POWER SYSTEMS LABORATORY

LAB MANUAL

Subject Code	:	BPSB20
Regulations	:	R18 – IARE
Class	:	II Semester (EPS)

DEPARTMENT OF ELECTRICAL AND ELECTRONICS ENGINEERING

INSTITUTE OF AERONAUTICAL ENGINEERING

(Autonomous)

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12	Over voltage and under voltage protection
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14	Performance of alternator against internal faults

POWER SYSTEMS LABORATOR

OBJECTIVE

The objective of the course is to provide an overview of basic protection methods such as earthing, milli volt drop test, soil resistivity and determination of breakdown voltage of air using horn gap apparatus. It provides in depth knowledge on working of microprocessor based over current relay and electromechanical over current relay. In addition to this, merz price protection of single phase transformer is studied. It provides in depth knowledge on working of various types of relays in protection of alternator.

OUTCOMES:

Upon the completion of Power Systems practical course, the student will be able to attain the following:

1. Determine earth resistance by using crank type earth tester.
2. Explain the concept of electrical integrity of connections and contacts in a circuit breaker using milli volt drop test.
3. Understand the concept of soil resistivity as function of salinity and time.
4. Understand the working principle of microprocessor based over current relay.
5. Understand the working principle of electromechanical over current relay.
6. Determine of breakdown voltage of air using horn gap apparatus.
7. Estimate the power angle characteristics of synchronous machine.
8. Analyze internal fault protection of single phase transformer using merz price protection.
9. Understand the concept of differential protection in three phase ac generator.
10. Examine the performance of over current relay, temperature relay and numerical type negative sequence protection scheme for alternator.
11. Examine the alternator during over voltage, under voltage, over and under frequency by using respective relays.
12. Examine the performance of alternator during internal faults.

EXPERIMENT - 1

DETERMINATION OF EARTH RESISTANCE BY USING CRANK TYPE EARTH TESTER

1.1 AIM:

To determine earth resistance by using crank type earth tester

1.2 APPARATUS:

S. No.	Equipments	Quantity
1	Earth Tester	1
2	Connecting wire	As Required
3	Measurement Tape	1

1.3 THEORY:

The process of electrically connecting to the earth itself is often called "earthing". The main reason for doing earthing in electrical network is for the safety. When all metallic parts in electrical equipments are grounded then if the insulation inside the equipments fails there are no dangerous voltages present in the equipment case. If the live wire touches the grounded case then the circuit is effectively shorted and fuse will immediately blow. When the fuse is blown then the dangerous voltages are away. The main reason for doing earthing in electrical network is for the safety. When all metallic parts in electrical equipments are grounded then if the insulation inside the equipments fails there are no dangerous voltages present in the equipment case. If the live wire touches the grounded case then the circuit is effectively shorted and fuse will immediately blow. When the fuse is blown then the dangerous voltages are away. Connection to earth is achieved by embedding a metal plate or rod or conductor in earth. This metal plate or rod or conductor is called as "Earth electrode". Effectiveness of the earthing connection made by embedding a metal plate in earth is quantified as "Earth Resistance". This earth resistance is measured in ohms.

Need of good earthing:

1. To save human life from danger of electrical shock or death by blowing a fuse i.e. to provide an alternative path for the fault current to flow so that it will not endanger the user.
2. To protect buildings, machinery & appliances under fault conditions ie. To ensure that all exposed conductive parts do not reach a dangerous potential.
3. To provide safe path to dissipate lightning and short circuit currents.
4. To provide stable platform for operation of sensitive electronic equipments i.e. To maintain the voltage at any part of an electrical system at a known value so as to prevent over current or excessive voltage on the appliances or equipment.
5. To provide protection against static electricity from friction

Main objectives of earthing systems are:

1. Provide an alternative path for the fault current to flow so that it will not endanger the user.
2. Ensure that all exposed conductive parts do not reach a dangerous potential.
3. Maintain the voltage at any part of an electrical system at a known value so as to prevent over current or excessive voltage on the appliances or equipment.

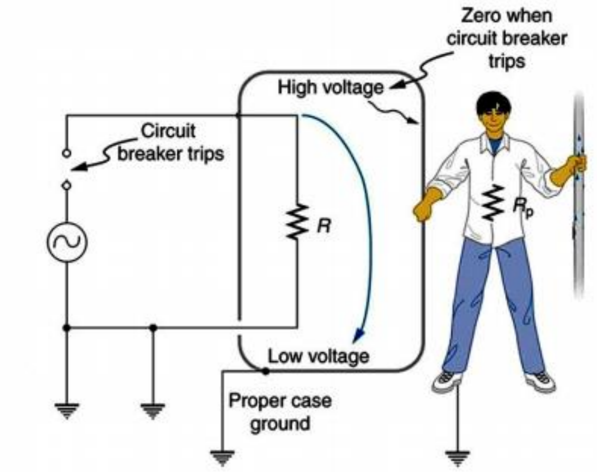
Types of Earthing

The earthing is broadly divided as

1. System or Neutral Earthing
2. Equipment Earthing System Earthing or Neutral Earthing

This is primarily concerned with the protection of Electrical equipment by stabilizing the voltage with respect to ground (Connection between part of plant in an operating system like LV neutral of a Power Transformer winding and earth). Ground or earth in a mains (AC power) electrical wiring system is a conductor that provides a low-impedance path back to the source to prevent hazardous voltages from appearing on equipment. Under normal conditions, a grounding conductor does not carry current. Neutral is a circuit conductor that may carry current in normal operation, and is connected to ground (earth) at the main electrical panel.

In a poly-phase or three-wire (single-phase) AC system, the neutral conductor is intended to have similar voltages to each of the other circuit conductors. Equipment Earthing. This is primarily concerned with the protection of personnel from electric shock by maintaining the potential of noncurrent carrying equipment at or near ground potential. Connecting frames of equipment (like motor body, Transformer tank, Switch gear box, operating rods of Air break switches, etc) to earth. The system earthing and safety earthing are interconnected and therefore fault current flowing through system ground raises the potential of the safety ground and also causes steep potential gradient in and around the Substation. But separating the two earthing systems have disadvantages like higher short circuit current, low current flows through relays and long distance to be covered to separate the two earths. After weighing the merits and demerits in each case, the common practice of common and solid (direct) grounding system designed for effective earthing and safe potential gradients is being adopted.



Types of Earth Electrode
1. Rod electrode.
2. Pipe electrode.

PROCEDURE

1. Connect the instrument for the particular test required as described later.
2. Set the RANGE SELECTOR to highest range, if any.
3. Rotate the generator handle at 160 RPM and observe the ohmmeter deflection.
4. If the ohmmeter deflection is very low, change the RANGE SELECTOR to the next lower range.

Testing Earth Electrodes:

(a) Normal Method of Test

1. Join together terminals C1 & P1 and connect a lead from them to the Earth electrode under test E as shown in Fig.1.

Keep this lead as short as possible, since its resistance will be included in the test.

2. This lead resistance can be eliminated by connecting separate leads to the electrode E from C1 & P1 instead of shorting them together (Fig.2).

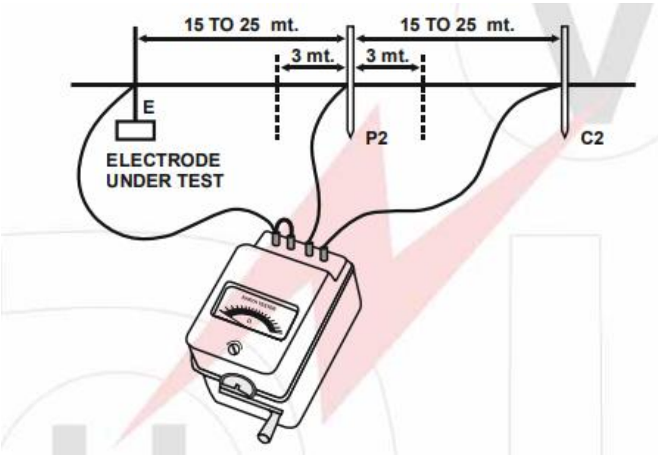


Figure 1.1: Connections for Testing Resistance to Earth of an Earth Electrode

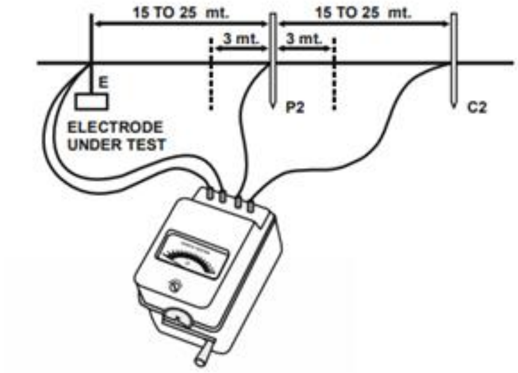


Figure 1.2: Alternate Connections for Testing Resistance to Earth of an Earth Electrode Compensating for Cable Resistance where long leads required

3. Alternatively the lead resistance can be determined and deducted from the total resistance. This is carried out by removing the lead from electrode E after the test and connecting it to P2 & C2 joined together. Its true resistance is then measured by the EARTH TESTER. The earth electrode resistance is measured as described previously.

(b)Alternate Method When 'Dead Earth' is available

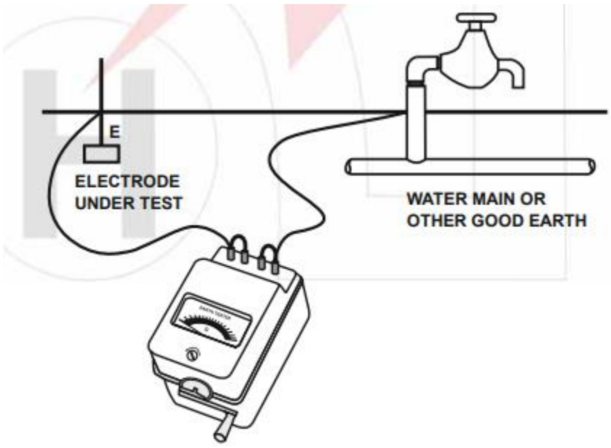


Figure1.3: Alternative method of Test when a Dead Earth is available

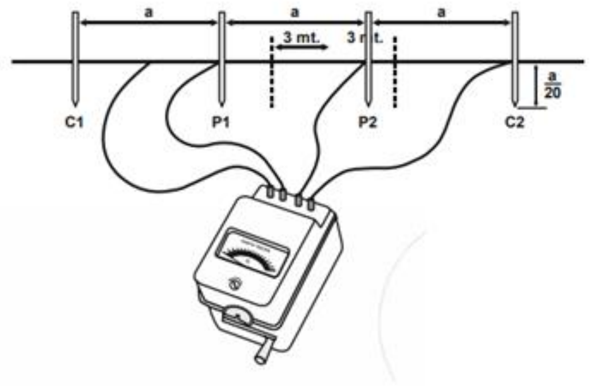


Figure1.4: Connections for Measuring Earth Resistivity

1. Four electrodes are driven into the ground, in a straight line at equal distances ‘a’.
2. The depth of insertion must not exceed 1/20th of ‘a’.
3. The instrument is connected to four spikes as in fig.4
4. The resistance is taken in the usual way.
5. The specific resistance or resistivity is calculated.
6. The four electrodes are repositioned for further tests. If the spacing is maintained, a direct comparative reading will be obtained each time, and areas of lower resistivity located at constant depth ‘a’.
7. The distance ‘a’ is the depth to which soil resistivity is being measured. Thus a profile of different readings for depths b, c, d etc., may be obtained by re-spacing electrodes to distances b, c, d, etc.

1.4 SAMPLE CALCULATION:

Calculation of Resistivity:

Assuming the soil to be homogenous, the resistivity is given by the formula $\rho = 2\pi aR$, where R is the resistance measured in Ohms (Ω), a is the electrode spacing in centimeters (cms) and ρ is the resistivity in ohms centimeter (Ωcm).
For non-homogenous ground, the formula will give an apparent resistivity which is very approximately the average value to a depth equal to the electrode spacing ‘a’.

If the value of R is around 2Ω and the distance between electrode is 300cm then the soil resistivity will be

$$\rho = 2\pi aR = 2\pi * 300 * 2$$
$$= 3769.911\ \Omega\ cm$$

PRECAUTION

1. When working near high tension systems where accidental high potentials on the structure and in the ground are possible, it is recommended to wear rubber gloves.

EXPERIMENT – 2

2.1 AIM:

Measurement of the voltage drop between the two test points. In effect it is a D.C digital voltage producer which will measure the voltage drop between the test points at a constant current.

2.2 APPARATUS:

S. No.	Equipments	Quantity
1	Milli-volt drop test setup	1
2	Patch cords	As required

2.3 PROCEDURE:

1) Switch on power supply, then switch
2) Start increasing the current using dimmer
3) Observe the voltage drop note the values of potential drop and current between two points
4) The circuit trips when max current flows and note the trip time.

Fig 2.1. Milli-volt drop setup

2.4 TABULAR COLUMN:

S.No	Input current	Voltage drop

Trip time:
Voltage:

2.5 RESULT

EXPERIMENT - 3

EARTH MEASUREMENT OF SOIL RESISTIVITY

3.1 AIM:

Measurement of electrical resistivity (in ohm-centimeter) of liquid or earth, sand or other Particulate material that can be tamped into the soil box.

3.2 APPARATUS:

S. No.	Equipments	Quantity
1	M.C. Miller Soil Box	1
2	Terminal Resistance Meter(ammetrr or voltmeter)	1
3	Insulated MCM Soil Box Test Leads	4

3.3 PROCEDURE:

1) Pour or tamp material to be tested into soil box until level with top of box.
a) If soil is the material being tested, remove the two brass potential pins. After removing the pins proceed to fill the soil box with the soil. When filling the box, compaction is very crucial to obtaining accurate results. Make sure that the compaction in the box resembles that of the compaction where the sample was taken replace the brass pins.
b) If liquid is the material being tested, pour the liquid sample into the box until the box is filled. To ensure that the box is completely filled make sure the bottom of the meniscus formed from the liquid is completely level with the top of the box. If the box is not consistently filled to the same level some inaccuracies will occur.
2) Connect the four test lead accessories for the MCM Soil Box as indicated in the diagram shown below. (The leads are labeled C1, C2, P1, and P2).

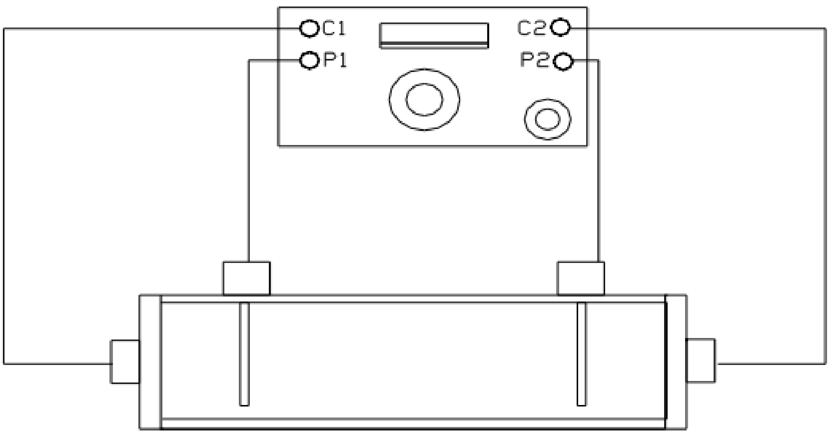


Fig 3.1. Connections to the soil box

3) The two outer end pins of the soil box should be connected to the resistance meter via the C1 and C2 terminals. (See diagram above)
4) The two inner pins of the soil box should be connected to the resistance meter via the P1 and P2 terminals.
5) When all of the connections are made, the resistance value can be read from the meter in ohms (see the section below entitled, “Resistance-to-Resistivity Conversion”) in order to convert the resistance reading to a resistivity value.

RESISTANCE-TO-RESISTIVITY CONVERSION:

Soil Box Critical Dimensions

The soil boxes are designed such that the cross-sectional area of the sample (A), with the box filled level, divided by the separation between the pins (L) is equal to 1cm.

Small Soil Box :

Cross-sectional area = 3cm x 2.4cm = 7.2cm2
Pin separation = 7.2cm
A/L = 1cm

Large Soil Box :

Cross-sectional area = 4cm x 3.2cm = 12.8cm2
Pin separation = 12.8cm
A/L = 1cm

SAMPLE RESISTIVITY DETERMINATION

Assuming that a change in current passing through the sample (ΔI) causes a change in voltage dropped across the pins of ΔV, the resistance of the sample would be ΔV/ΔI and the units would be Ω, assuming that the current is in Amps and the voltage is in Volts (or that the current is in milliamps and the voltage is in milli-volts).
Since,
Resistivity = Resistance x (A/L),
and since A/L is 1cm for the M. C. Miller soil boxes,
Sample Resistivity (Ω.cm) = Measured Resistance (Ω) x 1cm

3.4 PRECAUTIONS

1. The resistivity of both liquids and soils is a function of temperature. In order to obtain results which best agree with field conditions, the sample should be at the same temperature as would be experienced at the test site.
2. The resistivity of soils is also a function of moisture content, therefore, all soil samples should be kept tightly capped and measured as soon as possible after they are removed from their containers.
3. Soil boxes should be thoroughly cleaned with distilled water after each use.
4. The soil box may also be used with voltmeter/ammeter combinations together with a power supply.

3.5 RESULT:

EXPERIMENT - 4

PERFORMANCE CHARACTERISTICS OF MICROPROCESSOR BASED OVER CURRENT RELAY

4.1 AIM:

To determine the performance characteristics of microprocessor based over current relay

4.2 APPARATUS:

S. No.	Equipments	Quantity
1	Relay unit with Microprocessor based over current relay	1
2	Source unit	1
3	Measurement Tape	1

4.3 THEORY:

This type of relay works on the induction principle and initiates corrective measures when the current in the circuit exceeds the predetermined value. The actuating source is a current in the supplied to the relay from a current transformer. It consist of a metallic (aluminum) disc, which is free to rotate in-between the poles of two electromagnets. The upper electromagnet has a primary and secondary of a C T. in the line to be protected and is tapped at intervals. The tapping are connected to a plug operating coil can be varied, thereby giving the desired current settings. The secondary winding is energized by induction from primary and is connected in series with the winding on the lower magnet. The control torque is provided by spiral spring.

4.4 CONNECTION DIAGRAM:

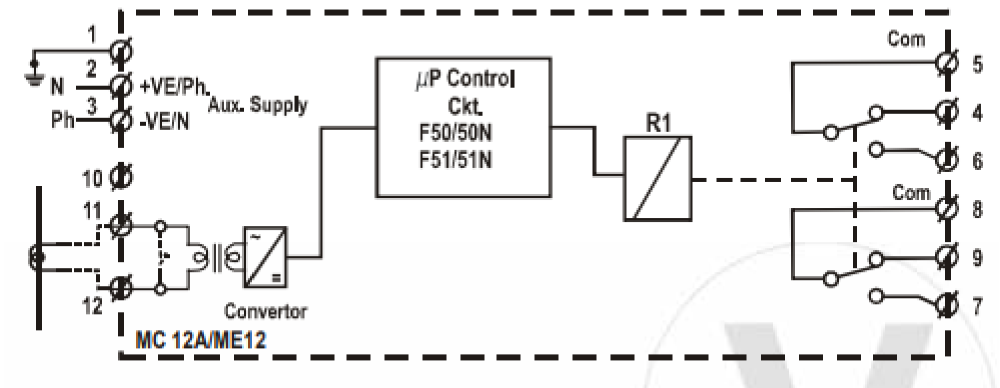


Figure 4.1: Connection Diagram of Relay unit

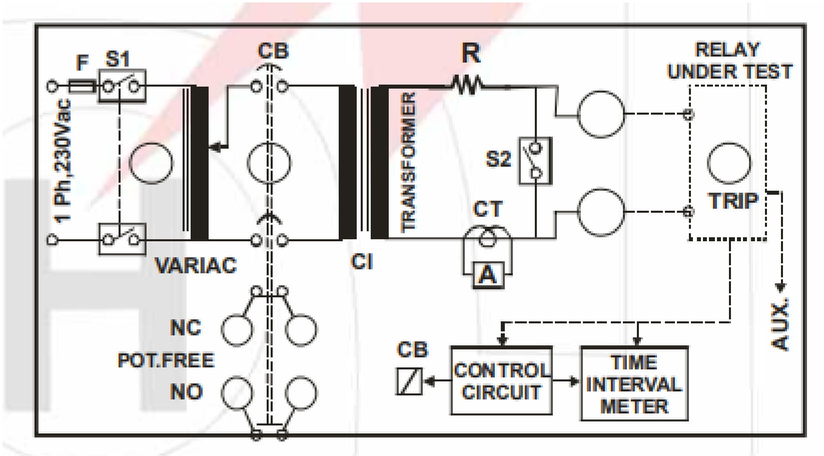


Figure 4.2: Connection diagram of Source unit

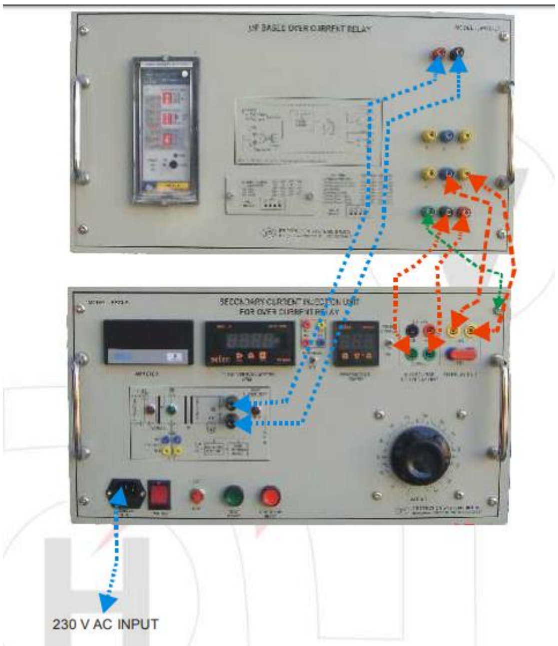


Figure 4.3: Interconnection diagram

4.5 PROCEDURE:

1. Connect as per interconnection diagram.
2. Set the relay current refer Setting chart.
3. Set TMS.
4. Ensure Time interval meter selection switch in TIM position.
5. Connect the power cord.
6. Bring dimmer to zero position.
7. Put on the mains using Mains on switch. Results (Mains on indicator, ammeter display, relay power and Timer display will glow).
8. Put the SHORT/INJECT switch to SHORT position.
9. Press TEST START push button, CB ON Indicator will glow.
10. For different range of current values, select using the selector switch provided on the side. 11. By adjusting the variac set the approximate injection current
12. Push TEST STOP/RESET push button.
13. Without disturbing the position of variac, Put the SHORT/INJECT switch to INJECT position.

14. Press TEST START push button, Note down the current. (Circuit breaker ON, CB ON indicator will glow, time interval meter starts up counting, over current relay trip occurs TRIP indicator will glow at relay and injector unit also.
15. Note down the Time Interval Meter reading. (Pick up time)
16. Press the RESET button.
17. Repeat operation (6 – 16) by adjusting different Current & TMS settings.
18. Draw the graph of Trip time vs PSM (plug setting Multiplier.)

FOR FINDING THE PICK UP CURRENT

1. Bring variac to zero, select the current range as required.
2. Put the SHORT/INJECT switch to INJECT position.
3. Press TEST START push button, gradually increase the variac from zero to the current setting value till trip indicator starts blinking.
4. The reading on ammeter multiplied by current range selector gives the actual pickup current value.

4.6 PRECAUTION

1. When working near high tension systems where accidental high potentials on the structure and in the ground are possible, it is recommended to wear rubber gloves.

4.7 CALCULATION

To find out the PSM (Plug setting Multiplier):

$$PSM = \frac{Fault\ current}{Plug\ setting}$$

If CT is used

$$PSM = \frac{Fault\ current(primary\ current)}{Plug\ setting\ (primary\ setting\ \ current) * CT\ Ratio}$$

$$TSM = \frac{Actual\ operating\ time\ in\ sec}{calibrated\ operating\ time\ for\ TSM = 1.0(Tc) in\ sec}$$

4.8 SAMPLE CALCULATION

Relay current setting is 150% (relay 100%=5A) and has Time multiplier setting of 0.5, the relay has connected in the circuit through a C.T. having ratio 500:5 amps 500/5A Fault current is 6000Amps. Relay characteristics as assume for PSM 8=3.15sec at TMS

Solution:

150 % = 1.5A

See fault current = 6000 $*\frac{5}{500}$ = 60A

Plug setting multiplier PSM = 60 * $\frac{1}{5*1.5}$ = 8

Time from graph against this multiplier is 3.15sec.

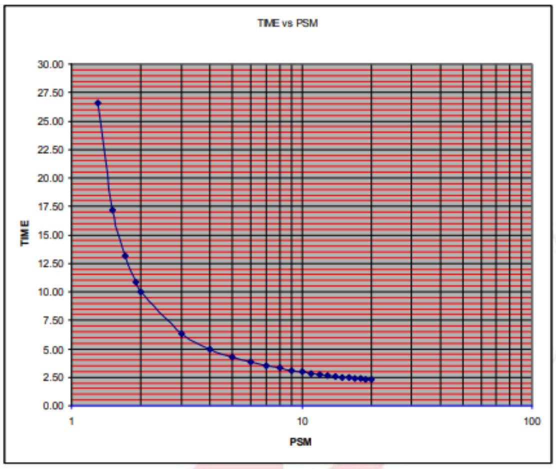
Operating time = 3.15 x 0.5 = 1.575sec

4.9 TABULAR COLUMN:

PLUG SETTING (SET CURRENT OF RELAY)
TSM=1

S. No	TSM	Plug Setting	Fault Current	PSM $Plug\ setting\ multiplier = \frac{Fault\ current}{Plug\ setting}$	Operating Time In Sec

4.10 MODEL GRAPH:



Time vs PSM

4.11 RESULT:

EXPERIMENT - 5

PERFORMANCE CHARACTERISTICS OF ELECTROMECHANICAL OVER CURRENT RELAY

5.1 AIM:

To determine the performance characteristics of electromechanical over current relay

5.2 APPARATUS:

S. No.	Equipments	Quantity
1	Relay unit with electromechanical over current relay	1
2	Source unit	1
3	Measurement Tape	1

5.3 THEORY:

ELECTROMECHANICAL RELAYS:

- Research Began at the End of the 19th Century.
- The Relay Family Was Completed in the 1930's, they Are Still in Use.

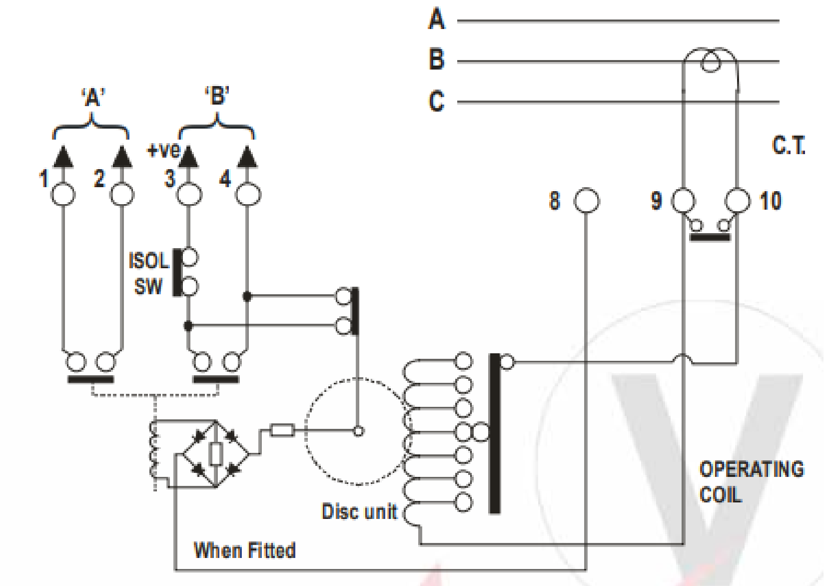
These relays were the earliest forms of relay used for the protection of power systems, and they date back nearly 100 years. They work on the principle of a mechanical force causing operation of a relay contact in response to a stimulus. The mechanical force is generated through current flow in one or more windings on a magnetic core or cores, hence the term electromechanical relay. The principle advantage of such relays is that they provide galvanic isolation between the inputs and outputs in a simple, cheap and reliable form – therefore for simple on/off switching functions where the output contacts have to carry substantial currents, they are still used.

Electromechanical relays can be classified into several different types as follows:

- Magnetic attracted armature relays
- Magnetic induction relays
- Moving coil
- Thermal

However, only attracted armature and induction types have significant application at this time, all other types having been superseded by more modern equivalents. Electromagnetic relays are constructed with electrical, magnetic and mechanical components, have an operating coil and various contacts and are very robust, inexpensive and reliable.

5.4 CONNECTION DIAGRAM:



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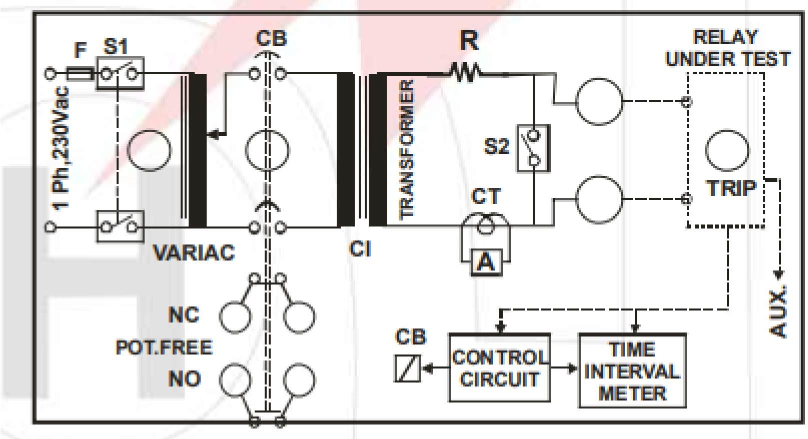

Figure 5.2: Connection diagram of Source unit

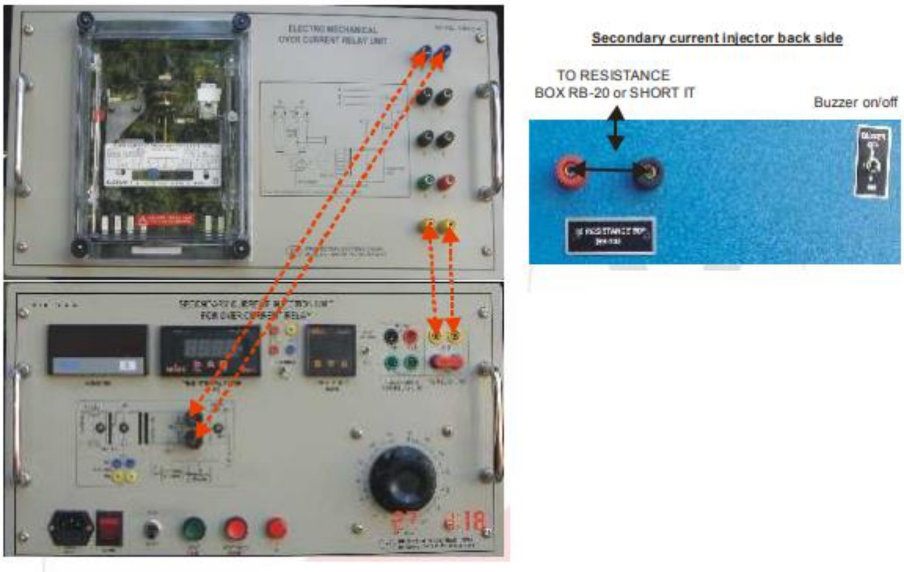

Figure 5.3: Interconnection diagram

5.5 PROCEDURE:

1. Connect as per interconnection diagram.
2. Set the relay current setting (Trip current value).
3. Set TMS.
4. Ensure Time interval meter selection switch in TIM position.
5. Connect the power cord.
6. Bring dimmer to zero position.
7. Put on the mains using Mains on switch. Results (Mains on indicator, ammeter display, relay power and Timer display will glow).
8. Put the SHORT/INJECT switch to SHORT position.
9. Press TEST START push button, CB ON Indicator will glow.
10. For different range of current values, select using the selector switch provided on the side.
    Position-1: 1A
    Position-2: 2A
    Position-3: 5A
    Position-4: 10A
    Position-5: 20A
    Position-6: 50A
11. By adjusting the variac set the approximate injection current
12. Push TEST STOP/RESET push button.
13. Without disturbing the position of variac, Put the SHORT/INJECT switch to INJECT position.
14. Press TEST START push button, Note down the current. (Circuit breaker ON, CB ON indicator will glow, time interval meter starts up counting, over current relay trip occurs TRIP indicator will glow at relay and injector unit also.
15. Note down the Time Interval Meter reading. (Pick up time)
16. Press the RESET button.
17. Repeat operation (6 – 16) by adjusting different Current & TMS settings.
18. Draw the graph of Trip time vs PSM (plug setting Multiplier.)

Actual Current = Meter reading * range selector position

FOR FINDING THE PICK UP CURRENT

1. Bring variac to zero, select the current range as required.
2. Put the SHORT/INJECT switch to INJECT position.
3. Press TEST START push button, gradually increase the variac from zero to the current setting value till the disc starts its rotation.
4. The reading on ammeter multiplied by current range selector gives the actual pickup current value.

5.6 PRECAUTION

1. When working near high tension systems where accidental high potentials on the structure and in the ground are possible, it is recommended to wear rubber gloves.

5.7 CALCULATION

To find out the PSM (Plug setting Multiplier):

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If CT is used

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150 % = 1.5A

See fault current = 6000 $*\frac{5}{500}$ = 60A

Plug setting multiplier PSM = 60 * $\frac{1}{5*1.5}$ = 8

Time from graph against this multiplier is 3.15sec.

Operating time = 3.15 x 0.5 = 1.575sec

5.9 TABULAR COLUMN:

PLUG SETTING (SET CURRENT OF RELAY)
TSM=1

S. No	TSM	Plug Setting	Fault Current	PSM $Plug\ setting\ multiplier = \frac{Fault\ current}{Plug\ setting}$	Operating Time In Sec

5.10 RESULT:

EXPERIMENT – 06

DETERMINATION OF BREAKDOWN VOLTAGE OF AIR USING HORN GAP APPARATUS

6.1 AIM

To determine the breakdown voltage of air using horn gap apparatus at atmospheric conditions.

6.2 APPARATUS

S. No.	Equipments	Quantity
1	Horn gap test kit	1

6.3 THEORY

It is often required to provide some protection to equipment against high voltages. Such protective equipments can be categorized as
a) Surge arrestor
b) Surge modifier

Surge arrestor: These are connected between line terminal and earth at substation terminal and always act in parallel with the equipment to be protected. They simply divert the surface to the earth.
Surge arrestors used in practice as follows
Horn gap arrestor

- Multiple gap arrestor
- Lightning arrestor
- Electrolytic arrestor
- Valve arrestor

Surge modifier: Surge modifiers are connected in series with the line at substation terminal. They absorb the surge energy and flatten the wave front of incoming wave. Commonly used surge modifiers are as
Surge absorbers

- Arcing ground suppressors
- Earthing coil (Peterson's coil)
- Water jet earthing resistance

Construction of horn gap arrester:

The equipment is known as horn gap because two high voltage electrode are of the apace of horn. There is specially designed high voltage transformer with centre tap grounded. The horns are connected to the high voltage outputs of the transformer. For the safety of the operator the horns, which are at high voltage are covered with transparent cover. A suitable push button is provided in the front panel of the equipment. The equipment starts operating as soon as we press the button. The input supply is 230V ac.

Structure and working of horn gap arrester:

The horn gap arresters are the oldest type among all the arrester and still they are used in low voltage lines because they are cheap and simple to construct. It consists of two horn shaped pieces of metal separated by a small air gap and mounted on a vertical plane. They are connected in parallel with the transmission lines between two conductors and earth. The gap between the metallic wires is such that under normal condition, it does not allow any flow of current but under over voltage condition the gap breaks down and diverts the surge voltage from the earth. An arc is produced at the bottom of the horn gap during high voltage surge. The arc is pushed out towards the top of the horns due to heat of the arc, the gap length towards the horn top is more than that at the base. The overvoltage cannot maintain such a long arc and arc get extinguished. The time taken for the completion operation is about 3 to 5 sec.

Limitations:

1. As the time taken for the complete operation is quite high, the scope is limited to low voltage systems only.
2. The breakdown voltage depends upon atmospheric conditions such as temperature and pressure. At higher altitudes, a longer gap is necessary. The gap length is to be determined by taking account the relative air density.
3. Roughness of horn gap also affects the performance of the arrester and the frequent settings are required to be made at the gap
4. The greatest disadvantage of the horn gap type of lightning arrester is its sensitivity to the corrosion and pitting of the horns and that it does not maintain the setting.

6.4 PROCEDURE:

1. Connections are as shown in fig.
2. High voltages are applied across the horn gap.
3. The arc is initiated at the bottom and extinguishes as it proceeds upward
4. The effect of gap length for different arrangements is observed.
5. For gap length observed average inception voltage is 20kV (rms)

6.6 BLOCK DIAGRAM:

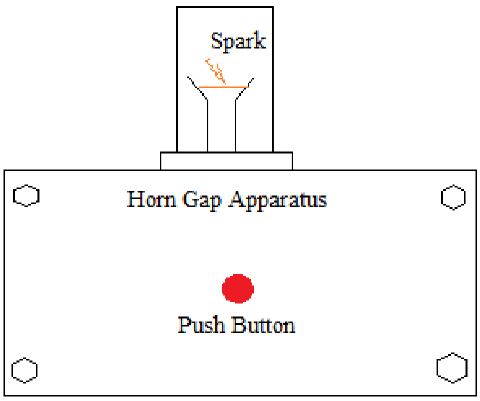

Figure 1:Horn Gap Apparatus Kit

Operation:

Provide 230V, ac to the equipment with the help of power chord provided with the equipment. Now press the push button in the front panel to see the Corona formation. The equipment continues to operate as long as we press the push button. We see that the spark starts from bottom of the horn, where the gap is minimum but sufficient to cause break down due to the application of 20kV. Now the gap goes on increasing and hence the spark also moves up and the length of the spark also increases as the gap increases and the spark vanishes at the end of the horns. This spark is nothing but corona formation.

How Corona Occurs

As we apply the high voltage to the horn gap. The spark over or breakdown will occur at the point of minimum gap of the horns. The upper layer of the air will get ionized and its density and resistance will decrease. So, the spark will move up progressively as the phenomenon goes on repeating until the corona reaches the peak of the horns.

6.7 PRECAUTIONS

1. Keep processing the push button as long as you want to see the corona.
2. Never touch the horns as long as the equipment is connected to 230v input supply.
3. Don’t touch the horns without grounding them.
4. The equipment must be grounded.

6.8 RESULT:

EXPERIMENT – 07

POWER ANGLE CHARACTERISTICS OF SYNCHRONOUS MACHINE

7.1 AIM

To study the power angle characteristics of a given synchronous machine

7.2 APPARATUS

S. No.	Equipments	Quantity
1	Horn gap test kit	1

7.3 THEORY

The Synchronous machine can be connected to the grid(represented by an equivalent generator) only when each of the voltages between the terminals R_g R_s,Y_g Y_s,$B_g B_s$ is zero at any instant of time. This condition is fulfilled when the line voltages on the generator side are equal, at all instants of time, to the corresponding voltages on the bus bar side. This is possible only if the following conditions are fulfilled:

- The voltages V_{grid} and $V_{synchronousMachine}$ are equal in magnitude and are in phase.
- Both the Grid and synchronous generator must have same frequency of supply voltage.
- The generator and grid voltages should have the same phase sequence.

When these conditions are fulfilled, the synchronizing switch between the generator and the grid can be switched on.

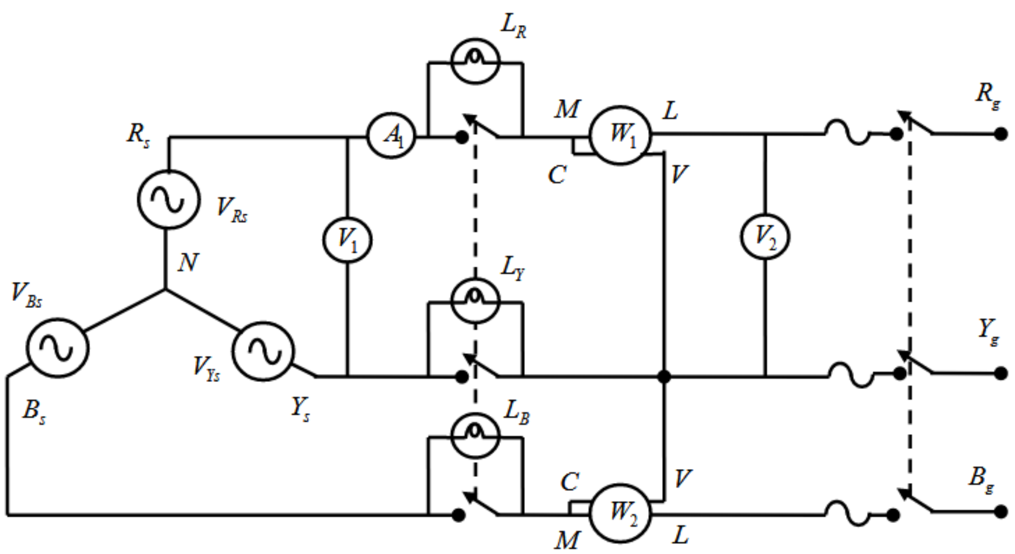

Fig. 1. Synchronization with grid using lamp method

Fulfillment of these conditions is checked by the following methods:

A. Synchronization by three dark lamp method:

Connect the D.C. motor - synchronous generator as shown in Fig 1. Start the D.C. motor and bring its speed to the synchronous speed of the generator (1500-rpm). Adjust the field excitation of the synchronous machine so that about rated voltage (200V, L-L) is obtained. Assume that the grid has 200V, L-L. Let the phase sequence of the generator terminals RYB be the same as that of the respective terminals of the grid, RYB. The voltage phasors for this condition are shown in Fig 2. If the generator frequency is slightly more than that of the bus, then the phasors R_g, Y_g and B_g move anti-clockwise relative to R_s, Y_s, and B_s.The voltages across the lamps L_R,L_Y and L_B(which are indicated by the phasors R_gR_s,Y_gY_s and B_g B_s) will increase & decrease simultaneously and therefore, the three lamps will brighten up and darken at the same time.

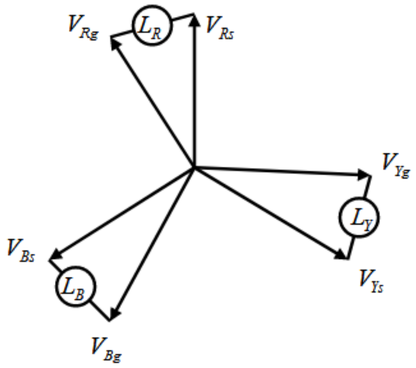

Fig.2. Voltage Phasors and Lamp connection for dark lamp method

B. Bright lamp method:

With the switches S1 & S2 closed and S3 open, if all the conditions of synchronization are satisfied lamp across C & c will remain dark and the other lamps will remain equally bright. This permits closing of the synchronization switch. If the frequencies are differ, a wave or light will travel and the speed of the incoming machine must be adjusted to makethe incoming machine must be adjusted to make the incoming machine frequency equal to that of mains. By lowering the beat frequency to a very low value, the darkness of one lamp and brightness of other lams are prolonged. Synchronizing switch is closed in the middle of this period.

B. Method of using synchroscope:

The instrument used to indicate the correct instant for synchronization is known as synchroscope. It's basically a single phase instrument and unlike synchronizing lamps which is capable to indicate whether the incoming machine is slow or fast.

7.5 CIRCUIT DIAGRAM:

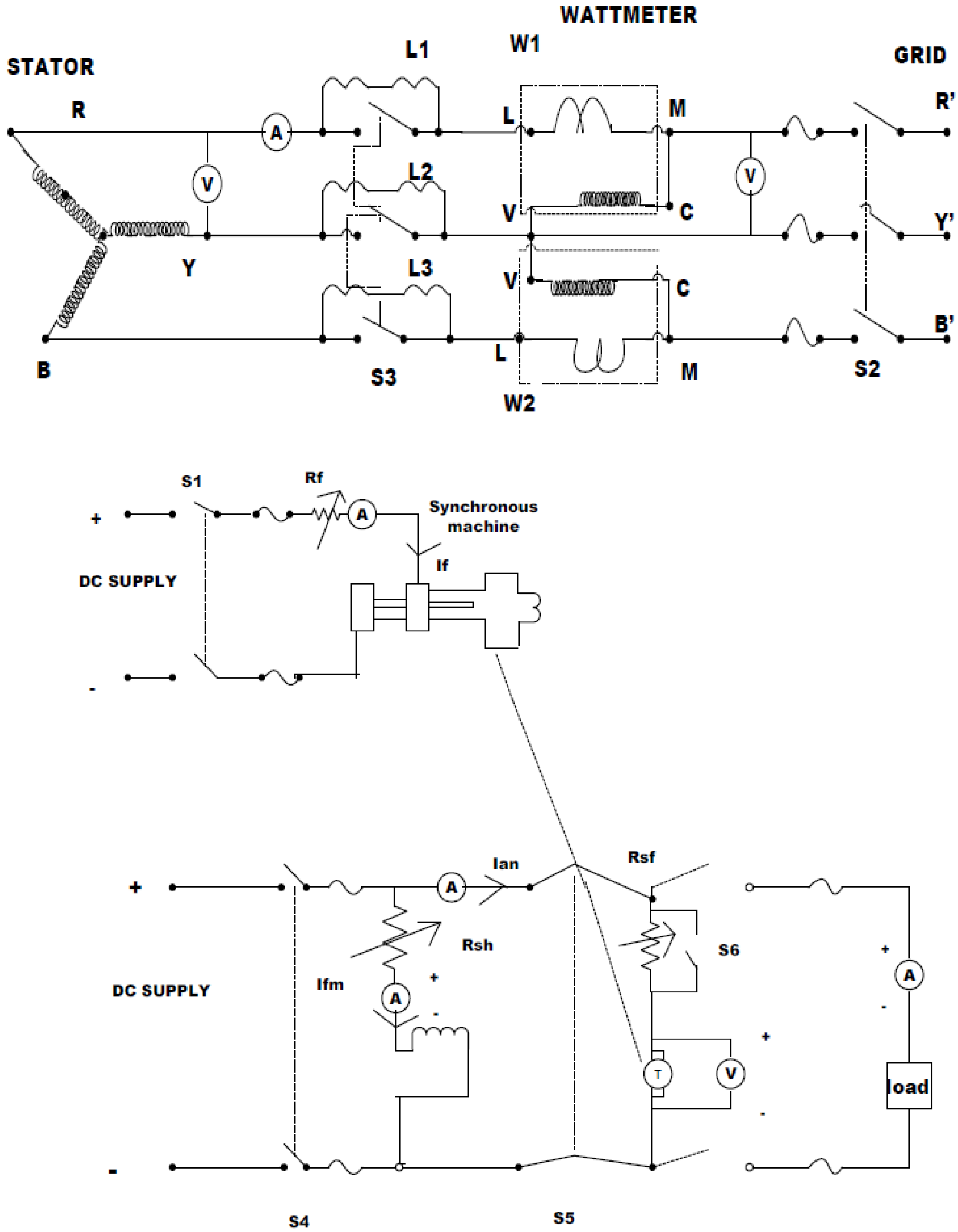

Fig 7.1 Circuit diagram to plot characteristics of a Synchronous Machine

7.6 MODEL GRAPH:

Power – Angle Characteristics of the Synchronous Machine:

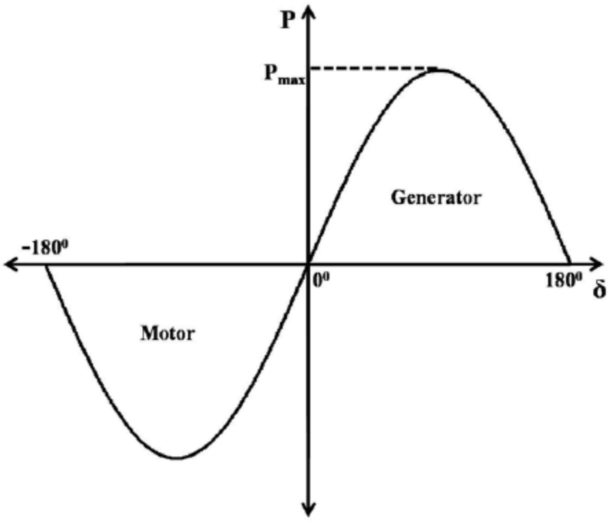

Fig 7.2. P – δ Characteristics of a Synchronous Machine.

7.6 PROCEDURE:

1. Make connections as per the circuit diagram. Initially keep all the switches open.
2. Switch ON the DC supply & start the DC machine by closing switch S5.
3. Adjust the speed of the DC machine to synchronous speed by field control.
4. Note the armature voltage V_{ao}, armature current I_{amo}, and field current I_{fmo}. R_{s1} is the starting resistance. If it has been cut out, close the switch S6.
5. Switch on the main supply to the alternator field by closing the switch S1 and adjust the excitation until the alternator voltage equal the bus voltage
6. Close the switch S3 and synchronize the machine with the supply system by dark lamp method as shown.
7. After synchronization the synchronous machine field current I_f is kept constant and the DC machine field current I_{fpm} is slowly decreased and as a consequence the power generated by the synchronous machine will increase and it will be shown by the wattmeter.
8. For each value of I_{fpm}, the values of Ia, W1, W2, V, and the power angle (δ) are to be noted. The power angle may be noted by using a stroboscope. This can be continued until the current in one of the machines reaches rated value.
9. The synchronous machine field current I_f is kept constant and the DC machine field current I_{fpm} is slowly increased until the power generated by the synchronous machine comes close to '0' or negative by few watts.
10. The synchronous machine now behaves as a motor. By increasing I_{fpm}, for each value of I_{fpm}, the values of Ia, W1, W2, V, and the power angle (δ) are to be noted. This can be continued until the current in one of the machines reaches rated value.

When load is applied to a synchronous machine, the machine poles fall back a certain angle δ behind the forward rotating poles of the stator. The value of this angle depends upon the load power factor and the excitation of the machine.

For cylindrical rotor machines these quantities are related by the expression:

$$P = \frac{EV}{X_S} Sin\delta$$

Where, *P* = Power developed

V = Applied voltage

E = Induced voltage due to field excitation
X_S =Synchronous reactance
δ = Load angle.

7.7 TABULAR COLUMN:

S.No	Synchronous Machine Armature current (Ia)	Synchronous Machine Voltage (V)	DC Machine Armature current	DC Machine Field current	Power (P) (Watts)	Power Angle (δ)

7.8 RESULT:

EXPERIMENT - 8

MERZ PRICE PROTECTION IN SINGLE PHASE TRANSFORMER

8.1 AIM:

To study the Merz price protection of single phase transformer and determine the characteristics of percentage biased relay.

8.2 APPARATUS:

S. No.	Equipments	Quantity
1	Merz-price protection unit	1
2	Rheostat(300Ω/1.5Amps)	2
3	Patch cards	As required

8.3 THEORY

The percentage differential protection or Merz-Price protection based on the circulating current principle can also be used for the transformers. This system gives protection against phase to phase faults and phase to ground faults to the power transformers. The principle of such a protection scheme is the comparison of the currents entering and leaving the ends of a transformer. The vector difference of currents passes through the operating coil while the average current passes through the restraining coil. In normal conditions, the two currents at the two ends of the transformer are equal and balance is maintained. So no currents flow through the operating coil of the relay and relay is inoperative. But when there is phase to phase fault or phase to ground fault, this balance gets disturbed. The difference current flows through the operating coil due to which relay operates, tripping the circuit breaker.

Compared to the differential protection used in generators, there are certain important points which must be taken care of while using such protection for the power transformers. These points are,

1. In a power transformer, the voltage rating of the two windings is different. The high voltage winding is low current winding while low voltage winding is high current winding. Thus there always exists difference in current on the primary and secondary sides of the power transformer. Hence if C.T.s of same ratio are used on two sides, then relay may get operated through there is no fault existing. To compensate for this difficulty, the current ratios of C.T.s on each side are different. These ratios depend on the line currents of the power transformer and the connection of C.T.s. Due to the different turns ratio, the currents fed into the pilot wires from each end are same under normal conditions so that the relay remains inoperative. For example if K is the turns ratio of a power transformer then the ratio of C.T.s on low voltage side is made K times greater than that of C.T.s on high voltage side.

2. In case of power transformers, there is an inherent phase difference between the voltages induced in high voltage winding and low voltage winding. Due to this, there exists a phase difference between the line currents on primary and secondary sides of a power transformer. This introduces the phase difference between the C.T. secondary currents, on the two sides of a power transformer. Through the turns ratio of C.T.s are selected to compensate for turns ratio of transformer, a differential current may result due to the phase difference between the currents on two sides. Such a different current may operate the relay though there is no fault. Hence it is necessary to correct the phase difference. To compensate for this, the C.T. connections should be such that the resultant currents fed into the pilot

wires from either sides are displaced in phase by an angle equal to the phase shift between the primary and secondary currents. To achieve this, secondaries of C.T.s on star connected side of a power transformer are connected in delta while the secondaries of C.T.s on delta connected side of a power transformer are connected in star.

8.4 CIRCUIT DIAGRAM:

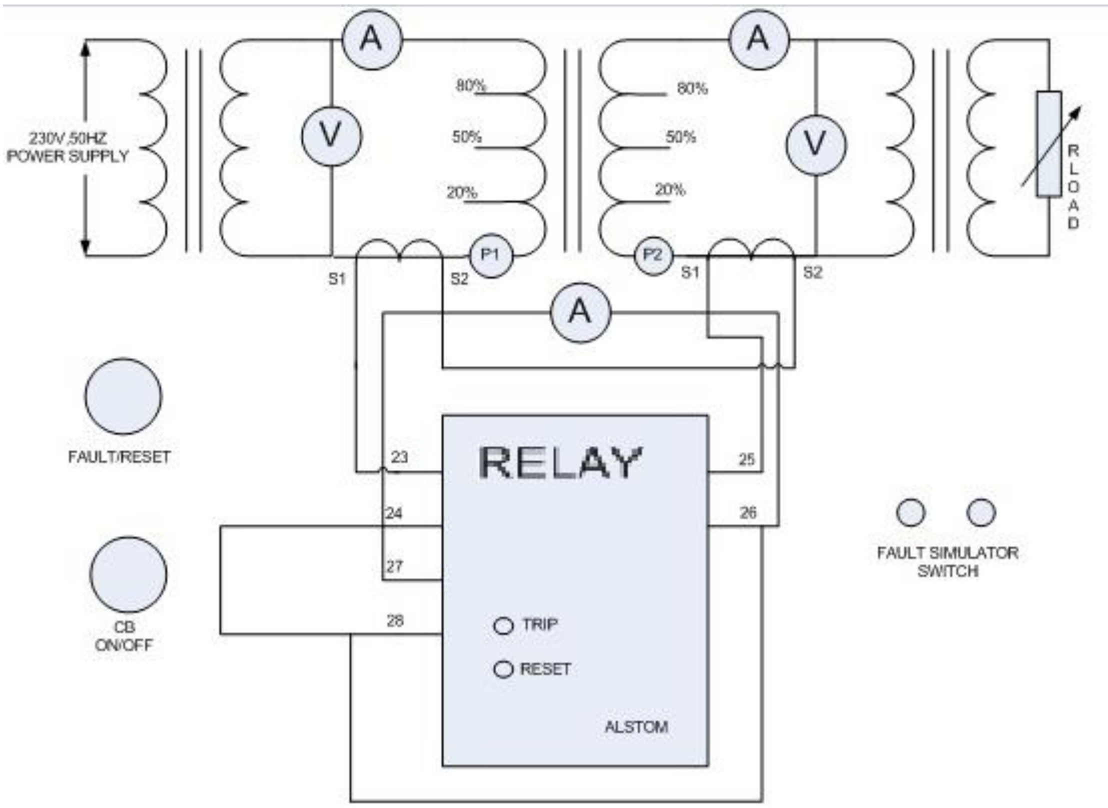

Fig – 8.1 Block Diagram of Merz-price protection of single phase transformer

8.5 PROCEDURE:

1. Connect the circuit as shown in the figure 8.1.
2. Note down the values of primary, secondary voltages and currents of test transformer.
3. Set the fault current of 0.2Amps (make sure that the set current should not be more than 0.4 amps) using the differential relay panel provided.
4. Now connect one of the rheostats across load terminals.
5. And also connect the fault simulator switch one end to P2 and other terminal to one of the rheostat terminal (this step is performed to introduce fault in the turns of the transformer).
6. Other end of the rheostat terminal to any one of the tapping is provided.
7. Now observe the circuit will trip when the difference current is more than the set current.
8. Note down the values of primary, secondary, and differential currents and time when the circuit trips.
9. After noting down the values reset the relay, fault switch and repeat the experiment for different set currents.

8.6 TABULAR COLUMN:

TABLE - 1:

S. NO	Primary current(I_1)	Primary voltage(V_1)	Secondary Voltage(V_2)	Secondary current(I_2)
1				

TABLE – 2

S. NO	Set current	Primary current(I_1)	Secondary current(I_2)	Differential current(I_D)	Time(sec)
1	0.1				
2	0.2				
3	0.3				
4	0.4				

8.7 PRECAUTIONS:

1 Take the reading accurately as the meter fluctuates.

2 Switch OFF the setup when not in use.

3 Set current should not exceed 0.4Amps.

8.9 RESULT:

EXPERIMENT – 09

DIFFERENTIAL PROTECTION SCHEME IN SYNCHRONOUS GENERATOR

9.1 AIM

To study differential protection in three phase AC generator

APPARATUS

S. No.	Equipments	Quantity
1	Generator protection system setup	1
2	Motor Drive	1
3	Power Analyzer	1
4	Patch Cords	As required

9.2 THEORY

Differential Protection for Generators:

The principle of differential protection of the circulating current protection – refer manual % relay. This type of protection provides a continuous check on the faults within the points, where the CTs are used as illustrated in the Fig1. There are two sets of C.T.s each set is mounted on either end of the rotor phase. The secondaries of these current transformers connected to the differential relay. If there is no fault in the generator, the same current will pass through the C.Ts at both ends and there will be no current spilling into the relay. Now assume that there is an earth fault in the rotor winding it will cause an increase in current through set CTs as compared to current through CT2. Thus there is no current balance any more resulting into spilling of a current through the relay R will trip the circuit.

9.3 CIRCUIT DIAGRAM:

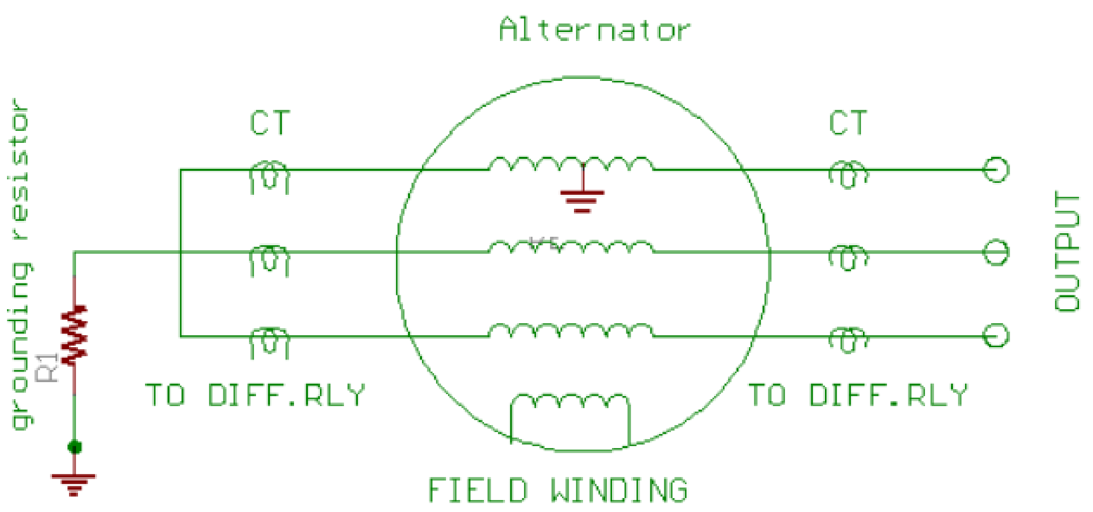

Figure 9.1. Arrangement of CT's to the alternator

9.4 PROCEDURE:

Starting the alternator:

1. Connect 3 Phase 4 wire power supply to the panel.
2. All the fault selector switch must be position ‘1’
3. Switch on the Mains MCB.
4. All meter display and power indication of R, Y, B will be glow.
5. IF Fault indicator will glow, hooter also on.
6. Press the Acknowledgement and reset button.
7. Press the INVERTER ON (VFD) push button.
8. Inverter display will be on.
9. Motor starts to rotate.
10. Adjust the RPM reaches 1500 rpm by Potentiometer.
11. Bring the dimmer to Zero position.
12. If rpm/HZ of the motor >40Hz and dimmer zero generator ready indicator will starts glow.
13. Press the Generator ON/ CB1 push button.
14. Switch on the Load MCB
15. Press the load push button.
16. Adjust the Motor rpm using the Multi turn Pot. (To get the 1500 rpm(Or) 50c/s).

9.5 TABULAR COLUMN

S.No	Voltmeter		
	RY	YB	BR

9.6 RESULT

EXPERIMENT - 10

OVER CURRENT AND TEMPERATURE PROTECTION IN ALTERNATOR

10.1 AIM

To study over current and temperature protection in three phase Alternator

10.2 APPARATUS

S. No.	Equipments	Quantity
1	Generator protection system setup	1
2	Motor Drive	1
3	Power Analyzer	1
4	Patch Cords	As required

10.3 CIRCUIT DIAGRAM:

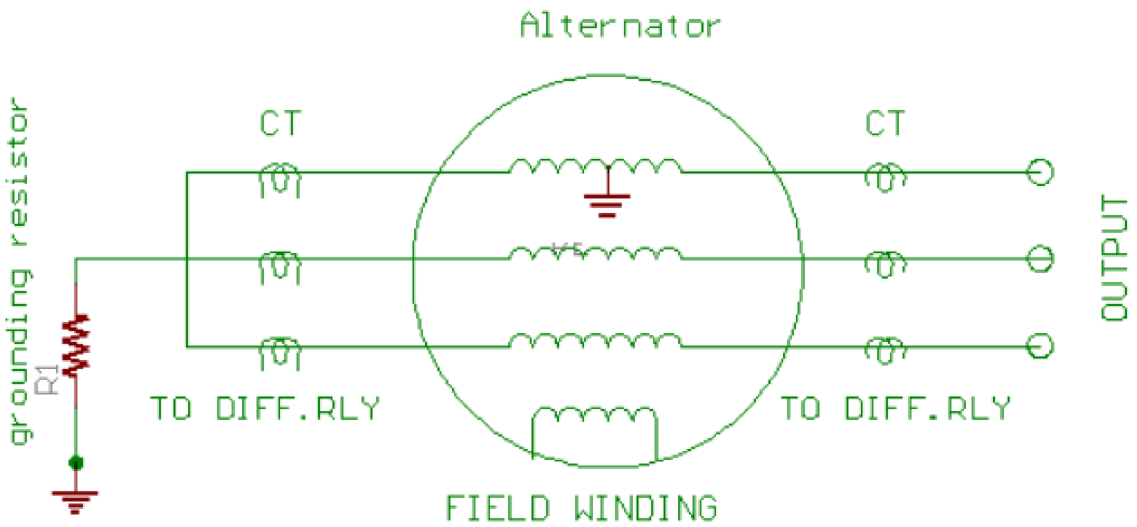

Figure 10.1. Arrangement of CT's to the alternator

10.4 PROCEDURE:

Starting the alternator:

1. Connect 3 Phase 4 wire power supply to the panel.
2. All the fault selector switch must be position '1'
3. Switch on the Mains MCB.
4. All meter display and power indication of R, Y, B will be glow.
5. IF Fault indicator will glow, hooter also on.
6. Press the Acknowledgement and reset button.
7. Press the INVERTER ON (VFD) push button.
8. Inverter display will be on.

9. Motor starts to rotate.
10. Adjust the RPM reaches 1500 rpm by Potentiometer.
11. Bring the dimmer to Zero position.
12. If rpm/HZ of the motor >40Hz and dimmer zero generator ready indicator will starts glow.
13. Press the Generator ON/ CB1 push button.
14. Switch on the Load MCB
15. Press the load push button.
16. Adjust the Motor rpm using the Multi turn Pot. (To get the 1500 rpm(Or) 50c/s).

10.5 TABULAR COLUMN

S. No	Relay setting	Voltage(V)	Current(I)

10.6 RESULT:

EXPERIMENT - 11

NEGATIVE SEQUENCE PROTECTION IN ALTERNATOR

11.1 AIM

To study negative sequence protection in three phase Alternator.

11.2 APPARATUS

S. No.	Equipments	Quantity
1	Generator protection system setup	1
2	Motor Drive	1
3	Power Analyzer	1
4	Patch Cords	As required

11.3 CIRCUIT DIAGRAM:

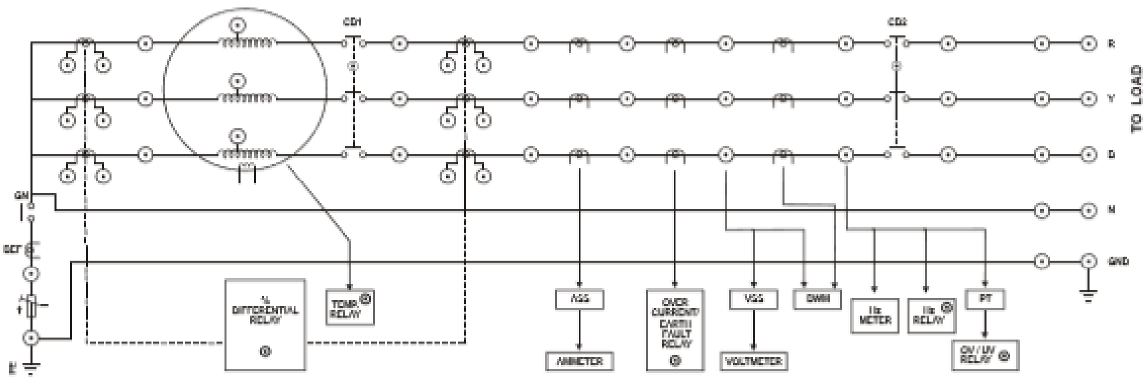

Figure 11.1. Connection diagram for negative sequence protection of alternator

11.4 PROCEDURE:

Starting the alternator:

1. Connect 3 Phase 4 wire power supply to the panel.
2. All the fault selector switch must be position ‘1’
3. Switch on the Mains MCB.
4. All meter display and power indication of R, Y, B will be glow.
5. IF Fault indicator will glow, hooter also on.
6. Press the Acknowledgement and reset button.
7. Press the INVERTER ON (VFD) push button.
8. Inverter display will be on.
9. Motor starts to rotate.
10. Adjust the RPM reaches 1500 rpm by Potentiometer.

11. Bring the dimmer to Zero position.
12. If rpm/HZ of the motor >40Hz and dimmer zero generator ready indicator will starts glow.
13. Set the negative sequence relay of the alternator set up to ON position.
14. Press the Generator ON/ CB1 push button.
15. Switch on the Load MCB
16. Press the load push button.
17. Adjust the Motor rpm using the Multi turn Pot. (To get the 1500 rpm(Or) 50c/s).

11.5 TABULAR COLUMN

S. No	Relay setting	Voltage(V)	Current(I)

11.6 RESULT:

EXPERIMENT - 12

OVER VOLTAGE AND UNDER VOLTAGE PROTECTION

12.1 AIM

To study over voltage and under voltage fault protection in three phase Alternator

12.2 APPARATUS

S. No.	Equipments	Quantity
1	Generator protection system embedded with OF/UF relays	1
2	Motor Drive	1
3	Power Analyzer	1
4	Patch Cords	As required

12.3 CIRCUIT DIAGRAM:

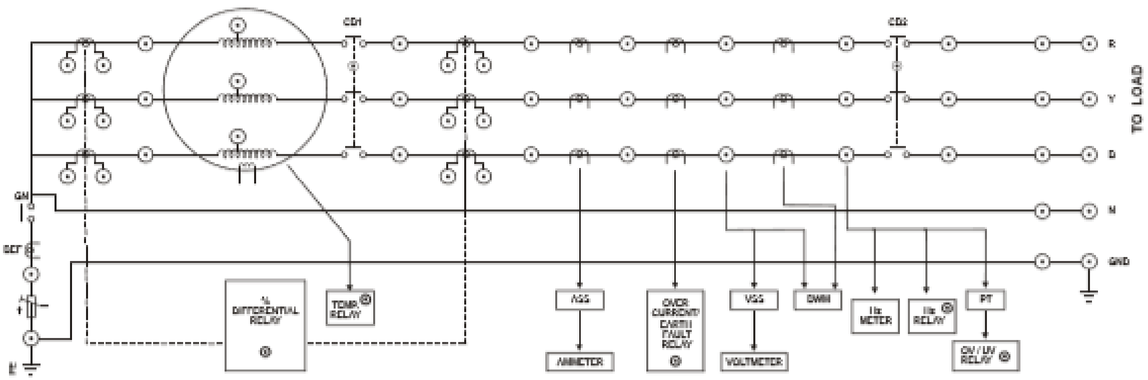

Figure 12.1 . Connection diagram ov/uv protection of alternator

12.4 PROCEDURE:

Starting the alternator:

1. Connect 3 Phase 4 wire power supply to the panel.
2. All the fault selector switch must be position ‘1’
3. Switch on the Mains MCB.
4. All meter display and power indication of R, Y, B will be glow.
5. IF Fault indicator will glow, hooter also on.
6. Press the Acknowledgement and reset button.
7. Press the INVERTER ON (VFD) push button.
8. Inverter display will be on.
9. Motor starts to rotate.
10. Adjust the RPM reaches 1500 rpm by Potentiometer.

11. Bring the dimmer to Zero position.
12. If rpm/HZ of the motor >40Hz and dimmer zero generator ready indicator will starts glow.
13. Set the under voltage and over voltage relay of the alternator set up to ON position.
14. Press the Generator ON/ CB1 push button.
15. Switch on the Load MCB
16. Press the load push button.
17. Adjust the Motor rpm using the Multi turn Pot. (To get the 1500 rpm(Or) 50c/s).

12.5 TABULAR COLUMN

S. No	Relay setting	Voltage(V)	Current(I)

12.6 RESULT:

EXPERIMENT – 13

GENERATOR PROTECTION DURING OVER AND UNDER FREQUENCY

13.1 AIM

To study the generator protection during over and under frequency using suitable relays

13.2 APPARATUS

S. No.	Equipments	Quantity
1	Generator protection system embedded with OF/UF relays	1
2	Motor Drive	1
3	Power Analyzer	1
4	Patch Cords	As required

13.3 THEORY

Over frequency & under frequency fault and protection for alternator

The frequency has a constant stable value, defined by the equation (Ns=120f/p). But frequency varies causing over and under frequency fault. Over or under frequency has its own severe effect on both the load side and generating equipment side, We are talking here about the generating set – alternator. The first thing we like to know why the over or under frequency occurs.

The frequency variation created by the load demand(excess or less then generation). Say when a generating station producing **power that equals the net consumption plus the los**s, then the system will be stable. But when the load demand is higher then production, that is production is low then use/demand then frequency will be low, on the other hand when the load demand is less then production or production is excess then frequency will be higher.

Over & Under frequency in a mathematical concept to understand and memorize as below-

Production>Loaddemand=frequencyhigh
Production<Loaddemand=frequencylow
Production = Load demand = frequency stable.

The remedy or protection of over and under protection is simple. When under frequency occurs that is more power consumer then the covering capacity, then the only solution is to effect load shedding or increase the power generation. For over frequency the only solution is to lower the power generation. A relay can be used to automatically control the loading, unloading of generator or effect the load shedding.

13.4 CIRCUIT DIAGRAM:

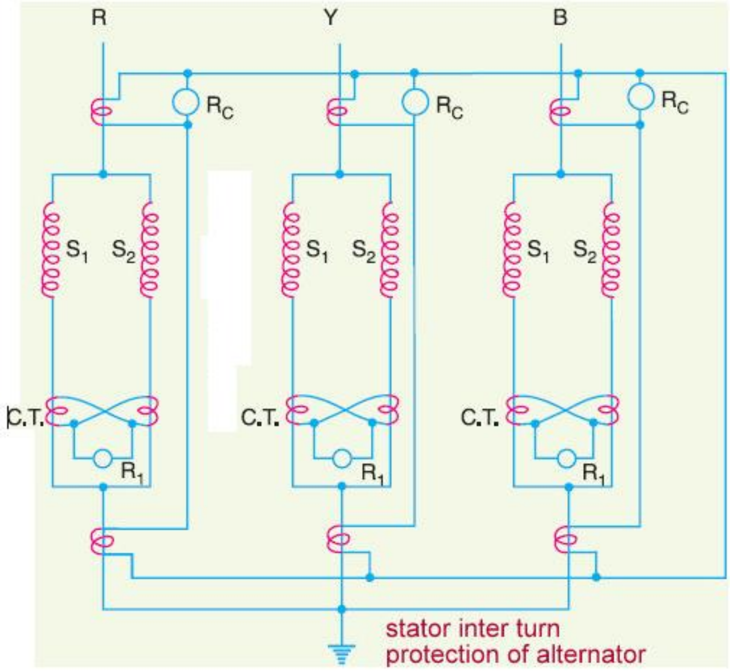

Figure 13.1: Circuit for Internal Fault Protection of Alternator

13.5 PROCEDURE

1. Connect 3 Phase 4 wire power supply to the panel.
2. All the fault selector switch must be position '1'
3. Switch on the Mains MCB.
4. All meter display and power indication of R, Y, B will be glow.
5. IF Fault indicator will glow, hooter also on.
6. Press the Acknowledgement and reset button.
7. Press the INVERTER ON (VFD) push button.
8. Inverter display will be on.
9. Motor starts to rotate.
10. Adjust the RPM reaches 1500 rpm by Potentiometer.
11. Bring the dimmer to Zero position.
12. If rpm/HZ of the motor >40Hz and dimmer zero generator ready indicator will starts glow.
13. Set the under frequency and over frequency relay of the alternator set up to ON position.
14. Press the Generator ON/ CB1 push button.
15. Switch on the Load MCB
16. Press the load push button.
17. Adjust the Motor rpm using the Multi turn Pot. (To get the 1500 rpm(Or) 50c/s).

13.6 TABULAR COLUMN

S. No	Relay setting	Voltage(V)	Current(I)

13.7 RESULT:

EXPERIMENT – 14

STUDY THE PERFORMANCE OF SYNCHRONOUS MACHINE

14.1 AIM

To study the performance of synchronous machine and protection scheme during internal faults

14.2 APPARATUS

S. No.	Equipments	Quantity
1	Generator protection system setup	1
2	Motor Drive	1
3	Power Analyzer	1
4	Patch Cords	As required

14.3 THEORY

INTERNAL PROTECTION OF ALTERNATOR

This specific protection is for alternators with multiple coils turns like in double phase winding used in large steam turbine alternators. The concept is that this protection scheme covers the stator coil inter turn to turn short circuit, not coil to coil(phase to phase) or coil to ground(phase to ground). It's like a local fault in one of the coil.

The protection scheme to cover stator inter turn fault is simply basing the theory of differential theory. In normal condition, the two coil or multi coils individually carry same magnitude of current but with a phase displacement. If this current is summed up in a common circuit then the result will be zero. So we can just place some CT's with their secondary's shorted and primaries with individual coils. If some fault persists, then there will be current in the secondary's which will energize the trip circuit.

14.4 CIRCUIT DIAGRAM:

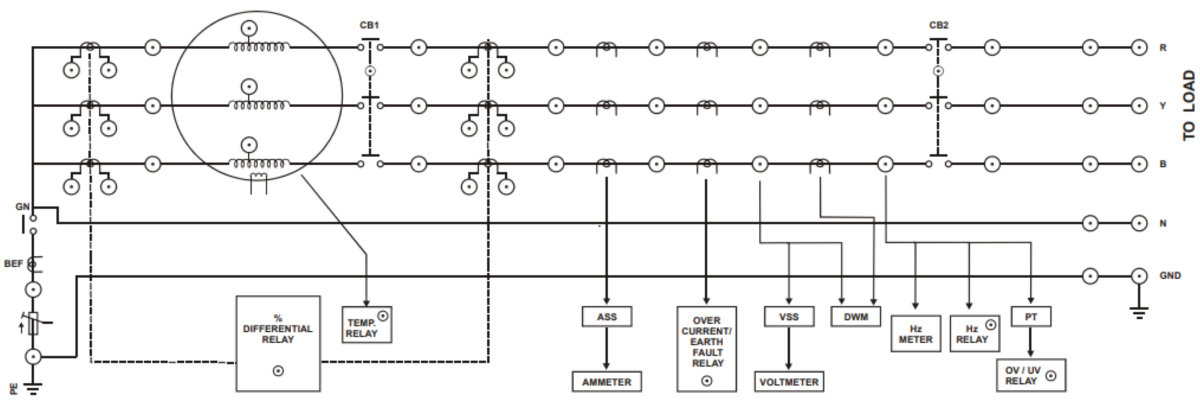

Figure 14.1: Circuit for Internal Fault Protection of Alternator

14.5 PROCEDURE

1. Connect 3 Phase 4 wire power supply to the panel.
2. All the fault selector switch must be position ‘1’
3. Switch on the Mains MCB.
4. All meter display and power indication of R, Y, B will be glow.
5. IF Fault indicator will glow, hooter also on.
6. Press the Acknowledgement and reset button.
7. Press the INVERTER ON (VFD) push button.
8. Inverter display will be on.
9. Motor starts to rotate.
10. Adjust the RPM reaches 1500 rpm by Potentiometer.
11. Bring the dimmer to Zero position.
12. If rpm/HZ of the motor >40Hz and dimmer zero generator ready indicator will starts glow.
13. Press the Generator ON/ CB1 push button.
14. Switch on the Load MCB
15. Press the load push button.
16. Adjust the Motor rpm using the Multi turn Pot. (To get the 1500 rpm(Or) 50c/s).
17. Insert the fault using fault simulation terminal.

14.6 TABULAR COLUMN:

S. No	Fault location(zone)	Voltage(V)	Current(I)

14.7 RESULT: