1. IDMT CHARACTERISTICS OF OVER CURRENT RELAY

Aim:

To study the Operation of a Non - Directional electromechanical type over current (IDMT relay) and plot the inverse time current characteristics.

Apparatus required:

S.No	Apparatus	Type	Quantity
1	IDMT Over current relay	Electro mechanical	1No
2	Timer	Digital	1No
3	Fault creation Panel	Digital	1No
4	Ammeter	30A MI	1No
5	Current Transformer-40/2A	Core type	1No

Theory:

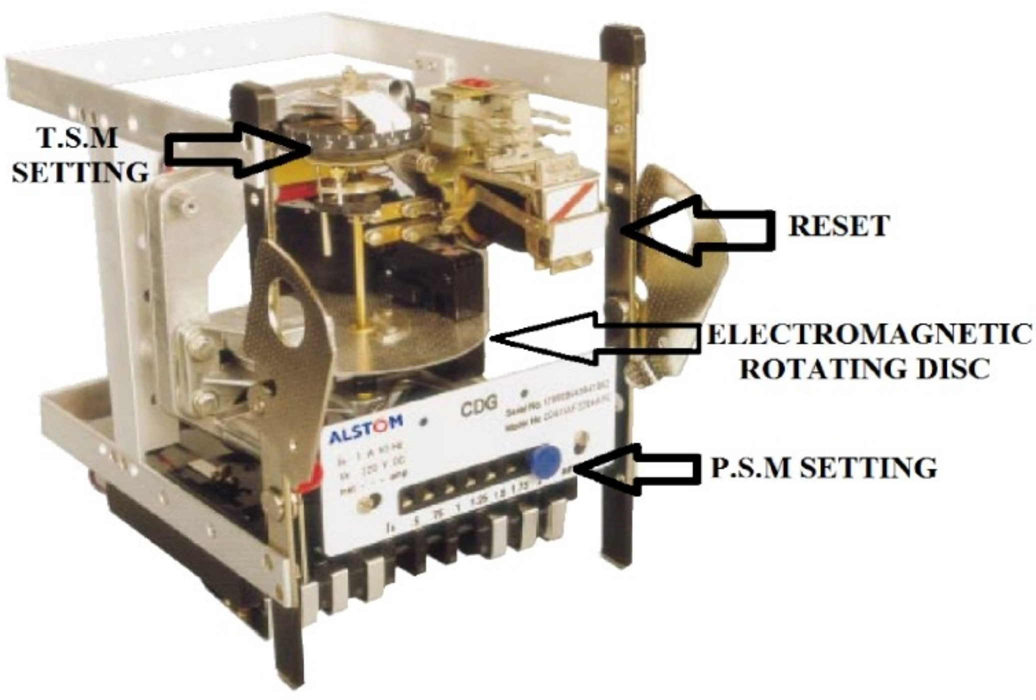


Fig. 1 ALSTOM CDG 11 IDMT over current relay

A non-directional heavily damped induction disc relay which has an adjustable inverse time/current characteristic with a definite minimum time. The relay has a high torque movement combined with low burden and low overshoot. The relay disc is so shaped that as it rotates the driving torque increases and offsets the changing restraining torque of the control spring. This feature combined with the high torque of the relay ensures good contact pressure even at currents near pick-up. Damping of the disc movement is by a removable high retentively permanent magnet. The unique method of winding the operating coil ensures that the time/current characteristics are identical on each of the seven current taps. Selection of the required current setting is by means of a plug setting bridge which has a single insulated plug. The maximum current tap is automatically connected when the plug is withdrawn from the bridge, allowing the setting to be changed under load without risk of open circuiting the current transformers. The IDMT relay has an auxiliary unit which is powered by a secondary winding on the electromagnet through a rectifier and as such a separate auxiliary supply is not required. The disc unit operates and closes its contacts, the auxiliary element connected across the secondary winding on the electromagnet operates, and one normally open contact of the auxiliary element reinforces the disc contact.

Pick Up Current of Relay:

In all electrical relays, the moving contacts are not free to move. All the contacts remain in their respective normal position by some force applied on them continuously. This force is called controlling force of the relay. This controlling force may be gravitational force, may be spring force, and may be magnetic force. The force applied on the relay's moving parts for changing the normal position of the contacts, is called deflecting force. This deflecting force is always in opposition of controlling force and presents always in the relay. Although the deflecting force always presents in the relay directly connected to live line, but as the magnitude of this force is less than controlling force in normal condition, the relay does not operate. If the actuating current in the relay coil increases gradually, the deflecting force in electro mechanical relay is also increased. Once, the deflecting force crosses the controlling force, the moving parts of the relay initiate to move to change the position of the contacts in the relay. The current for which the relay initiates it operation is called pick up current of relay.

Current Setting of Relay:

The minimum pick up value of the deflecting force of an electrical relay is constant. Again the deflecting force of the coil is proportional to its number of turns and current flowing through the coil. Now, if we can change the number of active turns of any coil, the required current to reach at minimum pick value of the deflecting force, in the coil also changes. That means if active turns of the relay coil is reduced, then proportionately more current is required to produce desired relay actuating force. Similarly if active turns of the relay coil are increased, then proportionately reduced current is required to produce same desired deflecting force.

Practically same model relays may be used in different systems. As per these systems requirement the pick-up current of relay is adjusted. This is known as current setting of relay. This is achieved by providing required number of tapping in the coil. These taps are brought out to a plug bridge. The number of active turns in the coil can be changed by inserting plug in different points in the bridge

The current setting of relay is expressed in percentage ratio of relay pick up current to rated secondary current of CT.

For example, an over current relay should operate when the system current just crosses 125% of rated current. If the relay is rated with 1 A, the normal pick up current of the relay is 1 A and it should be equal to secondary rated current of current transformer connected to the relay.

Then, the relay will be operated when the current of CT secondary becomes more than or equal 1.25 A. As per definition,

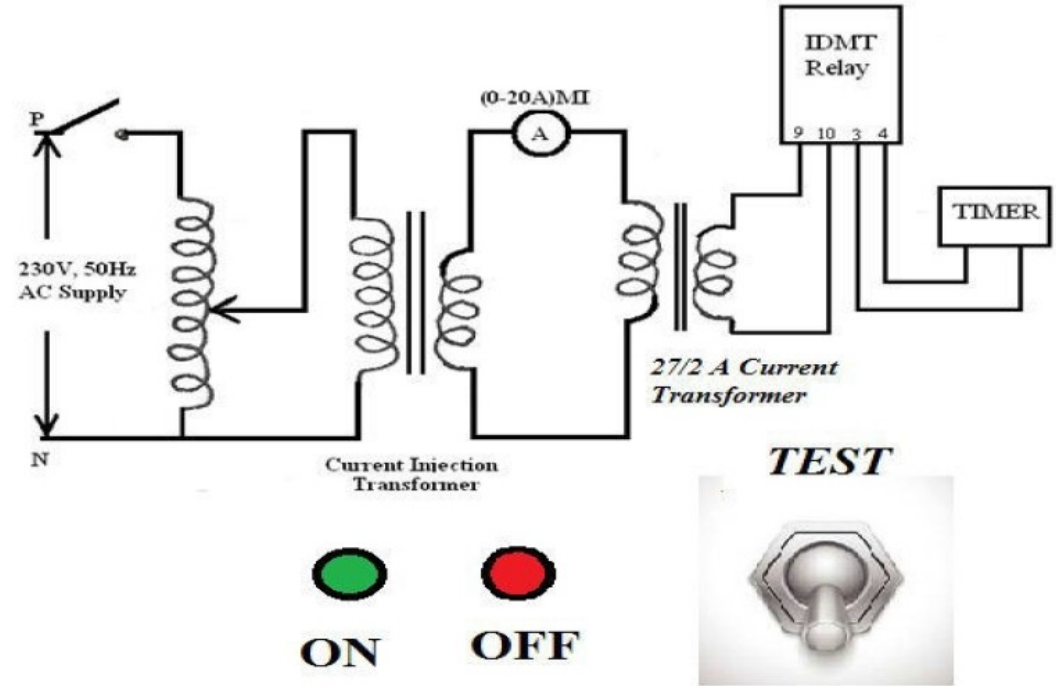
The current setting is sometimes referred as current plug setting. The current setting of over current relay is generally ranged from 50% to 200%, in steps of 25%. For earth fault relay it is from 10% to 70% in steps of 10%.

Hence, pick up current of the relay is, $1 \times 150\ \% = 1.5$ A. Now, suppose fault current in the CT primary is 1000 A. Hence, fault current in the CT secondary i.e. in the relay coil is, $1000 \times 1/200 = 5$ A. Therefore PSM of the relay is, $5\ /\ 1.5 = 3.33$

In order to adjust the relay operating time, both of the factors are to be adjusted. The adjustment of travelling distance of an electromechanical relay is commonly known as time setting. This adjustment is commonly known as time setting multiplier of relay. The time setting dial is calibrated from 0 to 1 in steps 0.05 sec. But by adjusting only time setting multiplier, we cannot set the actual time of operation of an electrical relay. As the time of operation also depends upon the speed of operation. The speed of moving parts of relay depends upon the force due to current in the relay coil. Hence it is clear that, speed of operation of an electrical relay depends upon the level of fault current. In time setting multiplier, this total travelling distance is divided and calibrated from 0 to 1 in steps of 0.05. So when time setting is 0.1, the moving part of the relay has to travel only 0.1 times of the total travelling distance, to close the contact of the relay.

IDMT relay is inverse definite minimum time relay. It is one in which Time of operation is inversely proportional to magnitude of fault current near pickup value and becomes substantially constant slightly above the pickup value of the Relay. This is achieved by using a core of the Electro Magnet which gets saturated for currents slightly greater than the pickup current. Fault current and measure relay operation time is used to conduct the experiment. Values recorded for various TSMs and PSMs. Characteristics studied with the help of a graph and correlated with theory. This relay consists of Induction disc unit with an operation indicator and in some cases an instantaneous high set unit all assembled are in standard frame. Type disc shaft carried silver rod moving contacts which complete the auxiliary unit circuit through the fixed contract Permanent magnet is used to control the disc speed. The setting is adjusted by the movement of the back stop which is controlled by the rotating a KNUR LED molded disc at the base of graduated time multiplier.

Circuit Diagram:



Procedure:

1 Connect the circuit as per the circuit diagram.

2. Select the P.S.M setting on the relay.

3. Make sure that the 1-phase dimmer stat is in minimum position, test switch is in ON position, and T.S.M settings of the relay are set to 0.5.

4. Increase the current in the circuit to the value calculated similar to step 2 depending on the PSM setting by varying the 1-phase variac.

5. Observe the relay tripping condition. The circuit will be in OFF position after relay tripping.

6. OFF the test switch, reset the timer and relay and push ON button. Make sure the rotating electromagnetic disc of relay is at initial position before switching ON.

7. Note down the value of tripping time and current.

8. Repeat the steps 3,4,5,6, 7to observe the operating time of the relay by increasing the fault current above calculated value of fault current in step 2 and tabulate the readings.

9. Repeat the same procedure for various T.S.M = 0.7

10. Plot the graph between time taken for relay to operate vs fault current for various T.S.M / P.S.M.

Precautions:-

1. Disc must be stationary before applying fault current.
2. TSM setting must be changed with due care.

Sample observations:

Rated Current : 0 to 25 Amps.

CT Ratio : 40/2 Amps = 20.

Pick-Up Current Setting = Plug setting Value X C.T ratio

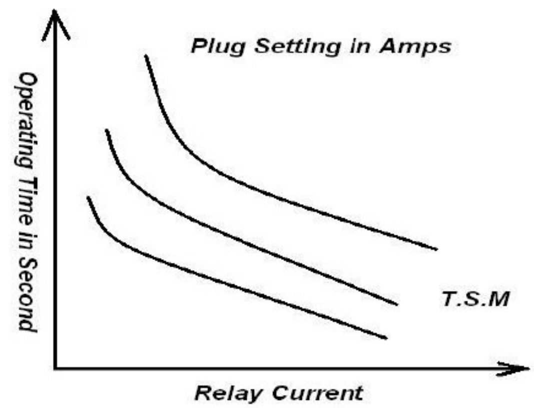
TSM = 0.1 to 0.6

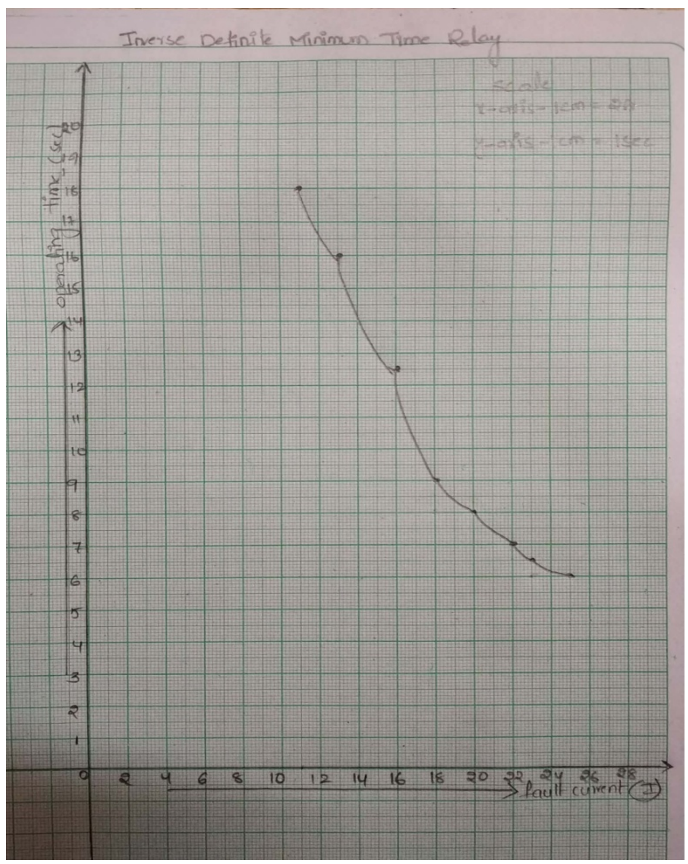
PSM	Pick up Current
0.5	**10**
0.75	**15**
1	**20**
1.25	**25**

Readings and Tabular forms:-

Fault current(A)	Time(sec)
11.5	18
13.55	16.1
16.22	11.1
18.21	8.9
20.08	8
22.45	6.9
23.63	6.4

Expected graphs:





RESULT: Fault current V/S time characteristics of IDMT relay observed on IDMT panel.

2. CHARACTERISTICS OF PERCENTAGE BIASED OF STATIC/ELECTRO MAGNETIC DIFFERENTIAL RELAY

Aim: To study the differential protection scheme for a Three phase transformer with Unequal turn's ratio.

Apparatus required:

S. no.	Apparatus	Type	Range	Quantity
1	3-ph variac	Shell type	(0-440)	1
2	3-transformer	Core type	(400/200)	1
3	Ammeters	Digital	(0-10)	7
4	Voltmeters	Digital	(0-500)	2
5	CT	-	-	6
6	Load bank	Resistive	5A	1

Theory:

The relays used in power system protection are of different types. Among them differential relay is very commonly used relay for protecting transformers and generators from localized faults. Differential relays are very sensitive to the faults occurred within the zone of protection but they are least sensitive to the faults that occur outside the protected zone. Most of the relays operate when any quantity exceeds beyond a predetermined value for example over current relay operates when current through it exceeds predetermined value.

But the principle of differential relay is somewhat different. It operates depending upon the difference between two or more similar electrical quantities.

Definition of Differential Relay:

The differential relay is one that operates when there is a difference between two or more similar electrical quantities exceeds a predetermined value. In differential relay scheme circuit, there are two currents come from two parts of an electrical power circuit. These two currents meet at a junction point where a relay coil is connected. According to Kirchhoff Current Law, the resultant current flowing through the relay coil is nothing but summation of two currents, coming from two different parts of the electrical power circuit. If the polarity and amplitude of both currents are so adjusted that the phasor sum of these two currents, is zero at normal operating condition. Thereby there will be no current flowing through the relay coil at normal operating conditions. But due to any abnormality in the power circuit, if this balance is broken, that means the phasor sum of these two currents no longer remains zero and there will be non-zero current flowing through the relay coil thereby relay being operated. In current differential scheme, there are two sets of current transformer each connected to either side of the equipment protected by differential relay. The ratio of the current transformers are so chosen, the secondary currents of both current transformers matches each other in magnitude. The polarity of current transformers is such that the secondary currents of these CTs oppose each other. From the circuit is clear that only if any nonzero difference is created between this to secondary currents, then only this differential current will flow through the operating coil of the relay.

If this difference is more than the peak up value of the relay, it will operate to open the circuit breakers to isolate the protected equipment from the system. The relaying element used in differential relay is attracted armature type instantaneously relay since differential scheme is only adapted for clearing the fault inside the protected equipment in other words differential relay should clear only internal fault of the equipment hence the protected equipment should be isolated as soon as any fault occurred inside the equipment itself. They need not be any time delay for coordination with other relays in the system.

Types of Differential Relay

There are mainly two types of differential relay depending upon the principle of operation. 1. Current Balance Differential Relay 2. Voltage Balance Differential Relay. In current differential relay two current transformers are fitted on the either side of the equipment to be protected. The secondary circuits of CTs are connected in series in such a way that the carry secondary CT current in same direction. The operating coil of the relaying element is connected across the CT's secondary circuit. Under normal operating conditions, the protected equipment (either power transformer or alternator) carries normal current. In this situation, say the secondary current of CT_1 is I_1 and secondary current of CT_2 is I_2. It is also clear from the circuit that the current passing through the relay coil is nothing but I_1-I_2. As we said earlier, the current transformer's ratio and polarity are so chosen, $I_1 = I_2$, hence there will be no current flowing through the relay coil. Now if any fault occurs external to the zone covered by the CTs, faulty current passes through primary of the both current transformers and thereby secondary currents of both current transformers remain same as in the case of normal operating conditions. Therefore at that situation the relay will not be operated.

But if any ground fault occurred inside the protected equipment as shown, two secondary currents will be no longer equal. At that case the differential relay is being operated to isolate the faulty equipment (transformer or alternator) from the system.

Principally this type of relay systems suffers from some disadvantages

1. There may be a probability of mismatching in cable impedance from CT secondary to the remote relay panel.
2. These pilot cables' capacitance causes incorrect operation of the relay when large through fault occurs external to the equipment.
3. Accurate matching of characteristics of current transformer cannot be achieved hence there may be spill current flowing through the relay in normal operating conditions.

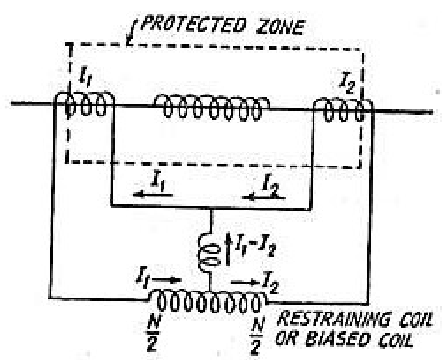


Fig 1`: Schematic diagram of differential relay

Percentage Differential Relay

This is designed to response to the differential current in the term of its fractional relation to the current flowing through the protected section. In this type of relay, there are restraining coils in addition to the operating coil of the relay. The restraining coils produce torque opposite to the operating torque. Under normal and through fault conditions, restraining torque is greater than operating torque. Thereby relay remains inactive. When internal fault occurs, the operating force exceeds the bias force and hence the relay is operated. This bias force can be adjusted by varying the number of turns on the restraining coils. As shown in the figure below, if I_1 is the secondary current of CT_1 and I_2 is the secondary current of CT_2 then current through the operating coil is $I_1 - I_2$ and current through the restraining coil is $(I_1 + I_2)/2$. In normal and through fault condition, torque produced by restraining coils due to current $(I_1 + I_2)/2$ is greater than torque produced by operating coil due to current $I_1 - I_2$ but in internal faulty condition these become opposite. And the bias setting is defined as the ratio of $(I_1 - I_2)$ to $(I_1 + I_2)/2$

Bias setting in percentage

$$= I1 - I2 \div (I1 + I2)/2 \times 100$$

It is clear from the above explanation, greater the current flowing through the restraining coils, higher the value of the current required for operating coil to be operated. The relay is called percentage relay because the operating current required to trip can be expressed as a percentage of through current. The percentage biased relay used in this experiment is DTH31 relay. The information of the relay is explained.

Description of DTH31 Relay

Fig. 2 represents the schematic diagram of a typical application of DTH 31 relay with a three- phase two-winding transformer. Input currents I_2 and I_1 from the power transformer line CTs are added vectorially in the center tapped restraint bias transactor T_1. Three taps in each half of the transactor primary enable bias settings of 15%, 30% and 45% to be obtained. The output of T_1 is full wave rectified and smoothed to obtain the restraint bias voltage level V_B. The center tap o T_1 is connected to the differential circuit which comprises transactors T_2, T_3 And current transformer T_4 connected is series. A tuned circuit which includes the secondary of T_2 is arranged to resonate at the second harmonic frequency. The output of this circuit is rectified and smoothed to obtain the harmonic restraint voltage level V_H. In addition, outputs of transactor T_3 and current transformer T_4 are rectified and smoothed to obtain the differential voltage V_D and the high set voltage level V_O respectively. The greater of the two restraining voltage levels V_B and V_H is detected in one comparator and compared in magnitude with the differential operating voltage level V_D in a second comparator stage. When the operate voltage exceeds the restraining voltage by more than a preset amount, the second comparator produces an output to operate the common relay drive circuit. The high set voltage level V_O operates the relay drive circuit if the differential current exceeds ten times the rated current.

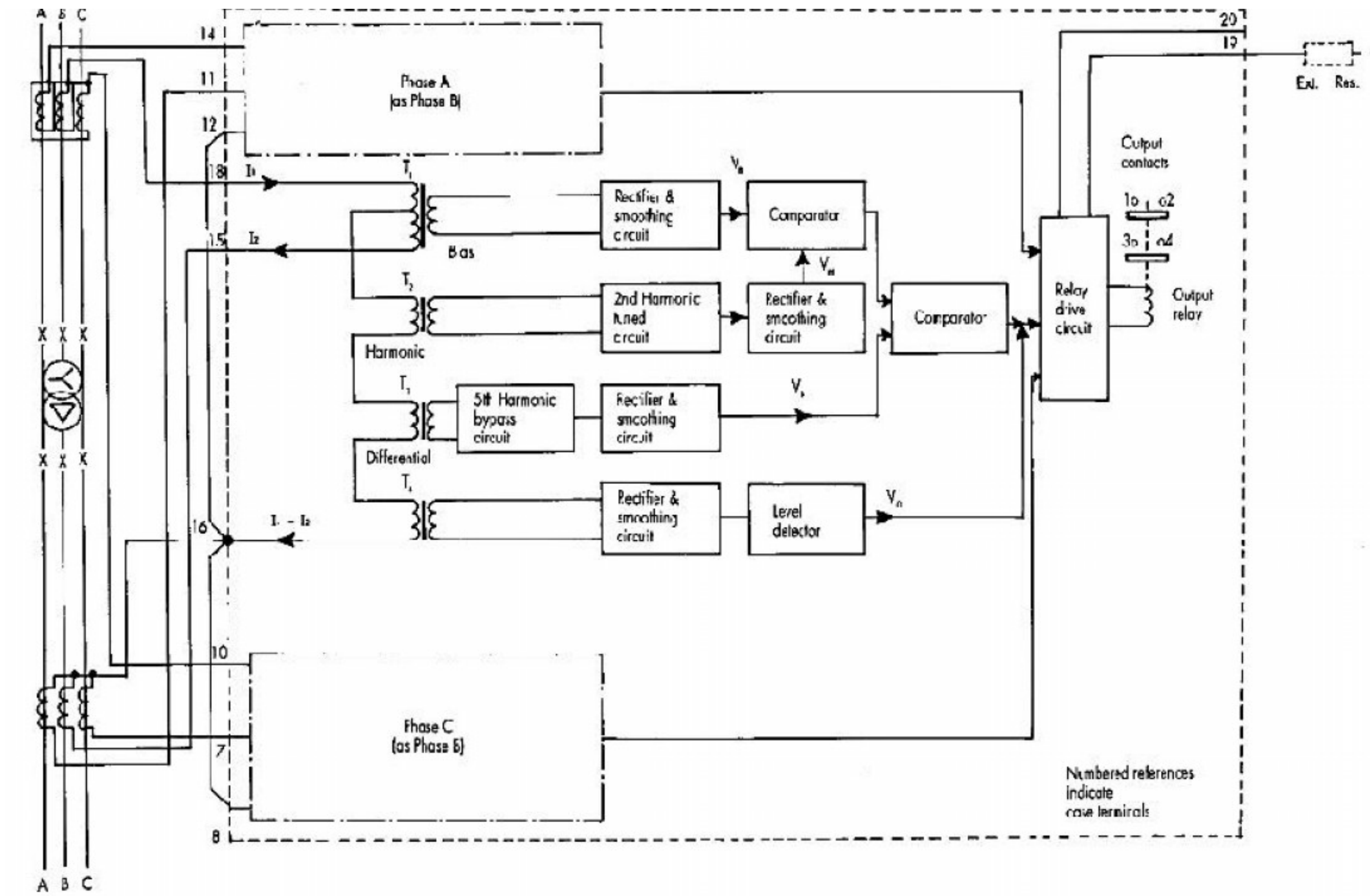


Fig 2: Schematic diagram of DTH31 relay with three phase two winding transformer

Technical data of the Relay

Current ratings

1A or 5A at 50 Hz.

Settings

Operate The relay operates when differential current exceeds 15% relay rated current (fixed).

Bias

The bias setting is adjustable to 15%, 30% or 45% by plugboard taps. Thermal ratings The relay will withstand twice rated current continuously, 40 times rated current for 3 s and 100 times rated current for 1 s. Limiting value is 170 times rated current. The limiting value must not be exceeded and can be withstood for a maximum period of 0.25 s.

Operating time

The relay operating time for differential currents in excess of twice rated current is typically about 45 ms.

Harmonic restraint

Operation is prevented when the second harmonic content of the differential current exceeds
20%

Burdes

0.33VA per phase at rated current. 1A relay. 1.0VA per phase at rated current 5A relay.

High set

The high set circuit operates when the differential current exceeds 10 times the rated current.

Contacts

Two pairs of normally open self-reset contacts rated to make and carry 7500VA for 0.5 s, with maxima of 30A and 660V.

Auxiliary supply

30, 110/125, 220/250V dc. Relays for use on 110/125 or 220/250V are supplied with suitable external resistors.

CT requirements

Star connected and delta connected current transformers must have a knee-point voltage given by:

$V_k = 40\ I\ (RCT + 2\ RL)$

Where V_k = Current transformer knee-point voltage (V).

I = Relay rated current (A).

RCT = Resistance of CT secondary winding (Ohms).

RL = Resistance of each pilot from the relay to the CTs (Ohms).

Magnetising current Less than 0.03 x I at Vk/4

Operation indicators

Independent flags for differential and highset are provided on types DTTM 11 and DTTM 12, common flag indicator for DTH 31/DTH 32.

Insulation

The relay meets the requirements of IS 3231/IEC 255-5 series C- 2 kV for 1 minute.

Impulse voltage

The relay complies with the requirements of IS 8686/IEC 255-4, Appendix E to class III.

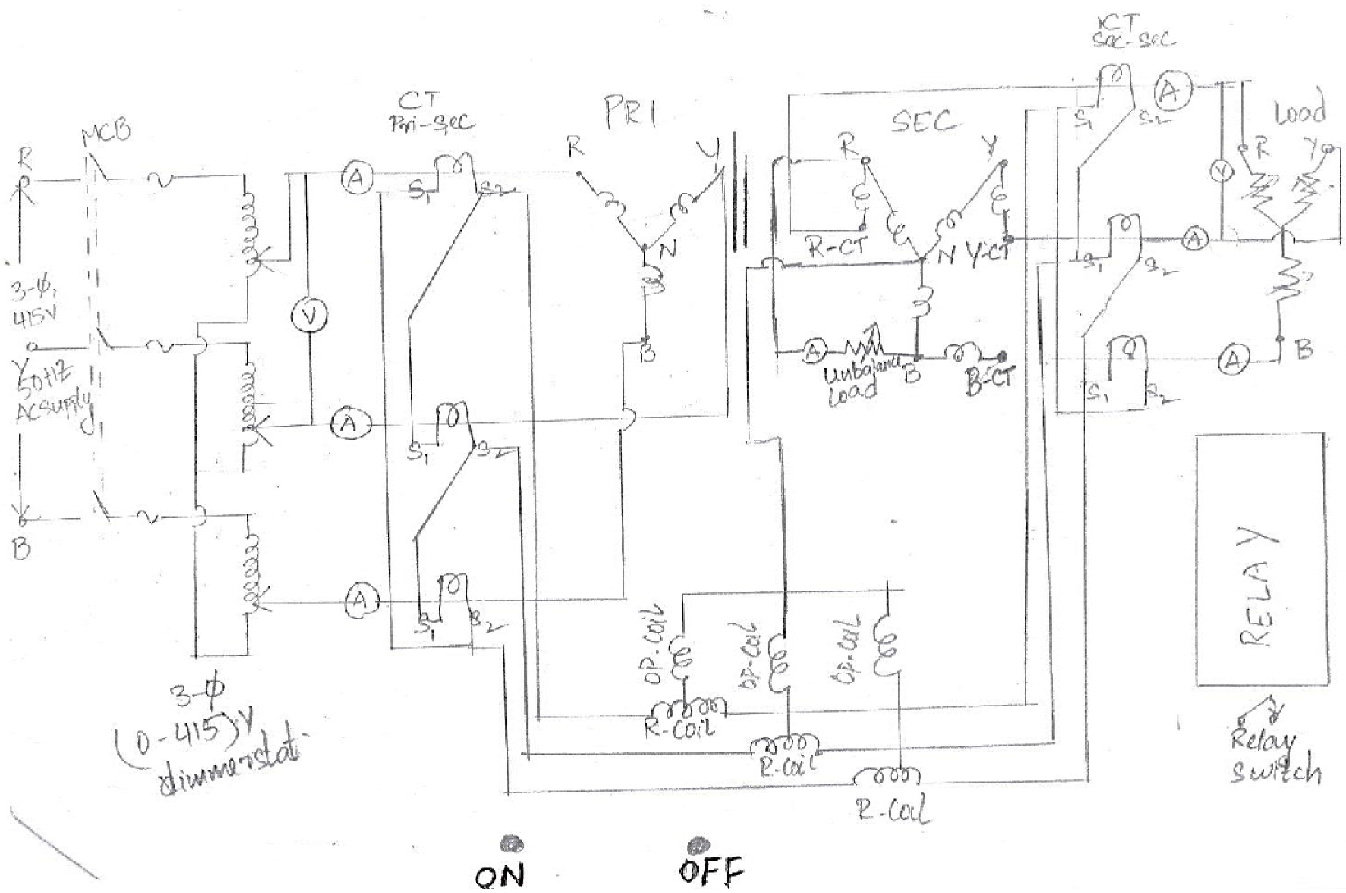
High frequency interference

The relay complies with IS 8686/IEC 255-22-1 Appendix C to class III.

Case

Relays are supplied in draw out case suitable for flush mounting and are finished eggshell black and tropicalized. The draw out feature considerably simplifies maintenance and permits testing to be carried out easily and quickly. A cradle mounted isolating switch is provided which automatically isolates the trip circuit when the cradle assembly is withdrawn from the case for maintenance. This prevents any inadvertent tripping of the circuit breaker. The case is fitted

Circuit Diagram:



Procedure:

a. Procedure for connecting the circuit:

1. From the dimmerstat, connect R, Y and B terminals to respective R, Y and B terminals of the primary side of main transformer through ammeter in each phase respectively as shown in the figure.
2. Similarly on the secondary side of the main transformer, connect R-CT, Y-CT and B- CT terminals to R, Y and B terminals of the load through ammeters respectively.
3. Connect the S1 and S2 terminals of CT primary-sec in Delta connection as shown in figure.
4. Connect the S1 and S2 terminals of CT sec-sec in Delta connection as shown in figure.
5. Connect the S2 terminals of CT primary-sec to the respective S1 terminals of CT sec-sec through an R-Coil.
6. Connect one terminal of op-coil to the respective R-coil and short all the other terminals of the three op coils and connect the common terminal to the neutral of secondary side of the main transformer.
7. Connect the unbalanced load between R and B terminals of the secondary side of main transformer through an ammeter.
8. Connect the voltmeter between R and Y phases on supply and load sides respectively.

b. Procedure for conducting the experiment

1. Switch ON MCB. Apply 385V on the primary side of the transformer using three phase autotransformer
2. Apply balanced load on the secondary side of the transformer by switching ON the switches 1 and 2 present on the three phase load bank.
3. Observe whether the relay is operating or not when the switches 1 and 2 are ON.
4. Note sown the reading of the primary side and secondary side voltages and currents at each stage of load.
5. Create a fault of 45% biased setting of relay by switching ON switch 3 present on the load bank.
6. Check whether relay is operating or not.
7. To note down the fault current and other primary and secondary side voltage and currents during the fault condition, switch off the relay switch to bypass the relay and press the ON button.
8. Reset the relay and repeat the steps 6 and 7 for 15% and 30% biased setting by switching ON switches 4 and 5 present on the load bank respectively.

For Balanced Load:

Sl.No	Swith ON	Primary Side of Transformer Parameters				Secondary Side of Transformer Parameters				
		V_S(V)	I_R(A)	I_Y(A)	I_B(A)	V_R(V)	I_R(A)	I_Y(A)	I_B(A)	I_F(A)
1	1	401.1	1.27	0.85	0.85	199.8	1.66	1.60	1.60	0
2	1,2	389.4	2.06	1.62	1.59	196.5	3.27	3.14	3.17	0

For Unbalanced Load:

Sl.No	Swith ON	Primary Side of Transformer Parameters				Secondary Side of Transformer Parameters				
		V_S(V)	I_R(A)	I_Y(A)	I_B(A)	V_S(V)	I_R(A)	I_Y(A)	I_B(A)	I_F(A)
1	1	400.3	1.81	1.87	1.60	197.2	3.26	3.13	3.16	0
2	2	400.2	1.80	1.87	1.60	197.2	3.26	3.13	3.16	0
3	3	398.3	5.01	1.85	4.64	193	3.11	3.13	3.04	6.49

Result / Conclusion: For different biased conditions fault currents on % Biased relay observed and tabulated

3. DETERMINATION OF SEQUENCE IMPEDANCES OF A CYLINDRICAL ROTOR SYNCHRONOUS MACHINE

Aim:

To determine the Positive, Negative and Zero sequence of impedances or sequence impedances of the given three phase Alternator

Apparatus Required:

S.No	Apparatus	Type	Quantity
1	DC motor coupled to alternator set	-----	01 No.
2	Ammeters (0-2 amps DC)	Digital	01 No.
3	Ammeters (0-2 amps DC)	Digital	01 No.
4	Ammeters (0-5 amps AC)	Digital	01 No.
5	Voltmeters (0-500 Volts, AC)	Digital	01 No.
6	Rheostat 370 ohms/1.7 amps	Tubular type	01 No.
7	Separate Excitation source(0-220V/2A DC)	-----	01 No.
8	Connecting wires		Required

Theory:

(i) A balanced system of 3-phase currents having positive (or normal) phase sequence. These are called positive phase sequence components.

(ii) A balanced system of 3-phase currents having the opposite or negative phase sequence. These are called negative phase sequence components.

(iii) A system of three currents equal in magnitude and having zero phase displacement. These are called zero phase sequence components.

The positive, negative and zero phase sequence components are called the symmetrical components of the original unbalanced system. The term 'symmetrical' is appropriate because the unbalanced3-phase system has been resolved into three sets of balanced (or symmetrical) components. The subscripts 1, 2 and 0 are generally used to indicate positive, negative and zero phase sequence components respectively. For instance, IR0 indicates the zero phase sequence component of the current in the red phase. Similarly, IY1 implies the positive phase sequence component of current in the yellow phase. The positive phase sequence currents (IR1, IY1 and IB1), negative phase sequence currents (IR2, IY2 and IB2) and zero phase sequence currents (IR0, IY0 and IB0) separately from symmetrical components of the applies equally to 3- phase currents and voltages both phase and line values. The symmetrical components do not have separate existence. They are only mathematical components of unbalanced currents (or voltages) which actually flow in the system. In a balanced 3- phase system, negative and zero phase sequence currents are zero. Synchronous generators. The positive, negative and zero sequence impedances of rotating machines are generally different. The positive sequence impedance of a synchronous generator is equal to the synchronous impedance of the machine. The negative sequence impedance is much less than the positive sequence impedance. The zero sequence impedance is a variable item and if its value is not given, it may be assumed to be equal to the positive sequence impedance. In short:

Negative sequence impedance < Positive sequence impedance

Zero sequence impedance = Variable item

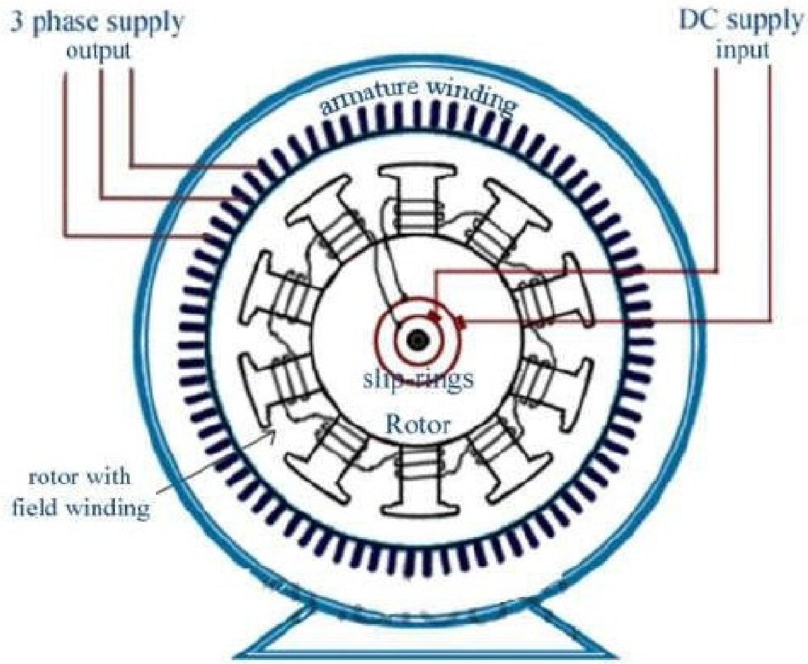
= may be taken equal to +ve sequence impedance if its value is not given

It may be worthwhile to mention here that any impedance Zn in the earth connection of a star connected system has the effect to introduce an impedance of 3Znper phase. It is because the three equal zero-sequence currents, being in phase, do not sum to zero at the star point, but they flow back along the neutral earth connection. Experimental set up to conduct OCC and SCC is made available. With the help of observations Synchronous impedance can be calculated.

The –ve sequence impedance is much less than +ve Sequence impedance. The zero sequence impedance is a variable item and if its value is not given, it may be assumed to be equal to the +ve sequence impedance. For Zero sequence impedance a separate model is used to conduct of experiment

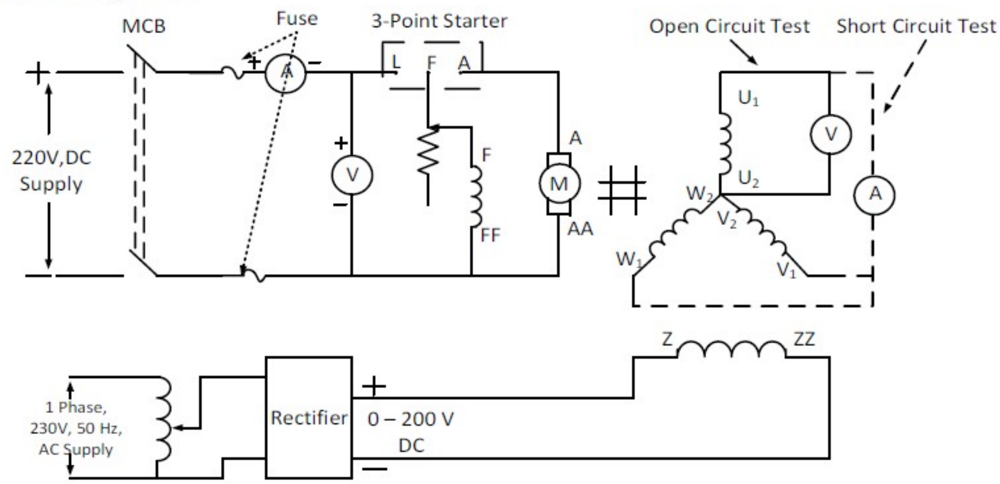
Sequence network of a 3-phase Alternator:

A three-phase synchronous generator, having a synchronous impedance of Zs per phase, with its neutral grounded through a impedance Zn is shown in Fig. The generator is supplying a balanced three phase load. The generator voltages Ea, Eb and Ec are balanced and hence treated



A. Determination of Positive Sequence Impedance Z1:

Circuit Diagram:



Procedure:

In order to determine the positive sequence impedance, open circuit and short circuit tests are to be performed.

Open Circuit:

1. Connect the circuit as shown in the circuit diagram.
2. Field rheostat of the motor should be kept in minimum position and single phase variac should be in minimum output position.
3. Switch on the DC supply and start the motor-alternator set with the help of a three point starter.
4. Adjust the field rheostat of the motor to set motor-alternator set to the rated speed.
5. Slowly vary the Variac to increase the field excitation of the synchronous machine. Note down the value if If and V up to the rated voltage 415V.
6. Bring back the single phase Variac to the initial position, field rheostat to the minimum resistance position and switch off the MCB.

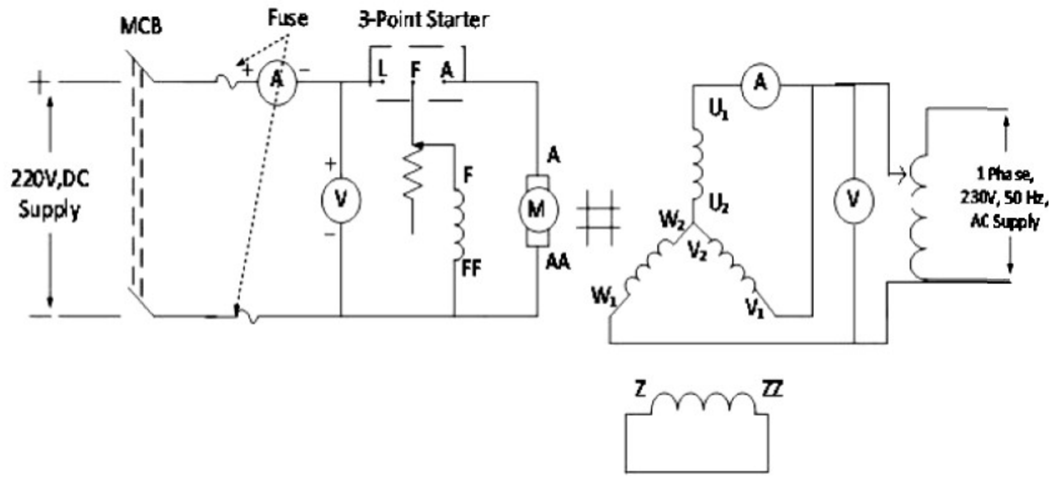
Short Circuit Test:

1. Connect the circuit as shown in the circuit diagram.
2. Field rheostat of the motor should be kept in minimum position and single phase variac should be in minimum output position.
3. Switch on the DC supply and start the motor-alternator set with the help of a three point starter.
4. Adjust the field rheostat of the motor to set motor-alternator set to the rated speed.
5. Slowly vary the variac such that the rated current flows through the alternator. Note down the field current and armature current.

6. Bring back the single phase variac to the initial position, field rheostat to the minimum resistance position and switch off the MCB.

B. **Determination of Negative Sequence Impedance**

Z2 : Circuit Diagram:

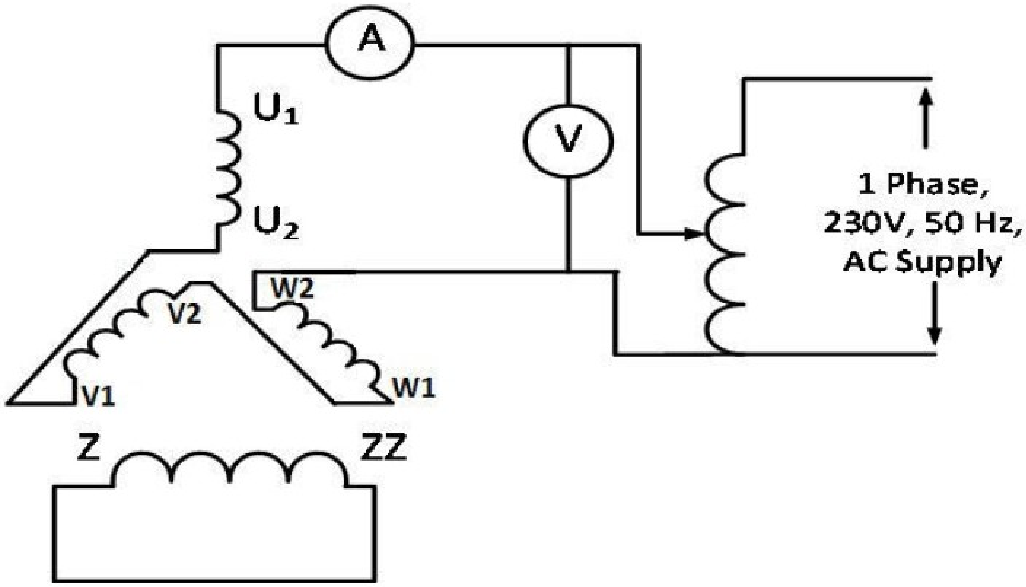


Procedure:

1. Connect the circuit as per the circuit diagram.
2. Keep the armature resistance of the motor at maximum resistance position, field rheostat of the motor at minimum position and single phase variac at minimum output position.
3. Switch on MCB and start the motor-alternator set using 3 point starter.
4. Slowly apply the voltage and observe the fluctuations in voltmeter and ammeter of the alternator.
5. Adjust the armature rheostat of the motor to get slow oscillations.Note down the minimum and maximum values of voltage and current.

7. Bring back all the rheostats and variac to the initial positions and switch off the supply.

C. Determination of Zero Sequence Impedance Z Circuit Diagram:



Procedure:

1. Connect the circuit as per the circuit diagram.
2. The three phase windings of the synchronous machine are connected in series.
3. Apply low voltage to the armature so that rated current flows in the series winding.
4. Note down the value of voltmeter and ammeter.
5. Reduce the voltage and switch off the supply.

Tabular Columns:

A. Positive Sequence Impedance

OC test

I_f(A)	E_{oc}(V)
0.06	10.7
0.18	135.7
0.2	162.4
0.29	262.9
0.35	327.8

SC test

I_f(A)	I_a(A)
0.18	0.5
0.19	0.9
0.25	1.2
0.27	1.67
0.33	2

Plot OCC and SC characteristics and calculate the positive sequence impedance

$$Z_1 = \frac{V_{OC}}{I_{SC}}\ \Omega \quad \text{For the same filed current.}$$

B. Negative Sequence Impedance

Input voltage V(V)	**Armature current I_a(A)**	**Z_2=V/1.732*I**
213.2	3	41.03

$$Z_2 = \frac{V}{\sqrt{3} * I}\ \Omega$$

C. Zero sequence impedance

Input voltage V(V)	**Armature current I_a(A)**	**Z_0=V/3*I**
125.4	4.2	9.95

RESULT: Sequence Impedance of an Alternator

Positive sequence impedance Z_1=76.19

Negative sequence impedance Z_2=41.03

Zero sequence impedance Z_0=9.95

4. ABCD PARAMETERS OF TRANSMISSION NETWORKS

Aim:

To determine ABCD constants of 3-phase transmission line with

a) Distributed Connection
b) Nominal – T connection

Apparatus:

a) For Open Circuit Test:
   Voltmeter - (0-300V) MI
   Ammeter - (0-10A) MI
b) For Short Circuit Test:
   Voltmeter - (0-30V) MI
   Ammeter - (0-10A) MI

Theory:

If a transmission line is erected, the constants are measured by conducting the OC&SC tests at the two ends of the line.

Using equations

$$V_s = AV_r + BI_r$$

$$I_s = CV_r + DI_r$$

Impedance measurement on the SE side: SE impedance with RE open circuitis

$$z_s - \frac{V}{I_s} = \frac{a}{c}(I_R = 0)$$

SE impedance with RE short circuited,

$$Z_{ss} = \frac{V_s}{I_r} = \frac{B}{D}(V_r = 0)$$

Measurement of impedance on RE side using equations

$$V_r = DV_s - BI_s$$

$$I_r = -CV_s + AI_s$$

While performing test, the current leaves the Network

$$I_s = -I_s, I_r = -I_r$$

$$V_r = DV_s - BI_s$$

$$-I_r = -CV_s - AI_s$$

$$I_r = CV_s + AI_s$$

RE impedance with SE open circuited, Z_{ro}

$$Z_{ro} = \frac{V_{sr}}{I_r} = \frac{D}{C}(I_s = 0)$$

RE impedance with SE short circuited, Z_{rs}

$$Z_{rs} = \frac{V_r}{I_r} = \frac{B}{A}(V_s = 0)$$

$$Z_{ro} - Z_{rs} = \frac{D}{C} - \frac{B}{A} = \frac{1}{AC}$$

$$Z_{so} = \frac{Z_{so}}{Z_{ro} \quad Z_{rs}} = A^2$$

$$A = \sqrt{\frac{Z_{so}}{(Z_{ro} - Z_{rs})}}$$

$$Z_{rs} = \frac{B}{A} \Rightarrow B = Z_{rs}A$$

$$B = Z_{rs}\sqrt{\frac{Z_{so}}{(Z_{ro} - Z_{rs})}}$$

$$Z_{so} = \frac{A}{C} \Rightarrow C = \frac{A}{Z_{so}} = \frac{1}{Z_{so}}\sqrt{\frac{Z_{so}}{(Z_{ro} - Z_{rs})}}$$

$$Z_{ro} = \frac{D}{C}$$

$$D = CZ_{ro} = \frac{Z_{ro}}{Z_{so}}\sqrt{\frac{Z_{so}}{(Z_{ro} - Z_{rs})}}(Z_{ro} = Z_{so})$$

$$D = A$$

Circuit Diagram:

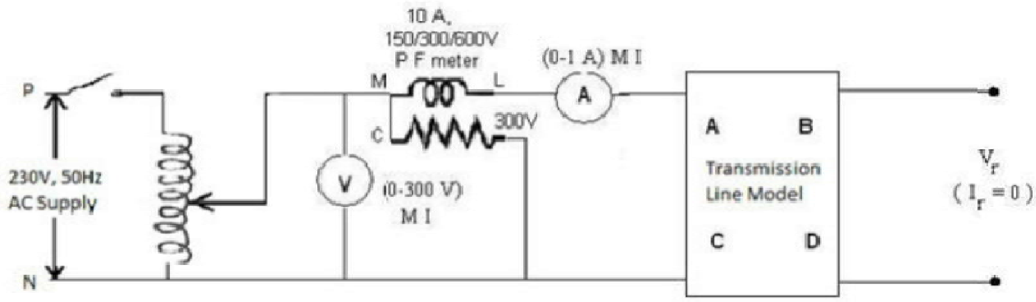


Fig-1 (OC test on SE side)

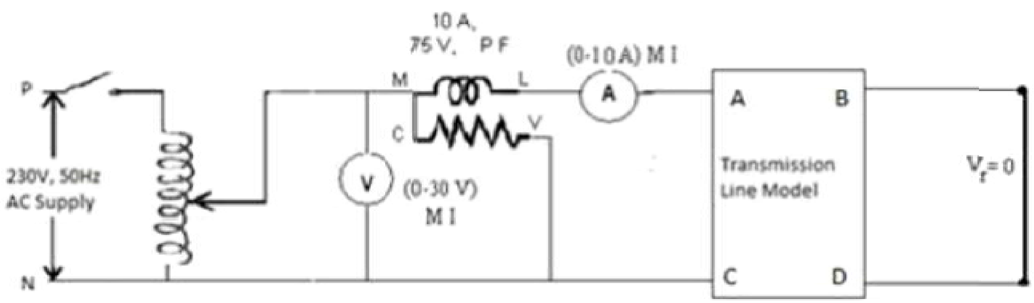


Fig-2 (SC test on SE)

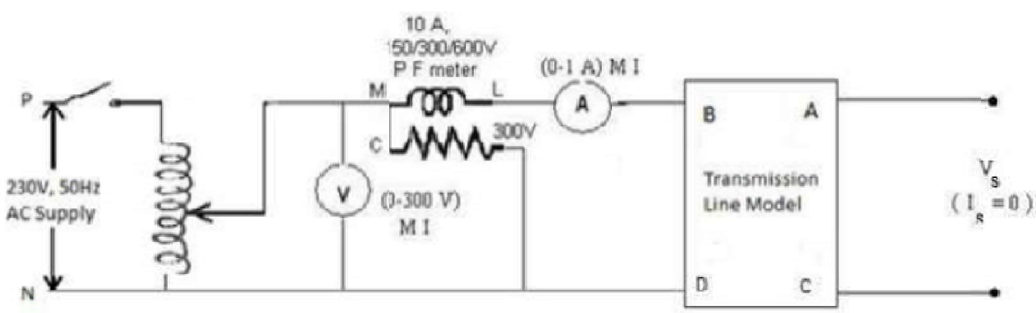


Fig-3 (OC test on RE side)

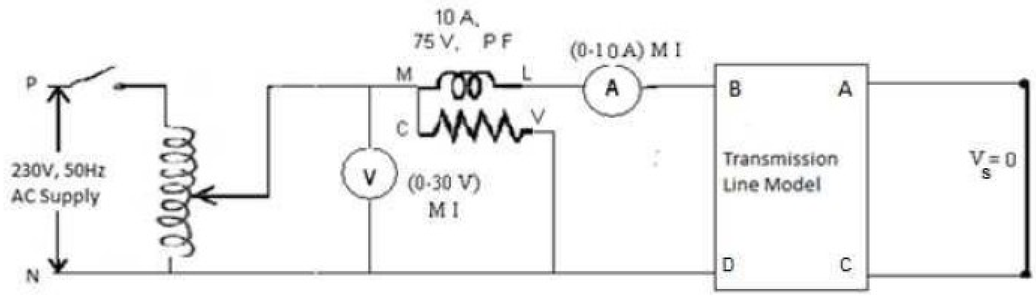


Fig.- 4 (SC test on RE side)

Procedure: **O.C& S.C. tests on SE side:**

1 Connect the circuit as per fig.(1) for O.C. test on SE.

2. Set 230V on Voltmeter using variac and note V_s, I_s and p.f. meter reading.

3. Connect the circuit as per fig (2) for S.C. test on SE.

4. Set rated current of the line on Ammeter and note V_s,I_s and wattmeter readings.

Procedure: **O.C& S.C. tests on RE side:**

1. Connect the circuit as per fig (3) for O.C test on RE.

2. Set 230V in Voltmeter & note V_r, I_r & p.f meter reading.

3. Connect the circuit as per fig (4) for SC test on RE.

4. Set rated current of the line in Ammeter & note V_r, I_r & Wattmeter reading.

6. Readings and Tabular forms

O.C. & S.C. tests on SE side:

Test	**V_s**	**I_s**	p.f/Wattmeter
O.C(I_r=0)	230	1.61	
S.C(V_r=0)	9.2	4.79	

O.C. & SC tests of RE side

Test	**V_r**	**I_r**	p.f/Wattmeter
O.C(I_s=0)	230	1.55	
S.C(V_s=0)	10.1	5.01	

Calculations:

$$Z_{so} = \frac{V_s}{I_s}(I_r = 0) \qquad Z_{ss} = \frac{V_s}{I_s}(V_r = 0)$$

$$Z_{ro} = \frac{V_r}{I_r}(I_s = 0) \qquad Z_{rs} = \frac{V_r}{I_r}(V_s = 0)$$

$$A = \sqrt{\frac{Z_{so}}{(Z_{ro} - Z_{rs})}}$$

$$B = Z_{rs}\sqrt{\frac{Z_{so}}{(Z_{ro} - Z_{rs})}}$$

$$C = \frac{1}{Z_{so}}\sqrt{\frac{Z_{so}}{(Z_{ro} - Z_{rs})}}$$

D =A

Note: Same 5. Procedure is repeated for Nominal – T Connection.

Result: ABCD parameters of given Tr.line model A=0.9891,B=1.9782,C=0.0069,D=0.9891

5. EFFICIENCY AND REGULATION OF LONG TRANSMISSION LINE

Aim:

To calculate the efficiency and regulation of long transmission line with R and RL loads in power system simulator and also performing VAR compensation for RL load using capacitor banks.

Apparatus Required:

S.NO.	APPARATUS	RATING	QUANTITY
1	Digital Voltmeters.	0-500Volts AC	02
2	Digital Ammeters.	0-20Amps AC	02
3	Wattmeters	500V/5Amps	04
4	MCB protection (3-pole type)	32 amps	01
5	Inductor Coils. (air core type)	0.32milli Henry	60
6	Capacitors (440Volts)	2 micro farad	60
7	Load Bank (R-Load)	5 Amps	01
8	Indication Lamps	(R, Y and B)	09
9	Three Phase transformers	415/415 Volts, 7KVA	02.
10	Connecting Wires	-----	

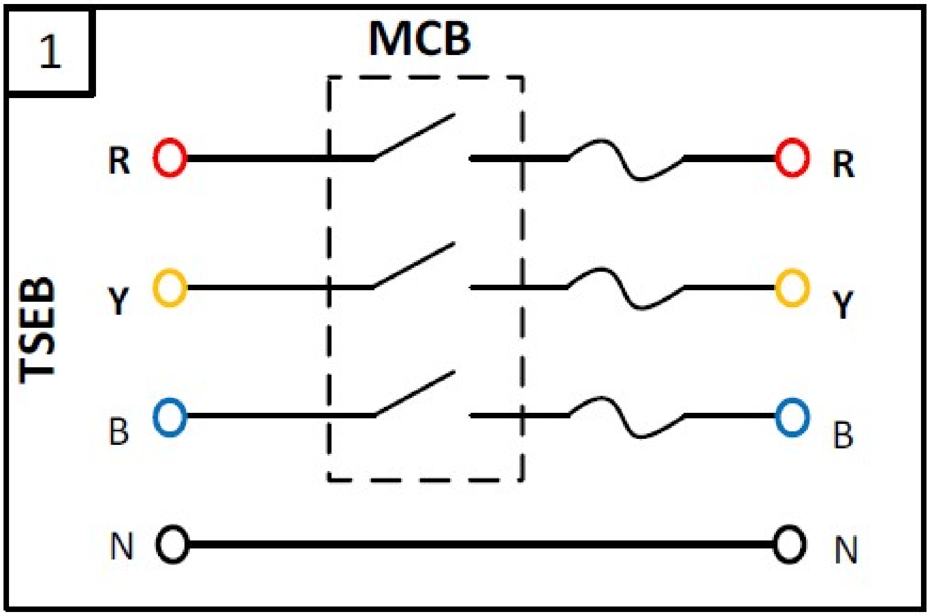
Theory:

Power System Simulator:

A power system simulator represents the total power system network consisting of generation, transmission and distribution systems in laboratory model. The schematic diagram of the power system simulator present in the power systems lab is given Fig1.

The supply to the power system simulator is from APSEB source.

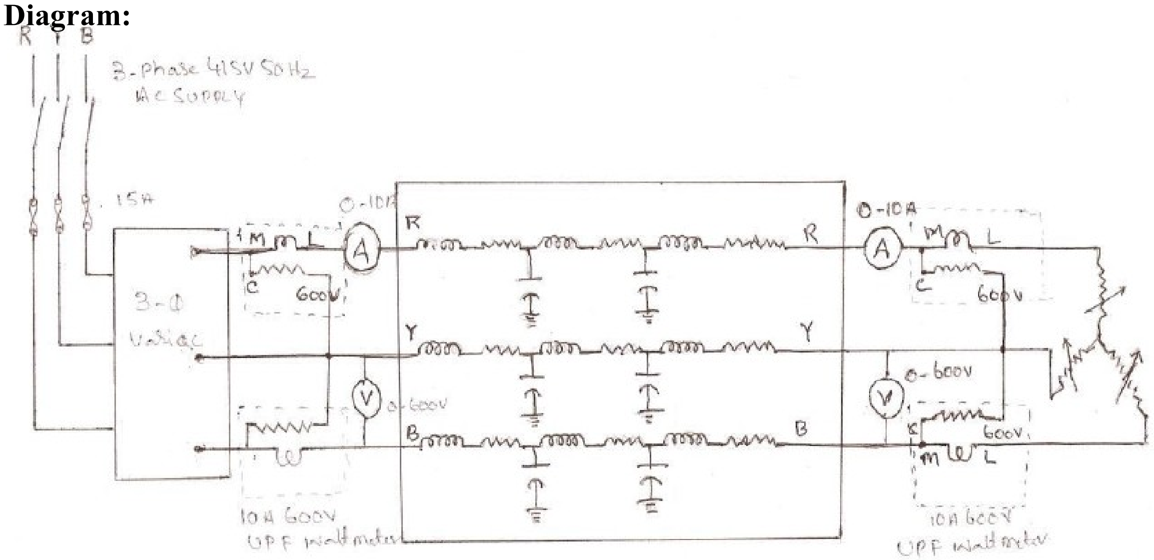
From AP State Electricity Board Supply



From the supply the power is transmitted to the load bank through different panels as listed.

Sending End Panel
Transmission line model
Receiving End panel
Load Bank panel

Circuit Diagram:



3-PHASE TRANSMISSION LINE MODEL

Precaution: -

Keep the voltage at sending end constant throughout the experiment.
Avoid loose connections.

Procedure: -

(For finding Efficiency and Regulation)

1. Make the connection as per the Circuit Diagram.
2. Switch ON supply and adjust rated voltage,
3. Note down voltage, no-load current readings.
4. Note down Current and power at sending end and receiving end at no load.
5. Now Switch ON some Load using R-load Bank provided.
6. Apply some Load like 3 amps in steps wise up to 5amps.
7. Note down all meter readings.
8. Tabulate the readings in tabular columns.
9. Find out Efficiency and Regulation using formulas.
10. Repeat the same procedure for short and medium lines.
11. Observe all parameter readings in all conditions.
12. Note down the readings and tabulate it.

Tabular columns:

R Load: - Loading Condition

S.No.	Vs(V)	Is(A)	Ws(kw)	Vr	Ir	Wr(kw)	Efficiency	Regulation(%Vr)
1	400	0.164	0.4	404.6	0	0	0	-1.136
2	400	0.875	0.5	405.2	1.072	0.75	93.75	-1.283
3	400	2.7	2.4	398.8	3.31	2.3	95.83	0.3
4	400	5.62	3.9	393.3	5.316	3.75	96.15	1.703

Sample calculations:

1. Voltage Regulation Formula:

   Voltage regulation of transmission line is defined as the ratio of difference between sending and receiving end voltage to receiving end voltage of a transmission line between conditions of no load and full load. It is also expressed in percentage.

$$\% \, VR = \frac{V_S - V_R}{V_R} \times 100$$

2. Transmission efficiency is defined as the ration of receiving end power PR to the sending end power PS and it is expressed in percentage value.
3.

$$\% \, \eta T = \frac{P_R}{P_S} \times 100 = \frac{V_R I_R \cos \theta_R}{V_S I_S \cos \theta_S} \times 100$$

RESULT: Efficiency and Regulation for different loaded conditions on 3-ph Tr line Obtained.

6. L-G, L-L & LL-G FAULT ANALYSIS OF AN ALTERNATOR

Aim:

To determine the fault currents on an unloaded synchronous generator for

1. Line to ground fault (L-G Fault)
2. Line to Line fault(L-L fault)
3. Double Line to ground fault(LL-G Fault)

APPARATUS REQUIRED:

S.No	Apparatus required	Type	Range	Quantity
1	Dc motor-Alternator set		-	01
2	voltmeter	AC	(0-500)V	01
3	Ammeters	DC	(0-2)A,(0-20)A	02
4	Ammeter	AC	(0-5)A	01
5	Rheostat	Wire wound	370Ω/1.7A	01

THEORY:

SINGLE LINE-TO-GROUND FAULT:

Consider a 3-phase system with an earthed neutral. Let a single line-to-ground fault occur on the red phase as shown in Fig. 18.13. It is clear from this figure that :

$$*\vec{V_R} = 0 \quad \text{and} \quad \vec{I_B} = \vec{I_Y} = 0$$

* Note that V_R is the terminal potential of phase R *i.e.* p.d. between N and R. Under line-to-ground fault, it will obviously be zero.

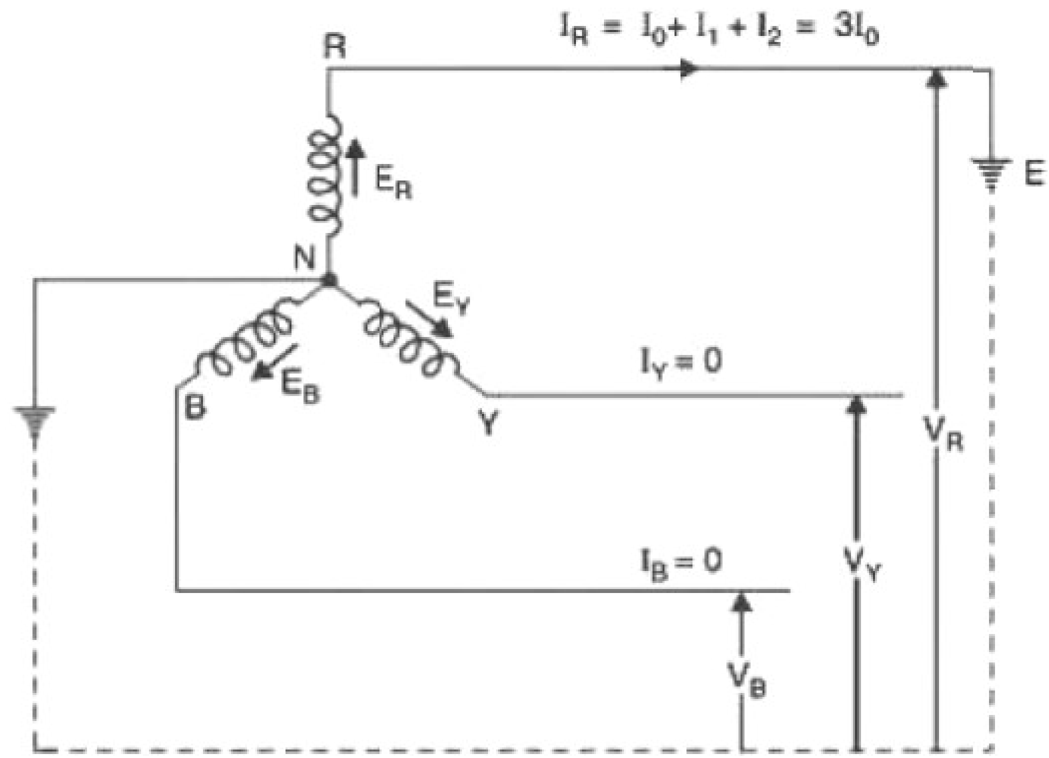
The sequence currents in the red phase in terms of line currents shall be

$$\vec{I_0} = \frac{1}{3}\left(\vec{I_R} + \vec{I_Y} + \vec{I_B}\right) = \frac{1}{3}\vec{I_R}$$

$$\vec{I_1} = \frac{1}{3}\left(\vec{I_R} + a\,\vec{I_Y} + a^2\,\vec{I_B}\right) = \frac{1}{3}\vec{I_R}$$

$$\vec{I_2} = \frac{1}{3}\left(\vec{I_R} + a^2\,\vec{I_Y} + a\,\vec{I_B}\right) = \frac{1}{3}\vec{I_R}$$

$$\vec{I_0} = \vec{I_1} = \vec{I_2} = \frac{1}{3}\vec{I_R}$$



For line (R-phase)-to-ground fault :

$$\overrightarrow{I_R} = \text{Fault current} = \frac{3\,\overrightarrow{E_R}}{\overrightarrow{Z_1} + \overrightarrow{Z_2} + \overrightarrow{Z_0}} \quad : \quad \overrightarrow{I_Y} = 0 \quad : \quad \overrightarrow{I_B} = 0$$

$$\overrightarrow{V_R} = 0$$

$$\overrightarrow{V_Y} = \overrightarrow{V_0} + a^2\,\overrightarrow{V_1} + a\,\overrightarrow{V_2}$$

$$\overrightarrow{V_B} = \overrightarrow{V_0} + a\,\overrightarrow{V_1} + a^2\,\overrightarrow{V_2}$$

For line (R-phase)-to-ground fault :

$$\overrightarrow{I_R} = \text{Fault current} = \frac{3\,\overrightarrow{E_R}}{\overrightarrow{Z_1} + \overrightarrow{Z_2} + \overrightarrow{Z_0}} \quad : \quad \overrightarrow{I_Y} = 0 \quad : \quad \overrightarrow{I_B} = 0$$

$$\overrightarrow{V_R} = 0$$

$$\overrightarrow{V_Y} = \overrightarrow{V_0} + a^2\,\overrightarrow{V_1} + a\,\overrightarrow{V_2}$$

$$\overrightarrow{V_B} = \overrightarrow{V_0} + a\,\overrightarrow{V_1} + a^2\,\overrightarrow{V_2}$$

Fault current. First of all expression for fault current $\overrightarrow{I_R}$ will be derived. Let $\overrightarrow{Z_1}$, $\overrightarrow{Z_2}$ and $\overrightarrow{Z_0}$ be the positive, negative and zero sequence impedances of the generator respectively. Consider the closed loop *NREN*. As the sequence currents produce voltage drops due only to their respective sequence impedances, therefore, we have,

$$\overrightarrow{E_R} = \overrightarrow{I_1}\,\overrightarrow{Z_1} + \overrightarrow{I_2}\,\overrightarrow{Z_2} + \overrightarrow{I_0}\,\overrightarrow{Z_0} + \overrightarrow{V_R}$$

As $\quad \overrightarrow{V_R} = 0$ and $\overrightarrow{I_1} = \overrightarrow{I_2} = \overrightarrow{I_0}$

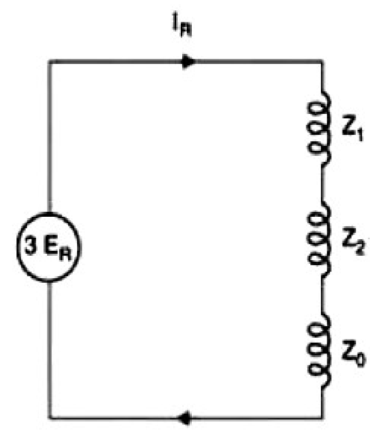
$$\overrightarrow{E_R} = \overrightarrow{I_0}\left(\overrightarrow{Z_1} + \overrightarrow{Z_2} + \overrightarrow{Z_0}\right)$$

or

$$\overrightarrow{I_0} = \frac{\overrightarrow{E_R}}{\overrightarrow{Z_1} + \overrightarrow{Z_2} + \overrightarrow{Z_0}}$$

Fault current,

$$\overrightarrow{I_R} = 3\,\overrightarrow{I_0} = \frac{3\,\overrightarrow{E_R}}{\overrightarrow{Z_1} + \overrightarrow{Z_2} + \overrightarrow{Z_0}} \quad \ldots(i)$$



For line (R-phase)-to-ground fault :

$$\overrightarrow{I_R} = \text{Fault current} = \frac{3\,\overrightarrow{E_R}}{\overrightarrow{Z_1} + \overrightarrow{Z_2} + \overrightarrow{Z_0}} \quad ; \quad \overrightarrow{I_Y} = 0 \quad ; \quad \overrightarrow{I_B} = 0$$

$$\overrightarrow{V_R} = 0$$

$$\overrightarrow{V_Y} = \overrightarrow{V_0} + a^2\,\overrightarrow{V_1} + a\,\overrightarrow{V_2}$$

$$\overrightarrow{V_B} = \overrightarrow{V_0} + a\,\overrightarrow{V_1} + a^2\,\overrightarrow{V_2}$$

SINGLE LINE-TO-LINE FAULT:

Consider a line-to-line fault between the blue (B) and yellow (Y) lines as shown in Fig. 18.15. The conditions created by this fault lead to :

$\overrightarrow{V_Y} = \overrightarrow{V_B}$; $\overrightarrow{I_R} = 0$ and $\overrightarrow{I_Y} + \overrightarrow{I_B} = 0$

Again taking R-phase as the reference, we have,

$$\overrightarrow{I_0} = \frac{1}{3}\left(\overrightarrow{I_R} + \overrightarrow{I_Y} + \overrightarrow{I_B}\right) = 0$$

Now $$\overrightarrow{V_Y} = \overrightarrow{V_B}$$

Expressing in terms of sequence components of red line, we have,

$$\overrightarrow{V_0} + a^2\,\overrightarrow{V_1} + a\,\overrightarrow{V_2} = \overrightarrow{V_0} + a\,\overrightarrow{V_1} + a^2\,\overrightarrow{V_2}$$

or $$\overrightarrow{V_1}\,(a^2 - a) = \overrightarrow{V_2}\,(a^2 - a)$$

$$\overrightarrow{V_1} = \overrightarrow{V_2} \qquad \text{...}(i)$$

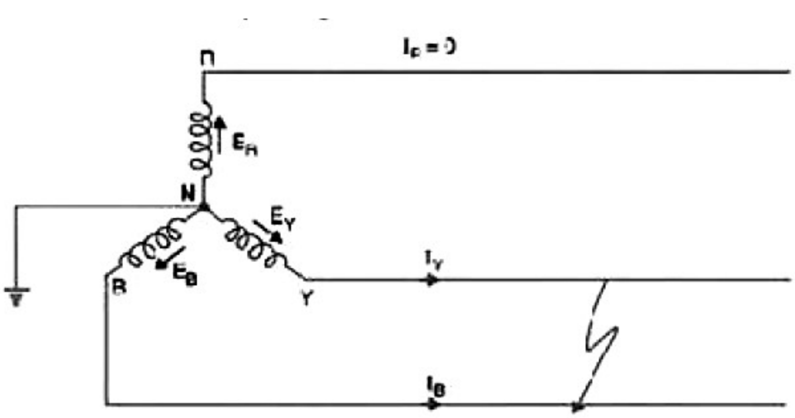


Fig. 18.15.

Also $\vec{I_Y} + \vec{I_B} = 0$

or $\left(\vec{I_0} + a^2 \vec{I_1} + a \vec{I_2}\right) + \left(\vec{I_0} + a \vec{I_1} + a^2 \vec{I_2}\right) = 0$

or $(a^2 + a)\left(\vec{I_1} + \vec{I_2}\right) + 2\vec{I_0} = 0$

or $\vec{I_1} + \vec{I_2} = 0$ $\quad [\because I_0 = 0]$ ...(*ii*)

Fault current. Examination of exp. (*i*) and exp (*ii*) reveals that sequence impedances should be connected as shown in Fig. 18.16. It is clear from the figure that :

$$\vec{I_1} = -\vec{I_2} = \frac{\vec{E_R}}{\vec{Z_1} + \vec{Z_2}}$$

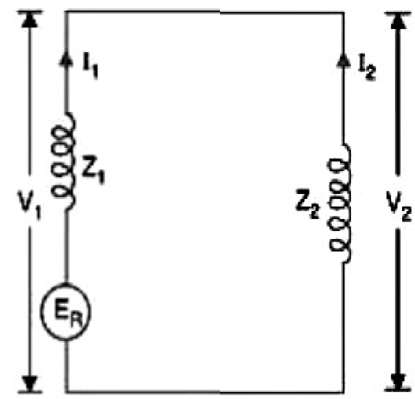


Fig. 18.16

Fault current, $\vec{I_Y} = \vec{I_0} + a^2 \vec{I_1} + a \vec{I_2}$

$$= 0 + a^2\left(\frac{\vec{E_R}}{\vec{Z_1} + \vec{Z_2}}\right) + a\left(\frac{-\vec{E_R}}{\vec{Z_1} + \vec{Z_2}}\right)$$

$$= (a^2 - a)\frac{\vec{E_R}}{\vec{Z_1} + \vec{Z_2}}$$

$$= \frac{-j\sqrt{3}\,\vec{E_R}}{\vec{Z_1} + \vec{Z_2}} = -\vec{I_B}$$

Summary of Results. For line-to-line fault (Blue and Yellow lines)

(*i*) $\vec{I_R} = 0 \;;\; \vec{I_Y} = -\vec{I_B} = \dfrac{-j\sqrt{3}\,\vec{E_R}}{\vec{Z_1} + \vec{Z_2}}$

(*ii*) $\vec{V_Y} = \vec{V_B} = -\dfrac{\vec{Z_2}}{\vec{Z_1} + \vec{Z_2}}\vec{E_R}$ and $\vec{V_R} = \dfrac{2\vec{Z_2}}{\vec{Z_1} + \vec{Z_2}}\vec{E_R}$

DOUBLE-TO-LINE-GROUND:

Consider the double line-to-ground fault involving Y–B lines and earth as shown in Fig. 18.17. The conditions created by this fault lead to :

$$\vec{I_R} = 0 \quad ; \quad \vec{V_Y} = \vec{V_B} = 0$$

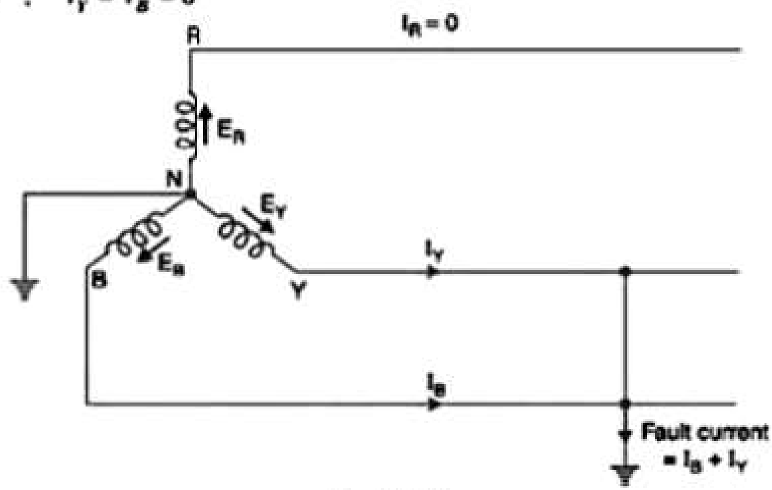


Fig. 18.17

Since $\vec{V_Y} = \vec{V_B} = 0$, it is implied that :

$$\vec{V_1} = \vec{V_2} = \vec{V_0} = \frac{1}{3}\vec{V_R} \quad ...(i)$$

Also

$$\vec{I_R} = \vec{I_1} + \vec{I_2} + \vec{I_0} = 0 \quad (given) \quad ...(ii)$$

Fault current. Examination of exp. (i) and exp. (ii) reveals that sequence impedances should be *connected as shown in Fig. 18.18. It is clear that :

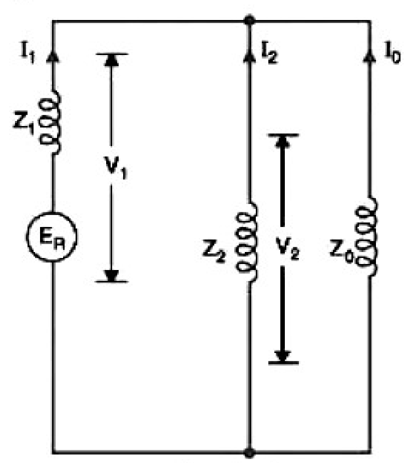


Fig. 18.18

$$\vec{I_1} = \frac{\vec{E_R}}{\vec{Z_1} + \dfrac{\vec{Z_2}\,\vec{Z_0}}{\vec{Z_2} + \vec{Z_0}}}$$

$$\vec{I_2} = -\vec{I_1}\,\frac{\vec{Z_0}}{\vec{Z_2} + \vec{Z_0}}$$

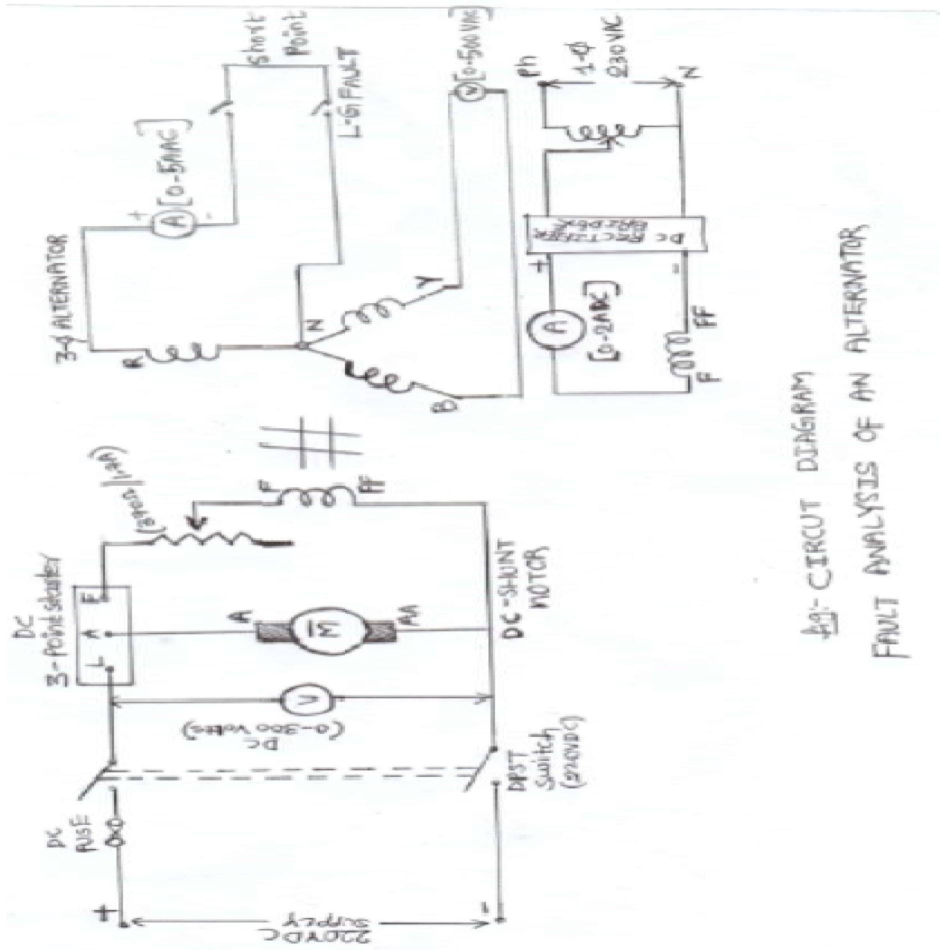
$$\vec{I_0} = -\vec{I_1}\,\frac{\vec{Z_2}}{\vec{Z_2} + \vec{Z_0}}$$

Fault current, $\vec{I_F} = \vec{I_Y} + \vec{I_B} = 3\,\vec{I_0} ** = 3\left(-\vec{I_1}\,\dfrac{\vec{Z_2}}{\vec{Z_2} + \vec{Z_0}}\right)$

$$= -\frac{3\,\vec{Z_2}}{\vec{Z_2} + \vec{Z_0}} \times \frac{\vec{E_R}}{\vec{Z_1} + \dfrac{\vec{Z_2}\,\vec{Z_0}}{\vec{Z_2} + \vec{Z_0}}}$$

$$= -\frac{3\,\vec{Z_2}\,\vec{E_R}}{\vec{Z_0}\,\vec{Z_1} + \vec{Z_0}\,\vec{Z_2} + \vec{Z_1}\,\vec{Z_2}}$$

Circuit Diagram for L-G Fault:



PROCEDURE:

L-G FAULT:

1 Connect the circuit as per the circuit diagram for a line to ground fault on phase A.

2. Calculate the determinate value of the fault current from impedances (+ve, -ve, Zero sequences).

3. Run the generator rated speed.

4. Increase the field current of excitation so that terminal voltage is constant value.

5. Close the switch to create the L-G fault on Phase A.

6. Note the current and voltage in the ammeter and voltmeter.

7. Open the switch and remove the L-G fault on phase A.

8. Reduce the excitation and open the field circuit witch and switch of the prime mover.

Note: This voltage must be such that it does not cause the rated current of the machine to be exceeded

TABULATION:

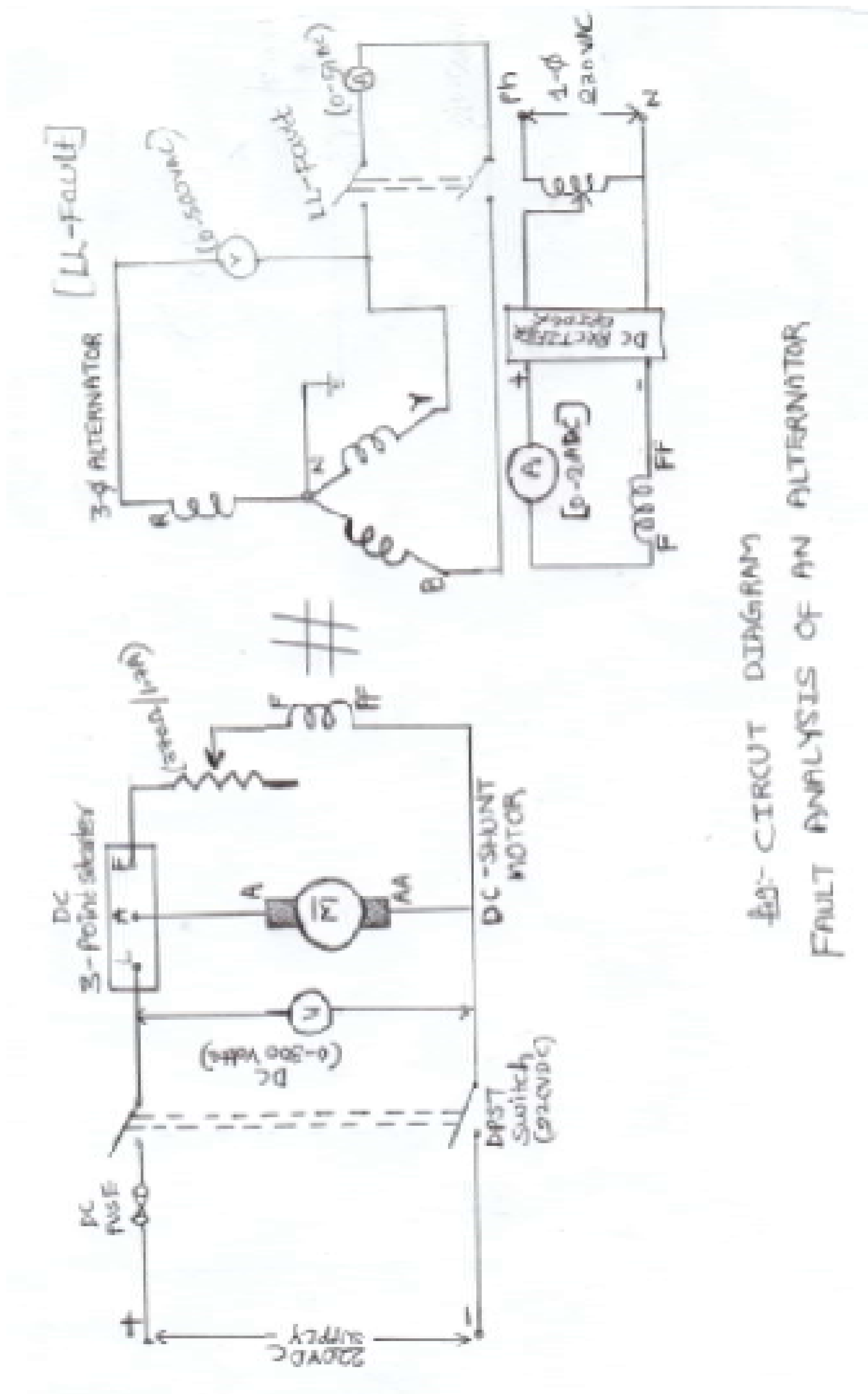
For 3KVA alternator

S.No.	Voltage(V)	Current(A)
1	102.8	4.234

Ia = 3Er/Z1+Z2+Z0 ------------------------------ (1)

Where Ia is fault current Ef is the voltage to which the machine is excited Z1+Z2+Z0are the positive, negative and zero sequence impedances of the machine. Verify the theoretical value calculated by using equation1 with the actual value noted by the ammeter.

Circuit diagram for line to line fault (L-L fault):



Procedure:

L-L Fault:

1. Repeat the steps 1 to 6 from L-G Fault procedure for L-L and L-G faults.
2. Connect the respective circuit in step 1.
3. Generator is excited it's a certain voltage as mention in step 2 of the procedure.
4. This voltage must be such that it does not cause the rated current of the machine to be exceeded.

TABULATION:

For 3KVA alternator

S.No.	**Voltage(V)**	**Current(A)**
1	216.6	4.237

Ia1=Ef/Z1+Z2

Ib =a2Ia1+a Ia2; Ia2=-Ia1

Where a2= (-0.5-j0.866) a= (-0.5+j0.866)

Fault current calculated which must be verified with the actual value.

CIRCUIT DIAGRAM FOR DOUBLE LINE TO GROUND FAULT (LL-G FAULT):

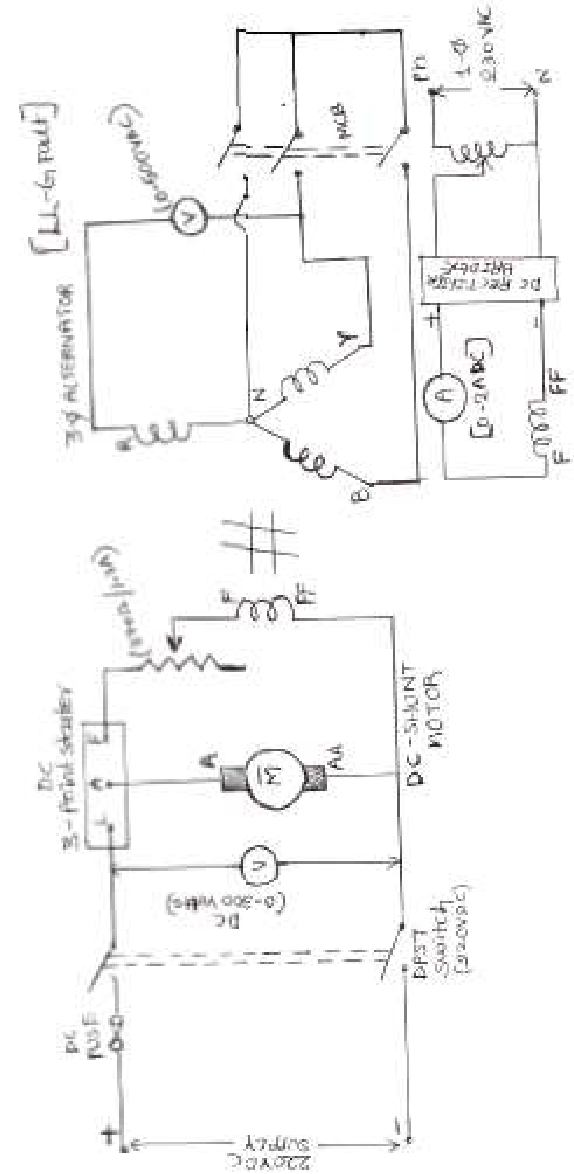


Fig: CIRCUIT DIAGRAM FAULT ANALYSIS OF AN ALTERNATOR

LL-G fault:

(1) Repeat the steps 1 to 6 from L-G Fault procedure for L-L and L-G faults.

(2) Connect the respective circuit in step 1.

(3) Generator is excited it's a certain voltage as mention in step 2 of the procedure.

TABULATION:

For 3KVA alternator

S.No.	Voltage(V)	Current(A)
1	47	4.2

E_f= Short circuit Voltage at Fault condition.

I = Rated Current of Alternator.

E_r = armature Voltage of alternator.

Calculations:

Va1=Va2=Va0=Ef-Ia1Z1

Ia1=Ef/Z1+ (Z2 x Z0/Z2+Z0) Ia2=-Va2/Z2; Ia0= -Va0/Z0

Ib= a^2Ia1+a Ia2+Ia0

Where a^2= (-0.5+j0.866);

a= (-0.5+j0.866) In =3Ia0= Ib+IC

Ic= -Ib=a Ia1-a^2Ia1

Fault Analysis of an Alternator

1) L-G Fault :- $E_r = \frac{187}{\sqrt{3}} = 108$ volts (L-G).

$\therefore$ Positive seq. Impedance $(Z_1) = 47\Omega$.

$\therefore$ Negative seq. Impedance $(Z_2) = 24\Omega$.

$\therefore$ zero seq. Impedance $(Z_0) = 6.8\Omega$.

$E_r = 108$ volts; $I = 4.2A$

$$\therefore I_R = 3 \times I_0 = \frac{3 \times E_R}{Z_1 + Z_2 + Z_0} = \frac{3 \times 108}{47 + 24 + 6.8} = 4.16\,A$$

$\therefore I_R = 4.16$ Amps.

2) L-L Fault :- $(E_F = 184$ Volts$)$ (L-L)

$$\therefore I_{a_1} = \frac{E_F}{Z_1 + Z_2} = \frac{184}{47 + 24} = 2.6 \text{ Amps.}$$

$$\therefore I_b = a^2 I_{a_1} + a I_{a_2}$$

$$\Rightarrow a^2 = (-0.5 + j0.866)$$
$$a = (-0.5 - j0.866).$$

$$\Rightarrow 3.554 + 0.866 = 4.46 \text{ Amps.}$$

$\therefore I_b = 4.46$ Amps.

3) L-L-G FAULT :- V = 155 volts. (L-L-G).

$$\therefore I_1 = \frac{E_R = 155}{Z_1 + \frac{Z_2 \times Z_0}{Z_2 + Z_0}} = 1.7 \text{ Amps.}$$

$$\therefore I_2 = -I_1 \frac{Z_0}{Z_2 + Z_0} = 0.385 \text{ Amps.}$$

$$\therefore I_0 = -I_1 \times \frac{Z_2}{Z_1 + Z_0} = +1.36 \text{ Amps.}$$

$$\therefore \text{Fault Current } (I_{f}) = 3 \times I_0 = 3 \times (1.36)$$
$$= 4.08 \text{ Amps.}$$

$$\Rightarrow \frac{3 \times Z_2 \times E_R}{Z_0 Z_1 + Z_0 Z_2 + Z_1 Z_2} = 3.98 \text{ Amps.}$$

$\therefore Z_1 = 47\Omega$
$\therefore Z_2 = 24\Omega$
$\therefore Z_0 = 6.8\Omega$

RESULT: Un-Balanced faults on a 3-ph Alternator performed.

7. DETERMINATION OF POSITIVE, NEGATIVE AND ZERO SEQUENCES OF A 3-PHASE TRANSFORMER

Aim:

To determine the Positive, Negative and Zero sequence (sequence impedance) of given three phase transformer.

Apparatus required:

S.No	Apparatus	Type	Quantity
1	Voltmeters	0-500V,	1 No
2	Ammeter	20A	1 No
3	3-Phase Transformer	Shell type	1 No
4	Auto transformer	Closed type	1 No
5	Patch cords		As required

Theory:

Each element of power system will offer impedance to different phase sequence components of current which may not be the same. For example, the impedance which any piece of equipment offers to positive sequence current will not necessarily be the same as offered to negative sequence current or zero sequence current. Therefore, in unsymmetrical fault calculations, each piece of equipment will have three values of impedance—one corresponding to each sequence current viz.

(i) Positive sequence impedance (Z1) (ii) Negative sequence impedance(Z2)

(iii) Zero sequence impedance (Z0)

The impedance offered by an equipment or circuit to positive sequence current is called positive sequence impedance and is represented by Z1. Similarly, impedances offered by any circuit or equipment to negative and zero sequence currents are respectively called negative sequence impedance(Z2) and zero sequence impedance (Z0).In a 3-phase balanced system, each piece of equipment or circuit offers only one impedance–the one offered to positive or normal sequence current. This is expected because of the absence of negative and zero sequence currents in the 3-phase balanced system. In a 3-phase unbalanced system, each piece of equipment or circuit will have three values of impedance viz.

positive sequence impedance, negative sequence impedance and zero sequence impedance. The positive and negative sequence impedances of linear, symmetrical and static circuits (e.g. transmission lines, cables, transformers and static loads) are equal and are the same as those used in the analysis of balanced conditions. This is due to the fact that impedance of such circuits is independent of the phase order, provided the applied voltages are balanced. It may be noted that positive and negative sequence impedances of rotating machines (e.g. Synchronous and induction motors) are normally different.

The zero sequence impedance depends upon the path taken by the zero sequence current. As this path is generally different from the path taken by the positive and negative sequence currents, therefore, zero sequence impedance is usually different from positive or negative sequence impedance.

The positive sequence impedance of a transformer equals the leakage impedance. It may be obtained usual short circuit test. Since the transformer is a static device, the leakage impedance does not change, if the phase sequence is altered from RYB to RBY. Therefore the negative sequence impedance of transformer is the same as the positive sequence impedance.

The zero sequence impedance of the transformer depends on the winding type (star or delta) and also on the type of earth connection. The positive & negative sequence per unit impedances are independent of whether the sequence currents are injected into the primary or the secondary.

However the zero sequence impedances will have different values, depending upon whether the sequence currents are injected into the primary or the secondary Since Transformers have the same impedance with reversed phase rotation, their +ve and – ve sequence impedances are equal. This value being equal to the impedance of the Transformer.

However, Zero sequence impedance depends upon the Earth connection. If there is a through Circuit for the earth current, zero sequence impedance will be equal to the +ve sequence impedance otherwise it will be infinite. Lab experiment is planned to find out sequence impedances by creation of faults at secondary suitably and measure impedances. Proper care is taken to ensure readings would not damage the equipment.

Formulae
used:

$$Z_1 = Z_2 = V / \sqrt{3}I \text{ ;}$$

$$Z_0 = V / 3I$$

Measurement of the positive and negative sequence impedances: Circuit Diagram:

Fig 1

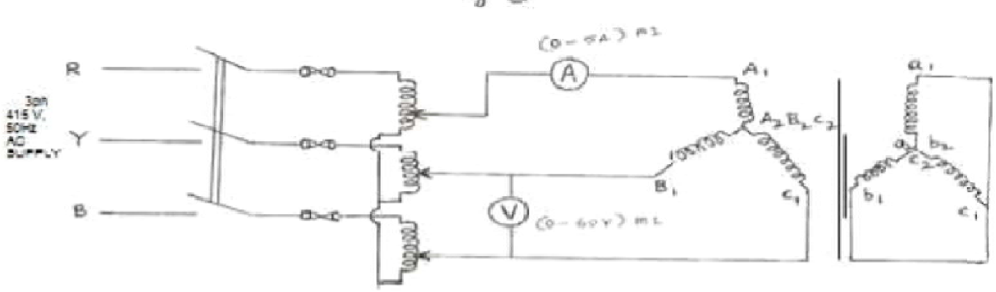
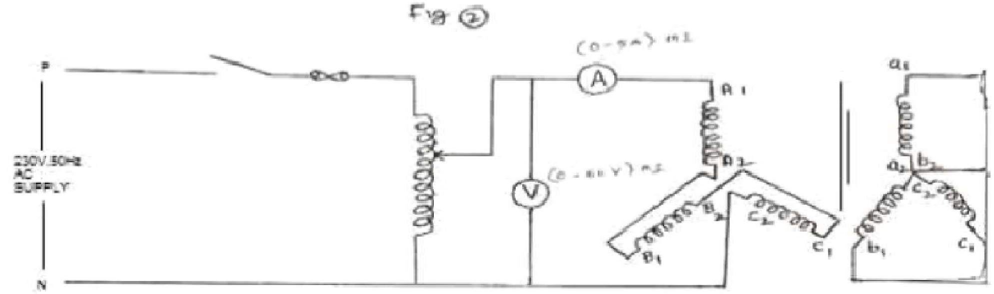


Fig 2



Transformer Details :

- Rating : 1 KVA
- Voltage Rating: 400V/200V (L-L)
- Primary Current : 1.4A (Per Phase)

Procedure:

1. Connect the transformer to the variable 3-phase supply (auto transformer) as shown in the figure. (1)
2. Connect active circuit on HV side (400V) and Short circuit on Low voltage side (200V).
3. Vary the 3-phase autotransformer so that the rated current (1.4) Amps flow through the HV side.
4. Note down the readings of wattmeter, voltmeter and Ammeter.

Readings and Tabular form: $Z_1=Z_2=Z_l$

Short circuit voltage Vsc (V)	Short circuit Current Isc (A)	Leakage impedance (Vsc/1.732* Isc)
22.3	3.02	4.24

Measurement of the Zero sequence impedance: Procedure:

1. Connect the transformer to the variable 1-phase supply (auto transformer) as shown in the figure. (2)
2. Connect active circuit on HV side (400V) Short circuit on Low voltage side (200V).
3. Vary the 3-phase autotransformer so that the rated current (1.4) Amps flow through the HV side.
4. Note down the readings of wattmeter, voltmeter and Ammeter.

Readings and Tabular form:

Applied voltage V (V)	Line Current I (A)	Z0= (V/3* I)
48	3.11	5.145

Result: Sequence impedances of Transformer

$Z_1=Z_2=Z_L=4.24$

Zero sequence impedance $Z_0=5.14$

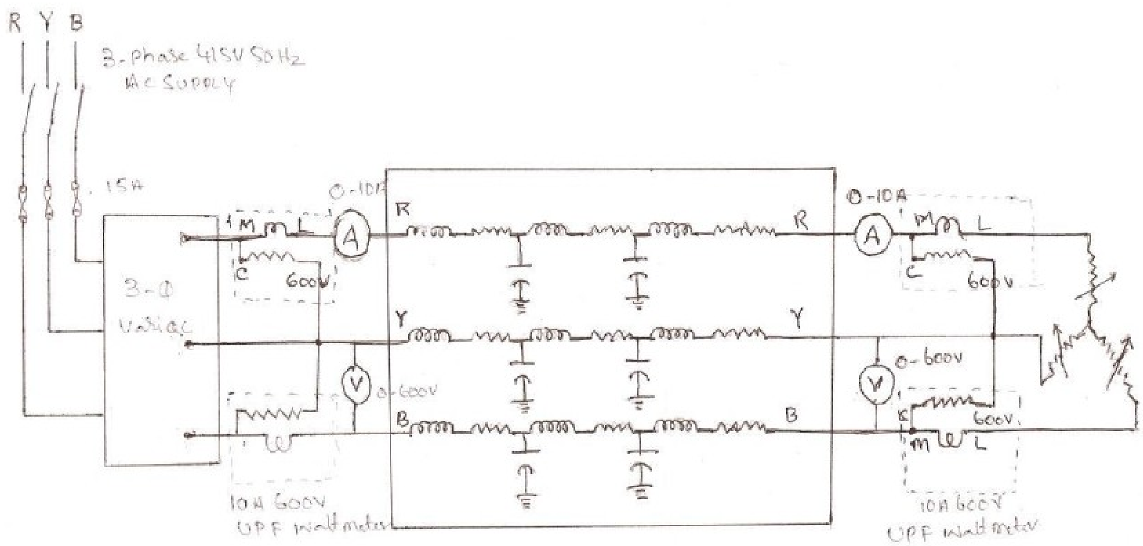
8. STATIC VAR COMPENSATION

Aim: Improvement of power factor of load by connecting static capacitor across the load

Apparatus required:

S NO	Apparatus Required	Range	Type	Quantity
1	Transmission line Model		Long	01
2	Voltmeter	(0-500)V	Digital	02
3	Ammeter	(0-10)A	Digital	02
4	Capacitor bank		Fixed	04
5	Wattmeter	(0-500)V/10A	Electro dynamo	02

Circuit Diagram:



Theory:

Capacitor will give reactive power rather taking reactive power from supply unlike inductor. To improve power factor they are connected in parallel with load. It will give reactive power to load so that reactive power requirement from the source decreases.

1) This way transmission loss can be reduced.
2) No need to erect new transmission line as load increases.
3) For improving stability limits of the system.

   Capacitors are generally connected to a bus bar and are disposed along the route to minimize the losses and voltage drops. Capacitors are constant impedance type load and its value is proportional to square of the magnitude of the voltage.

   As the voltage falls, the VARs produced by a shunt capacitor falls. Thus, when need most, their effectiveness falls.

Procedure:

1) Connections are given as per circuit diagram.
2) Take readings under no load conditions where Ferranti Effect may be observed.
3) Connect 1A load at receiving end side and measure all the quantities.
4) Apply 1 Capacitor across load so that power will be improved.
5) Repeat the same for all loaded conditions with and without compensation.

6) Switch off supply after completion of experiment.

Tabular Column:

Sl. No	Vs (V)	Is (A)	W1 (kw)	W2 (kw)	Vr (V)	Ir (A)	W1 (kw)	W2 (kw)	V_{L-L} (V)	Load in Amps	Power factor
1	400	1.604	0.25	0	403.4	0	0	0	413.4	-	-
2	400	1.376	0.4	0	400.8	0.87	0.15	0	409.9	1	0.89 lag
3	398.4	1.878	0.45	0	397.8	0.51	0.2	0.25	409.7	8μF	0.833 lead
4	400	1.07	0.35	0.12	399.6	1.36	0.15	0.4	408.7	2	0.69 lag
5	402.2	2.48	0.4	0.12	397.1	0.95	0.15	0.4	413.6	28 μF	0.65 lead
6	400	1.64	0.55	0.42	396.1	2.19	0.2	0.8	404.8	3	0.77 lag
7	400.6	2.62	0.6	0.42	392	1.17	0.3	0.8	408.6	38 μF	0.753 lead

Precautions:

1) Connections are made properly and neutral should properly inserted.
2) Measuring instruments should be choosen according to rated conditions.

Result:

Power factor of load improved of a load from lagging to leading by consequent addition of capacitors which are suitable to maintain power factor at unity.