executed.
- All the panel covers are closed.
- All safety action taken, like keeping fire extinguisher and first aid items.

19.3.2. POST - ENERGISATION CHECKS:

The following points shall be checked during and after commissioning.

- No abnormality in the system after energization.
- Voltage measurement shall be done for all points and found normal.
- Phase sequence check for correct rotation.
- Phasing check before paralleling two circuits by either hot stick or VT secondary side. The procedure has been explained later in this section.
- If the circuit is loaded, CT secondary current of all cores and phases shall be measured with angle with respect to any one of the phase voltages.
- Directional test shall be done for directional protection, like directional O/C, E/F, and distance protection. This test has been explained later.
- Stability test shall be done for differential protection.

- If applicable, on load test for automatic voltage controller shall be done for transformer.
- Check for correct readings on indicating meters.
- Live test for auto-changer over scheme, auto-reclosing scheme shall be done.
-

19.3.3. SYNCHRONISING/PHASING CHECKS:

Phasing checks:
Before making two live feeders parallel, the phasing must be checked though the source is same. This could be done in two methods. One method is hot phasings, most reliable method, since the check is done on the primary. The voltage difference between feeders shall be monitored by connecting hot stick (Voltage detector equipment, rated for system voltage, that will indicate presence of voltage) between Rph-Rph, Yph-Yph, Bph-Bph of two feeders respectively. Another method is phasing between VT secondaries, and a caution be taken for this method, that there is no mistake on secondary wiring. To ensure correct connection of primary and secondary, energise both the VTs by any one supply and do phasing between secondaries. For correct connection no voltage difference shall be observed during phasing. Now the VTs could be energised with respective feeder's supply and repeat the phasing between VT secondaries. If there is no considerable voltage difference between the feeders voltage, they are ready to parallel.

Synchronising Check:
Before making to different source of same voltage level, in addition to phasing check, synchronisation must be done. The following steps shall be followed.

- Adopt proper setting for synchro-check relay.
- Check the secondary grounding for all VTs are at same point (star point or Y phase).
- Energise both the VTs with same source.
- Do phasing between VT secondaries, check synchro-check relay picks up continuously and synchroscope is staying at 12'o clock position. This ensures that the primary and secondary connections of VTs are correct.
- Now energise the VTs with respective sources.
- Check the synchroscope the pointer continues to rotate. This rotation (incoming voltage vector is rotating with respect to running voltage) is due to slip frequency between the sources, i.e., phase angle between the voltages varying time to time due to frequency difference of supplies.
- If the observed rotation is fast, try to make it slow by increasing or decreasing speed of the machines.
- Once the rotation is slow, when the incoming voltage phase angle difference falling with in the setting value the synchronising relay will pick up and it will drop off as soon as the phase angle difference exceeds.
- It is allowed to parallel the sources with in this period.

19.3.4. DIRECTIONAL TEST:

This test to verify the directional protection / distance relay is looking in desired direction (trip direction). This could be confirmed by on load test. The principle of the test is that the load current and voltage shall be simulated in trip direction and observe the relay operation. The VT or CT input to the relay shall be reversed and observe the relay is reset.

The procedural method could be difference with different type of relays. The relay manufacturer's procedure shall be followed for directional check. The following precautions shall be taken during directional test.

- Protection shall be put out of service, i.e. all out put contacts are isolated.
- Never open circuit CT circuit.
- At the end of the test all the connections shall be restored back.

19.3.5. ONLOAD STABILITY TEST:

This is the test to confirm the stability of a differential protection for through fault with load current. The following precautions shall be taken during test.

- Protection shall be put out of service, i.e. all out put contacts are isolated.
- Never open circuit CT circuit.
- At the end of the test all the connections shall be restored back.

Transformer Differential protection:

The current inputs to the relay from all the windings of the transformer shall be measured with angle WRT any phase voltage of VT. The differential current also is measured externally or internally by relay. There should be no differential current (practically not zero) during this test. If sufficient load is not available on the transformer, this test could be done by making two transformers parallel and keeping at different taps (A circulating current will be flowing between them).

Pilot wire differential protection:

The CT currents at both the ends shall be measured with phase angle. The pilot current shall be measured between the relays at normal load condition. The following steps are followed.

- Isolate trip and alarm.
- Enable the pilot wire relay with O/C check input energised (if applicable).
- Measure the relay CT input current at both ends in all phases.
- Measure the pilot current with normal pilot connection.
- Connect only 'R' phase CT to the relay and other phase's CT short and isolate at both the ends fig 4.1.
- Now check the pilot current and observe the relay is stable.
- Reverse the pilot connection and measure the pilot current. Should pilot current reduce and relay operates for correct function.
- It shall be repeated for 'Y','B','RY','YB','BR',"RYB' combinations.

Busbar differential protection:

The entire feeder's current shall be measured with phase angle. The differential current at main relay and voltage across CT bus shall be measured. At normal load condition there should be no differential current and voltage.

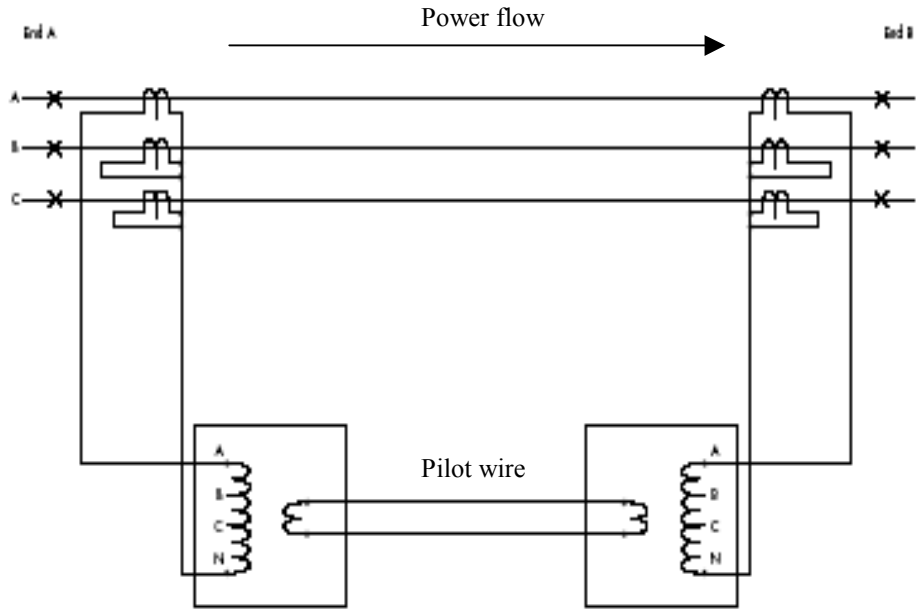
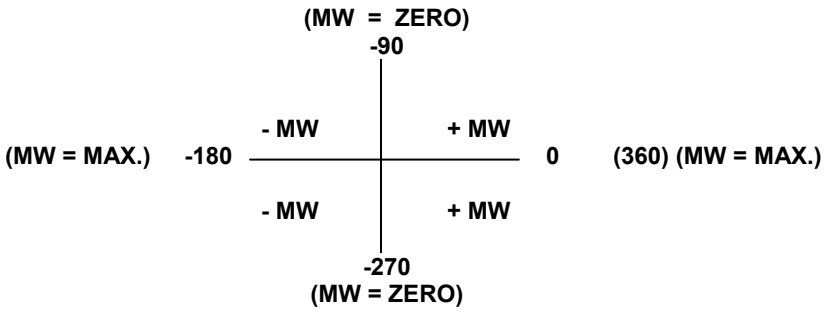


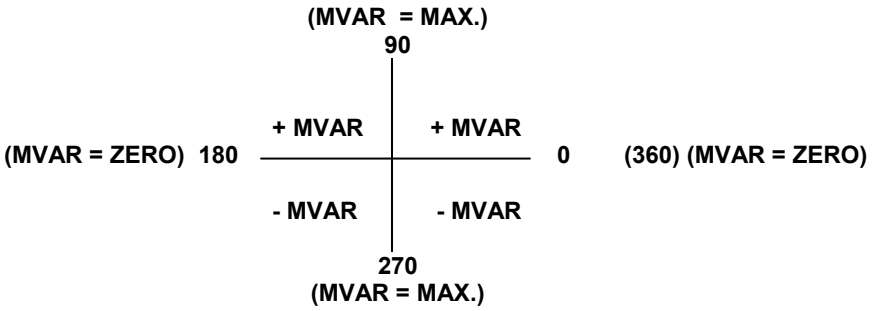
Fig 19.1
Pilot wire protection on load test

19.3.6. METERING VERIFICATION:

All the meters show the primary quantity with secondary input quantities. Sometime it is impart to check the meter reading with actual inputs for correct polarity, particularly in power, energy measurement.

For power meter the input current and voltage shall be measured with angle. The meter reading could be validated as shown in fig 19.2.





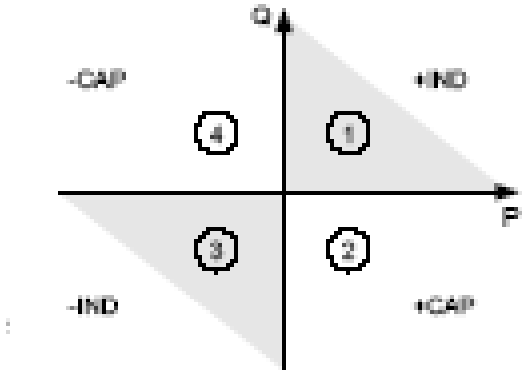


Fig 19.2
Nature of load