ABCD constants, Regulation and Efficiency of 3-φ Transmission line model

AIM: 1. Determine ABCD constants of a 3-Φ Transmission line model
2. Determine efficiency and Regulation of a 3-Φ Transmission line model

APPARATUS:

S.No	Apparatus	Range	Quantity
1.	3-Φ Auto transformer	415/0-440V	01
2.	Transmission line Model	--	01
3.	Inductors		
4.	Capacitors		
5.	Digital Ammeters	0 – 10A	01
6.	Digital Voltmeters	0 – 500V	01
7.	Digital Wattmeter	500V,10A	01
8.	3-Φ Resistive load	4kW	01
9.	Connecting Wires	-	As required

THEORY:

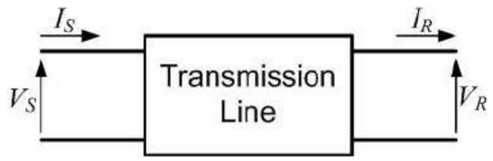


Fig. Two port representation of a transmission network.

Consider the power system shown in Fig. The sending and receiving end voltages are denoted by V_S and V_R respectively and the currents I_S and I_R are entering and leaving the network respectively. The sending end voltage and current are then defined in terms of the ABCD parameters as

$$V_S = AV_R + BI_R$$
$$I_S = CV_R + DI_R$$

$$A = \left.\frac{V_S}{V_R}\right|_{I_R=0} \qquad B = \left.\frac{V_S}{I_R}\right|_{V_R=0}$$

$$C = \left.\frac{I_S}{V_R}\right|_{I_R=0} \qquad D = \left.\frac{I_S}{I_R}\right|_{V_R=0}$$

ABCD constants, Regulation and Efficiency of 3-φ Transmission line model

A,B,C,D Parameters of a transmission line should be determined by performing 'open-circuit' and 'short-circuit' test on the both sending and receiving end sides. Let,

Z_{SO}= V_S / I_S = Line impedance measured at sending end with receiving end open-circuited.

Z_{SS}= V_S / I_S = Line impedance measured at sending end with receiving end short-circuited.

Z_{RO}= V_R / I_R = Line impedance measured at receiving end with sending end open-circuited.

Z_{RS}= V_R / I_R = Line impedance measured at receiving end with sending end short-circuited.

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

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

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

D =A

Regulation of Transmission Line:

When the load is supplied, there is a voltage drop in the line due to resistance and inductance of the line and, therefore, receiving-end voltage V_R is usually less than sending-end voltage V_S. The voltage drop i.e., difference of sending-end voltage and receiving- end voltage expressed as a percentage of receiving-end voltage is called the regulation.

Mathematically percentage voltage regulation of a transmission line is given by the expression:

$$\%\ \text{voltage regulation} = \frac{V_S - V_R}{V_R} \times 100$$

Efficiency of Transmission Line:

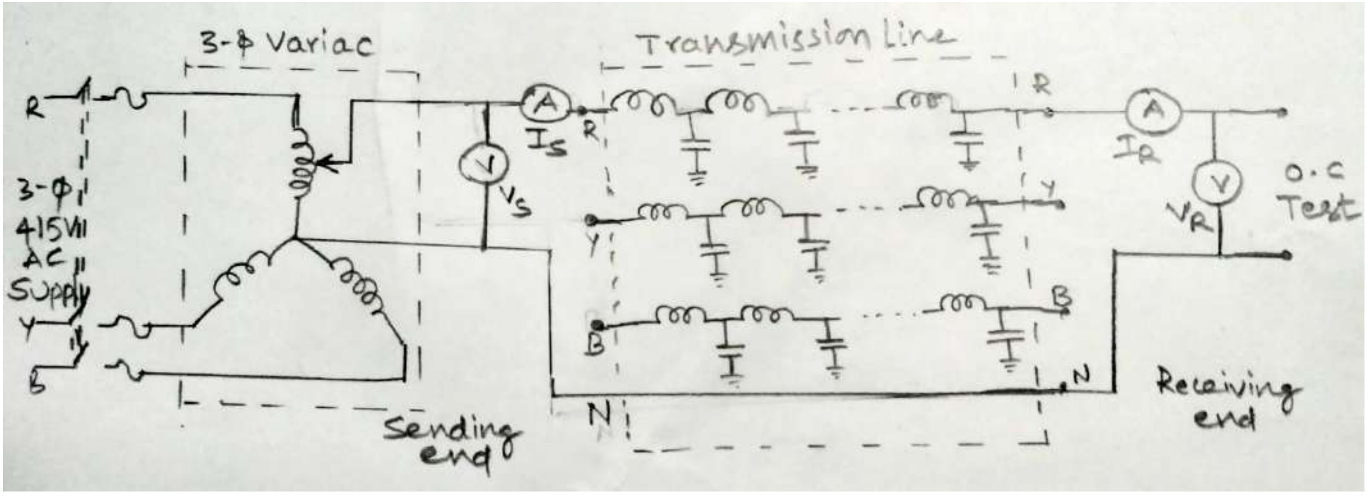
Efficiency of a transmission line is defined as the ratio of power delivered at the receiving end to the power sent from the sending end.

Mathematically transmission efficiency is given by the expression:

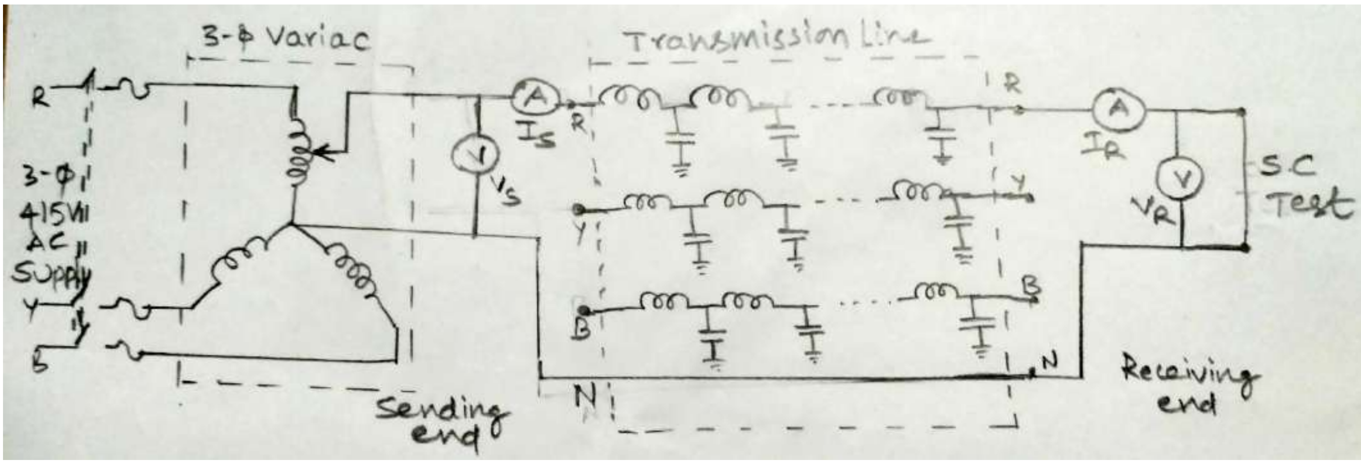
$$\%\ \eta T = \frac{P_R}{P_S} \times 100 = \frac{V_R I_R \cos\theta_R}{V_S I_S \cos\theta_S} \times 100$$

ABCD constants, Regulation and Efficiency of 3-φ Transmission line model

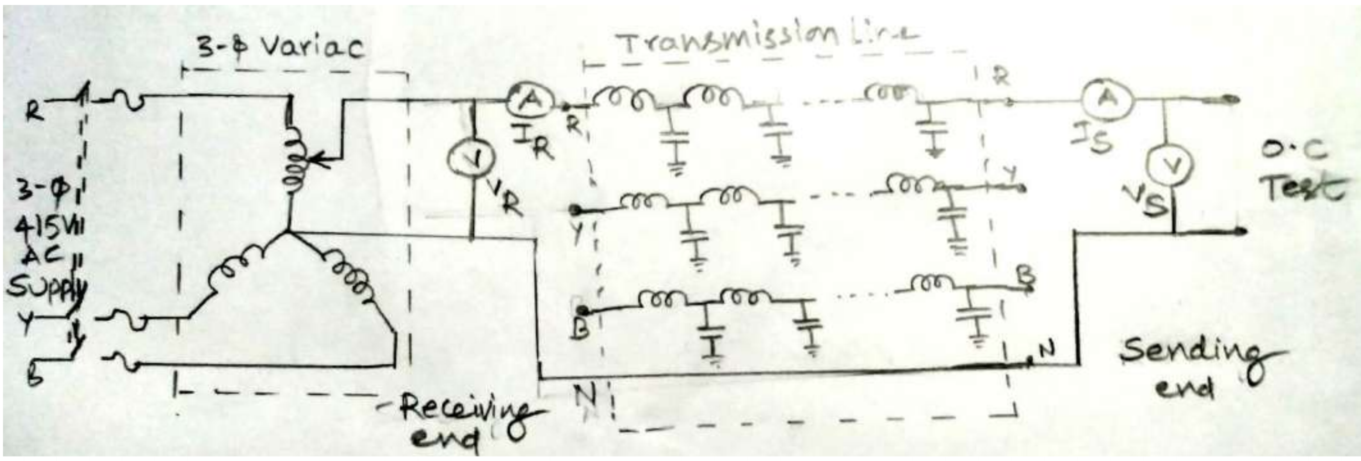
CIRCUIT DIAGRAMS for ABCD CONSTANTS:



Fig(1). O.C.Test at Receiving end side.

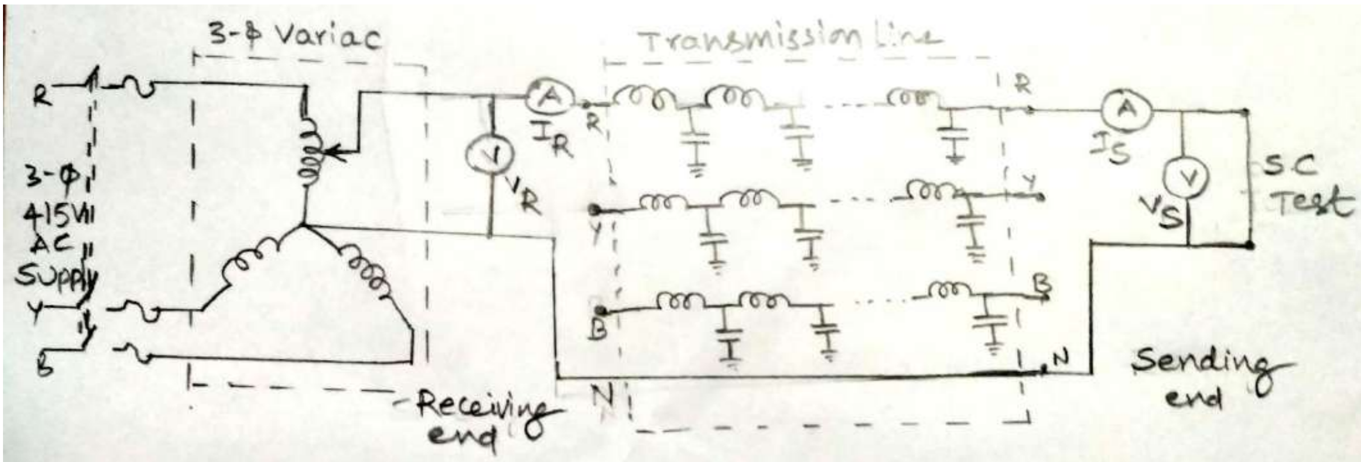


Fig(2). S.C.Test at Receiving end side.



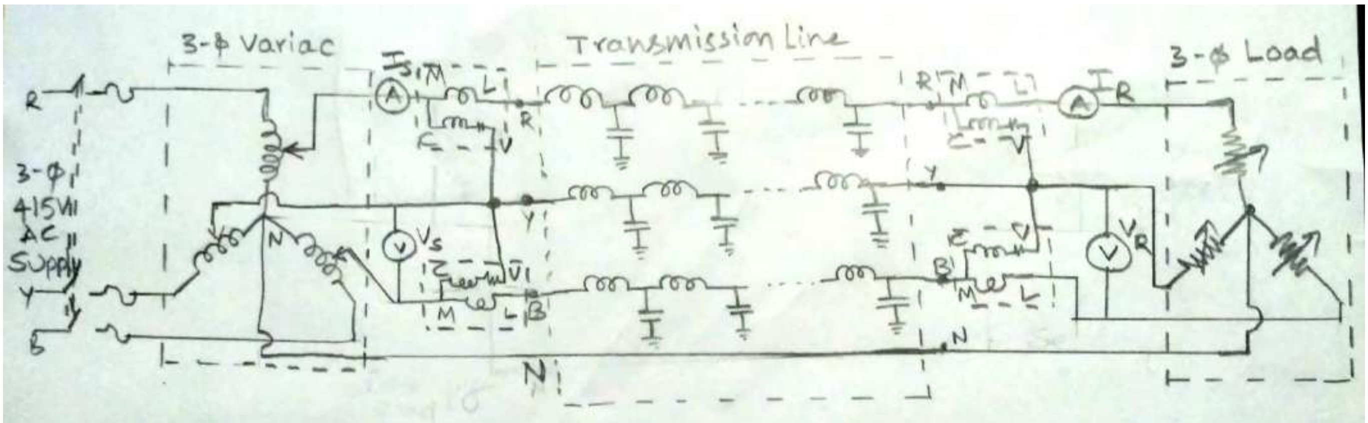
ABCD constants, Regulation and Efficiency of 3-φ Transmission line model

Fig(3). O.C.Test at sending end side.



Fig(4). S.C.Test at sending end side.

<u>CIRCUIT DIAGRAM for REGULATION and EFFICIENCY</u>:



Fig(5). Regulation and efficiency test.

PROCEDURE:

<u>O.C& S.C. tests at Receiving end side:</u>

1. Connect the circuit as per Fig.(1) for O.C. test at receiving end side.
2. 3-Φ Variac should be in minimum position and receiving end should be kept open.
3. Switch on mains.
4. Apply 230V at sending end side using 3-Φ Variac.
5. Note down Vs, Is, V_R and I_R meter readings.
6. Bring back the 1-Φ Variac to its minimum position and switch off the mains.
7. Connect the circuit as per Fig.(2) for S.C. test at receiving end side.
8. 3-Φ Variac should be in minimum position and receiving end should be short with ammeter.

9. Switch on mains.
10. Apply rated current of 5A at sending end side using 3-Φ Variac.
11. Note down Vs, Is, V_R and I_R meter readings.
12. Bring back the 1-Φ Variac to its minimum position and switch off the mains.

O.C& S.C. tests at sending end side:

1. Connect the circuit as per Fig.(3) for O.C. test at sending end side.
2. 3-Φ Variac should be in minimum position and sending end should be kept open.
3. Switch on mains.
4. Apply 230V at receiving end side using 3-Φ Variac.
5. Note down Vs, Is, V_R and I_R meter readings.
6. Bring back the 1-Φ Variac to its minimum position and switch off the mains.
7. Connect the circuit as per Fig.(4) for S.C. test at sending end side.
8. 3-Φ Variac should be in minimum position and sending end should be short with ammeter.
9. Switch on mains.
10. Apply rated current of 5A at receiving end side using 3-Φ Variac.
11. Note down Vs, Is, V_R and I_R meter readings.
12. Bring back the 1-Φ Variac to its minimum position and switch off the mains.
13. Calculate ABCD constants using appropriate equations.

Regulation and efficiency of 3-Φ transmission line model:

1. Connect the circuit as per the circuit diagram shown in Fig.(5).
2. 3-Φ Variac should be in minimum position and the 3-Φ resistive load should be kept in OFF position.
3. Switch on mains.
4. Apply 400V at sending end side using 3-Φ Variac.
5. Apply half load i.e 2.5A by switching ON load switch1.
6. Note down Vs, Is, W_{1S}, W_{2S}, V_R, I_R, W_{1R} and W_{2R} meter readings under half-load condition.
7. Apply full load i.e 5A by switching ON load switch1 and 2.
8. Note down Vs, Is, W_{1S}, W_{2S}, V_R, I_R, W_{1R} and W_{2R} meter readings under full-load condition
9. Switch OFF all Load.
10. Note down Vs, Is, W_{1S}, W_{2S}, V_R, I_R, W_{1R} and W_{2R} meter readings under no-load condition.
11. Bring back the 3-Φ Variac to its minimum position and switch off the mains.
12. Calculate Regulation and efficiency under half load, full load and no load conditions using appropriate equations.

ABCD constants, Regulation and Efficiency of 3-φ Transmission line model

TABULAR FORM:

ABCD constants

	V_S (V)	I_S (A)	V_R (V)	I_R (A)	
O.C test on receiving end side				0	$Z_{SO}= V_S / I_S =$
S.C test on receiving end side			0		$Z_{SS}= V_S / I_S =$
O.C test on sending end side		0			$Z_{RO}= V_R / I_R =$
S.C test on sending end side	0				$Z_{RS}= V_R / I_R =$

A	B	C	D

Regulation

	V_S (V)	I_S (A)	V_R (V)	I_R (A)	**% Regulation=** $(V_S - V_R) / V_R * 100$
Half-load					
Full-load					
No-load					

	Sending end power			Receiving end power			
	W_{1S} (w)	W_{2S} (w)	$P_S = W_{1S}+ W_{2S}$ (w)	W_{1R} (w)	W_{2R} (w)	$P_R = W_{1R}+ W_{2R}$ (w)	**% Efficiency=** $P_R / P_S * 100$
Half-load							
Full-load							
No-load							

RESULT:

Name	Roll No	Sign	Date	Marks	Incharge

SEQUENCE IMPEDANCES OF 3-Φ TRANSFORMER

AIM: Determine the Positive, Negative and Zero sequence (sequence impedance) of given three phase transformer.

APPARATUS:

S.No	Apparatus	Range	Quantity
1.	3-Phase Auto transformer	400/0-440Volt	01
2.	3-phase Transformer	1 kVA, 400/200Volt	01
3.	Digital Voltmeter	0-60V	01
4.	Digital Ammeter	0-5A	01
5.	MCB protection		01
6.	Connecting wires		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 (Z_1)

(*ii*) Negative sequence impedance (Z_2)

(*iii*) Zero sequence impedance (Z_0)

The impedance offered by an equipment or circuit to positive sequence current is called positive sequence impedance and is represented by Z_1. Similarly, impedances offered by any circuit or equipment to negative and zero sequence currents are respectively called negative sequence impedance(Z_2) and zero sequence impedance (Z_0). 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 by the 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.

In short,

Positive sequence impedance = Negative sequence impedance

= Impedance of Transformer

Zero sequence impedance = Positive sequence impedance, if there is circuit for earth current

= Infinite, if there is no through circuit for earth current.

Formulae used:

$Z_1 = Z_2 = V/\sqrt{3}I$ **;** 1 kVA Transformer, I=1000/ (√3*400)= 1.443A (rated current)

$Z_0 = V/3I$

Circuit Diagram:

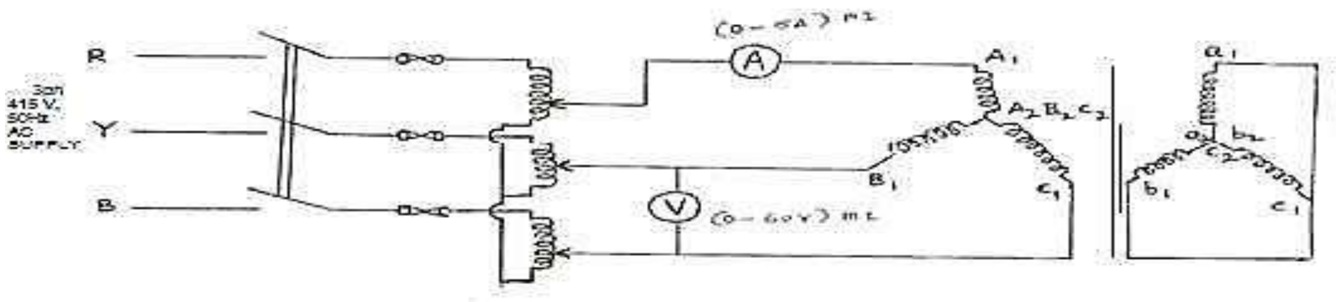


Fig. (1) Measurement of positive/ negative sequence impedance

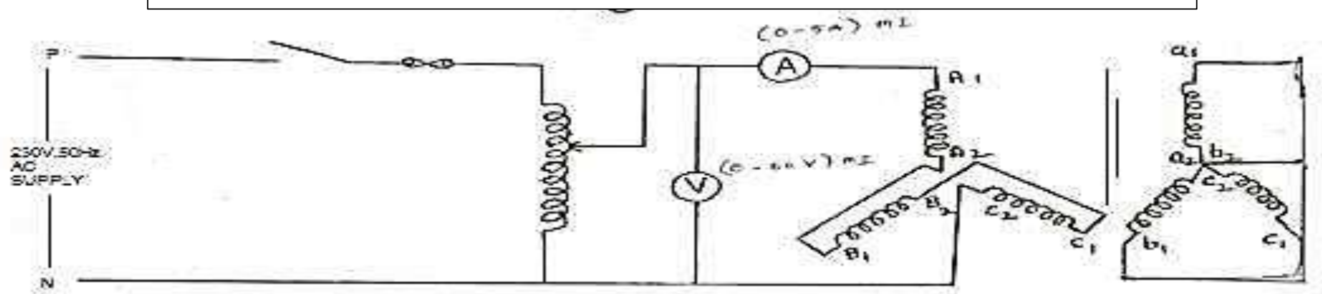


Fig. (2) Measurement of zero sequence impedance

SEQUENCE IMPEDANCES OF 3-Φ TRANSFORMER

PROCEDURE:

1. Connect circuit as per the circuit diagram shown in Fig (1) for measurement of positive/negative sequence impedance.
2. Connect active circuit on HV side (400V) and Short circuit on Low voltage side (200V).
3. Ensure that the 3-Ø variac is in zero position, then switch ON MCB.
4. Vary the 3-phase autotransformer so that the rated current (about 1.443A) flow through the HV side.
5. Note down and tabulate Primary current and Voltage.
6. Bring back the 3-Ø variac to its minimum position and switch OFF MCB.
7. Connect circuit as per the circuit diagram shown in Fig (2) between 'R' phase and 'N' neutral (1-phase supply) for measurement of zero sequence impedance.
8. Connect all the 3-Ø windings in series on HV side (400V) and ***Short circuit all three phases and Neutral on Low voltage side*** (200V).
9. Ensure that variac is in zero position, then switch ON MCB.
10. Vary the autotransformer so that the rated current (1.433A) flow through the HV side.
11. Note down and tabulate Primary current and Voltage.
12. Bring back the variac to its minimum position and OFF MCB.

Tabular Columns:

V	I	$Z_1=Z_2 = V / (\sqrt{3}*I)$

V	I	$Z_0 = V / 3 I$

RESULT:

Name	Roll No	Sign	Date	Marks	Incharge

DETERMINATION OF SEQUENCE IMPEDANCES OF AN ALTERNATOR

AIM: Determine the Positive, Negative and Zero sequence impedances of a given three phase alternator.

APPARATUS:

S.No	Apparatus	Range	Quantity
1.	DC motor coupled to alternator set	415/0-440V	01
2.	Digital Ammeter (DC)	0-5A	01
3.	Digital voltmeter (DC)	0-300V	01
4.	Ammeters (AC)	0-5A	01
5.	Voltmeters (AC)	0 – 500V	01
6.	Rheostat	370 ohms/1.7 amps	01
7.	Separate Excitation source	(0-220V/2A DC) 4 kW	01
8.	Tachometer	Digital	01
9.	Connecting wires	-	As 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, I_{R0} indicates the zero phase sequence component of the current in the red phase. Similarly, I_{Y1} implies the positive phase sequence component of current in the yellow phase. The positive phase sequence currents (I_{R1}, I_{Y1} and I_{B1}), negative phase sequence currents (I_{R2}, I_{Y2} and I_{B2}) and zero phase sequence currents (I_{R0}, I_{Y0} and I_{B0}) separately from balanced system of currents. Hence, they are called symmetrical components of the unbalanced system. The symmetrical component theory 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.

DETERMINATION OF SEQUENCE IMPEDANCES OF AN ALTERNATOR

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:

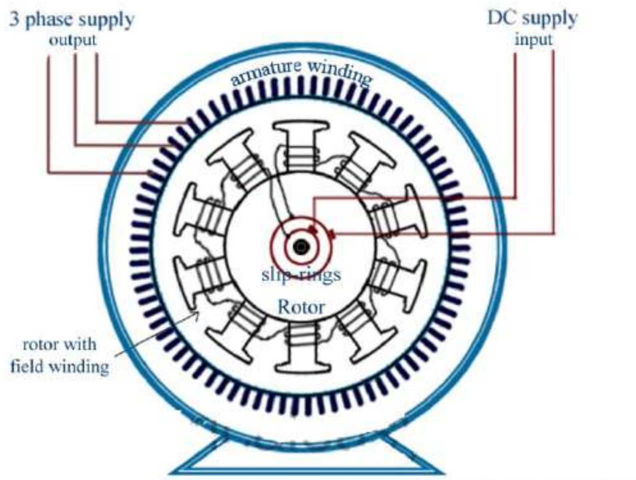
Negative sequence impedance < Positive sequence impedance

Zero sequence impedance = Variable item

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

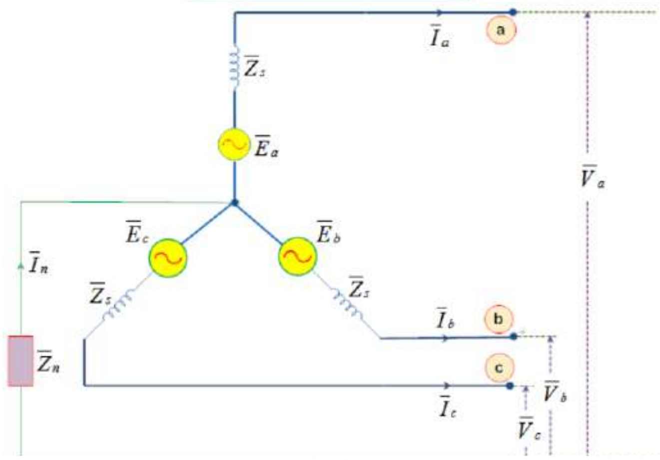
It may be worthwhile to mention here that any impedance Z_n in the earth connection of a star connected system has the effect to introduce an impedance of $3Z_n$per phase. It is because the three equal zero-sequence currents, being in phase, do not sum to zero at the star point, but they flow back along 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 Z_s per phase, with its neutral grounded through a impedance Z_n is shown in Fig. The generator is supplying a balanced three phase load. The generator voltages E_a, E_b and E_c are balanced and hence treated



Three phase synchronous generator supplying a balanced load $\mathbf{E_{abc}}$ as positive sequence set of voltage phasors and can be expressed as:

$$[\bar{\mathrm{E}}]_{\mathrm{abc}} = \begin{bmatrix} 1 \\ \mathrm{a}^2 \\ \mathrm{a} \end{bmatrix} [\bar{E}a]$$

DETERMINATION OF SEQUENCE IMPEDANCES OF AN ALTERNATOR

As the generator is supplying a three-phase balanced load, the following KVL equations can be written for each phase:

$$\bar{V}_a = \bar{E}_a - \bar{Z}_s\bar{I}_a - \bar{Z}_n\bar{I}_n$$

$$\bar{V}_b = \bar{E}_b - \bar{Z}_s\bar{I}_b - \bar{Z}_n\bar{I}_n$$

$$\bar{V}_c = \bar{E}_c - \bar{Z}_s\bar{I}_c - \bar{Z}_n\bar{I}_n$$

Substituting the neutral current I_n= I_a+ I_b+ $I_c$in equation, and writing the resulting equationin matrix form, we get:

$$\begin{bmatrix}\bar{V}_a\\ \bar{V}_b\\ \bar{V}_c\end{bmatrix} = \begin{bmatrix}\bar{E}_a\\ \bar{E}_b\\ \bar{E}_c\end{bmatrix} - \begin{bmatrix}\bar{Z}_s+\bar{Z}_n & \bar{Z}_n & \bar{Z}_n\\ \bar{Z}_n & \bar{Z}_s+\bar{Z}_n & \bar{Z}_n\\ \bar{Z}_n & \bar{Z}_n & \bar{Z}_s+\bar{Z}_n\end{bmatrix}\begin{bmatrix}\bar{I}_a\\ \bar{I}_b\\ \bar{I}_c\end{bmatrix}$$

The above matrix equation can be expressed in a compact form as:

$$[\bar{\mathbf{V}}]_{\mathbf{abc}} = [\bar{\mathbf{E}}]_{\mathbf{abc}} - [\bar{\mathbf{Z}}]_{\mathbf{abc}}[\bar{\mathbf{I}}]_{\mathbf{abc}}$$

where,

V$_{abc}$ is the vector of terminal phase voltages.
I$_{abc}$ is the vector of terminal phase currents.
Z$_{abc}$ is the impedance matrix which can be easily identified from equation

Replacing the phase quantities of equation (4.90) by corresponding sequence quantities, using the transformation equation (4.83) and equation (4.85) one can write:

$$[\bar{\mathbf{A}}][\bar{\mathbf{V}}]_{\mathbf{012}} = [\bar{\mathbf{A}}][\bar{\mathbf{E}}]_{\mathbf{012}} - [\bar{\mathbf{Z}}]_{\mathbf{abc}}[\bar{\mathbf{A}}][\bar{\mathbf{I}}]_{\mathbf{012}}$$

Pre multiplying both sides of the equation by $\mathbf{A}^{-1}$and after simplifications one gets:

$$[\bar{\mathbf{V}}]_{012} = [\bar{\mathbf{E}}]_{012} - [\bar{\mathbf{Z}}]_{012}[\bar{\mathbf{I}}]_{012}$$

where, **Z**$_{012}$is Generator Sequence Impedance Matrix and is defined as:

$$[\bar{\mathbf{Z}}]_{012} = [\bar{\mathbf{A}}]^{-1}[\bar{\mathbf{Z}}]_{\mathbf{abc}}[\bar{\mathbf{A}}] = \begin{bmatrix}\bar{Z}_s+3\bar{Z}_n & 0 & 0\\ 0 & \bar{Z}_s & 0\\ 0 & 0 & \bar{Z}_s\end{bmatrix}$$

DETERMINATION OF SEQUENCE IMPEDANCES OF AN ALTERNATOR

E_{012} is the generated sequence voltage vector and has only **E_a** component since the generated voltages are always balanced and contain only the positive sequence component. Substituting **E_{012}** and **Z_{012}** in equation we get:

$$\begin{bmatrix} \bar{V}_{a0} \\ \bar{V}_{a1} \\ \bar{V}_{a2} \end{bmatrix} = \begin{bmatrix} 0 \\ \bar{E}_a \\ 0 \end{bmatrix} - \begin{bmatrix} \bar{Z}_0 & 0 & 0 \\ 0 & \bar{Z}_1 & 0 \\ 0 & 0 & \bar{Z}_2 \end{bmatrix} \begin{bmatrix} \bar{I}_{a0} \\ \bar{I}_{a1} \\ \bar{I}_{a2} \end{bmatrix}$$

Where, $Z_1 = Z_s$ is the positive sequence generator impedance, $Z_2 = Z_s$ is the negative sequence generator impedance and $Z_0 = Z_s + 3\,Z_n$ is the zero sequence generator impedance. Expanding the above equation, one can write separate equation for each of the sequence components as:

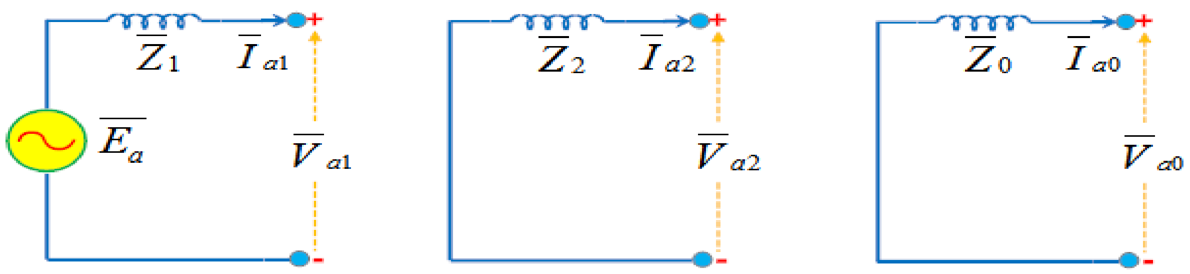
$$\bar{V}_{a0} = -\bar{Z}_0 \bar{I}_{a0}$$

$$\bar{V}_{a1} = \bar{E}_a - \bar{Z}_1 \bar{I}_{a1}$$

$$\bar{V}_{a2} = -\bar{Z}_2 \bar{I}_{a2}$$

From the above equation, it is evident that the three sequence components are independent of each other. The current of a particular sequence produces a voltage drop of that sequence only,

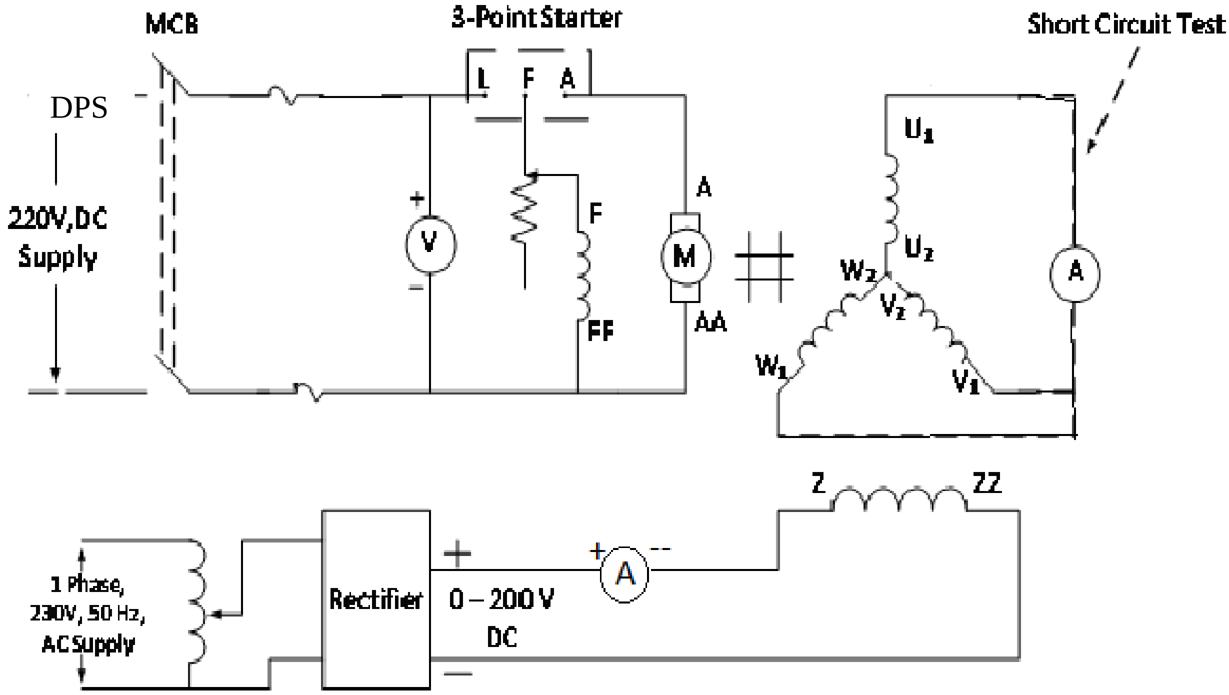
Hence the three sequences are decoupled from each other. The three sequence networks of a synchronous generator are shown in Fig.



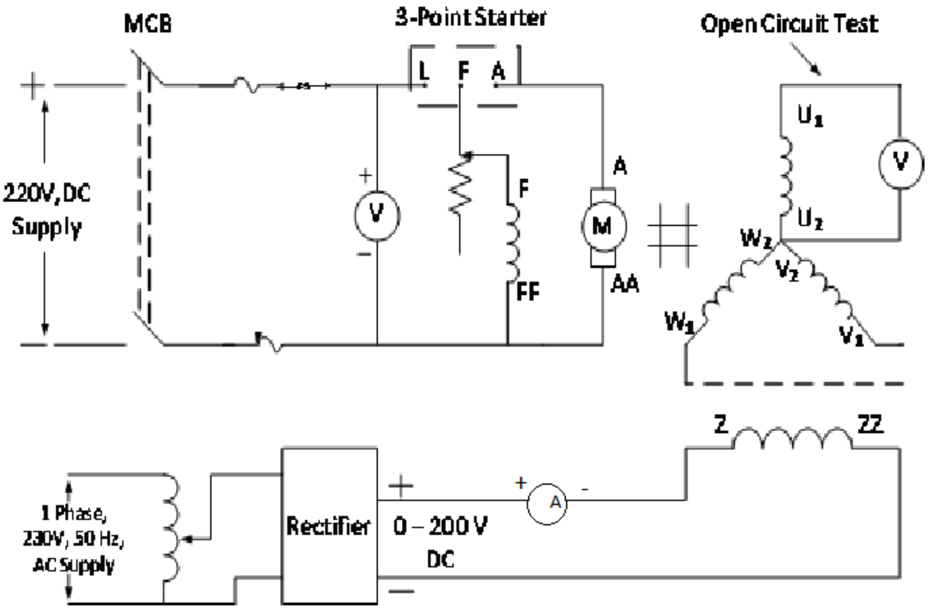
(a) Positive Sequence (b) Negative sequence (c) Zero sequence

DETERMINATION OF SEQUENCE IMPEDANCES OF AN ALTERNATOR

PART A: Determination of Positive Sequence Impedance Z_1:



Fig(1) Circuit Diagram for S.C test



Fig(2) Circuit Diagram for O.C test

PROCEDURE:

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

Short Circuit Test:

1. Connect the circuit as per the circuit diagram shown in Fig(1).
2. Field rheostat of the motor should be kept in minimum position and single phase variac should be in minimum position.
3. Close the DPST switch and start the motor-alternator set with the help of a three-point starter.
4. Adjust the field rheostat of the motor to the rated speed.
5. Slowly vary the variac such that the rated current flows through the alternator. Note down the field current(I_f) and armature current(Isc).
6. Bring back the single phase variac to the initial position, field rheostat to the minimum resistance position and open the DPST.

Open Circuit Test:

1. Connect the circuit as per the circuit diagram shown in Fig(2).
2. Field rheostat of the motor should be kept in minimum position and single phase variac should be in minimum position.
3. Close the DPST switch and start the motor-alternator set with the help of a three point starter.
4. Adjust the field rheostat of the motor to the rated speed.
5. Slowly vary the Variac to increase the field excitation of the synchronous machine. Note down the value of I_f and V up to the rated voltage (415/√3 =230V).
6. Bring back the single phase Variac to the initial position, field rheostat to the minimum resistance position and open the DPST.

SC test

I_{sc}	
I_f	

OC test

I_f									
Voc									

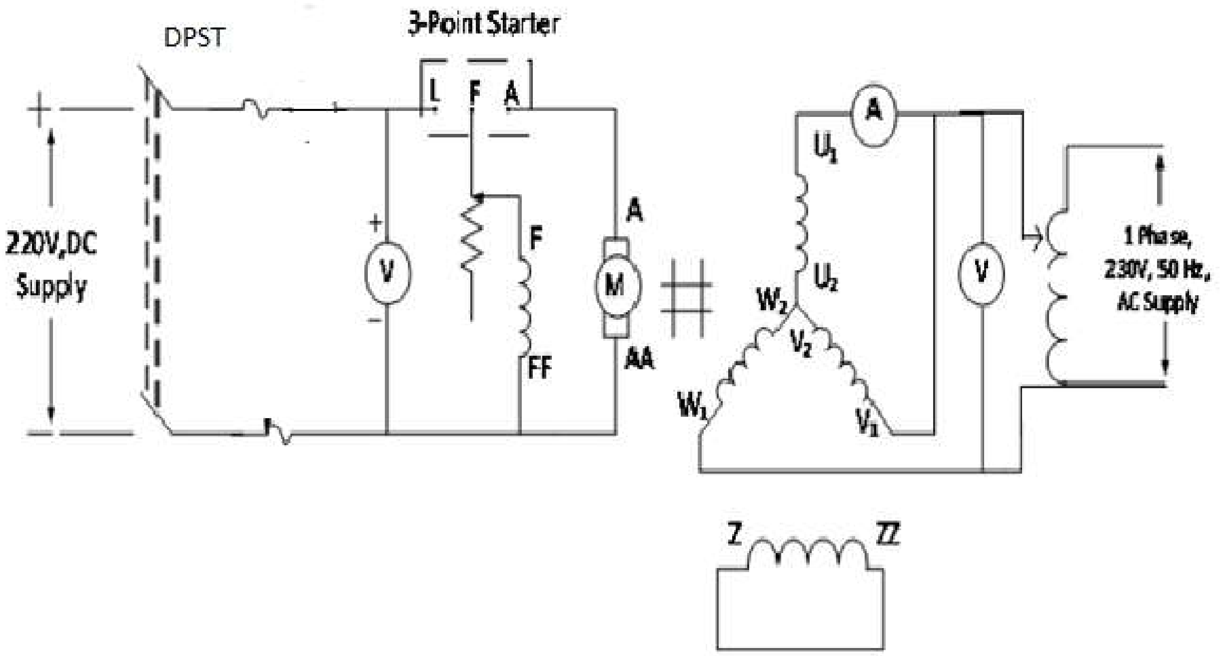
Plot OCC and SC characteristics and calculate the positive sequence impedance

Voc is the open circuit voltage for the same filed current I_f(S.C test) when Isc is the rated current

Voc	Isc	$Z_1 = \frac{V_{OC}}{I_{SC}}\ \Omega$

DETERMINATION OF SEQUENCE IMPEDANCES OF AN ALTERNATOR

PART B: Determination of Negative Sequence Impedance Z_2:



Fig(3) Circuit Diagram for Negative sequence impedance test

PROCEDURE:

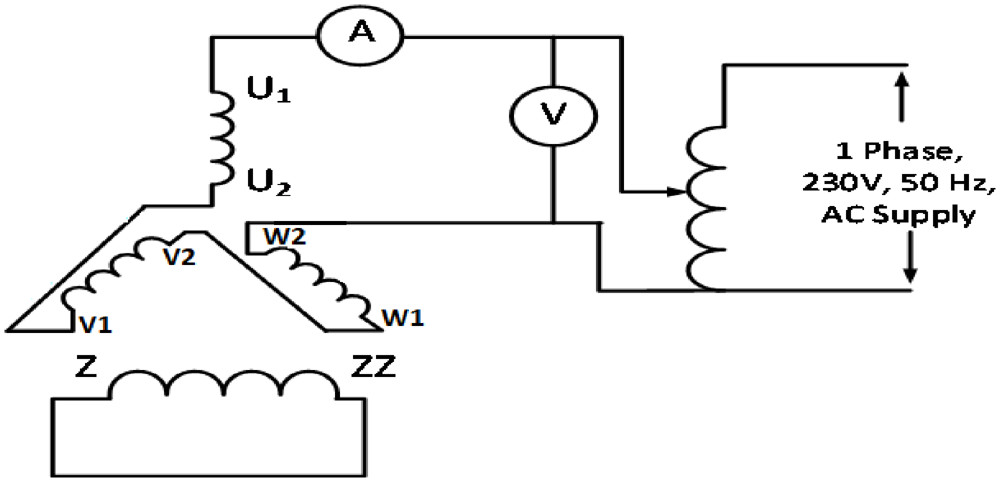
1. Connect the circuit as per the circuit diagram shown in Fig(3).
2. Keep the field rheostat of the motor at minimum position and single phase variac at minimum position.
3. Close the DPST and start the motor-alternator set using 3 point starter.
4. The speed of the motor is at below the rated speed.
5. Slowly apply the some A.C voltage and observe the fluctuations in voltmeter and ammeter of the alternator.
6. Adjust the armature rheostat of the motor to get slow oscillations.
7. Note down the minimum and maximum values of voltage and current.
8. Bring back all the rheostats and variac to the initial positions and open the DPST.

Negative Sequence Impedance

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

DETERMINATION OF SEQUENCE IMPEDANCES OF AN ALTERNATOR

PART C: Determination of Zero Sequence Impedance Z_0:



Fig(4) Circuit Diagram for Zero sequence impedance test

PROCEDURE:

1. Connect the circuit as per the circuit diagram shown in Fig(4).
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.

Zero sequence impedance

V	I	$Z_0 = \frac{V}{3\times I}\,\Omega$

RESULT:

Z_1 =______________Ω, Z_2 =______________Ω, Z_0 =______________Ω,

Name	Roll No	Sign	Date	Marks	Incharge

CHARACTERISTICS OF IDMT OVER CURRENT RELAY

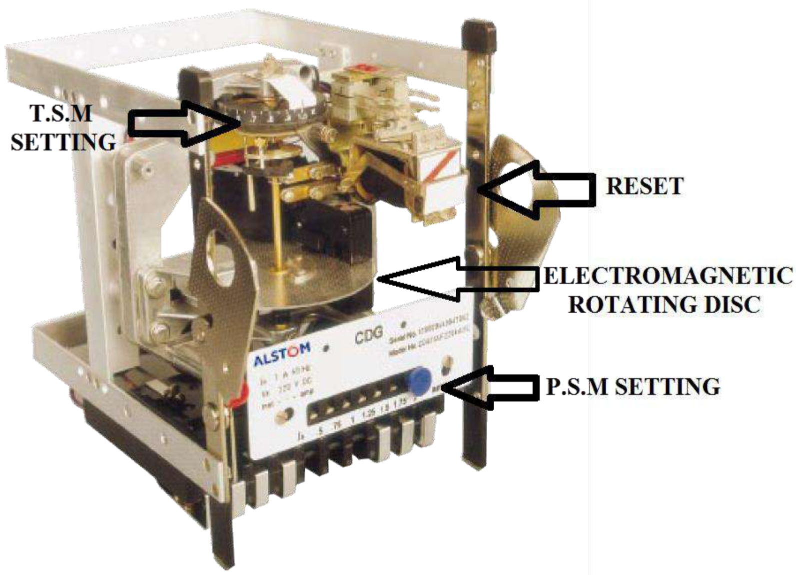
AIM: Study the Operation of a Non- Directional electromechanical type over current (I D M T relay) and plot the inverse time current characteristics.

APPARATUS:

S.No	Apparatus	Range	Quantity
1.	1-Phase Auto transformer	230/0-230Volt	01
2.	Current Injection Transformer	230V/ 50Volt-20Amp	01
3.	IDMT Over current relay	Electromechanical Type	01
4.	Timer	Digital	01
5.	Digital Ammeter	0-50A	01
6.	MCB protection		01
7.	Test switch		01
8.	ON switch and OFF switch		01
9.	Connecting wires		As required

THEORY:

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 retentivity 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.

Current Setting of Relay:

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

That means,

$$Current Setting = \frac{Pick up urrent}{Rated\ Secondary Current of\ CT} \times 100$$

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,

$$Current\ Setting = \frac{1.25}{1} \times 100 = 125\%$$

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%.

Plug Setting Multiplier of Relay:

Plug setting multiplier of relay is referred as ratio of fault current in the relay to its pick up current.

$$PSM = \frac{Fault\,current\,in\,realy\,coil}{Pick\,up\,current}$$

$$= \frac{Fault\,current\,in\,relay\,coil}{Rated\,CT\,secondary\,current \times Current\,setting}$$

Suppose we have connected on protection CT of ratio 200/1 A and current setting is 150%. Hence, pick up current of the relay is, 1 × 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 × 1/200 = 5 A. Therefore PSM of the relay is, 5 / 1.5 =3.33

Time Setting Multiplier of Relay:

The operating time of an electrical relay mainly depends upon two factors:

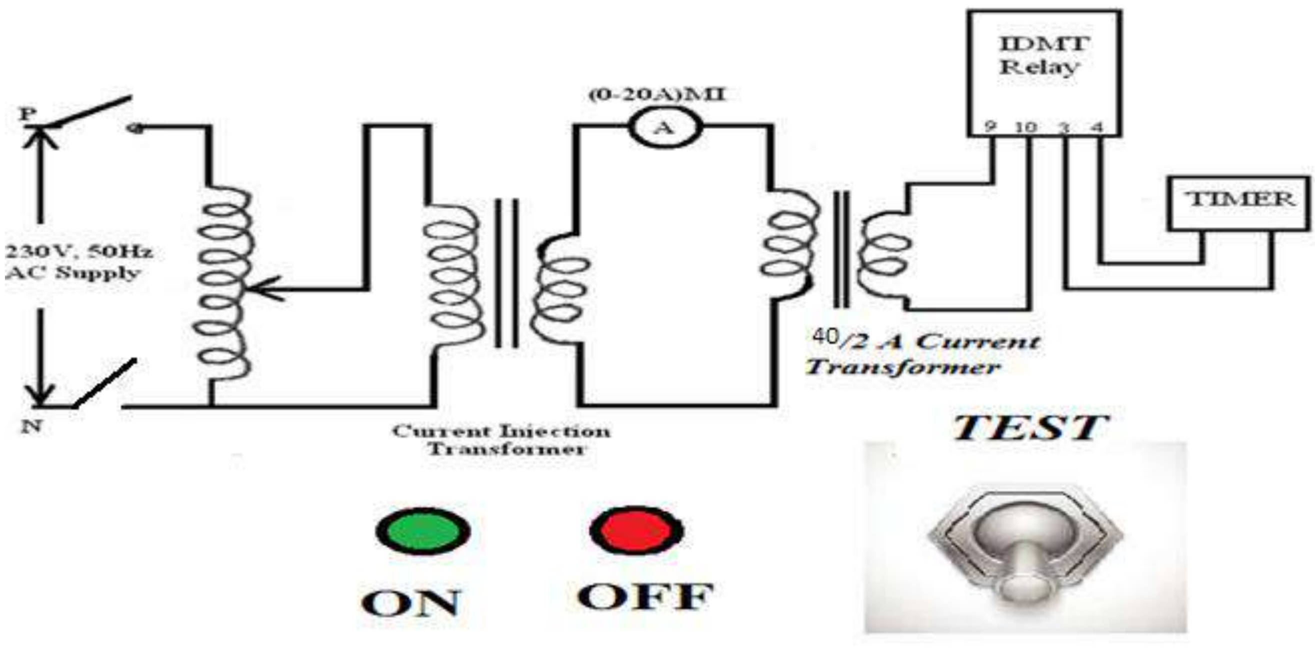
1. How long distance to be traveled by the moving parts of the relay for closing relay contacts and
2. How fast the moving parts of the relay cover this distance.

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.

CHARACTERISTICS OF IDMT OVER CURRENT 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:



CHARACTERISTICS OF IDMT OVER CURRENT RELAY

PROCEDURE:

1. Connect circuit as per the circuit diagram shown in Fig.
2. Select the P.S.M setting on the relay. Place the plug in 0.5 of PSM setting in the relay then the fault current in the relay = PSM*CT secondary*current setting =0.5*2*50/100 =0.5. Then the fault current in the Ct primary will be 0.5*(40/2)= 10A.
3. Ensure that the variac is in zero position, the switch 'TEST' is ON position and TSM setting are to be 0.3 Sec.
4. Switch ON MCB, increase the current in the circuit to the value calculated in step 2 for the 0.5 PSM setting by varying the 1-phase variac.
5. Switch 'TEST' in OFF mode, then make sure that the rotating electromagnet disc reaches to initial position and press Reset timer switch.
6. Switch ON the green button and observe the tripping condition.
7. The circuit will be in OFF position after relay tripping, if relay does not trip press RED switch for reset condition.
8. Note down the time from timer and the current from the digital Ammeter.
9. Repeat steps from 3 to 8 to 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.
10. Repeat all the above procedure for TSM of 0.5
11. Repeat all the above procedure for PSM of 1.0
12. Plot the graph between Time taken for the relay to operate Vs fault current for various TSM and PSM.

Precautions:-

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

Tabular Columns:

Ct Ratio= 40/2= 20

Rated current= 0 to 20A

Fault current= PSM * C.T Ratio

PSM	MIN. FAULT CURRENT
0.5	10
0.75	15
1.0	20
1.25	25

CHARACTERISTICS OF IDMT OVER CURRENT RELAY

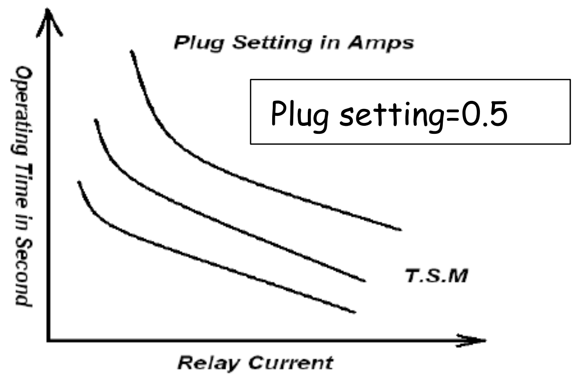
Plug setting = 0.5

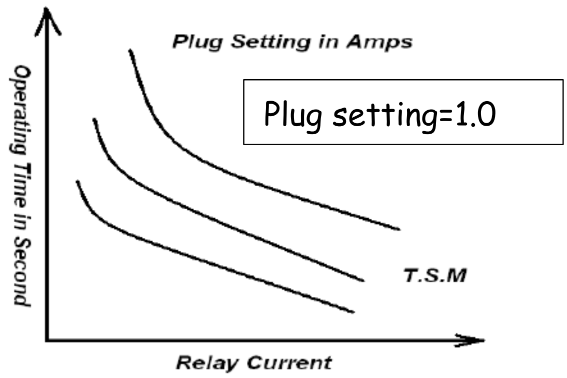
S.No	Fault current (A)	Time of operation (Sec) TSM= 0.3	Time of operation (Sec) TSM= 0.5
1	10		
2	13		
3	17		
4	21		
5	25		

Plug setting = 1.0

S.No	Fault current (A)	Time of operation (Sec) TSM= 0.3	Time of operation (Sec) TSM= 0.5
1	20		
2	21		
3	22		
4	23		
5	25		

Model graphs:





RESULT:

Name	Roll No	Sign	Date	Marks	Incharge

CHARECTERISTICS OF OVER VOLTAGE & UNDER VOLTAGE RELAY

AIM: To study the operation of Microprocessor Based type under voltage relay and hence to obtain inverse time/voltage characteristics.

APPARATUS:

S.No	Apparatus	Range	Quantity
1.	1-Phase Auto transformer.	230/0-230Volt/1Amp	01
2.	Transformer.	0-230V/ 0-110Volt/1Amp 0-230V/ 0-220Volt/1Amp	01
3.	Overvoltage/under voltage relay	μp based	01
4.	Timer	Digital	01
5.	Digital Voltmeter	0-300V	01
6.	MCB protection		01
7.	Test switch		01
8.	Selector switch	Over voltage/under voltage	01
9.	Connecting wires		As required

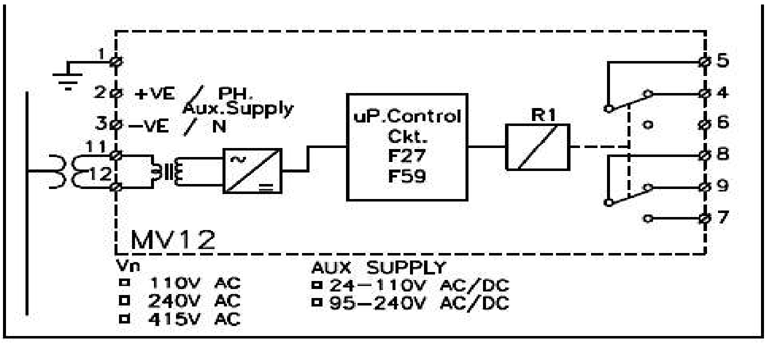
THEORY:

Over Voltage/Under Voltage Relay is an electronic microcontroller based single-phase voltage relay. It is suitable for over voltage/under voltage protection schemes in LV, MV and HV power distribution systems. It is also suitable for over voltage protection of AC circuits, capacitors, machines such as generators, synchronous motor and under voltage protection of AC circuits, Induction motors, automatic change over schemes etc. The microcontroller-based design offers a wide range of Trip-Time characteristics, under voltage or over voltage mode and PT rating (110V, 240V, 415V), which can all be selected in the field at the time of commissioning. It accepts very wide auxiliary supply range. Relay is designed for flush mounting. It is very compact in size, which results in saving of panel space. Its draw-out construction makes installation and maintenance very easy.

Details of L&T Under voltage/Over voltage relay:

Relay MV12 is a single phase, over voltage or under voltage relay with one measuring element. The relay can be used for feeder protection in all low voltage, medium voltage and high voltage sub-stations. DIP switches are provided on the front panel for pick up and time delay settings. User has a choice of 7 trip time characteristics.

CHARECTERISTICS OF OVER VOLTAGE & UNDER VOLTAGE RELAY



CATALOG NOs.

MV12AA00X00
MV12AB00X00

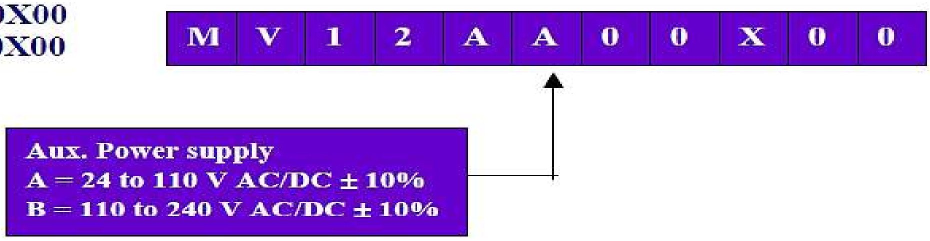


Fig 2: Inter circuit diagram of the relay

Technical Specifications of the relay are:

1.0	Rated Voltage(Vn)	110 / 240 / 415 V AC (FieldSelectable)
2.0	Rated Frequency	50Hz±2.5Hz
3.0	Auxiliary PowerSupply	24Vto110VAC/DC OR 95V to 240VAC/DC
4.0	Relay Settings:	Pick up voltage(Vs)
	Over Voltage Mode	105% to 180% of Vn in steps of 5%
	Under Voltage mode	95% to 20% of Vn in steps of 5%
	Time Multiplier TMS	0.1 to 1.6 in steps of 0.1
5.0	Operating Characteristics	
	Time /Current characteristics	
	Normal Inverse	3.5 sec in O/V mode
	Normal Inverse	5.7 sec in U/V mode
	Definite time	1, 10, 100sec
	Pick up voltage:	Same as set voltage Vs
	Reset Voltage:	(90% to 95%) of set voltage Vs for Overvoltage (105% to 110%) of set voltage Vs for Under voltage
	Accuracy	±5%ofVs

6.0 Burden Less than 0.25 VA at PT input
Less than 8 VA at Auxiliary Power supply

7.0 Operation Indicators Separate LED indications for:

- Power on
- Over Voltage
- Under Voltage
- Trip status (LED blinks when input crosses set point and becomes steady on when relay has tripped. LED has to be manually reset)
- Time current characteristics elected

8.0 Output Relay Contacts • 2 c/o contacts for trip signal (self reset)
9.0 Output contact rating Rated voltage 250 V AC / 30 VDC
10.0 Max. S/W voltage Rated current 440 V AC / 300 VDC
Max Current 8A
Rated Breaking Capacity 14 A
Over Load capacity 2000VA / 240 W(Resistive) 800Volts
11.0 Electrical performance Specifications
Please refer separate document" General Electrical Characteristics"
12.0 Case Front Bezel 158 x 71mm
Panel Cut out Depth 150 x 62mm 224 mm
13.0 Weight 0.9 kg approx.

CHARECTERISTICS OF OVER VOLTAGE & UNDER VOLTAGE RELAY

Circuit Diagram:

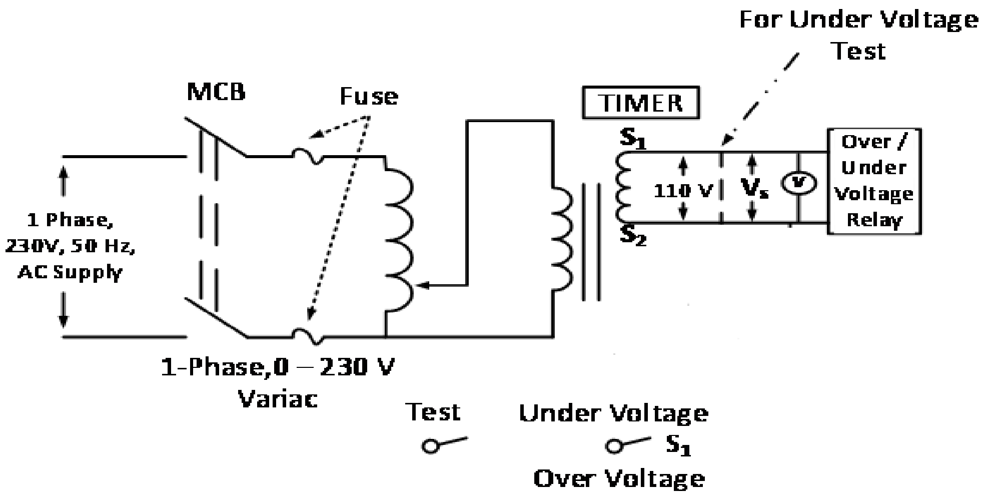


Fig: (1) UNDER VOLTAGE

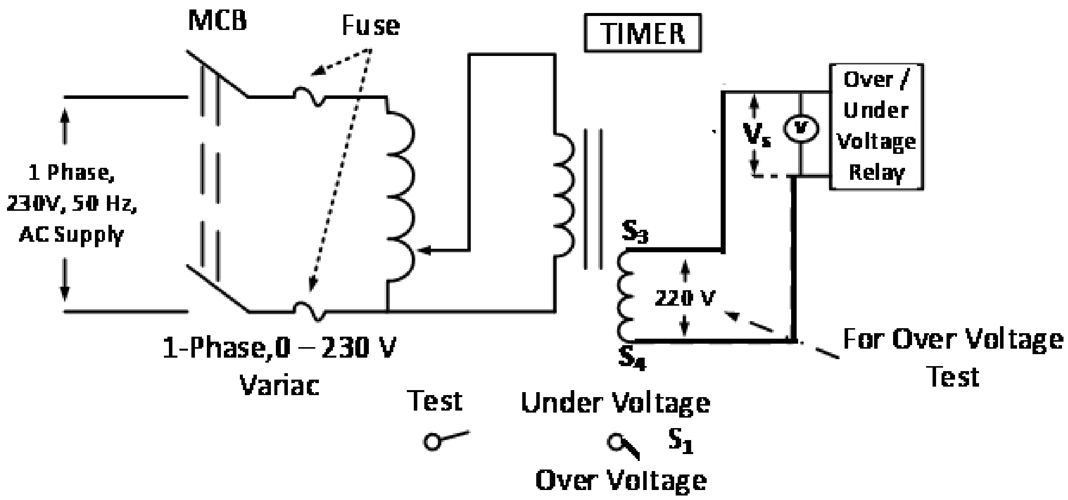


Fig: (2) OVER VOLTAGE

CHARECTERISTICS OF OVER VOLTAGE & UNDER VOLTAGE RELAY

PROCEDURE:

Under Voltage Testing:

1. Connect circuit as per the circuit diagram shown in Fig(1) for under voltage testing
2. Calculate V_s from voltage setting equations and TMS setting equations for different values of 'a' and 't' and tabulate the values in table 1 and table 2.

   Voltage setting (from relay manufacturer)

   $$V_s = [1-(0.05+\Sigma a)]V_n$$

   a= weight of switches {0.05, 0.1, 0.2, 0.4} in ON position
   V_n is P.T. rating i.e. 110V.

   T.M.S:

   Trip time $T = K(0.1+\Sigma t)$

   t = weight of switches {0.1, 0.2, 0.4, 0.8} in ON position
   K = 5.7 for under voltage

Table 1

a	Vs
0.05	
0.1	
0.2	
0.4	

Table 2 (value of K=5.7)

t	T
0.1	
0.2	
0.4	
0.8	

3. Ensure that the switch S_1 in the circuit diagram is in 'Under Voltage condition', variac is in zero position and the switch 'TEST' is OFF position.
4. Now apply a voltage from variac which is less than the calculated setting voltage V_s for a=0.05 in order to test the operating condition of relay.
5. Press RED switch for reset condition.
6. Switch 'TEST' in ON mode and press Reset timer switch.
7. Switch ON the green button and observe the tripping condition.
8. Switch 'TEST' in OFF position and note down the time from timer and the applied under voltage Vs from the digital voltmeter.
9. Repeat steps from 3 to 8 for different under voltage values.

CHARECTERISTICS OF OVER VOLTAGE & UNDER VOLTAGE RELAY

Over Voltage Testing:

1. Connect circuit as per the circuit diagram shown in Fig(2) for over voltage testing
2. Calculate V_s from voltage setting equations and TMS setting equations for differen values of 'a' and 't' and tabulate the values in table 3 and table 4.

Voltage setting (from relay manufacturer)

$$V_s = [1 + (0.05 + \Sigma a)]V_n$$

a= weight of switches {0.05, 0.1, 0.2, 0.4} in ON position

V_n is P.T. rating i.e. 110V.

T.M.S:

Trip time $T = K(0.1 + \Sigma t)$

t = weight of switches {0.1, 0.2, 0.4, 0.8} in ON position

K = 3.5 for under voltage

Table 3

a	Vs
0.05	
0.1	
0.2	
0.4	

Table 4 (value of K=3.5)

t	T
0.1	
0.2	
0.4	
0.8	

3. Ensure that the switch S_1 in the circuit diagram is in 'Over Voltage condition', variac is in zero position and the switch 'TEST' is OFF position.
4. Now apply a voltage from variac which is greater than the calculated setting voltage V_s for a=0.05 in order to test the operating condition of relay.
5. Press RED switch for reset condition.
6. Switch 'TEST' in ON mode and press Reset timer switch.
7. Switch ON the green button and observe the tripping condition.
8. Switch 'TEST' in OFF position and note down the time from timer and the applied over voltage Vs from the digital voltmeter.
9. Repeat steps from 3 to 8 for different over voltage values.

CHARECTERISTICS OF OVER VOLTAGE & UNDER VOLTAGE RELAY

Tabular Columns:

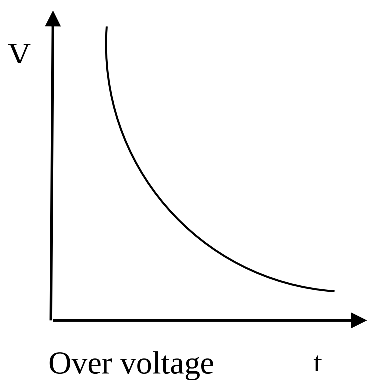
Under Voltage testing

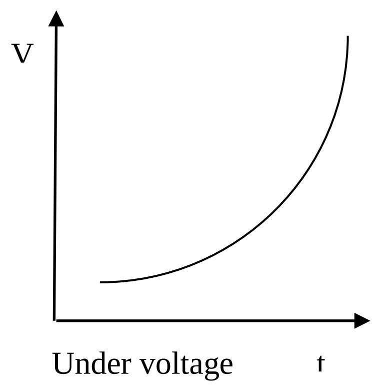
S.No	T.M.S	Voltage Setting (Vs)	Applied Voltage	Operating time
1				
2				
3				
4				
5				

Over Voltage testing

S.No	T.M.S	Voltage Setting (Vs)	Applied Voltage	Operating time
1				
2				
3				
4				
5				

Model graphs:



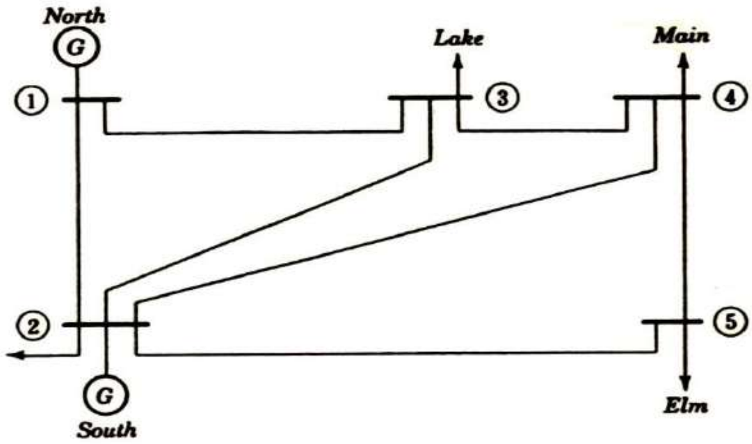


RESULT:

Name	Roll No	Sign	Date	Marks	Incharge

Formation of Y_{BUS} and Z_{BUS}

AIM: 1. Obtain the bus admittance matrix for a given power system model using MATLAB.
2. Obtain the bus impedance matrix for a given power system model using MATLAB.



Bus code p–q	Impedance z_{pq}	Line charging $y'_{pq}/2$
1–2	0.02 + j0.06	0.0 + j0.030
1–3	0.08 + j0.24	0.0 + j0.025
2–3	0.06 + j0.18	0.0 + j0.020
2–4	0.06 + j0.18	0.0 + j0.020
2–5	0.04 + j0.12	0.0 + j0.015
3–4	0.01 + j0.03	0.0 + j0.010
4–5	0.08 + j0.24	0.0 + j0.025

Software Required: MATLAB software

Theory:

Bus admittance matrix or Y_{bus} is matrix which gives the information about the admittances of lines connected to the node as well as the admittance between the nodes. Principal diagonal elements are called self admittances of node and is equal to the algebraic sum of all the admittances terminating at the node. Off diagonal elements are called mutual admittances and are equal to the admittances between the nodes. The size of ybus is n*n where n is the number of buses in the system and m= n+1(the total number of buses including the reference buses).

$I_{bus} = Y_{bus} * V_{bus}$ where I_{bus} = vector of impressed bus currents

Y_{bus} = bus admittance matrix.

V_{bus} = vector of bus voltages measured with respect to reference bus.

Inspection method makes use of KVL at all the nodes to get the current equations. From these equations, Y_{bus} can be directly written. It is the simplest and direct method of obtaining all the diagonal elements as well as off diagonal elements in the matrix of any power system. Bus admittance matrix is a sparse matrix. It is often used in solving load flow problems. Sparsity is one of its greatest advantages as it heavily reduces computer memory and time requirements.

The bus admittance matrix can be obtained by taking inverse of Y_{BUS}

Z_{BUS} = inv(Y_{BUS})

Formation of Y_{BUS} and Z_{BUS}

PROCEDURE:-

1. Open MATLAB
2. Open new M-file
3. Type the program
4. Save in current directory
5. Compile and Run the program
6. For the output see command window\ Figure window

Algorithm:

Step 1: Read the number of busses and Initialize all the y bus elements to zero, all the impedances to infinity.

Step 2: Read the self-admittance of each bus and the mutual admittance between the buses.

Step 3: Calculate the diagonal element term called the bus driving point admittance, Yii which is the sum of the admittance connected to bus i.

Step 4: The off-diagonal term called the transfer admittance, Yij which is the negative of the admittance connected from bus i to bus j.

Step 5: Check for the end of bus count and print the computed Y-bus matrix.

Step 6: Compute the Z-bus matrix by inverting the Y-bus matrix.

Step 7: Stop the program and print the results.

PROGRAM FOR BUS ADMITTANCE and IMPEDANCE MATRICES

```
% Program for Admittance Bus Formation
clear all
clc
% Read number of busses
n=5
% Initialize all admittances to zero
YY=zeros(n,n)
% Initialize all charging admittances to zero
ych=zeros(n,n)
 % Initialize all line impedances to infiity
z=inf(n,n)
% Get  Line impedances between the busses p and q

z(1,2)=0.02+0.06i;
z(1,3)=0.08+0.24i;
```

```
z(2,3)=0.06+0.18i;
z(2,4)=0.06+0.18i;
z(2,5)=0.04+0.12i;
z(3,4)=0.01+0.03i;
z(4,5)=0.08+0.24i;

% Find   the Line admittances between the busses p and q
% Or   Convert the line impedance into the Line admittances
for i=1:n
    for j=1:n
        y(i,j)=1/z(i,j);
    end
end

 for i=1:n
    for j=1:n
        y(j,i)=y(i,j);   % Symetrical network
    end
end

y

% Get the half line charging Admittances between the busses p and q
ych(1,2)= 0.00+0.03i;
ych(1,3)= 0.00+0.025i;
ych(2,3)= 0.00+0.02i;
ych(2,4)= 0.00+0.02i;
ych(2,5)= 0.00+0.015i;
ych(3,4)= 0.00+0.010i;
ych(4,5)= 0.00+0.025i;

for i=1:n
    for j=1:n
        ych(j,i)=ych(i,j);   % Equally divide the admittances
   end
end

% Formation of Diagonal Elements....
for i=1:n
    for j=1:n
```

```
        YY(i,i)=YY(i,i)+y(i,j)+ych(i,j);
    end
end

% Formation of the Off Diagonal Elements...
for i=1:n
    for j=1:n
        if(i~=j)
        YY(i,j)=YY(i,j)-y(i,j);
        end
    end
end
YY       % Bus Admittance Matrix.

ZZ= inv(YY)   % Bus Impedance Matrix.
```

RESULT:

YY =

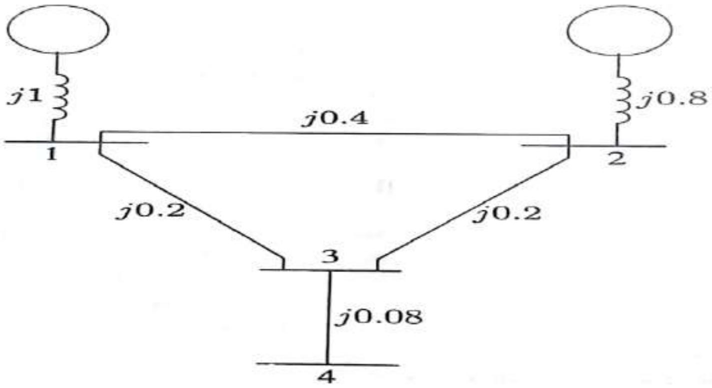
6.25 -18.70i	-5.00 +15.00i	-1.25 + 3.75i	0	0
-5.00 +15.00i	10.83 -32.42i	-1.67 + 5.00i	-1.67 + 5.00i	-2.50+ 7.50i
-1.25 + 3.75i	-1.67 + 5.00i	12.92 -38.70i	10.00 +30.00i	0
0	-1.67 + 5.00i	-10.00 +30.00i	12.92 -38.48i	-1.25 + 3.75i
0	-2.50 + 7.50i	0	-1.25 + 3.75i	3.75 -10.99i

ZZ =

0.0125- 3.41i	0.0004 - 3.45i	-0.0042 - 3.46i	-0.0052 - 3.46i	-0.0052 - 3.46i
0.0004 - 3.45i	0.0053 - 3.43i	-0.0037 - 3.46i	-0.0038 - 3.46i	-0.0014 - 3.45i
-0.0042 - 3.46i	-0.0037 - 3.46i	0.0089 - 3.42i	0.0045 - 3.44i	-0.0047 - 3.46i
-0.0052 - 3.46i	-0.0038 - 3.46i	0.0045 - 3.44i	0.0090 - 3.42i	-0.0032 - 3.46i
-0.0052 - 3.46i	-0.0014 - 3.45i	-0.0047 - 3.46i	-0.0032 - 3.46i	0.0211 - 3.39i

Formation of Y_{BUS} and Z_{BUS}

Exercise:1 Write MATLAB program and obtain the Bus Admittance Matrix for the give system where the impedances are expressed in per unit.



RESULT:

YY =

ZZ =

Name	Roll No	Sign	Date	Marks	Incharge

LG, LL, LLG AND 3-Φ FAULT ANALYSIS OF 3-Φ ALTERNATOR

AIM: Determine the fault currents on an unloaded Alternator 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)
4. 3-Ø fault

APPARATUS:

S.No	Apparatus	Range	Quantity
1.	DC motor coupled to alternator set		01
2.	Digital Ammeter (DC)	0-2A	01
3.	Digital Ammeter (AC)	0-5A	01
4.	Digital Voltmeter (AC)	0-500V	01
5.	Rheostat	370 ohms/1.7 amps	01
6.	Separate Excitation source (0-220V/2A DC)		01
7.	Tachometer	Digital	01
8.	Fault switch	3-pole	01
9.	Connecting wires		As required

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 :

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

* 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.

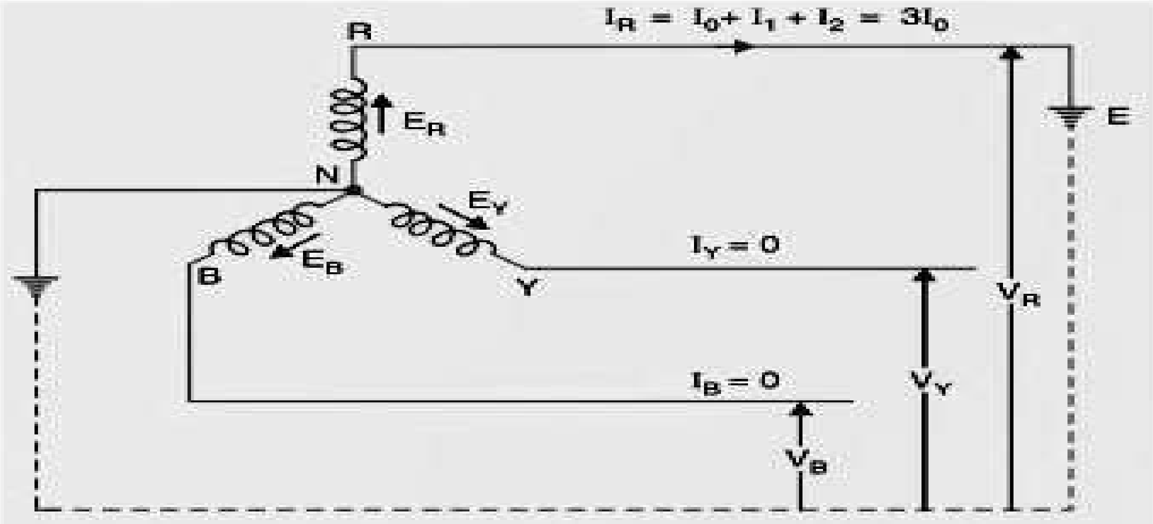
The sequence currents in the red phase in terms of line currents shall be

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

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

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

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



Fault current. First of all expression for fault current $\vec{I_R}$ will be derived. Let $\vec{Z_1}$, $\vec{Z_2}$ and $\vec{Z_0}$ 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,

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

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

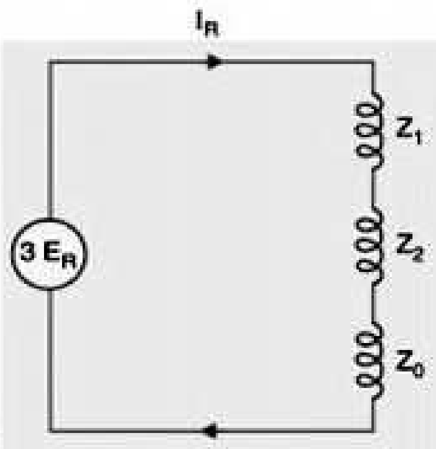
$$\therefore \quad \vec{E_R} = \vec{I_0}\left(\vec{Z_1} + \vec{Z_2} + \vec{Z_0}\right)$$

or

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

$\therefore$ Fault current,

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



LG, LL, LLG AND 3-Φ FAULT ANALYSIS OF 3-Φ ALTERNATOR

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

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

$$\vec{V_R} = 0$$

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

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

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 :

$$\vec{V_Y} = \vec{V_B} \quad ; \quad \vec{I_R} = 0 \quad \text{and } \vec{I_Y} + \vec{I_B} = 0$$

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

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

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

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

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

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

∴ $\vec{V_1} = \vec{V_2}$ ...(*i*)

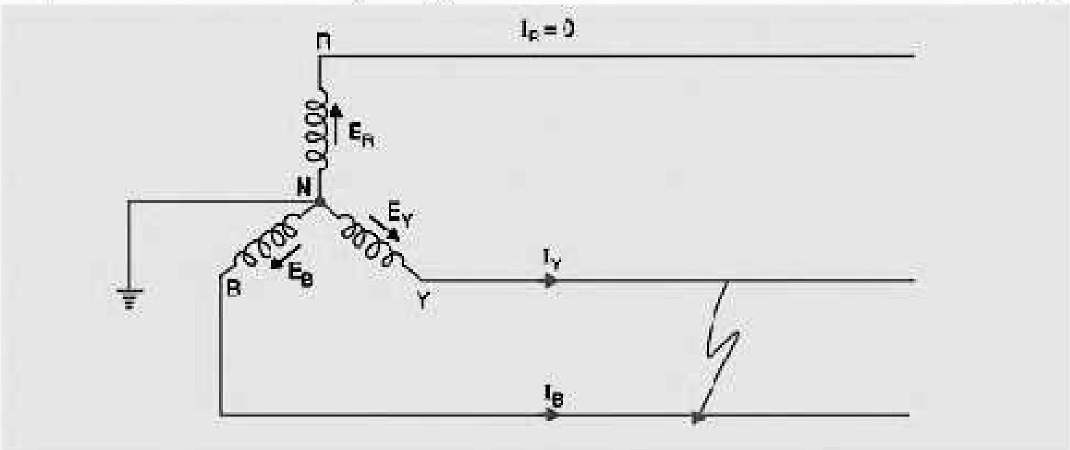


Fig. 18.15.

LG, LL, LLG AND 3-Φ FAULT ANALYSIS OF 3-Φ ALTERNATOR

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 $\vec{I_1} + \vec{I_2} = 0$ $[\because I_0 = 0]$ ...(*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 :

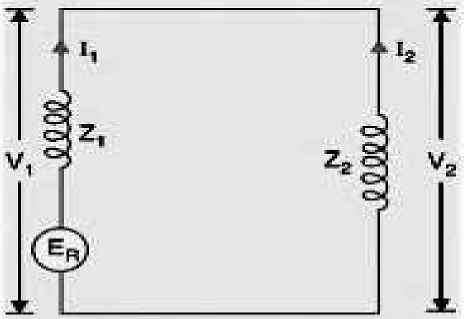


Fig. 18.16

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

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 $\vec{V_R} = \dfrac{2\,\vec{Z_2}}{\vec{Z_1} + \vec{Z_2}}\,\vec{E_R}$

LG, LL, LLG AND 3-Φ FAULT ANALYSIS OF 3-Φ ALTERNATOR

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 :

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

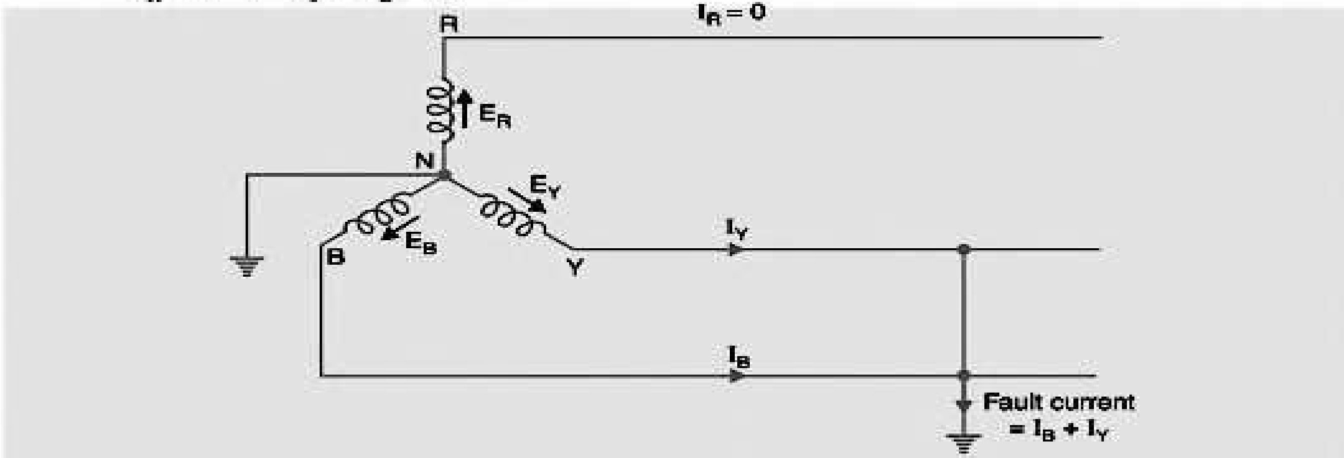


Fig. 18.17

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

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

Also $\vec{I_R} = \vec{I_1} + \vec{I_2} + \vec{I_0} = 0$ *(given)* ...(*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 :

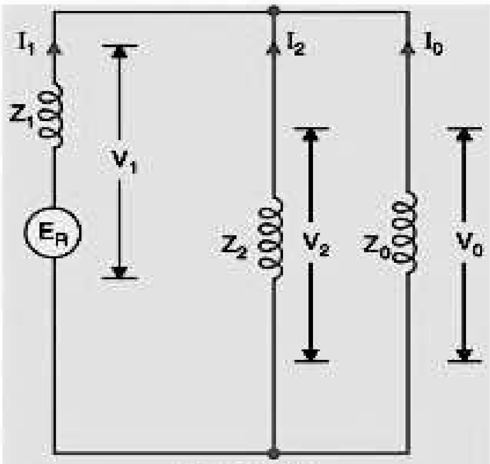


Fig. 18.18

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

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

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

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

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

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

LG, LL, LLG AND 3-Φ FAULT ANALYSIS OF 3-Φ ALTERNATOR

CIRCUIT DIAGRAM FOR L-G FAULT:

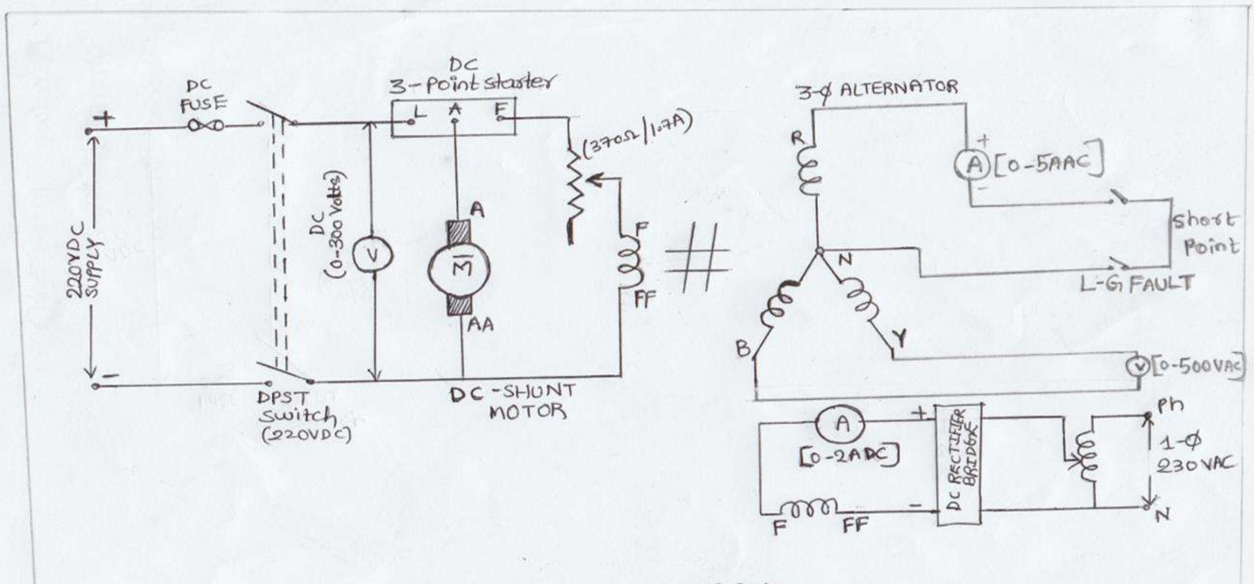


fig:- CIRCUT DIAGRAM
FAULT ANALYSIS OF AN ALTERNATOR

PROCEDURE:

1. Connect circuit as per the circuit diagram shown in Fig(1) for Line to Ground (LG) fault on 'R' phase .
2. The DC shunt motor field rheostat is in minimum position, the alternator field excitation variac should be in zero position, Switch ON MCB, start DC shunt motor with the help of 3-point starter.
3. Run the alternator at its rated speed of 1500rpm by adjusting DC shunt motor field Rheostat.
4. Increase the alternator field excitation till it reaches the E= 200V(Line voltage).
5. Close the switch to create the L-G fault on 'R' phase.
6. Note down fault current in 'R' phase.
7. Open the fault switch and remove the L-G fault on 'R' phase.
8. Reduce the alternator excitation, bring back the DC shunt motor field rheostat to its minimum position and stop DC shunt motor by opening DPST switch.
9. Switch OFF MCB.

LG, LL, LLG AND 3-Φ FAULT ANALYSIS OF 3-Φ ALTERNATOR

Tabular Column:

S.No.	E (v)	Field current I_f (A)	Theoretical I_{fault} in 'R' phase (A)	Measured I_{fault} in 'R' phase (A)
01	200V			

Calculations:

Z_1 = ____________Ω; Z_2 = ____________Ω; Z_0 = ____________Ω;

Where Z_1, Z_2, Z_0 are the phase sequence impedances of an alternator. The phase sequence values are to be taken from the previous cycle experiment.

$I_{fault} = (\sqrt{3} \cdot E)/(Z_1+Z_2+Z_0)$= ______________A

CIRCUIT DIAGRAM FOR L-L FAULT:

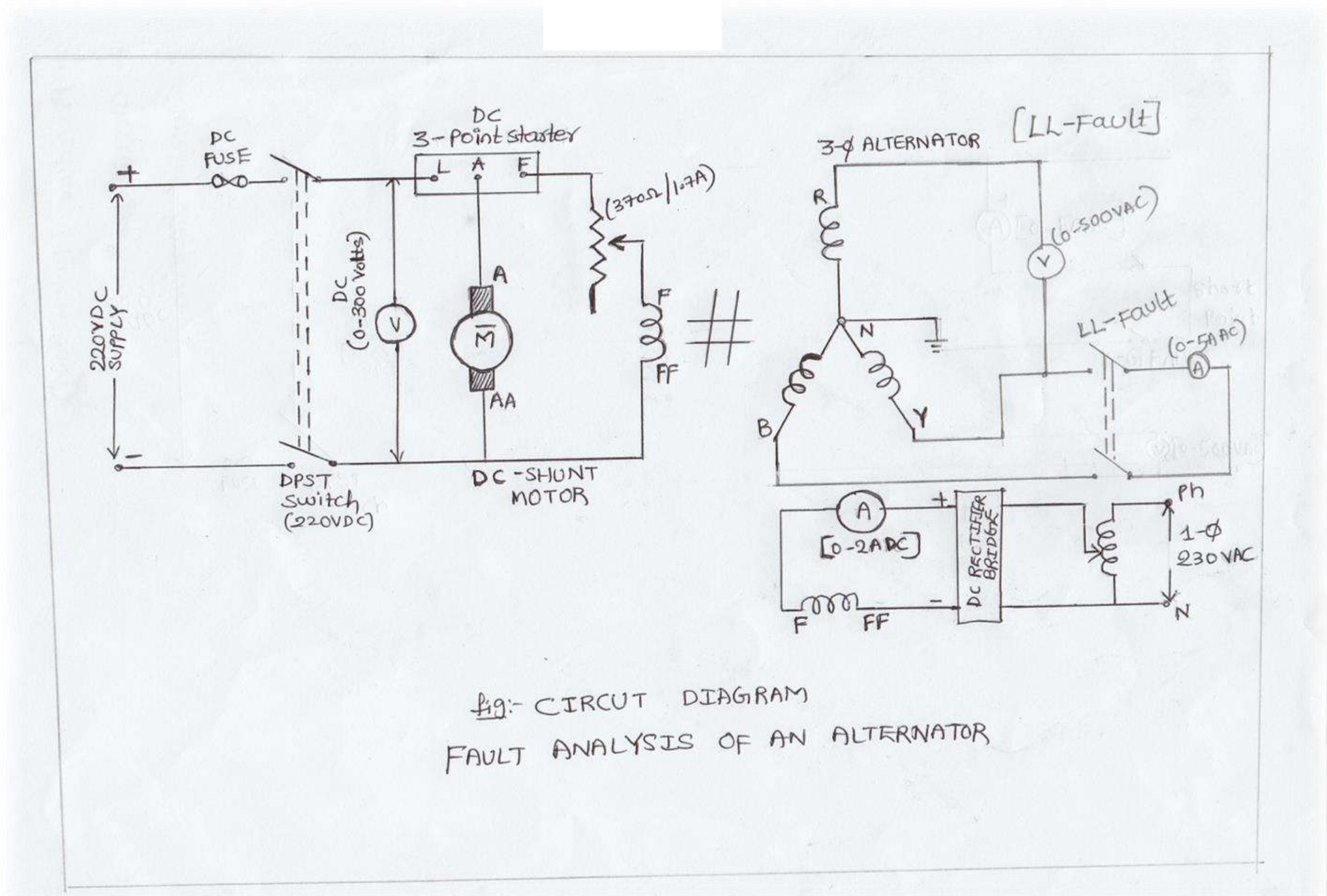


fig:- CIRCUT DIAGRAM
FAULT ANALYSIS OF AN ALTERNATOR

LG, LL, LLG AND 3-Φ FAULT ANALYSIS OF 3-Φ ALTERNATOR

PROCEDURE:

1. Connect circuit as per the circuit diagram shown in Fig(2) for Line to Line (LL) fault between 'Y' phase and 'B' phase.
2. The DC shunt motor field rheostat is in minimum position, the alternator field excitation variac should be in zero position, Switch ON MCB, start DC shunt motor with the help of 3-point starter.
3. Run the alternator at its rated speed of 1500rpm by adjusting DC shunt motor field Rheostat.
4. Increase the alternator field excitation till it reaches the E= 200V(Line voltage).
5. Close the switch to create the L-L fault between 'Y' phase and 'B' phase.
6. Note down fault current in 'Y' phase and 'B' phase.
7. Open the fault switch and remove the L-L fault.
8. Reduce the alternator excitation, bring back the DC shunt motor field rheostat to its minimum position and stop DC shunt motor by opening DPST switch.
9. Switch OFF MCB.

Tabular Column:

S.No.	E (v)	Field current I_f (A)	Theoretical I_{fault} in 'R' phase (A)	Measured I_{fault} in 'R' phase (A)
01	200V			

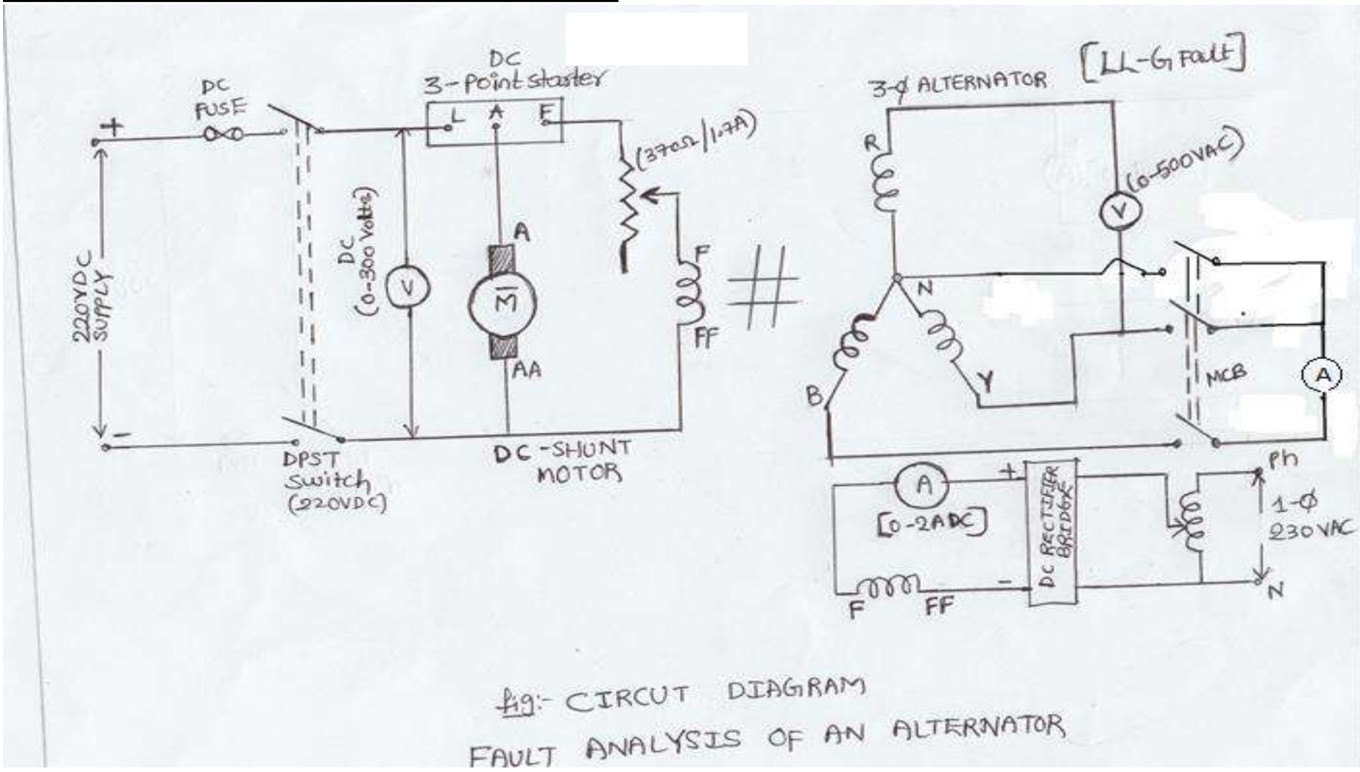
Z_1 = ____________Ω; Z_2 = ____________Ω;

Where Z_1, Z_2 are the positive and negative phase sequence impedances of an alternator. The phase sequence values are to be taken from the previous cycle experiment.

$I_{fault} = (E)/(Z_1+Z_2)$= ___________A.

LG, LL, LLG AND 3-Φ FAULT ANALYSIS OF 3-Φ ALTERNATOR

CIRCUIT DIAGRAM FOR LL-G FAULT:



PROCEDURE:

1. Connect circuit as per the circuit diagram shown in Fig(3) for Double Line to ground (LL-G) fault between 'YB' phase and 'N' neutral.
2. The DC shunt motor field rheostat is in minimum position, the alternator field excitation variac should be in zero position, Switch ON MCB, start DC shunt motor with the help of 3-point starter.
3. Run the alternator at its rated speed of 1500rpm by adjusting DC shunt motor field Rheostat.
4. Increase the alternator field excitation till it reaches the E= 200V(Line voltage).
5. Close the switch to create the LL-G fault between 'YB' phase and 'N' neutral.
6. Note down the fault current.
7. Open the fault switch and remove the LL-G fault.
8. Reduce the alternator excitation, bring back the DC shunt motor field rheostat to its minimum position and stop DC shunt motor by opening DPST switch.
9. Switch OFF MCB.

LG, LL, LLG AND 3-Φ FAULT ANALYSIS OF 3-Φ ALTERNATOR

Tabular Column:

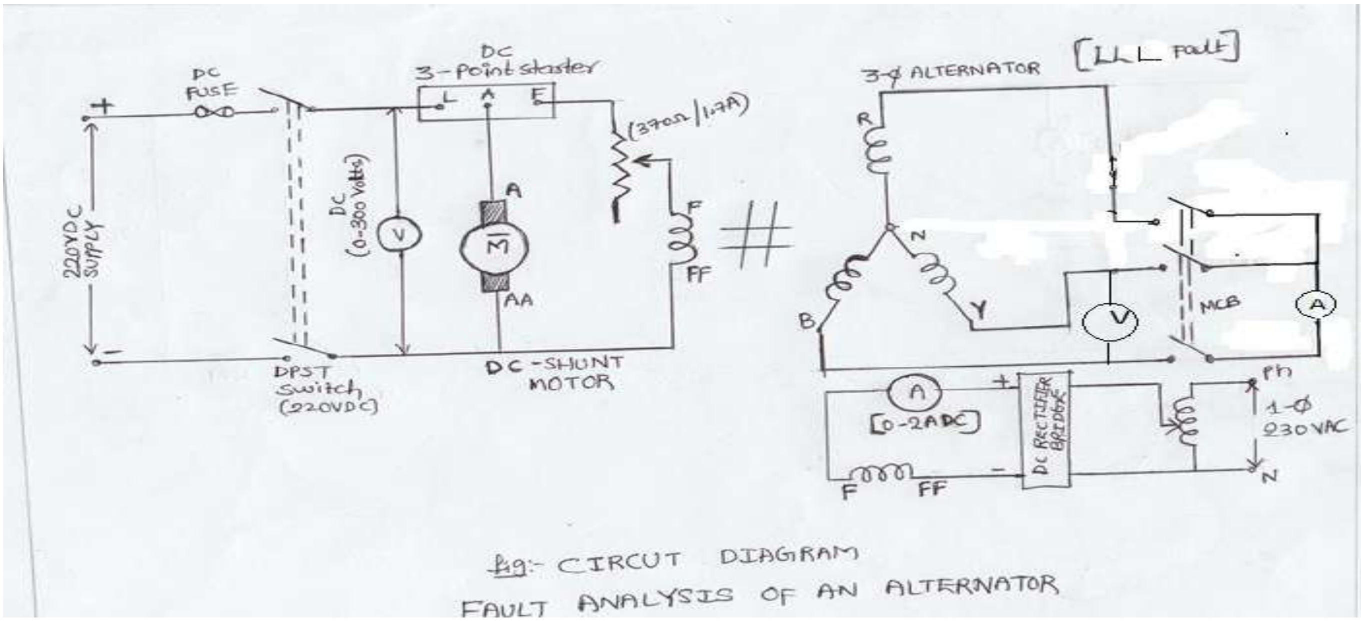
S.No.	E (v)	Field current I_f (A)	Theoretical I_{fault} in 'R' phase (A)	Measured I_{fault} in 'R' phase (A)
01	200V			

Z_1 = ____________Ω; Z_2 = ____________Ω; Z_0 = ____________Ω;

Where Z_1, Z_2, Z_0 are the positive, negative and zero phase sequence impedances of an alternator. The phase sequence values are to be taken from the previous cycle experiment.

$I_{fault} = (3 * E * Z_2)/(Z_0 Z_1 + Z_0 Z_2 + Z_1 Z_2)$ = ________________A

CIRCUIT DIAGRAM FOR LLL FAULT



PROCEDURE:

1. Connect circuit as per the circuit diagram shown in Fig(4) for 3-Ø Line (LLL) fault between 'RYB' phases.
2. The DC shunt motor field rheostat is in minimum position, the alternator field excitation variac should be in zero position, Switch ON MCB, start DC shunt motor with the help of 3-point starter.

LG, LL, LLG AND 3-Φ FAULT ANALYSIS OF 3-Φ ALTERNATOR

3. Run the alternator at its rated speed of 1500rpm by adjusting DC shunt motor field Rheostat.
4. Increase the alternator field excitation till it reaches the E=200V (Line voltage).
5. Close the switch to create the LLL fault between 'RYB' phases.
6. Note down the fault current.
7. Open the fault switch and remove the LLL fault.
8. Reduce the alternator excitation, bring back the DC shunt motor field rheostat to its minimum position and stop DC shunt motor by opening DPST switch.
9. Switch OFF MCB.

Tabular Column:

S.No.	E (v)	Field current I_f (A)	Theoretical I_{fault} in 'R' phase (A)	Measured I_{fault} in 'R' phase (A)
01	200V			

Z_1 = ____________Ω;
Where Z_1 is the positive sequence impedances of an alternator. The phase sequence values are to be taken from the previous cycle experiment.

$I_{fault} = E / Z_1$ =_______________A

RESULT:

	LG FAULT	LL FAULT	LLG FAULT	LLL FAULT
Line voltage				
Fault current				

Name	Roll No	Sign	Date	Marks	Incharge

DIFFERENTIAL PROTECTION OF SINGLE PHASE TRANSFORMER

AIM: Study the differential protection scheme for a single phase transformer.

APPARATUS:

S.No	Apparatus	Range	Quantity
1.	1-Phase Auto transformer	230/0-260Volt	01
2.	Transformer	230V/50Volt	01
3.	CT'S	10/5A, 20/5A	01 Each
4.	Digital Voltmeters	0-300V, 0-150V	01 Each
5.	Digital Ammeters	0-20A, 0-10A, 0-5A	01 Each
6.	Ammeter	0-2A(MI)	01
7.	Differential Relay	Numerical Type	01
8.	Resistive load	Internally connected	02
9.	MCB protection		01
10.	Fault switch (Switch No:3)		01
11.	Load switches(Switch No's: 1,2)		02
12.	Connecting wires		As required

THEORY:

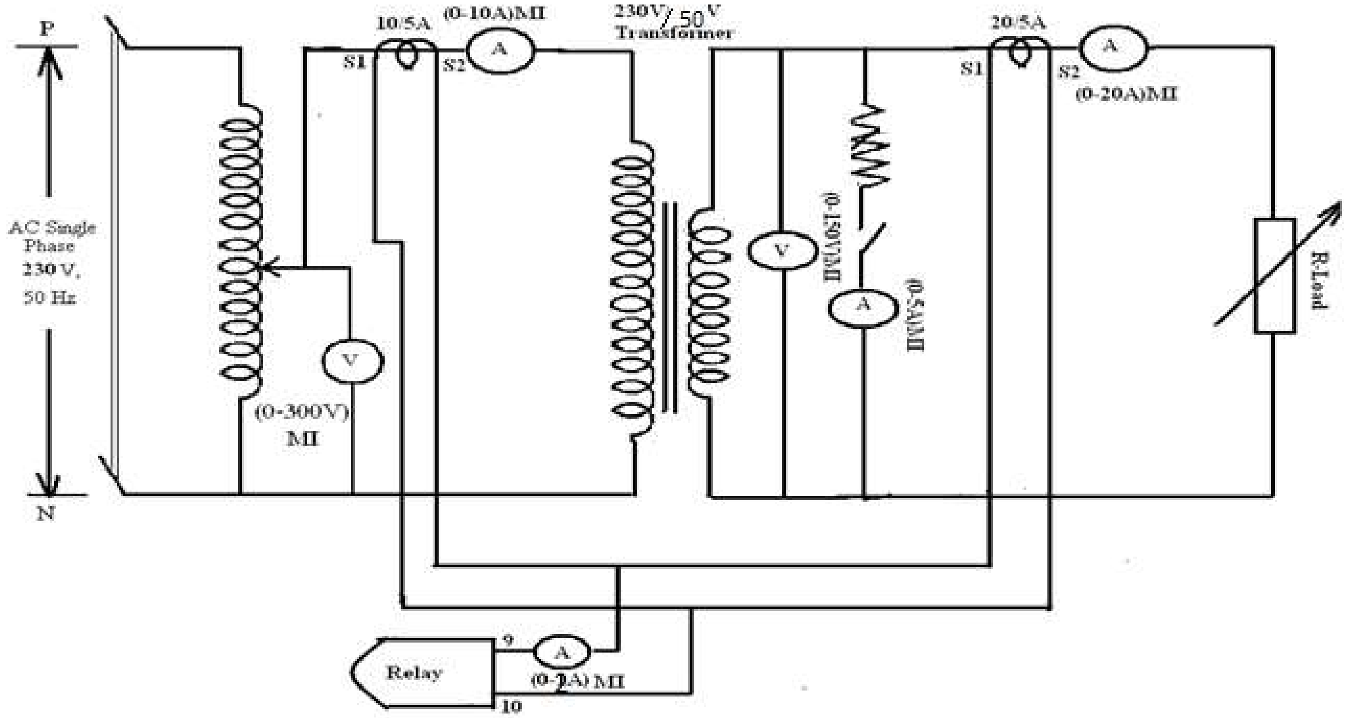
A Differential relay responds to vector difference between two or more similar electrical quantities. From this definition the Differential relay has at least two actuating quantities say 1-1 and 2-1. The two or more actuating quantities should be same.

Ex: Current/Current.

The Relay responds to vector difference between 1-1 &2-1which includes magnitude and /or phase angle difference. Differential protection is generally unit protection. The protection zone is exactly determined by location of CTs. The vector difference is actuated by suitable connection of CTs or PTs secondary's. Most differential relays are current differential relays in which vector difference between current entering the winding & current leaving the winding is used for relay operation. Differential protection is used for protection of Generators, Transformers etc. Internal fault is created using switch and relay operation observed for various TSMs. Relay operations for external faults can also be studied.

DIFFERENTIAL PROTECTION OF SINGLE PHASE TRANSFORMER

Circuit Diagram:



PROCEDURE:

1. Connect circuit as per the circuit diagram shown in Fig.
2. Ensure that the variac is in zero position, Load switches are in OFF condition and Fault switch is also in OFF condition. Then switch ON MCB.
3. Test switch is in Upward direction and switch on "GREEN" switch.
4. Apply rated voltage 230V on primary side of the transformer by varying the 1-phase variac.
5. Note down Primary current, secondary current, fault current, relay current and Relay status.
6. Apply load using switch1, then observe and note down all the meter readings and Relay status.
7. Now switch ON fault switch 3 so as to create an internal fault.
8. Observe and note down all the meter readings and Relay status.
9. Switch OFF fault switch 3, so that internal fault cleared. Now apply additional load using switch 2, then observe and note down all the meter readings and Relay status.
10. Now switch ON fault switch 3 so as to create an internal fault.
11. Observe and note down all the meter readings and Relay status.

DIFFERENTIAL PROTECTION OF SINGLE PHASE TRANSFORMER

12. Switch OFF fault switch 3, so that internal fault cleared. Switch OFF load switch 1, and load switch 2, then bring back the single phase variac to its minimum position and OFF MCB.
13. RESET relay.

Tabular Columns:

S. No		PRIMARY CURRENT (A)	SECONDARY CURRENT (A)	FAULT CURRENT (A)	RELAY CURRENT (A)	RELAY STATUS (TRIP/NOT)
1	NO LOAD					
2	WITH LOAD SWITCH 1					
3	WITH FAULT SWITCH 3					
4	WITH LOAD SWITCH 1 & 2					
5	WITH FAULT SWITCH 3					

RESULT:

Name	Roll No	Sign	Date	Marks	Incharge

LOAD FLOW ANALYSIS USING GAUSS SEIDAL (GS) METHOD

AIM: To obtain the complex bus voltages for a given power system using Gauss - Seidel Load Flow Analysis.

Software Required: MATLAB software

Theory:

Gauss-Seidel Method:

Load flow analysis is the study conducted to determine the steady state operating condition of the given system under given conditions. A large number of numerical algorithms have been developed and Gauss Seidel method is one of such algorithm.

Problem Formulation

The performance equation of the power system may be written of

$[I_{bus}] = [Y_{bus}]*[V_{bus}]$ (1)

Selecting one of the buses as the reference bus, we get (n-1) simultaneous equations. The bus loading equations can be written as

$I_i = (P_i-jQ_i)/(V_i)^*$, (i=1,2,3,…………..n) (2)

Where, $P_i=\mathrm{Re}\,[\sum_{k=1}^{n} V_i * Y_{ik} V_k]$ (3)

$Q_i= -\mathrm{Im}\,[\sum_{k=1}^{n} V_i * Y_{ik} V_k]$ (4)

The bus voltage can be written in form of

$V_i=(1.0/Y_{ii})[I_i- \sum_{\substack{j=1 \\ j\neq i}}^{n} Y_{ij} V_j]$ (5)

(i=1,2,…………n)& i≠ slack bus

Substituting I_i in the expression for V_i, we get

$V_{i\,new}=(1.0/Y_{ii})[(P_i-jQ_i)/(V_{io})^* - \sum_{j=1}^{n} Y_{ij} V_{io}]$ (6)

The latest available voltages are used in the above expression, we get

$V_{i\,new}=(1.0/Y_{ii})[(P_i-jQ_i)/(V_{io})^* - \sum_{j=1}^{n} Y_{ij} * V_j^n - \sum_{j=i+1}^{n} Y_{ij} * V_{io}]$ (7)

The above equation is the required formula .This equation can be solved for voltages in iterative manner. During each iteration we compute all the bus voltages and check for convergence is carried out by comparison with the voltages obtained at the end of previous iteration. After the solution is obtained, the slack bus real and reactive powers, the reactive power generation at other generator buses and line flows can be calculated.

LOAD FLOW ANALYSIS USING GAUSS SEIDAL (GS) METHOD

Line data:

Line Data for Y-Bus Formation.

From bus	To Bus	R	X	B/2
1	2	0.029	0.118	0
1	3	0.059	0.235	0
2	3	0.088	0.353	0
2	4	0.059	0.235	0
3	4	0.029	0.118	0

% Bus data for Load Flow Analysis.

Bus	Type	Vsp	Theta	PGi	QGi	PLi	QLi	Qmin	Qmax
1	1	1.06	0	0.0	0	0	0	0	0
2	2	1.04	0	0.5	0	0	0	0.1	1.0
3	3	1.0	0	0	0	0.4	0.3	0	0
4	3	1.0	0	0.0	0	0.3	0.1	0	0

PROCEDURE:-

1. Open MATLAB
2. Open new M-file
3. Type the program
4. Save in current directory
5. Compile and Run the program
6. For the output see command window\ Figure window

1. Program for Gauss - Seidel Load Flow Analysis

```
% Program for Gauss - Seidel Load Flow Analysis
clc
% Assumption, Bus 1 is considered as Slack bus.
ybus = ybusP();              % Calling program "ybusppg.m" to get Y-Bus.
busdata = busdata6();           % Calling "busdata6.m" for bus data.
bus = busdata(:,1);          % Bus number.
type = busdata(:,2);          % Type of Bus 1-Slack, 2-PV, 3-PQ.
```

LOAD FLOW ANALYSIS USING GAUSS SEIDAL (GS) METHOD

```
V = busdata(:,3);            % Initial Bus Voltages.
th = busdata(:,4);            % Initial Bus Voltage Angles.
GenMW = busdata(:,5);           % PGi, Real Power injected into the buses.
GenMVAR = busdata(:,6);          % QGi, Reactive Power injected into the buses.
LoadMW = busdata(:,7);          % PLi, Real Power Drawn from the buses.
LoadMVAR = busdata(:,8);          % QLi, Reactive Power Drawn from the buses.
Qmin = busdata(:,9);           % Minimum Reactive Power Limit
Qmax = busdata(:,10);           % Maximum Reactive Power Limit

P = GenMW - LoadMW;             % Pi = PGi - PLi, Real Power at the buses.
Q = GenMVAR - LoadMVAR;   % Qi = QGi - QLi, Reactive Power at the buses.
Vprev = V;
toler = 1;                     % Tolerence.
iteration = 1;                % iteration starting
 while (toler > 0.00001)          % Start of while loop
   for i = 2:nbus
       sumyv = 0;
       for k = 1:nbus
          if i ~= k
  sumyv = sumyv + ybus(i,k)* V(k);  % Vk * Yik
          end
       end
       if type(i) == 2          % Computing Qi for PV bus
  Q(i) = -imag(conj(V(i))*(sumyv + ybus(i,i)*V(i)));
       if (Q(i) > Qmax(i)) || (Q(i) < Qmin(i))  % Checking for Qi Violation.
            if Q(i) < Qmin(i)       % Whether violated the lower limit.
                 Q(i) = Qmin(i);
                 else                % No, violated the upper limit.
                 Q(i) = Qmax(i);
                 end
   type(i) = 3;                 % If Violated, change PV bus to PQ bus.
          end
       end
 V(i) = (1/ybus(i,i))*((P(i)-j*Q(i))/conj(V(i)) - sumyv);
                                            % Compute Bus Voltages.
       if type(i) == 2
                                     % For PV Buses, Voltage Magnitude remains
                                     same, but Angle changes.
V(i) = pol2rect(abs(Vprev(i)), angle(V(i))); % call function polar to rectangular.
       end
   end
   toler = max(abs(abs(V) - abs(Vprev)));       % Calculate tolerance.
   Vprev = V;                    % Vprev is required for next iteration,
   disp('voltage at iteration:');
   disp(iteration);
   disp(V);
   iteration = iteration + 1;               % Increment iteration count.
```

```
end                                      % End of while loop / Iteration

iteration                                % Total iterations.
V                                        % Bus Voltages in Complex form.
Vmag = abs(V)                            % Final Bus Voltages.
Ang = 180/pi*angle(V)                    % Final Bus Voltage Angles in Degree.
```

2. Program to form Admittance and Impedance Bus Formation....

% Save this program with separate file name **ybusP.m**

```
 % Program for Admittance Bus Formation
function ybus = ybusP();
% Read number of busses
n=4;
 % Initialize all admittances to zero.
YY=zeros(n,n) ;

% Initialize all charging admittances to zero.
ych=zeros(n,n);

% Initialize all line impedances to infinity.
z=inf(n,n);

% Get  Line impedances between the busses p and q

z(1,2)=0.029+0.118i;
z(1,3)=0.059+0.235i;
z(2,3)=0.088+0.353i;
z(2,4)=0.059+0.235i;
z(3,4)=0.029+0.118i;

% Find   the Line admittances between the busses p and q
for i=1:n
   for j=1:n
      y(i,j)=1/z(i,j);
   end
end

 for i=1:n
   for j=1:n
      y(j,i)=y(i,j);  % Symmetrical network
   end
end

% Get the half line charging Admittances between the busses p and q
ych(1,2)= 0.00;
ych(1,3)= 0.00;
ych(2,3)= 0.00;
```

LOAD FLOW ANALYSIS USING GAUSS SEIDAL (GS) METHOD

```
ych(2,4)= 0.00;
 ych(3,4)= 0.00;

for i=1:n
   for j=1:n
      ych(j,i)=ych(i,j);  % Symmetrical network
   end
end


% Formation of Diagonal Elements....
for i=1:n
   for j=1:n
     YY(i,i)=YY(i,i)+y(i,j)+ych(i,j);
   end
end


% Formation of the Off Diagonal Elements...
for i=1:n
   for j=1:n
      if(i~=j)
     YY(i,j)=YY(i,j)-y(i,j);
      end
   end
end
ybus=YY      % Bus Admittance Matrix.

ZZ= inv(YY);   % Bus Impedance Matrix.
```

3. Function for Bus data

```
function busdata = busdata6()                    % Returns busdata.

%          | Bus | Type | Vsp  | theta|  PGi|   QGi|   PLi|  QLi|  Qmin|  Qmax|

busdata = [   1     1     1.06    0      0.0     0     0      0      0      0;
              2     2     1.04    0      0.5     0     0      0     0.1    1.0;
              3     3     1.0     0      0       0     0.4    0.3    0      0;
              4     3     1.0     0      0.0     0     0.3    0.1    0      0
                                                                          ];
```

LOAD FLOW ANALYSIS USING GAUSS SEIDAL (GS) METHOD

4. Function to convert bus voltage from polar to rectangular.

```
% Function to convert bus voltage from polar to rectangular.

function rect = pol2rect(r,o)   % r = magnitude, o = angle in radians.
rect = r*cos(o) + j*r*sin(o);   % rect = real + j*imag
```

RESULT:

Name	Roll No	Sign	Date	Marks	Incharge

LOAD FLOW ANALYSIS USING GAUSS-SEIDAL (GS) METHOD

AIM: Obtain the complex bus voltages for a given power system using Gauss - Seidel Load Flow Analysis.

Software Required: MATLAB software

Theory:

Gauss-Seidel Method:

Load flow analysis is the study conducted to determine the steady state operating condition of the given system under given conditions. A large number of numerical algorithms have been developed and Gauss Seidel method is one of such algorithm.

Problem Formulation

The performance equation of the power system may be written of

$[I_{bus}] = [Y_{bus}]*[V_{bus}]$ (1)

Selecting one of the buses as the reference bus, we get (n-1) simultaneous equations. The bus loading equations can be written as

$I_i = (P_i-jQ_i)/(V_i)^*$, (i=1,2,3,…………..n) (2)

Where, $P_i=\text{Re}\left[\sum_{k=1}^{n} V_i * Y_{ik} V_k\right]$ (3)

$Q_i= -\text{Im}\left[\sum_{k=1}^{n} V_i * Y_{ik} V_k\right]$ (4)

The bus voltage can be written in form of

$V_i=(1.0/Y_{ii})\left[I_i- \sum_{\substack{j=1 \\ j\neq i}}^{n} Y_{ij} V_j\right]$ (5)

(i=1,2,…………n)& i≠ slack bus

Substituting I_i in the expression for V_i, we get

$V_{i\ new}=(1.0/Y_{ii})\left[(P_i-jQ_i)/(V_{io})^* - \sum_{j=1}^{n} Y_{ij} V_{io}\right]$ (6)

The latest available voltages are used in the above expression, we get

$V_{i\ new}=(1.0/Y_{ii})\left[(P_i-jQ_i)/(V_{io})^* - \sum_{j=1}^{n} Y_{ij} * V_j^n - \sum_{j=i+1}^{n} Y_{ij} * V_{io}\right]$ (7)

The above equation is the required formula .This equation can be solved for voltages in iterative manner. During each iteration we compute all the bus voltages and check for convergence is carried out by comparison with the voltages obtained at the end of previous iteration. After the solution is obtained, the slack bus real and reactive powers, the reactive power generation at other generator buses and line flows can be calculated.

LOAD FLOW ANALYSIS USING GAUSS-SEIDAL (GS) METHOD

Line data:

Line Data for Y-Bus Formation.

From bus	To Bus	R	X	B/2
1	2	0.029	0.118	0
1	3	0.059	0.235	0
2	3	0.088	0.353	0
2	4	0.059	0.235	0
3	4	0.029	0.118	0

Bus data for Load Flow Analysis.

Bus	Type	Vsp	Theta	PGi	QGi	PLi	QLi	Qmin	Qmax
1	1	1.06	0	0.0	0	0	0	0	0
2	2	1.04	0	0.5	0	0	0	0.1	1.0
3	3	1.0	0	0	0	0.4	0.3	0	0
4	3	1.0	0	0.0	0	0.3	0.1	0	0

PROCEDURE:-

1. Open MATLAB
2. Open new M-file
3. Type the program
4. Save in current directory
5. Compile and Run the program
6. For the output see command window\ Figure window

1. Program for Gauss - Seidel Load Flow Analysis

```
% Save this program with separate file name gsmethod.m
clc                            % Assumption, Bus 1 is considered as Slack bus.
ybus = ybusP();                % Calling program "ybusP.m" to get Y-Bus.
busdata = busdata6();          % Calling "busdata6.m" for bus data.
bus = busdata(:,1);            % Bus number.
type = busdata(:,2);           % Type of Bus 1-Slack, 2-PV, 3-PQ.
V = busdata(:,3);              % Initial Bus Voltages.
th = busdata(:,4);             % Initial Bus Voltage Angles.
GenMW = busdata(:,5);          % PGi, Real Power injected into the buses.
GenMVAR = busdata(:,6);        % QGi, Reactive Power injected into the buses.
LoadMW = busdata(:,7);         % PLi, Real Power Drawn from the buses.
```

LOAD FLOW ANALYSIS USING GAUSS-SEIDAL (GS) METHOD

```
LoadMVAR = busdata(:,8);        % QLi, Reactive Power Drawn from the buses.
Qmin = busdata(:,9);            % Minimum Reactive Power Limit
Qmax = busdata(:,10);           % Maximum Reactive Power Limit
nbus=max(bus);                  % No.of buses
P = GenMW - LoadMW;             % Pi = PGi - PLi, Real Power at the buses.
Q = GenMVAR - LoadMVAR;         % Qi = QGi - QLi, Reactive Power at the buses.
Vprev = V;
toler = 1;                      % Tolerence.
iteration = 1;                  % iteration starting
 while (toler > 0.00001)        % Start of while loop
    for i = 2:nbus
        sumyv = 0;
        for k = 1:nbus
            if i ~= k
   sumyv = sumyv + ybus(i,k)* V(k);  % Vk * Yik
            end
        end
        if type(i) == 2         % Computing Qi for PV bus
  Q(i) = -imag(conj(V(i))*(sumyv + ybus(i,i)*V(i)));
        if (Q(i) > Qmax(i)) || (Q(i) < Qmin(i))  % Checking for Qi Violation.
              if Q(i) < Qmin(i)     % Whether violated the lower limit.
                    Q(i) = Qmin(i);
                    else            % No, violated the upper limit.
                    Q(i) = Qmax(i);
                    end
    type(i) = 3;                % If Violated, change PV bus to PQ bus.
            end
        end
 V(i) = (1/ybus(i,i))*((P(i)-j*Q(i))/conj(V(i)) - sumyv);
                                    % Compute Bus Voltages.
         if type(i) == 2            % For PV Buses, Voltage Magnitude remains same,
         but Angle changes.
V(i) = pol2rect(abs(Vprev(i)), angle(V(i))); % call function polar to rectangular.
        end
    end
    toler = max(abs(abs(V) - abs(Vprev)));     % Calculate tolerance.
    Vprev = V;                  % Vprev is required for next iteration,
    disp('voltage at iteration:');
    disp(iteration);
    disp(V);
    iteration = iteration + 1;          % Increment iteration count.
end                                % End of while loop / Iteration
 iteration                         % Total iterations.
V                                  % Bus Voltages in Complex form.
Vmag = abs(V)                      % Final Bus Voltages.
Ang = 180/pi*angle(V)              % Final Bus Voltage Angles in Degree.
```

2. Program to form Admittance and Impedance Bus Formation....

% Save this program with separate file name **ybusP.m**

```
 % Program for Admittance Bus Formation
function ybus = ybusP();
% Read number of busses
n=4;
 % Initialize all admittances to zero.
YY=zeros(n,n) ;

% Initialize all charging admittances to zero.
ych=zeros(n,n);

% Initialize all line impedances to infinity.
z=inf(n,n);

% Get  Line impedances between the busses p and q

z(1,2)=0.029+0.118i;
z(1,3)=0.059+0.235i;
z(2,3)=0.088+0.353i;
z(2,4)=0.059+0.235i;
z(3,4)=0.029+0.118i;

% Find   the Line admittances between the busses p and q
for i=1:n
    for j=1:n
        y(i,j)=1/z(i,j);
    end
end

 for i=1:n
    for j=1:n
        y(j,i)=y(i,j);  % Symmetrical network
    end
end

% Get the half line charging Admittances between the busses p and q
ych(1,2)= 0.00;
ych(1,3)= 0.00;
ych(2,3)= 0.00;
ych(2,4)= 0.00;
 ych(3,4)= 0.00;

for i=1:n
    for j=1:n
        ych(j,i)=ych(i,j);  % Symmetrical network
```

```
   end
end

% Formation of Diagonal Elements....

for i=1:n
   for j=1:n
      YY(i,i)=YY(i,i)+y(i,j)+ych(i,j);
   end
end

% Formation of the Off Diagonal Elements...


for i=1:n
   for j=1:n
       if(i~=j)
      YY(i,j)=YY(i,j)-y(i,j);
       end
   end
end
ybus=YY       % Bus Admittance Matrix.

ZZ= inv(YY);   % Bus Impedance Matrix.
```

3. Function for Bus data

% Save this program with separate file name **busdata6.m**

```
function busdata = busdata6()                    % Returns busdata.

%            | Bus | Type | Vsp  | theta | PGi |  QGi |  PLi |  QLi | Qmin | Qmax |

busdata = [   1     1     1.06    0     0.0    0     0     0     0     0;
              2     2     1.04    0     0.5    0     0     0     0.1   1.0;
              3     3     1.0     0     0      0     0.4   0.3   0     0;
              4     3     1.0     0     0.0    0     0.3   0.1   0     0
                                                                          ];
```

LOAD FLOW ANALYSIS USING GAUSS-SEIDAL (GS) METHOD

4. Function to convert bus voltage from polar to rectangular.
% Save this program with separate file name **pol2rect.m**

```
function rect = pol2rect(r,o)   % r = magnitude, o = angle in radians.
rect = r*cos(o) + j*r*sin(o);   % rect = real + j*imag
```

RESULT:

ame	Roll No	Sign	Date	Marks	Incharge

LOAD FREQUENCY CONTROL OF SINGLE AREA & TWO AREA POWER SYSTEM

Aim: To obtain the frequency deviation response for a sudden (step) load change in single area and two area power systems.

Theory:

LOAD FREQUENCY CONTROL:

Change in real power affect mainly the system frequency, while reactive power is less sensitive to changes in frequency and is mainly dependent on changes in voltage magnitude. Thus, real and reactive powers are controlled separately. The *load frequency control* (LFC) loop controls the real power and frequency and the *automatic voltage regulator* (AVR) loop regulates the reactive power and voltage magnitude. Load frequency control has gained in importance with the growth of inter connected power systems and has made the operation of interconnected systems possible.

The operation objectives of the LFC are to maintain reasonably uniform frequency, to divide the load between generators, and to control the tie-line interchange schedules.

MATHEMATICAL MODELLING OF A GENERATOR:

The Model of the generator and load is given by

$$\Delta F(s) = \frac{1}{2Hs}[\Delta Pm(s) - \Delta Pe(s)]$$

Where $\Delta F(s)$ is the Change in frequency , $\Delta Pm(s)$ is the mechanical power input to the generator and $\Delta Pe(s)$ is the electrical power output of generator. The block diagram is given below

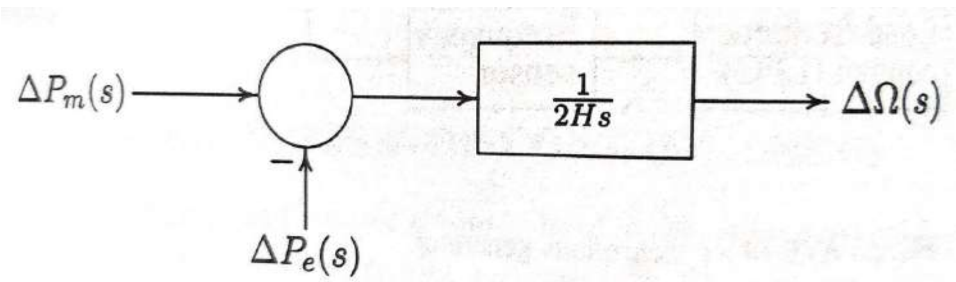


Fig1. Generator Block Diagram

LOAD FREQUENCY CONTROL OF SINGLE AREA & TWO AREA POWER SYSTEM

MATHEMATICAL MODELLING OF LOAD:

The load on a power system consists of variety of electrical drives. The speed-load characteristic of the composite load is given by:

$$\Delta P_e = \Delta P_L + D\,\Delta\omega$$

Where ΔP_L is the non-frequency sensitive change in load, $D\Delta\omega$ is the load change that is frequency sensitive. D is expressed as % change in load divided by % change in frequency. Including the load model in the generator block diagram results in following block diagram

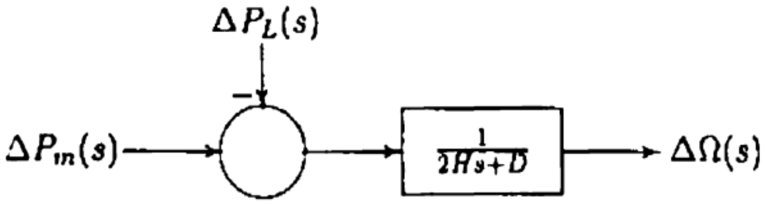


Fig 2. Generator-Load Block Diagram.

MATHEMATICAL MODELLING OF PRIMEMOVER:

The model of turbine relates the changes in mechanical power output ΔP_m and the changes in the steam valve position ΔP_V. The simplest prime mover model for non-reheat steam turbine can be approximated with a single time constant τ_T, results in the following transfer function

$$G_T(s) = \frac{\Delta P_m(s)}{\Delta P_V(s)} = \frac{1}{1+\tau_T s}$$

The block diagram of simplest turbine model is given by

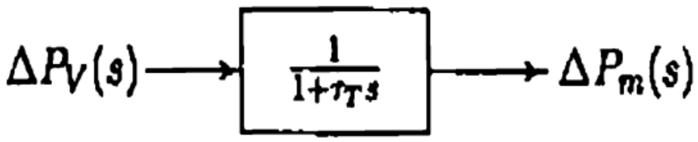


Fig 3. Block Diagram of Steam Turbine

MATHEMATICAL MODELLING OF GOVERNOR:

The model of governor relates the changes in the steam valve position ΔP_V and the Speed changer setting ΔP_{ref} and also the Change in frequency ΔF. The Model of the governor is given below

LOAD FREQUENCY CONTROL OF SINGLE AREA & TWO AREA POWER SYSTEM

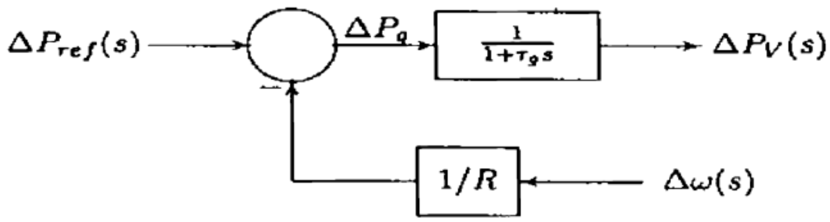


Fig 4. Block Diagram of Speed Governor.

Where T_g is the time constant of governor and , R is the speed regulation.

BLOCK DIAGRAM OF LOAD FREQUENCY CONTROL SYSTEM:

Combining all the above block diagrams, complete block diagram of load frequency control of an isolated power system shown in the following figure

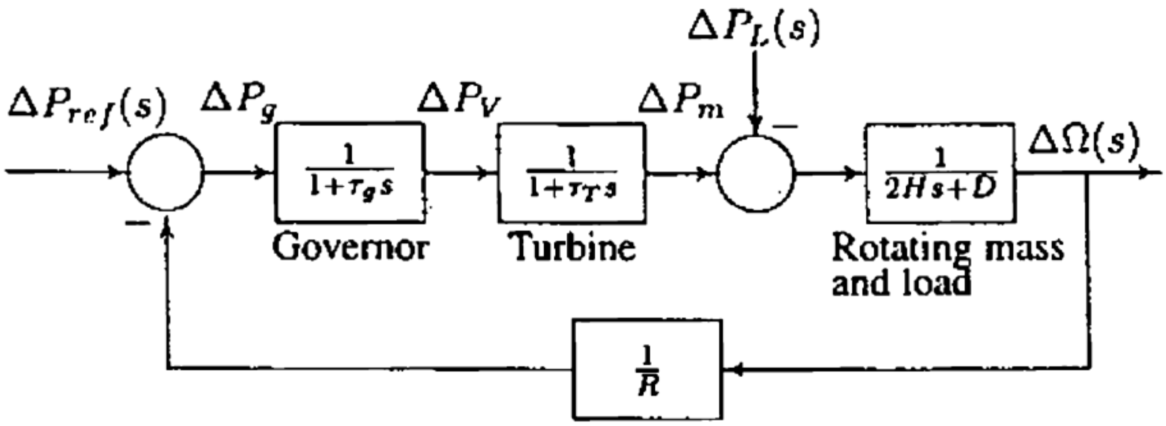


Fig 5. LFC Block diagram of an Isolated Power System

The closed loop transfer function that relates the load change ΔP_L to the frequency deviation ΔF is

$$\frac{\Delta\Omega(s)}{-\Delta P_L} = \frac{(1+\tau_g s)(1+\tau_T s)}{(2Hs+D)(1+\tau_g s)(1+\tau_T s)+1/R}$$

LOAD FREQUENCY CONTROL OF SINGLE AREA & TWO AREA POWER SYSTEM

AUTOMATIC GENERATION CONTROL IN SINGLE AREA:

If the load on the system is suddenly increased, then the speed of the turbine drops before the governor could adjust the input of the steam to this new load. As the change in the value of speed decreases the error signal becomes lesser and the position of the governor and not of the fly balls gets nearer to the point required to keep the speed constant. One way to regain the speed or frequency to its actual value is to add an integrator on its way. The integrator will monitor the average error over a certain period of time and will overcome the offset.

The closed loop transfer function of the control system is given by:

$$\frac{\Delta\Omega(s)}{-\Delta P_L} = \frac{s(1+\tau_g s)(1+\tau_T s)}{s(2Hs+D)\left(1+\tau_g s\right)(1+\tau_T s)+k_i+s/R}$$

The block diagram of AGC for an isolated power system is given in the following figure

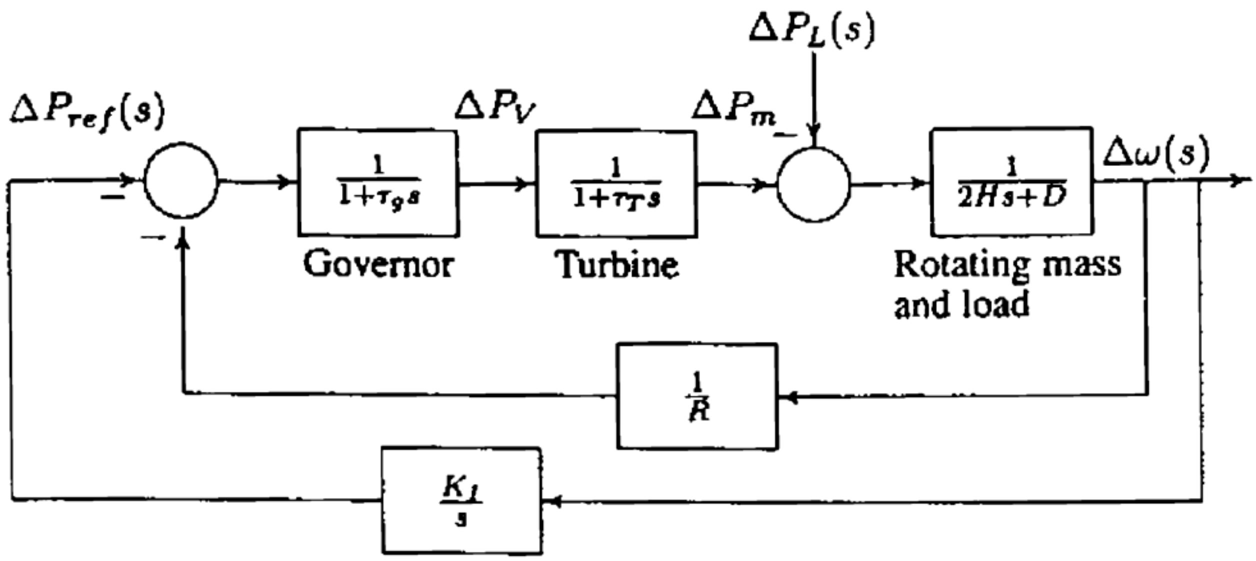
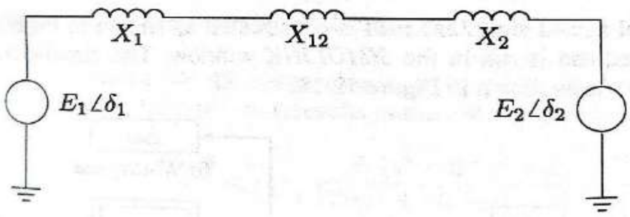


Fig 6.AGC for an isolated Power System

AGC IN THE MULTI AREA SYSTEM:

Consider two areas represented by an equivalent generating unit interconnected by lossless tie line with reactance X_{tie}.

LOAD FREQUENCY CONTROL OF SINGLE AREA & TWO AREA POWER SYSTEM



During normal operation, the real power transferred over the tie line is given by

$$P_{12} = \frac{|E_1||E_2|}{X_{12}} sin\delta_{12}$$

Where $X_{12}=X_1+X_{tie}+X_2$, and $\delta_{12}=\delta_1-\delta_2$. This equation can be linearized for a small deviation in the Tie-line flow ΔP_{12} from the nominal value, i.e.,

$$\Delta P_{12} = \left.\frac{dP_{12}}{d\delta_{12}}\right|_{\delta_{12_0}} \Delta\delta_{12} = P_s\Delta\delta_{12}$$

The tie-line power deviation then takes on the form

$$\Delta P_{12}=Ps *(\Delta\delta_1- \Delta\delta_2)$$

Let us consider a load change ΔPL_1 in area 1. In steady-state,

$$\Delta\omega= \Delta\omega_1= \Delta\omega_2,$$

$$\text{and } \Delta Pm_1- \Delta P_{12}- \Delta PL_1= \Delta\omega*D_1$$

$$\Delta Pm_2+ \Delta P_{12}= \Delta\omega*D_2$$

Also, the Change in mechanical power is given by

$$\Delta Pm_1= -\Delta\omega/R_1$$

$$\Delta Pm_2= -\Delta\omega/R2$$

Also $\Delta\omega= -\Delta PL_1/(B_1+B_2)$

Where $B_1=(1/R_1) +D_1$,
$B_2=(1/R_2) +D_2$

B_1 and B_2 are known as frequency bias factors.

The Change in the tie-line power is $\Delta P_{12}=(B_2/B_1+B_2)*(- \Delta PL_1)$

LOAD FREQUENCY CONTROL OF SINGLE AREA & TWO AREA POWER SYSTEM

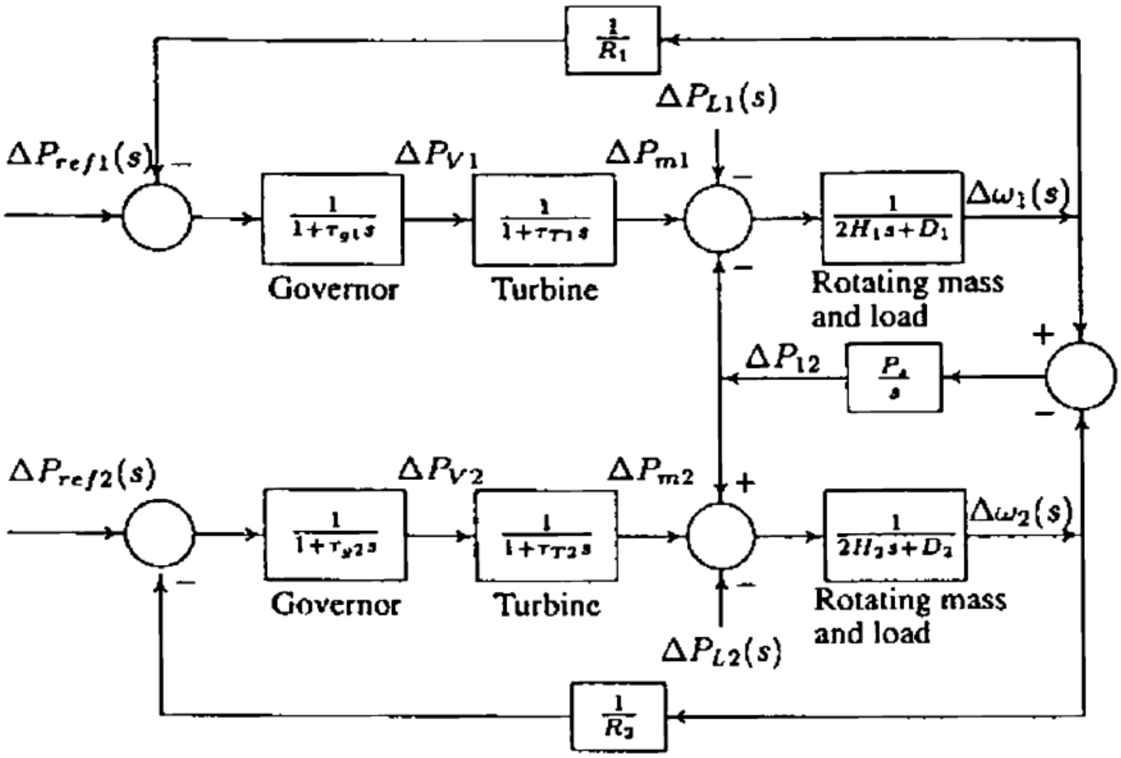


Fig 7.Two-Area System with only Primary LFC Loop.

TIE-LINE BIAS CONTROL:

Conventional LFC is based upon tie-line bias control, where each area tends to reduce the area control error (ACE) to zero. The control error for each area consists of a linear combination of frequency and tie-line error.

$$ACE_i=\sum_{j=1}^{n} \Delta Pij+K_i * \Delta\omega$$

The ACES for a two-area system are

$$ACE1= \Delta P_{12}+ B_1* \Delta\omega_1$$

$$ACE2= \Delta P_{12}+ B_2* \Delta\omega_2$$

LOAD FREQUENCY CONTROL OF SINGLE AREA & TWO AREA POWER SYSTEM

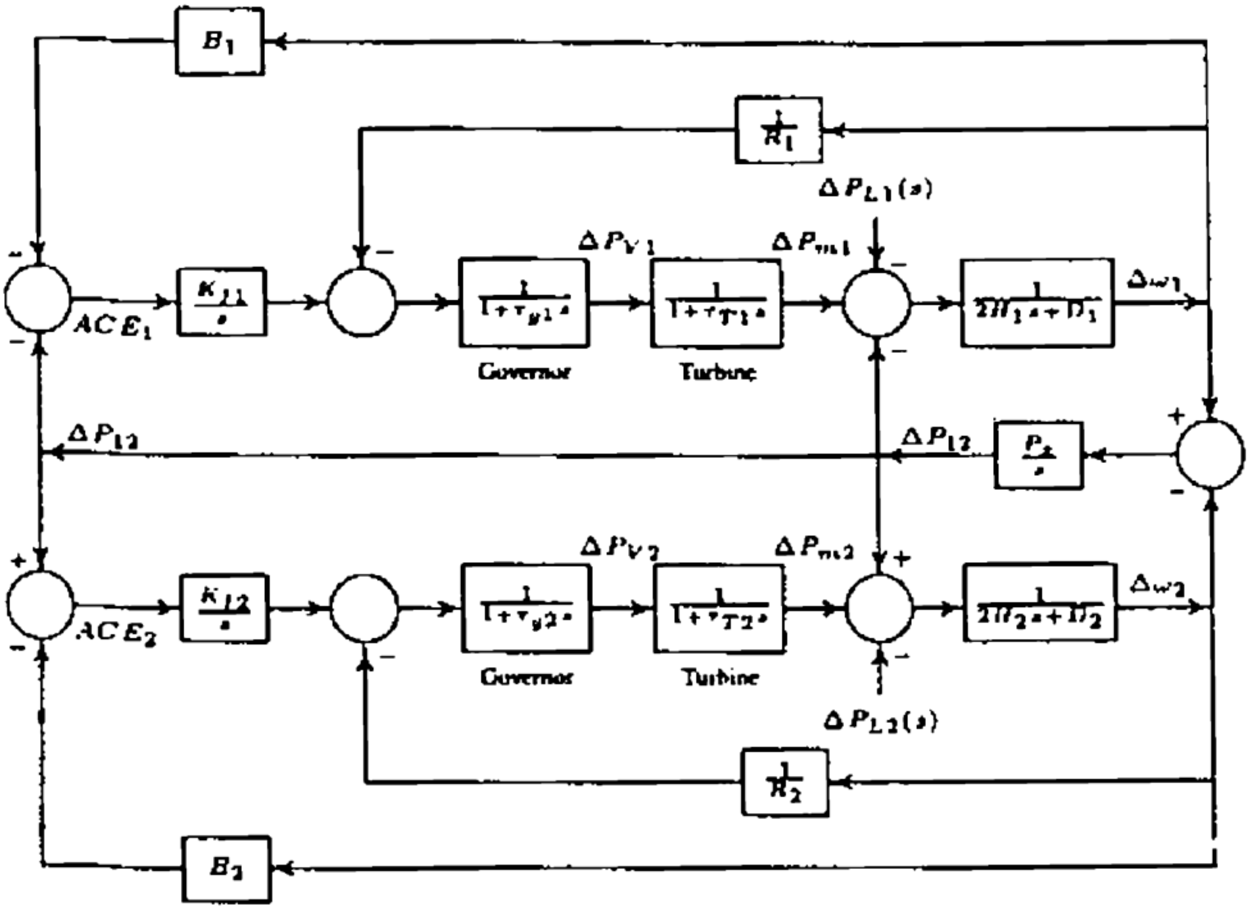


Fig 8.AGC Block Diagram for a Two-Area System.

PROBLEM 1: An isolated power station has the following parameters

Turbine time constant τ_T = 0.5 sec

Governor time constant T_g = 0.2 sec

Generator Inertia Constant H = 5 sec

Governor speed regulation R = 0.05 p.u

The load varies by 0.8 percent for a 1 percent change in frequency, i.e., D=0.8. A sudden load change of ΔP_L=0.2 per unit occurs.

A) Construct the SIMULINK block diagram and obtain the frequency deviation step response.
B) If the LFC is equipped with the secondary integral control loop for AGC with K_i=7, Construct the SIMULINK block diagram and obtain the frequency deviation step response.

LOAD FREQUENCY CONTROL OF SINGLE AREA & TWO AREA POWER SYSTEM

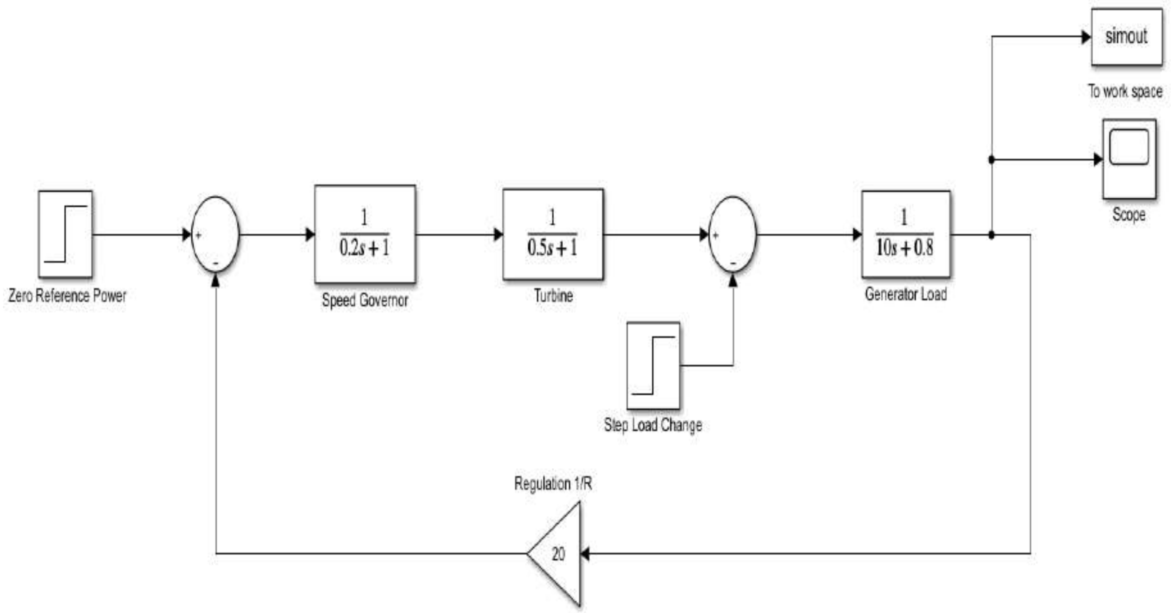


Fig 9. SIMULINK Model of an Isolated Power System

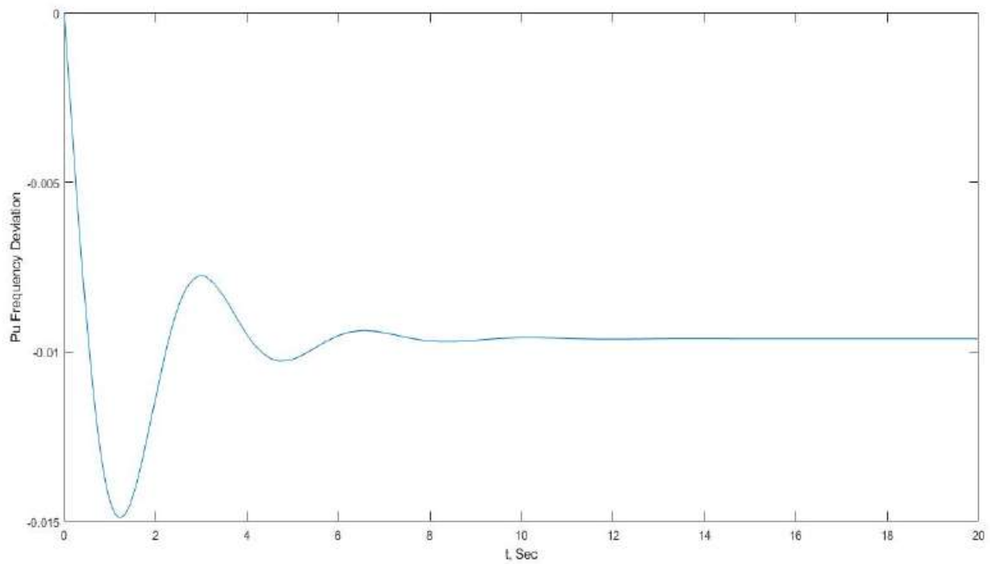


Fig 10. Frequency Deviation Step Response.

LOAD FREQUENCY CONTROL OF SINGLE AREA & TWO AREA POWER SYSTEM

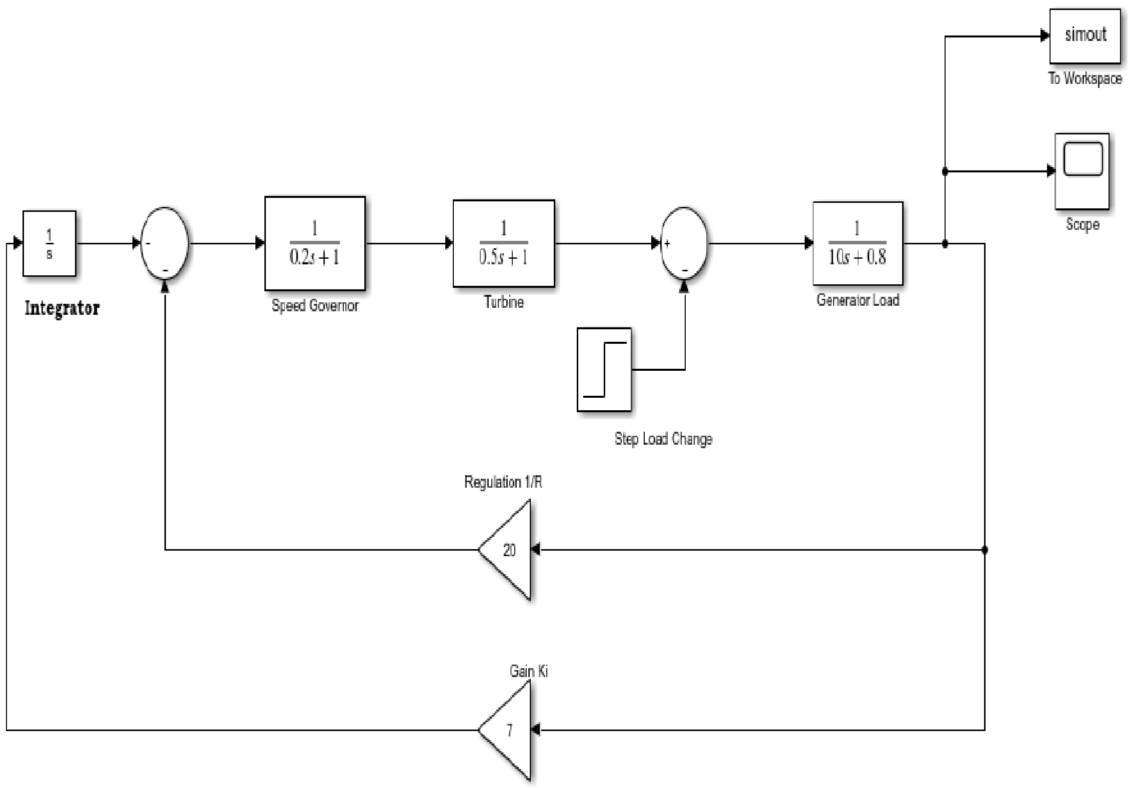


Fig 11. SIMULINK Model of AGC for an isolated Power System

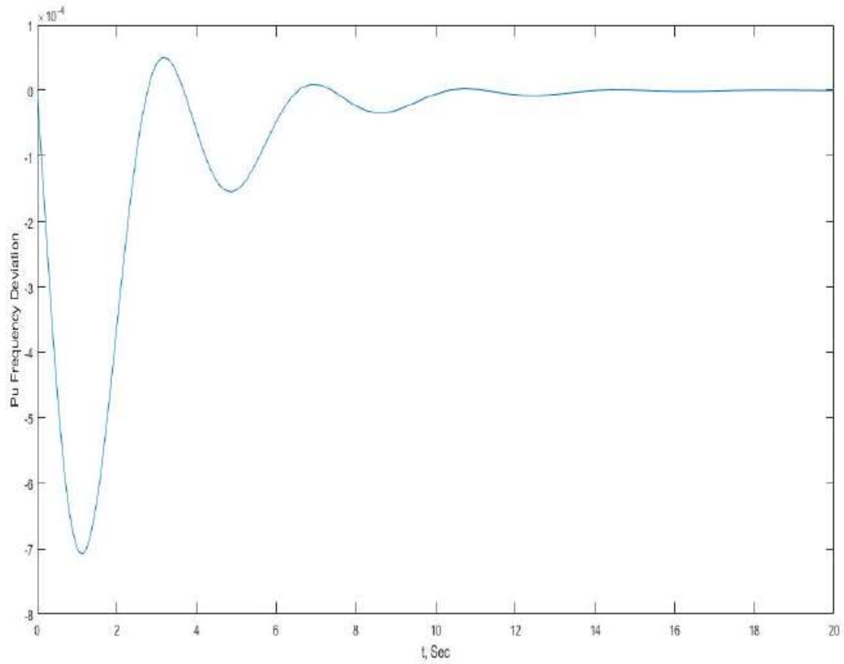


Fig 12. Frequency Deviation Step Response.

LOAD FREQUENCY CONTROL OF SINGLE AREA & TWO AREA POWER SYSTEM

PROBLEM2: A Two-area system connected by a tie line has the following parameters on a 1000 MVA common base

Area	1	2
Speed regulation	$R_1 = 0.05$	$R_2 = 0.0625$
Frequency-Sensitive Load Coefficient	$D_1 = 0.6$	$D_2 = 0.9$
Inertia Constant	$H_1 = 5$	$H_2 = 4$
Base power	1000 MVA	1000 MVA
Governor Time Constant	$T_{g1} = 0.2$ sec	$T_{g2} = 0.3$ sec
Turbine Time Constant	$\tau_{T1}=0.5$ sec	$\tau_{T2} = 0.6$ sec

The units are operating in parallel at the nominal frequency of 60 Hz. The synchronizing power coefficient is computed from the initial operating condition is Ps = 2.0 pu. A Load change of 0.2 pu occurs in area 1.

A) Construct the SIMULINK block diagram and obtain the frequency deviation step responses, Change in tie-line power flow as well as mechanical power flows in both the areas.

B) With the inclusion of ACEs, Construct the SIMULINK block diagram and obtain the frequency deviation step responses, Change in tie-line power flow as well as mechanical power flows in both the areas.

Where $ACE_1=20.6$ and $ACE_2=16.9$ and $K_{i1}=K_{i2}=0.3$

LOAD FREQUENCY CONTROL OF SINGLE AREA & TWO AREA POWER SYSTEM

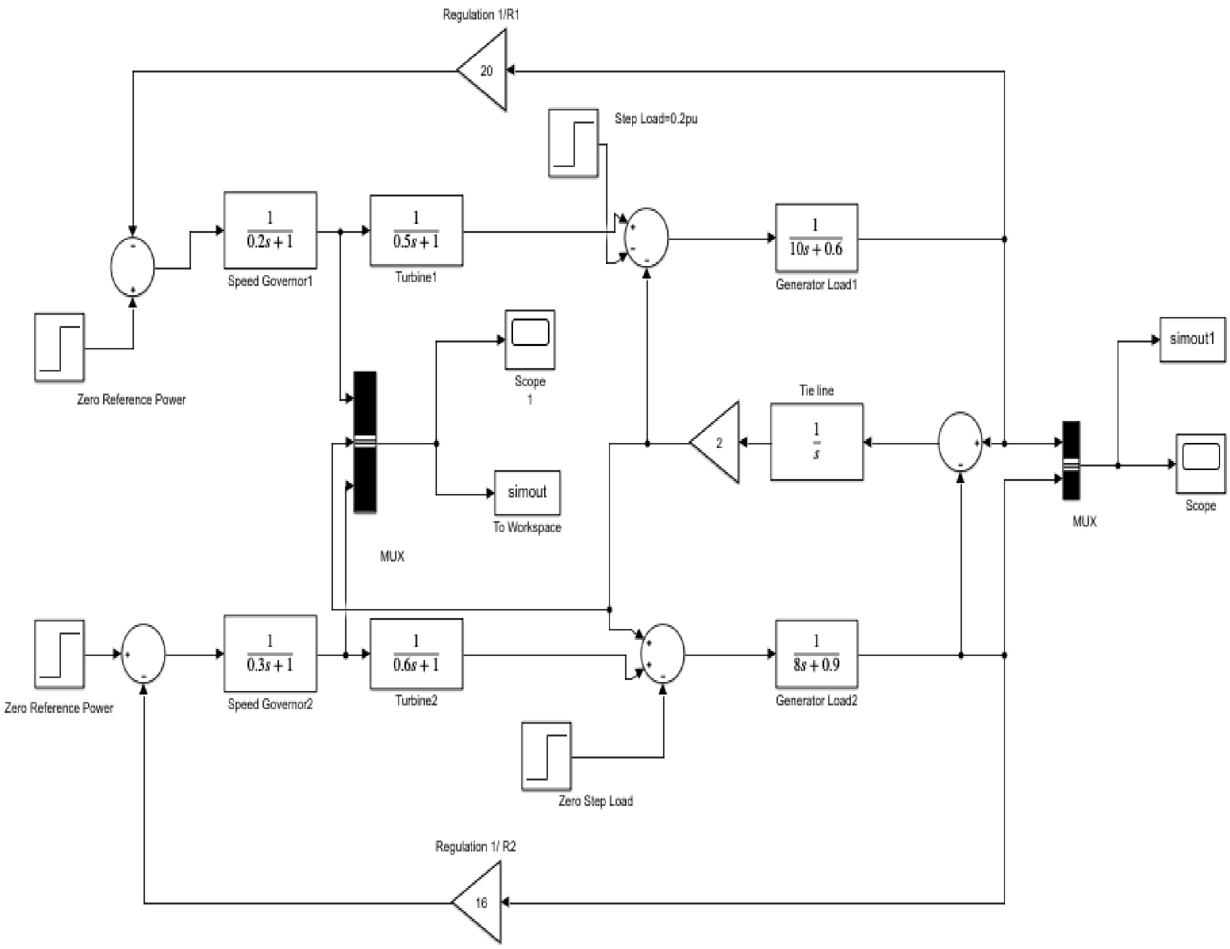


Fig13. SIMULINK Model of Two-Area System with only Primary LFC Loop.

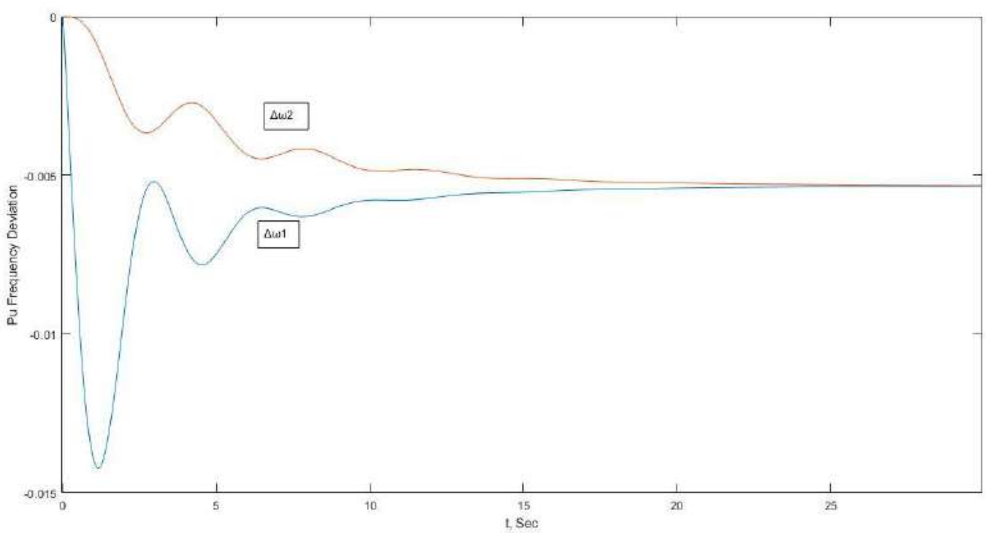


Fig14. Frequency Deviation Step Response.

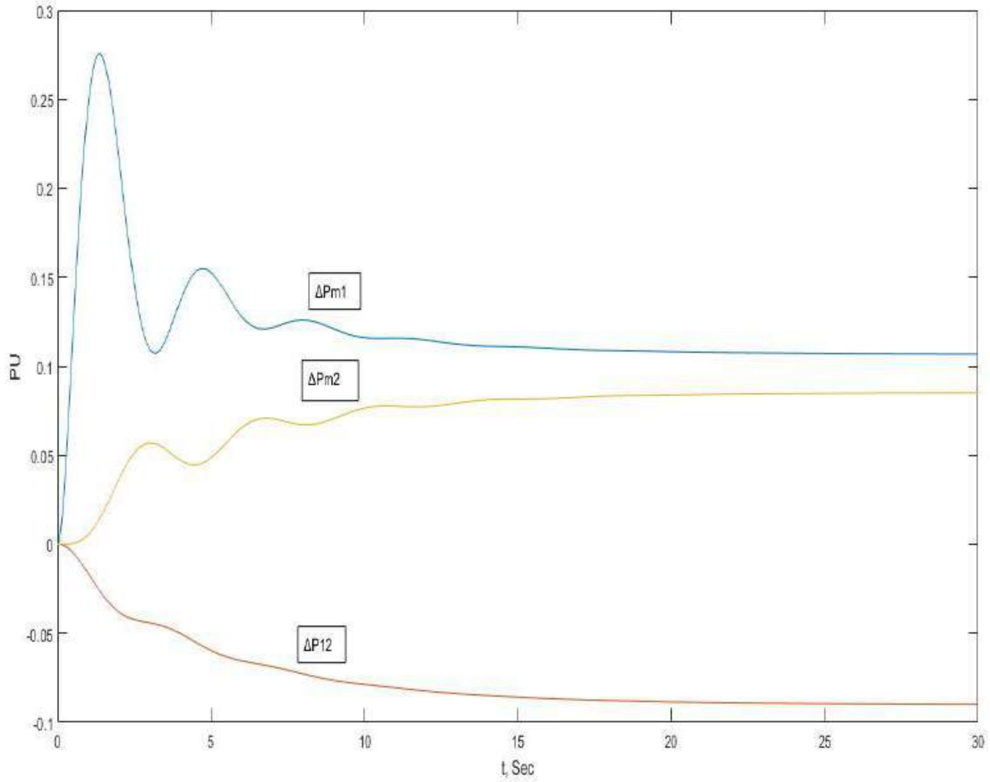


Fig15. Power Deviation Step Response.

LOAD FREQUENCY CONTROL OF SINGLE AREA & TWO AREA POWER SYSTEM

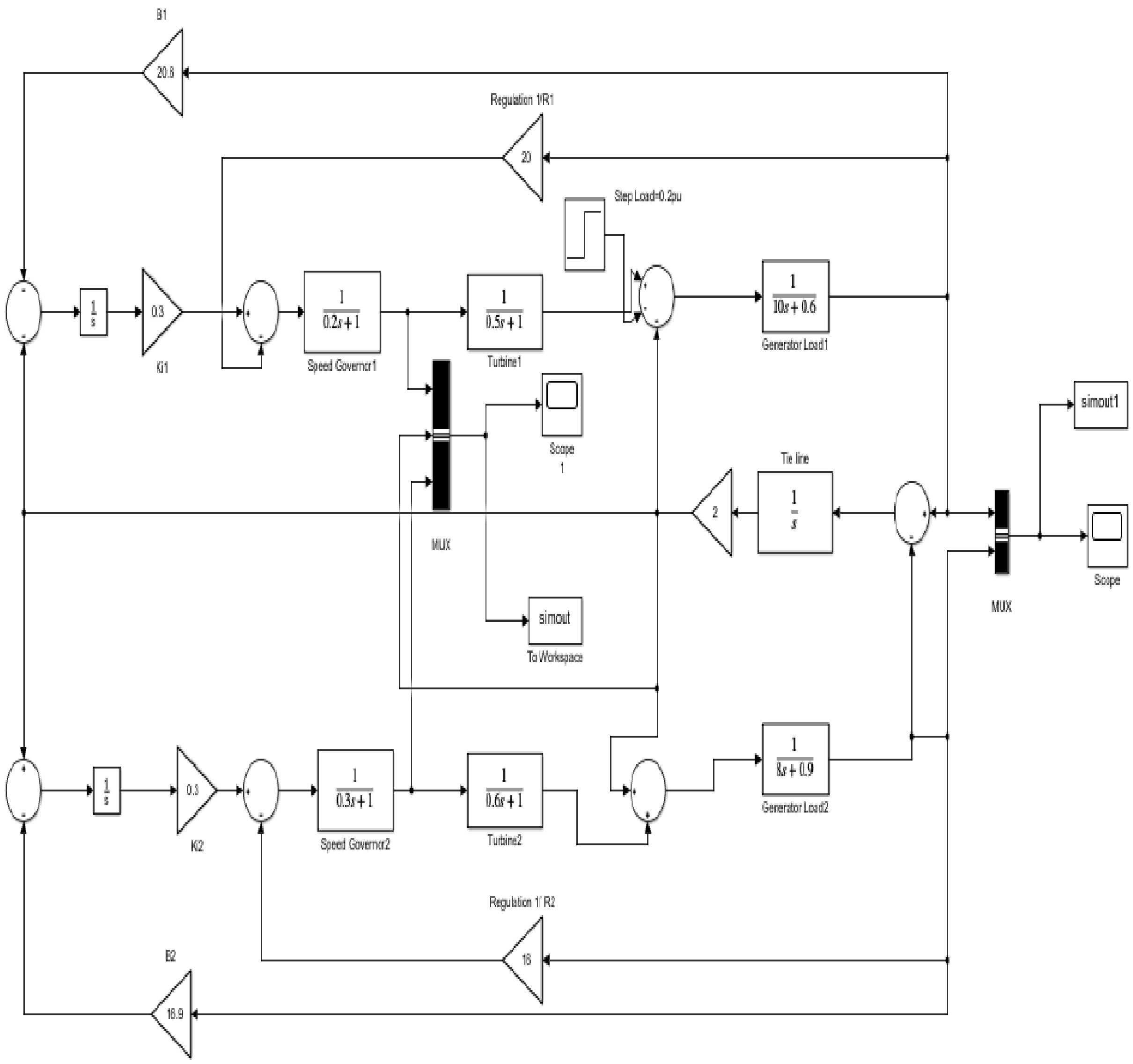


Fig16. SIMULINK Model of AGC for a Two-Area System.

LOAD FREQUENCY CONTROL OF SINGLE AREA & TWO AREA POWER SYSTEM

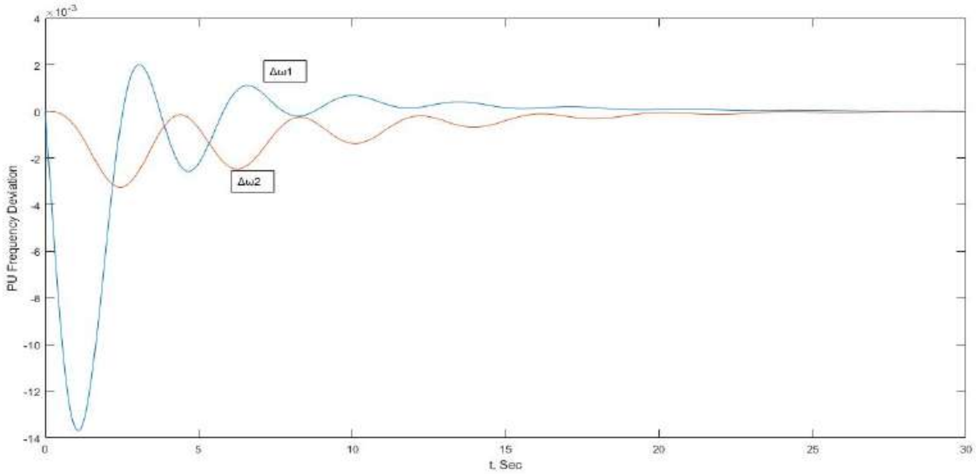


Fig17. Frequency Deviation Step Response.

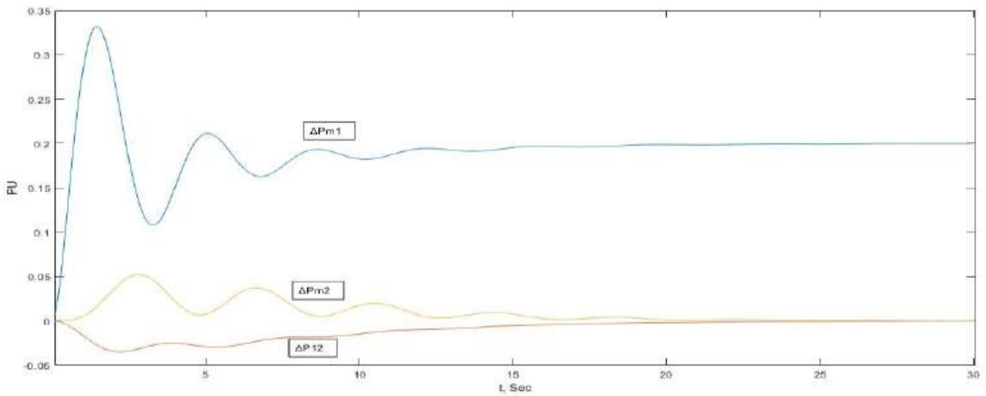


Fig18. Power Deviation Step Response.

RESULT:

Name	Roll No	Sign	Date	Marks	Incharge

Testing of CT, PT and Insulator String

AIM: 1. Study the performance of current Transformer and potential Transformers.
2. Determine voltage distribution and string efficiency of suspension insulator with and without guard ring.

APPARATUS:

For CT and PT			
S.No	Apparatus	Range	Quantity
1.	1-Φ Auto transformer	230/0-260V	01
2.	Current source transformer	0-20A	01
3.	Voltage source transformer	0-400V	01
4.	Current transformer	10/5A, 20/5A	01 01
5.	Voltage transformer	400/110V, 220/110V	01 01
6.	Digital Ammeters	0 – 20A	02
7.	Digital Voltmeters	0 – 500V	02
8.	Connecting Wires	-	As required

For Insulator			
S.No	Apparatus	Rating	Quantity
1.	1-Φ Auto transformer	230/0-110V	01
2.	Digital Voltmeter	300V	01
3.	Capacitors	2 μF 10 μF 1 μF	03 04 03
4.	Connecting wires	---	As required

THEORY:

1. **Current transformers** reduce high voltage currents to a much lower value and provide a convenient way of safely monitoring the actual electrical current flowing in an AC transmission line using a standard ammeter. The principal of operation of a basic current transformer is slightly different from that of an ordinary voltage transformer. Current transformers can reduce or "step-down" current levels from thousands of amperes down to a standard output of a known ratio to either 5 Amps or 1 Amp for normal operation. Thus, small and accurate instruments and control devices can be used with CT's because they are insulated away from any high-voltage power lines. There are a variety of metering applications and uses for current transformers such as with Wattmeter's, power factor meters, watt-hour meters, protective relays, or as trip coils in magnetic circuit breakers, or MCB's.

Testing of CT, PT and Insulator String

2. **Potential transformer** or voltage transformer gets used in electrical power system for stepping down the system voltage to a safe value which can be fed to low ratings meters and relays. The system voltage is applied across the terminals of primary winding of that transformer, and then proportionate secondary voltage appears across the secondary terminals of the PT. The secondary voltage of the PT is generally 110V. In an ideal potential transformer or voltage transformer, when rated burden gets connected across the secondary; the ratio of primary and secondary voltages of transformer is equal to the turn's ratio and furthermore, the two terminal voltages are in precise phase opposite to each other. But in actual transformer, there must be an error in the voltage ratio as well as in the phase angle between primary and secondary voltages.
3. **Insulator** A string of suspension insulators consists of a number of porcelain discs connected in series through metallic links. Each disc forms a capacitor C as shown in Fig. This is known as mutual capacitance or self-capacitance. However, in actual practice, capacitance also exists between metal fitting of each disc and tower or earth. This is known as shunt capacitance C_1. Due to shunt capacitance, charging current is not the same through all the discs of the string. Therefore, voltage across each disc will be different. Obviously, the disc nearest to the line conductor will have the maximum voltage. Thus referring to Fig. V_1 will be much more than V_2 or V_3.

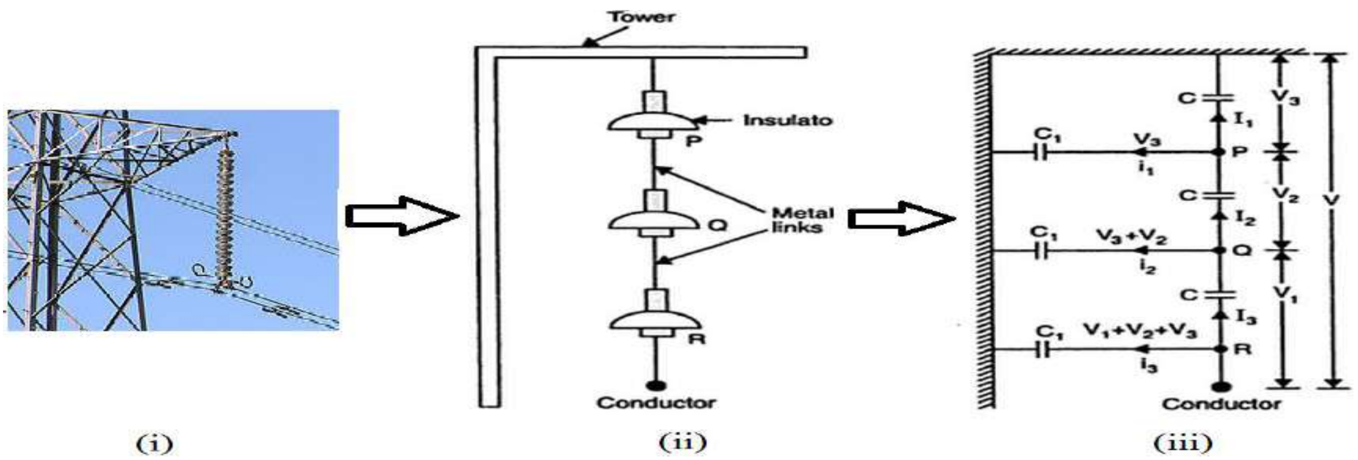


Fig. String of Suspension insulators

STRING EFFICIENCY:

The voltage applied across the string of suspension insulators is not uniformly distributed across various units or discs. The ratio of voltage across the whole string to the product of number of discs and the voltage across the disc nearest to the conductor is known as string efficiency.

$$\text{String efficiency} = \frac{\text{Voltage across the string}}{n \times \text{Voltage across disc nearest to conductor}}$$

Where n = number of discs in the string.

Testing of CT, PT and Insulator String

String efficiency is an important consideration since it decides the potential distribution along the string. The greater the string efficiency, the more uniform is the voltage distribution.

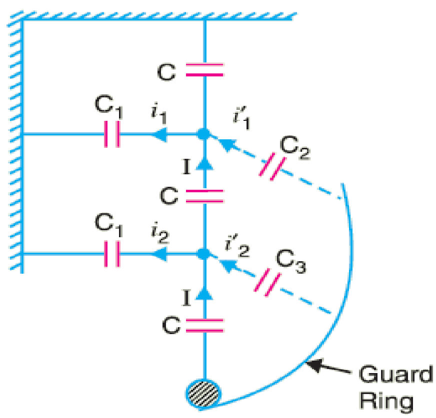
METHODS OF IMPROVING STRING EFFICIENCY:

(I) BY USING LONGER CROSS-ARMS. The value of string efficiency depends upon the value of K i.e., ratio of shunt capacitance to mutual capacitance. The lesser the value of K, the greater is the string efficiency and more uniform is the voltage distribution. In practice, K = 0·1 is the limit that can be achieved by this method.

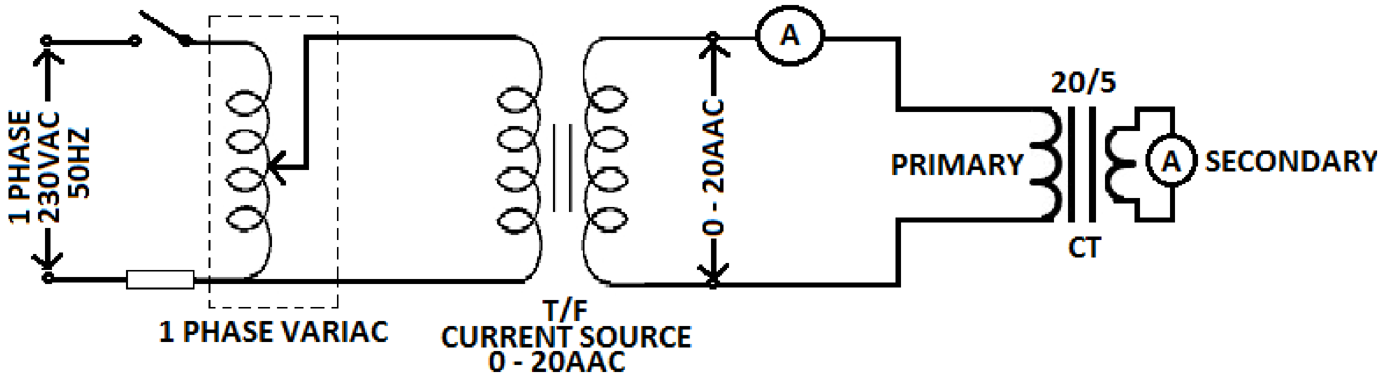
(II)BY GRADING THE INSULATORS. In this method, insulators of different dimensions are so chosen that each has a different capacitance. The insulators are capacitance graded i.e. they are assembled in the string in such a way that the top unit has the minimum capacitance, increasing progressively as the bottom unit (i.e., nearest to conductor) is reached. This method has the disadvantage that a large number of different-sized insulators are required.

(III) BY USING A GUARD RING.

The potential across each unit in a string can be equalized by using a guard ring which is a metal ring electrically connected to the conductor and surrounding the bottom insulator as shown in the Fig. The guard ring introduces capacitance between metal fittings and the line conductor. The guard rings contoured in such a way that shunt capacitance currents i_1, i_2 etc. are equal to metal fitting line capacitance currentsi$'_1$, i'_2 etc. The result is that same charging current I flows through each unit of string. Consequently, there will be uniform potential distribution across the units.



CURRENT TRANSFORMER CIRCUIT DIAGRAM:



CURRENT TRANSFORMER CIRCUIT

Testing of CT, PT and Insulator String

PROCEDURE:

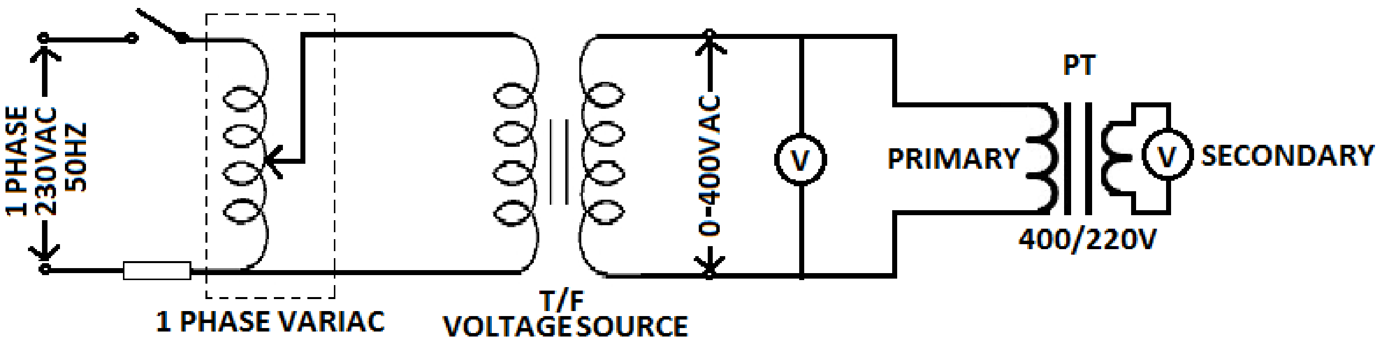
1. Connect the circuit diagram for 10/5A CT.
2. 1-Φ Variac should be in minimum position.
3. Keep change over switch in CT mode, then switch on mains.
4. Apply current by varying 1-Φ Variac to primary side of CT in steps of 2A starting from 2A upto 10A.
5. Note down the primary and secondary digital ammeter readings.
6. Bring back the 1-Φ Variac to its minimum position and switch off the mains.
7. Connect the circuit diagram for 20/5A CT.
8. Repeat steps 2 and 3.
9. Apply current by varying 1-Φ Variac to primary side of CT in steps of 4A starting from 4A upto 20A.
10. Note down the primary and secondary digital ammeter readings.
11. Bring back the 1-Φ Variac to its minimum position and switch off the mains.

TABULAR FORM:

For 10/5A CT Ratio is 0.5				
S.No	CT Primary (A)	CT Secondary (A)	Calculated Ratio	% Error
1.				
2.				
3.				
4.				
5.				
For 20/5A CT Ratio is 0.25				
S.No	CT Primary (A)	CT Secondary (A)	Calculated Ratio	% Error
1.				
2.				
3.				
4.				
5.				

Testing of CT, PT and Insulator String

POTENTIAL TRANSFORMER CIRCUIT DIAGRAM:



POTENTIAL TRANSFORMER CIRCUIT

PROCEDURE:

1. Connect the circuit diagram for 220/110V PT.
2. 1-Φ Variac should be in minimum position.
3. Keep change over switch in PT mode, then switch on mains.
4. Apply voltage from the 1-Φ Variac to primary side of PT in steps of 40V starting from 40V upto 200V.
5. Note down the primary and secondary digital voltmeter readings.
6. Bring back the 1-Φ Variac to its minimum position and switch off the mains.
7. Connect the circuit diagram for 440/110V PT.
8. Repeat steps 2 and 3.
9. Apply voltage from the 1-Φ Variac to primary side of PT in steps of 80V starting from 80V upto 400V.
10. Note down the primary and secondary digital voltmeter readings.
11. Bring back the 1-Φ Variac to its minimum position and switch off the mains.

TABULAR FORM:

For 220/110V PT			Ratio is 0.5	
S.No	PT Primary (V)	PT Secondary (V)	Calculated Ratio	% Error
1.				
2.				
3.				
4.				
5.				

Testing of CT, PT and Insulator String

For 440/110V PT			Ratio is 0.25	
S.No	PT Primary (V)	PT Secondary (V)	Calculated Ratio	% Error
1.				
2.				
3.				
4.				
5.				

INSULATOR CIRCUIT DIAGRAM:

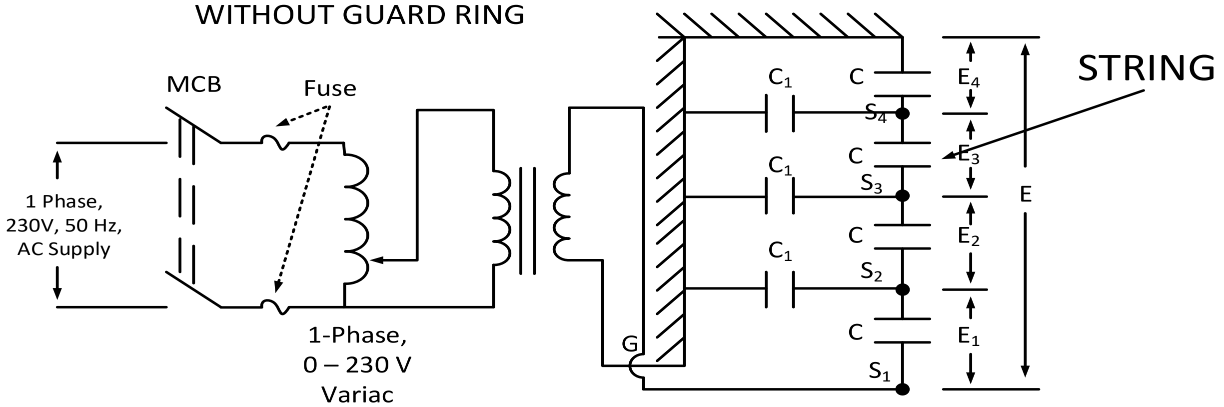


Fig : Without Guard Ring

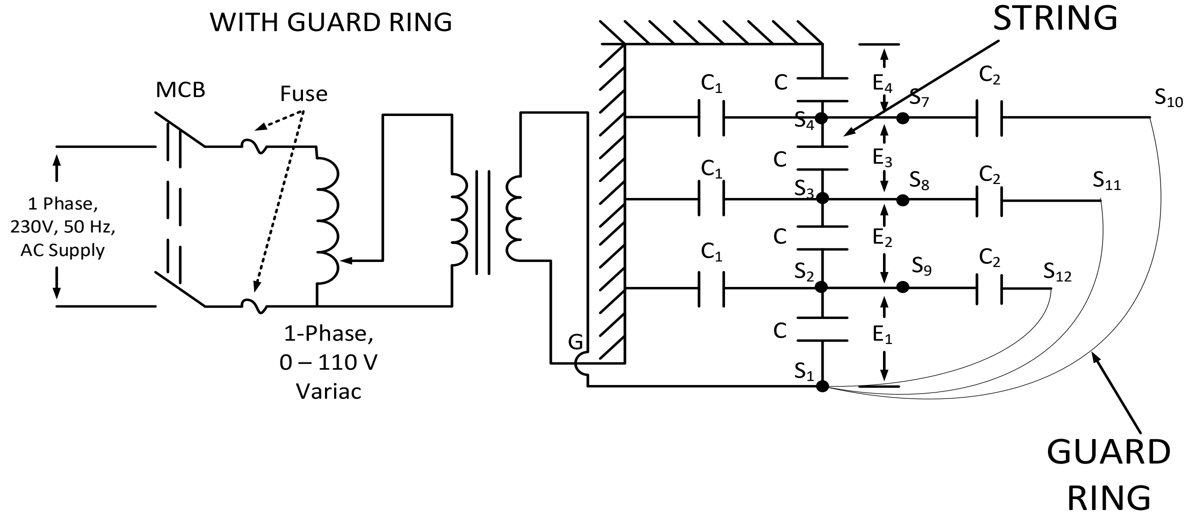


Fig : With Guard Ring

Testing of CT, PT and Insulator String

PROCEDURE:

Without Guard Ring:

1. Connect the circuit as per circuit diagram for without guard ring.
2. Switch on the mains.
3. Apply voltage from the 1-Φ Variac across the string in steps of 20V starting from 30V upto 110V.
4. Note down voltage across S_1 and S_2(which is to be noted as E_1); S_2 and S_3(which is to be noted as E_2); S_3 and S_4(which is to be noted as E_3) ; S_4 to G(which is to be noted as E_4); S_1 to G(which is to be noted as E).
5. Bring back the 1-Φ Variac to its minimum position and switch off the mains.
6. Calculate the string efficiency without guard ring.

With Guard Ring:

1. Connect the circuit as per circuit diagram for with guard ring. Make connections between S_1-S_{10}, S_1-S_{11} and S_1-S_{12}
2. Switch on the mains.
3. Apply voltage from the 1-Φ Variac across the string in steps of 20V starting from 30V to 110V.
4. Note down voltage across S_1 and S_2(which is to be noted as E_1); S_2 and S_3(which is to be noted as E_2); S_3 and S_4(which is to be noted as E_3) ; S_4 to G(which is to be noted as E_4); S_1 to G(which is to be noted as E).
5. Bring back the 1-Φ Variac to its minimum position and switch off the mains.
6. Calculate the string efficiency with guard ring.

CALCULATIONS:

$$String\ Effciency = \frac{Voltage\ across\ the\ string}{number\ of\ units\ in\ the\ string \times Voltage\ across\ the\ unit\ near\ the\ power\ conductor}$$

TABULAR COLUMNS:

Without Guard Ring:

S.No	E(V)	E1(V)	E2(V)	E3(V)	E4(V)	String Efficiency
1.						
2.						
3.						
4.						
5.						

Testing of CT, PT and Insulator String

With Guard Ring:

S.No	E(V)	E1(V)	E2(V)	E3(V)	E4(V)	String Efficiency
1.						
2.						
3.						
4.						
5.						

RESULT:

Name	Roll No	Sign	Date	Marks	Incharge

POWER SYSTEMS LAB (EE604PC)
LIST OF EXPERIMENTS

CYCLE-I

1. TESTING OF CT, PT AND INSULATOR STRING.
2. ABCD CONSTANTS, REGULATION AND EFFICIENCY OF A 3-Φ TRANSMISSION LINE MODEL
3. FORMATION OF Y_{BUS} AND Z_{BUS} .

CYCLE-II

4. CHARACTERISTICS OF OVER VOLTAGE AND UNDER VOLTAGE RELAY.
5. FINDING SEQUENCE IMPEDANCES OF 3-Φ SYNCHRONOUS MACHINE.
6. LOAD FLOW ANALYSIS USING GAUSS SEIDAL (GS) METHOD.

CYCLE-III

7. CHARACTERISTICS OF IDMT OVER CURRENT RELAY.
8. DIFFERENTIAL PROTECTION OF 1-Φ TRANSFORMER.
9. FINDING SEQUENCE IMPEDANCES OF 3-Φ TRANSFORMER.
10. LG, LL AND 3-Φ FAULT ANALYSIS OF 3-Φ SYNCHRONOUS MACHINE.

Additional Experiment:

11. LOAD FLOW ANALYSIS USING FAST DECOUPLED (FD) METHOD.
12. TRANSIENT STABILITY ANALYSIS FOR SINGLE MACHINE CONNECTED TO INFINITE BUS BY POINT BY POINT METHOD.

(Dr.P.R.K.REDDY)	(Dr.N.MALLA REDDY)
Faculty In charge	HOD – EEE