



Estd:2008

# METHODIST

## COLLEGE OF ENGINEERING AND TECHNOLOGY

(Affiliated to Osmania University & Approved by AICTE, New Delhi)



### LABORATORY MANUAL

### POWER SYSTEMS LABORATORY

B.E - VII Semester (AICTE): 2022-23

NAME: \_\_\_\_\_

ROLL NO: \_\_\_\_\_

BRANCH: \_\_\_\_\_

SEM: \_\_\_\_\_

DEPARTMENT OF ELECTRICAL AND ELECTRONICS  
ENGINEERING

*Empowering youth- Architects of Future World*



**Estd:2008**

# **METHODIST COLLEGE OF ENGINEERING AND TECHNOLOGY**

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## **VISION**

To produce ethical, socially conscious and innovative professionals who would contribute to sustainable technological development of the society.

## **MISSION**

To impart quality engineering education with latest technological developments and interdisciplinary skills to make students succeed in professional practice.

To encourage research culture among faculty and students by establishing state of art laboratories and exposing them to modern industrial and organizational practices.

To inculcate humane qualities like environmental consciousness, leadership, social values, professional ethics and engage in independent and lifelong learning for sustainable contribution to the society.

**DEPARTMENT  
OF  
ELECTRICAL AND ELECTRONICS ENGINEERING**

**LABORATORY MANUAL  
POWER SYSTEM LABORATORY**

**Prepared**

**By**

Mr. Rajini Kanth P,  
Assistant Professor



# METHODIST

## COLLEGE OF ENGINEERING AND TECHNOLOGY

### DEPARTMENT OF ELECTRICAL AND ELECTRONICS ENGINEERING

## VISION

To become a reputed centre for imparting quality education in Electrical and Electronics Engineering with human values, ethics and social responsibility.

## MISSION

- To impart fundamental knowledge of Electrical, Electronics and Computational Technology.
- To develop professional skills through hands-on experience aligned to industry needs.
- To undertake research in sunrise areas of Electrical and Electronics Engineering.
- To motivate and facilitate individual and team activities to enhance personality skills.



# METHODIST

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### DEPARTMENT OF ELECTRICAL AND ELECTRONICS ENGINEERING

#### PROGRAM EDUCATIONAL OBJECTIVES

BE-Electrical Engineering graduates shall be able to:

- **PEO1.** Utilize domain knowledge required for analyzing and resolving practical Electrical Engineering problems.
- **PEO2.** Willing to undertake inter-disciplinary projects, demonstrate the professional skills and flair for investigation.
- **PEO3.** Imbibe the state of the art technologies in the ever transforming technical scenario.
- **PEO4.** Exhibit social and professional ethics for sustainable development of the society.



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### DEPARTMENT OF ELECTRICAL AND ELECTRONICS ENGINEERING

#### PROGRAM OUTCOMES

Engineering Graduates will have ability to:

- **PO1. Engineering knowledge:** Apply the knowledge of mathematics, science, engineering fundamentals, and an engineering specialization to the solution of electrical and electronics engineering problems.
- **PO2. Problem analysis:** Identify, formulate, review research literature, and analyze complex electrical and electronics engineering problems reaching substantiated conclusions using first principles of mathematics, natural sciences, and engineering sciences.
- **PO3. Design/development of solutions:** Design solutions for complex electrical and electronics engineering problems and design system components or processes that meet the specified needs with appropriate consideration for the public health and safety, and the cultural, societal, and environmental considerations.
- **PO4. Conduct investigations of complex problems:** Use research-based knowledge and research methods including design of experiments, analysis and interpretation of data, and synthesis of the information to provide valid conclusions.
- **PO5. Modern tool usage:** Create, select, and apply appropriate techniques, resources, and modern engineering and IT tools including prediction and modelling to complex electrical and electronics engineering activities with an understanding of the limitations.
- **PO6. The engineer and society:** Apply reasoning informed by the contextual knowledge to assess societal, health, safety, legal and cultural issues and the consequent responsibilities relevant to the professional electrical and electronics engineering practice.
- **PO7. Environment and sustainability:** Understand the impact of the professional engineering solutions in societal and environmental contexts, and demonstrate the knowledge of, and need for sustainable development.
- **PO.8 Ethics:** Apply ethical principles and commit to professional ethics and responsibilities and norms of the electrical and electronics engineering practice.
- **PO9. Individual and team work:** Function effectively as an individual, and as a member or leader in diverse teams, and in multidisciplinary settings.
- **PO10. Communication:** Communicate effectively on complex engineering activities with the engineering community and with society at large, such as, being able to comprehend and write effective reports and design documentation, make effective presentations, and give and receive clear instructions.
- **PO11. Project management and finance:** Demonstrate knowledge and understanding of the engineering and management principles and apply these to one's own work, as a member and leader in a team, to manage projects and in multidisciplinary environments.
- **PO12. Life-long learning:** Recognize the need for, and have the preparation and ability to engage in independent and life-long learning in the broadest context of technological change.

#### PROGRAM SPECIFIC OUTCOMES

At the end of BE program Electrical and Electronics Engineering graduates will be able to:

- **PSO1.** Provide effective solutions in the fields of Power Electronics, Power Systems and Electrical Machines using MATLAB/MULTISIM.
- **PSO2.** Design and Develop various Electrical and Electronics Systems, particularly Renewable Energy Systems.
- **PSO3.** Demonstrate the overall knowledge and contribute for the betterment of the society.



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### DEPARTMENT OF ELECTRICAL AND ELECTRONICS ENGINEERING

#### I. PREREQUISITE(S):

Level	Credits	Semester	Prerequisites
UG	1	1	Power Systems

#### II. SCHEME OF INSTRUCTIONS

Lectures	Tutorials	Practicals	Credits
0	0	2	1

#### III. SCHEME OF EVALUATION & GRADING

S. No	Component		Duration	Maximum Marks				
	<b>Continuous Internal Evaluation (CIE)</b>							
1.	Internal Examination – I and II		1 hour each	25				
	<b>CIE (Total)</b>			<b>25</b>				
2.	<b>Semester End Examination</b> (University Examination)		3 hours	<b>50</b>				
			<b>TOTAL</b>	<b>75</b>				
<b>%Marks Range</b>	$\geq 90$	80 to < 90	70 to < 80	60 to < 70	50 to < 60	40 to < 50	< 40	Absent
<b>Grade</b>	S	A	B	C	D	E	F	Ab
<b>Grade Point</b>	10	9	8	7	6	5	0	-



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#### COURSE OUTCOMES

After completing this course, the student will be able to:

CO No.	Course Outcome	Taxonomy Level
C462.1	Interpret positive, negative and zero sequence Impedance of Transformer and Alternator	Understand
C462.2	Analyze the performance of transmission lines	Analyze
C462.3	Determine the dielectric strength of oil and the efficiency of string insulators	Evaluate
C462.4	Explain Voltage and current relay settings	Understand
C462.5	Measure the capacitance of three core cable	Evaluate
C462.6	Understand the operation of Differential protection of transformer	Understand

#### MAPPING OF COs WITH POs & PSOs

Correlation Level: High – 3; Medium – 2; Low – 1

PO / CO	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10	PO 11	PO 12	PS 01	PS 02	PS 03
C462.1	2	1	-	-	-	-	-	1	3	1	-	-	1	1	2
C462.2	3	3	1	2	1	-	-	1	3	1	-	-	3	3	1
C462.3	3	3	2	3	2	-	-	1	3	1	-	-	2	2	2
C462.4	2	1	-	-	-	-	-	1	3	1	-	-	3	3	3
C462.5	3	3	2	3	2	-	-	1	3	1	-	-	2	2	1
C462.6	2	1	-	-	-	-	-	1	3	1	-	-	3	3	2
C462	2.5	2	1.7	2.7	1.7	-	-	1	3	1	-	-	2.3	2.3	1.8





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### LABORATORY CODE OF CONDUCT

1. Students should report to the labs concerned as per the scheduled time table.
2. Students, who report late to the labs will not be permitted to perform the experiment scheduled for the day.
3. Students to bring 100 pages note book to enter the readings /observations while performing the experiment.
4. After completion of the experiment, certification of the staff in-charge concerned, in the observation book is necessary.
5. Staff member in-charge shall evaluate for 25 marks, each experiment, based on continuous evaluation which will be entered in the continuous internal evaluation sheet.
6. The record of observations, along with the detailed procedure of the experiment performed in the immediate previous session should be submitted for certification by the staff member in-charge.
7. Not more than three students in a group would be permitted to perform the experiment on the equipment-based lab set up. However only one student is permitted per computer system for computer-based labs.
8. The group-wise division made at the start of the semester should be adhered to, and no mix up with any other group would be allowed.
9. The components required, pertaining to the experiment should be collected from the stores in-charge, after duly filling in the requisition form / log register.
10. After the completion of the experiment, students should disconnect the setup made by them, and return all the components / instruments taken for the purpose, in order.
11. Any damage of the equipment or burn-out of components will be charged at cost as a penalty or the total group of students would be dismissed from the lab for the semester/year.
12. Students should be present in the lab for the total time duration, as scheduled.
13. Students are required to prepare thoroughly, before coming to Laboratory to perform the experiment.
14. Procedure sheets / data sheets provided to the students, if any, should be maintained neatly and returned after the completion of the experiment.



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#### DOS AND DON'TS IN THE LABORATORY

##### Dos

- All bags must be left at the place indicated.
- There must be at least two people in the laboratory while working on live circuits.
- Shoes and apron must be worn at all times, while in the lab.
- Consider all circuits to be "hot" unless proven otherwise.
- When making measurements, form the habit of using only one hand at a time.
- Keep the work area and workbench clear by removing items not used during the experiment.
- Ensure power switch is OFF, before plugging into the outlet and turn instrument/s or equipment OFF before unplugging from the outlet.
- De energize the circuit before dis assembly.
- The lab timetable must be followed strictly.
- Be PUNCTUAL for your laboratory session.
- Experiment must be completed within the given time.
- Keep discussions within the group to a bare minimum and of low decibel.
- Handle all the apparatus with care.

##### Don'ts

- Strictly avoid touching any live part of the circuit by bare hand.
- No ungrounded electrical or electronic apparatus is to be used in the laboratory unless it is double insulated or battery operated.
- Catch the PLUG to unplug a power cord, and do not pull by the cable.
- Students are strictly PROHIBITED from taking out any items from the laboratory.

##### Before Leaving Lab:

- Re arrange seating stool under the lab bench.
- Turn off the power to all instruments.
- Return all the equipment to lab assistant.
- Turn off the main power switch to the lab bench.
- Please check the laboratory notice board regularly for updates.



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### DEPARTMENT OF ELECTRICAL AND ELECTRONICS ENGINEERING

### CONTENTS

S. No.	Name of Experiment	Page No.
1	Determination of regulation & efficiency of Short, Medium and Long transmission lines.	
2	IDMT characteristics of Over-current relay & Study of Bucholz relay	
3	Determination of A, B, C, D constants of Short, Medium and Long lines. Drawing of circle diagrams.	
4	Differential protection of transformer	
5	Sequence impedance of 3-Phase Alternators.	
6	Determination of positive, negative and zero-sequence reactance of 3-phase transformers using sequence current excitation fault calculation.	
7	Characteristics of Static relays.	
8	Determination of dielectric strength of oils and study of Megger	
9	Measurement of capacitance of 3-core cables.	
10	Simulation of string of insulators for determination of Voltage distribution and String efficiency	
<b>Beyond the Syllabus</b>		
11	Simulation of Load frequency control	
12	Fault analysis on unloaded alternator	

## **Expt. No.1. Determination of Regulation & Efficiency of Short, Medium and Long Transmission lines.**

### **Aim:**

- 1) To determine the efficiency and regulation of a transmission line model, with resistive load.
- 2) To Observe Ferranti effect.

### **Apparatus:**

S. No.	Apparatus	Range	Type	Quantity
1.	Voltmeters	(0 – 600V)	MI	2
2.	Ammeters	(0 – 10 A)	MI	2
3.	Watt meters	5A, 600V	UPF	4

### **Theory:**

The transmission lines are categorized as three types

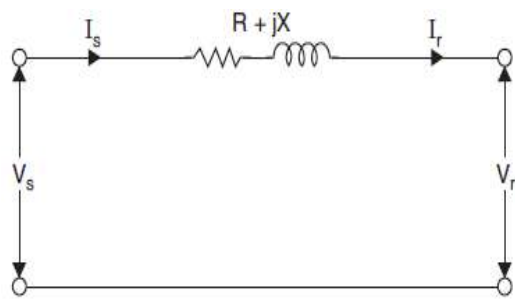
- 1) Short transmission line – the line length is up to 80 km
- 2) Medium transmission line – the line length is between 80km to 160 km
- 3) Long transmission line – the line length is more than 160 km



Whatever may be the category of transmission line, the main aim is to transmit power from one end to another. Like other electrical system, the transmission network also will have some power loss and voltage drop during transmitting power from sending end to receiving end.

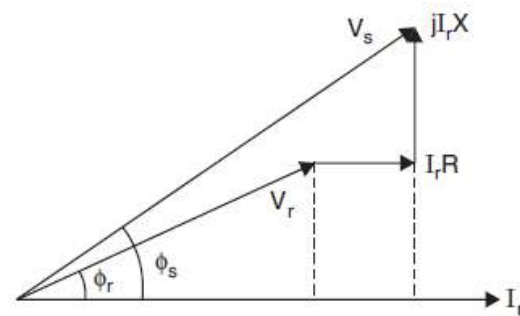
Hence, performance of transmission line can be determined by its efficiency and voltage regulation.

**Short Transmission line:** The equivalent circuit of a single-phase transmission line is shown in fig.1. The phasor diagram of the short transmission line for lagging load power factor is shown in fig. 2



equivalent circuit,

**Fig. 1**



phasor diagram.

**Fig. 2**

$$\% \text{ regulation} = \frac{V_s - V_r}{V_r} \times 100$$

**Medium transmission line:**

The representation of a medium transmission line is done by considering the line parameters as lumped parameters, as:

**(a) Nominal – T:**

The whole line capacitance is assumed to be concentrated at the middle point of the line and half the line resistance and reactance are lumped on its either side as shown in fig. 3

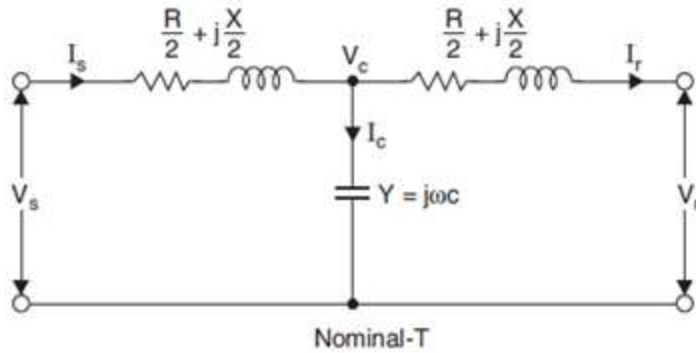


Fig. 3

$$V_c = (|V_r| \cos \phi_r + j|V_r| \sin \phi_r) + I_r \left( \frac{R}{2} + j \frac{X}{2} \right)$$

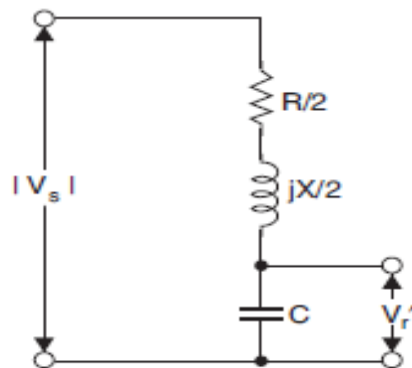
$$I_c = j\omega C V_c$$

$$I_s = I_c + I_r = I_r + j\omega C V_c$$

$$V_s = V_c + I_s \left( \frac{R}{2} + j \frac{X}{2} \right)$$

$$= (|V_r| \cos \phi_r + j|V_r| \sin \phi_r) + I_r \left( \frac{R}{2} + j \frac{X}{2} \right) + I_s \left( \frac{R}{2} + j \frac{X}{2} \right)$$

- To calculate regulation it is required to calculate  $V_r'$  the receiving end no load voltage keeping  $V_s$  as calculated above fixed in magnitude. The nominal- $T$  circuit for this condition is shown in fig. 4:



Equivalent circuit  
under no load.

Fig. 4

**(b) Nominal –  $\pi$**

In this method, capacitance of each conductor is divided into two halves; one half being lumped at the sending end and the other half at the receiving end as shown in fig. 5

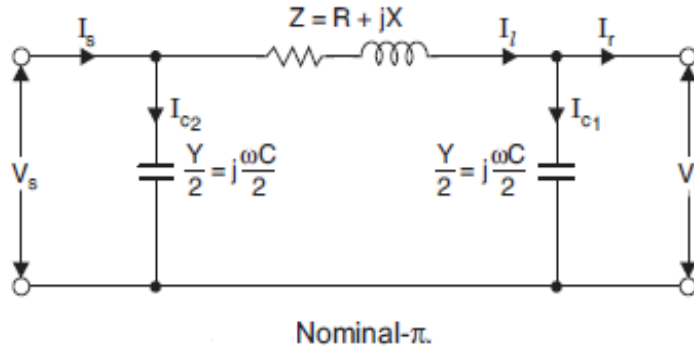


Fig. 5

$$I_{c_1} = jV_r \frac{\omega C}{2}$$

$$I_l = |I_r| (\cos \phi_r - j \sin \phi_r) + jV_r \frac{\omega C}{2}$$

$$V_s = V_r + I_l Z$$

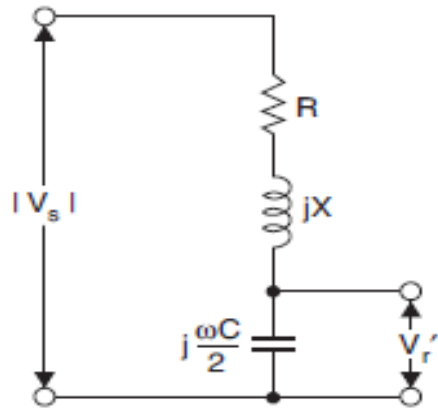
$$= V_r + \left\{ |I_r| (\cos \phi_r - j \sin \phi_r) + jV_r \frac{\omega C}{2} \right\} (R + jX)$$

$$I_s = I_l + I_{c_2} = I_l + jV_s \frac{\omega C}{2}$$

$$I_s = |I_r| (\cos \phi_r - j \sin \phi_r) + jV_r \frac{\omega C}{2}$$

$$+ j \frac{\omega C}{2} \left[ V_r + \left\{ |I_r| (\cos \phi_r - j \sin \phi_r) + jV_r \frac{\omega C}{2} \right\} (R + jX) \right]$$

Nominal- $\pi$  Equivalent circuit under no load is shown in fig. 6



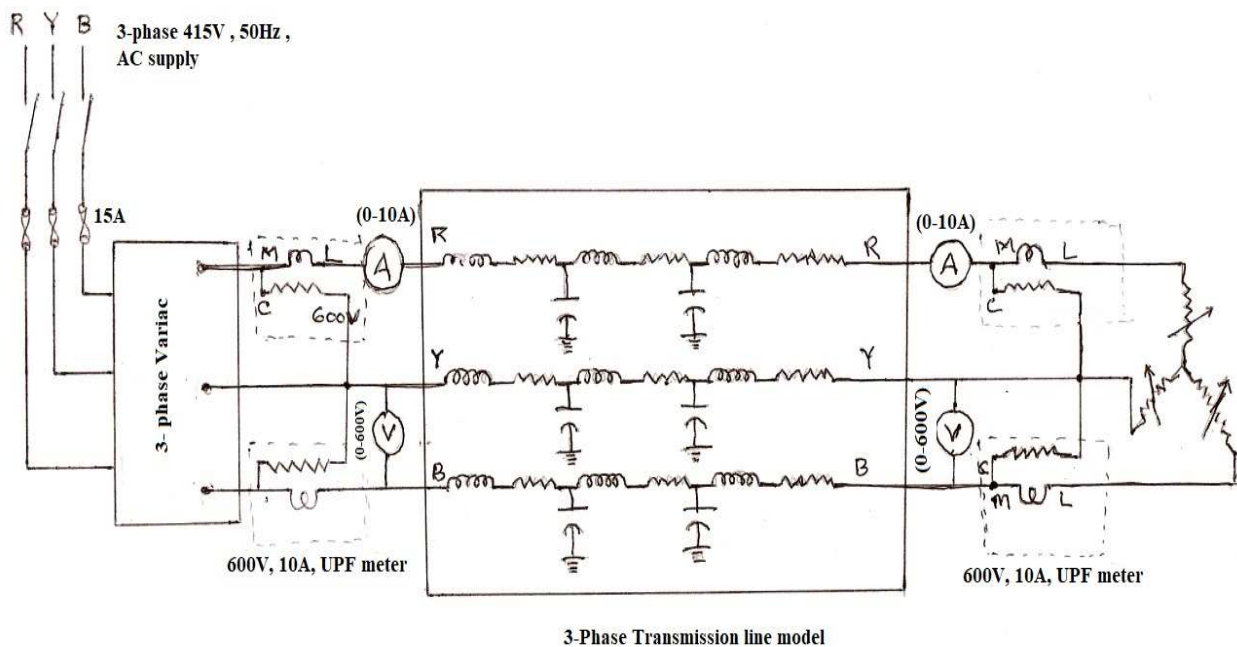
$$V_r' = \frac{|V_s| \left( -\frac{j}{\omega C} \right)}{\frac{R}{2} + j \frac{X}{2} - \frac{j}{\omega C}}$$

$$\% \text{ regulation} = \frac{V_r' - V_r}{V_r} \times 100$$

Equivalent circuit under no load.

Fig. 6

**Circuit Diagram:**



3-Phase Transmission line model

Fig. 7

**Note:**

- For short transmission line connect any one section
- For medium transmission line connect any two sections
- For long transmission line connect all sections





### Long Transmission lines:

S No	V <sub>s</sub>	I <sub>s</sub>	P <sub>s</sub>	V <sub>r</sub>	I <sub>r</sub>	P <sub>r</sub>	% Voltage Regulation	% Efficiency
1								
2								
3								
4								

\*\*\*\* write a note on observation of Ferranti effect

### Sample Calculations:

$$\% \text{ Efficiency} = \frac{P_{\text{receiving end}}}{P_{\text{sending end}}} * 100$$

$$\% \text{ Voltage Regulation} = \frac{V_{rNL} - V_{rFL}}{V_{rFL}} * 100$$

### Result:

S. No.	Performance	Short T/lines	Medium T/ lines	Long T/ lines
1	% Voltage Regulation.			
2	% Efficiency			

### Viva Questions:

- 1) Classify transmission lines by their lengths.
- 2) What is the difference between nominal T or  $\pi$  network and equivalent T or  $\pi$ ?
- 3) Draw a phasor diagram for a long transmission line delivering lagging current.
- 4) What is the need for knowing voltage regulation of transmission line?
- 5) What do you understand by 'Ferranti effect'? Is it an advantage or disadvantage?

## Expt. No. 2. (a) IDMT Characteristics of over current relay

### Aim:

To study the operation of a non-directional electromechanical over current relay and hence to obtain its inverse time current characteristics.

### Apparatus:

- 1) A panel consisting of One Non-directional over current relay,
- 2) A timer
- 3) A current injection variac
- 4) A digital Ammeter.

### Theory:

The purpose of protective relay and relay system is to operate the switch gear automatically to isolate the faulty equipment, thus minimizing the damage caused by the faults. The switch gear is designed for interrupting both normal and fault currents through a protective relay which must be able to recognize any abnormal condition in the power system and initiate suitable steps for its removal with the least disturbance to the system. IDMT relay is inverse definite minimum time relay in which the 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 measured relay operation time is used to conduct the experiment. Values recorded for various Time Setting Multipliers( TSMs) and Plug Setting Multipliers(PSMs). Characteristics are studied with the help of a graph and correlated with theory. Permanent magnet is used to control the disc speed. The TSM 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.

$$PSM = \frac{\text{Primary Current}}{\text{Primary Current setting}} \quad \text{or} \quad PSM = \frac{\text{Fault current}}{\text{Plug Setting}}$$

$$PSM = \frac{\text{Fault current}}{\text{Relay Current Setting} \times \text{C.T Ratio}}$$

### Circuit diagram:

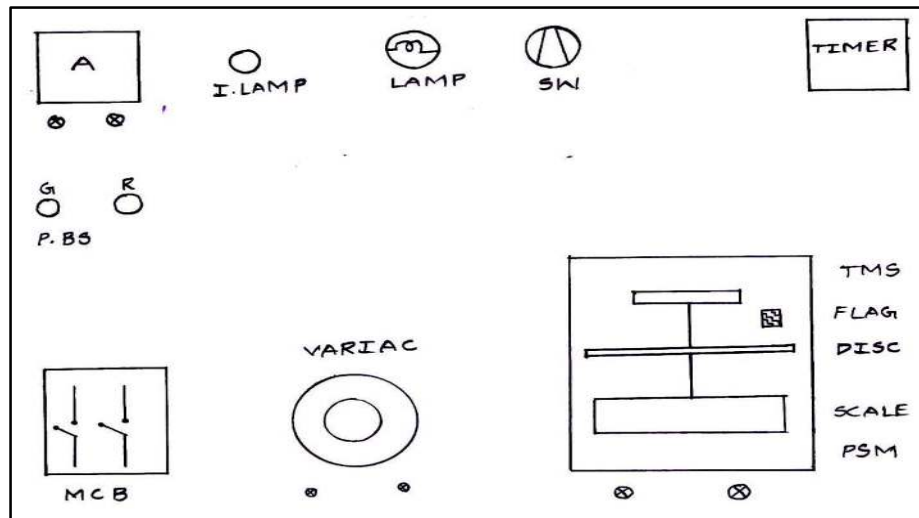


Fig. 1

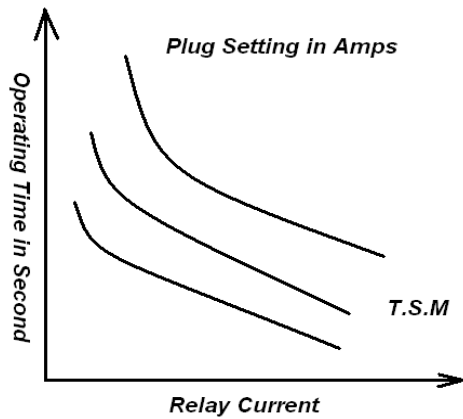
### Procedure:

- 1) Initially check the setting of current plug multiplier and Time Multiplier and note them down.
- 2) Give connections as shown in fig. 1
- 3) Switch on the MCB.
- 4) Switch on the rotary switch by turning clockwise
- 5) Set the desired current as shown by ammeter.
- 6) Switch off the rotary switch and wait till the aluminium disc of the relay returns to its initial position. Rest the timer to zero position.
- 7) At the press of the green bush button, the bulb should glow and time counter should start counting of seconds.
- 8) Depending on the settings, the relay would trip the circuit, which is indicated by the dark bulb and the flag of the relay.
- 9) Note and record the current and time for each set up of ammeter.
- 10) Plot a curve, with current in abscissa and the time in ordinate. Observe the inverse time characteristics.

**Tabular form:**

S.No	Fault Current (A)	Time of operation (Sec)
1.		
2.		
3.		
4.		
5.		

**Expected Graph:**



**Results:**

**Viva Questions:**

- 1) What does IDMT stand for?
- 2) What is a relay? Explain its function as a protective device.
- 3) Why an over current relay is required in a transmission line?
- 4) What do you understand by current multiplier and time multiplier?
- 5) Do you require a C.T. to use this relay? If so, why?
- 6) Can there be an over current relay with directional properties?

## Expt. No. 2. (b) Study of Buchholz Relay

### Aim:

To study the working of Buchholtz relay

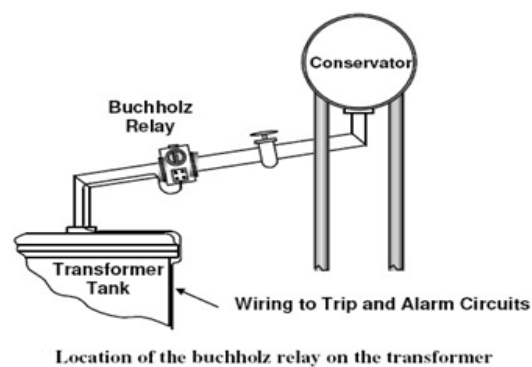
### Apparatus:

- 1) Buchholz relay fitted on stand with pipeline valves and conservator
- 2) Air compressor to produce air pressure
- 3) Transformer oil
- 4) Supply panel with tripping arrangement
- 5) An audible Alarm.

### Theory:

Whenever a fault takes place in a transformer , the oil of the tank gets over heated and gases are formed. The generation of gases may be slow or violent , depending on whether the fault is a minor or incipient one or heavy short circuit. The detection of generation of gas is used as a means of fault detection.

Buchholtz relay is the simplest form of protection commonly used , in all transformers provided with conservators. It consists of two hinged floats in a metallic chamber, which is connected in the upper side of the pipe run between the oil conservator and the transformer tank. One of the floats is near the top of the chamber and the other opposite the orifice of pipe to the transformer. Location of the buchholz relay on the transformer is shown in fig. 1



**Fig. 1**

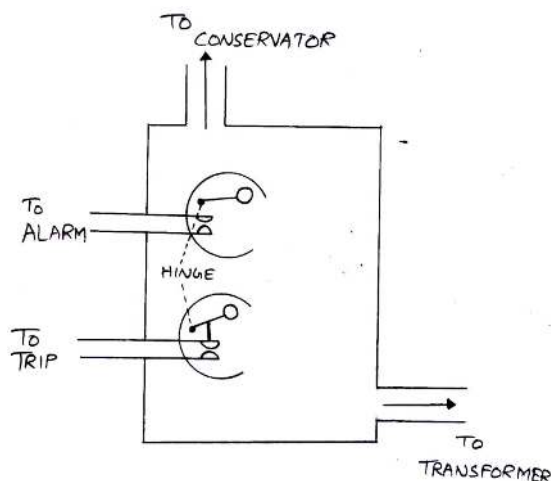
For a minor or incipient fault, the slow generation of gas gives rise to bubbles which try to go to the conservator but are trapped in the upper portion of the relay chamber; thereby a fall in the oil level occurs. This disturbs the equilibrium of the gas float. The float tilts and an alarm circuit is closed through the switch contacts. The alarm rings, thus giving an audible indication that transformer oil is bubbling.

For a heavy fault, large volume of gases are generated which cause violent displacement of oil and impinge upon the baffle plates of the lower float and thus the balance of the lower float is disturbed. The lower float is tilted and the contacts are closed which are arranged to trip the circuit breaker to isolate the transformer. It is customary to connect the contacts in the trip circuit to ensure that the transformer is disconnected on the operation of this switch and thus prevent further damage.

- Faults which cause operation of this type are:
  - a. Low oil level in the transformer due to any reason.
  - b. Accumulation of air.
  - c. Fault in the core laminations
  - d. Breakdown of core bolt insulation.
  - e. Local overheating in the windings
  - f. Bad connections.
  - g. Bad switch contacts.
- Faults which may cause operation of the contacts are:
  - a. Internal short circuit between turns
  - b. Short circuit between phase and earth.
  - c. Phase to phase short circuit.
  - d. Insulation breakdown of a major nature
- The contacts would also operate if the oil level falls below that of float due to any reason.
- The basic characteristics of the Gas-and-Oil relay are as follow:

- 1) The relay is particularly sensitive and a simple indicator for internal faults of all kinds, in all Oil-immersed transformers, by examining the gases collected it is possible to infer the nature of fault. Thus:
  - a. If the gas is Grayish white with sharp and penetrating odor and non-inflammable, it is due to overheated or faulty insulation (fuller board etc)
  - b. If the gas is yellowish in color and inflammable, it may be due to surface leakage on material like wood.
  - c. If the gas is dark Grey and inflammable it may be due to flashover in oil or due to excessive overheating of the oil, caused by a fault in the winding or the core
- 2) Due to its high sensitivity combined with quick operation of the tripping contacts the relay effectively limits the damage and reduces the cost of repairs
- 3) On the operation of the alarm, investigation of the collected gas, does not indicate a serious fault, it is possible to leave the transformers in service till it is convenient to carry out a thorough inspection. This occurrence is possible on a newly commissioned transformer due to air trapped in the oil on the insulation. On repeated and frequent alarm signal the transformer should be taken out of service for a thorough check up.
- 4) The relay can serve to some extent as a protection against heavy overloads but cannot be trusted for all overloads and should be backed by a temperature operated device to prevent sustained overloads.
- 5) The relay is not responsive to external faults unless they are of the nature of heavy overloads leading to excessive heating.

**Circuit Diagram:**





### **Procedure:**

- 1) Check that the cock to the conservator is open and the air vent valve is closed [In actual transformer these cock and valve will not be present]
- 2) Check that the oil level is full in the relay by viewing at the sight glass.
- 3) Check the air pressure is sufficient to operate. Otherwise switch ON the air compressor and fill the air tank.
- 4) Pushing the green push button makes the lamp ON.
- 5) Open the airline cocks slowly to displace some oil from the relay to the conservator. This can be ascertained by viewing through the sight glass
- 6) The alarm should operate and ring without stopping [Unless it is disconnected manually]
- 7) Fill the relay by opening the air vent valve allowing oil to enter the relay chamber. Once the relay chamber is full, shut off the air vent valve.
- 8) Open slightly the cock of air tank and open fully the cock at the relay allowing a sudden gush of air into the relay. This action will also displace the oil in the chamber albeit very suddenly. The supply line should trip which is indicated by the dark lamp.

***NOTE: The supplies to the tripping and alarm circuits are independent of the main supply.***

### **Result:**

### **Viva Questions:**

- 1) What is Bucholz relay. What is it used for? Where it is connected on a transformer?
- 2) What are the parts present in Bucholz relay?
- 3) What are the different relays used for protection of the transformer?
- 4) What are incipient faults?
- 5) What is breather and why it is required?
- 6) What is an explosion vent ?

### Expt. No. 3. Determination of A, B, C, D constants of Short, Medium and Long lines.

#### Aim:

To determine ABCD constants of transmission lines.

#### Apparatus:

##### **For Open Circuit Test:**

S. No	Apparatus	Range	Type	Quantity
1.	P.F. meter	10A, 150/300/600V (0.5-1-0.5)	LPF	1
2.	Voltmeter	(0-300V)	MI	1
3.	Ammeter	(0-1A)	MI	1

##### **For Short Circuit Test:**

S. No	Apparatus	Range	Type	Quantity
1.	P.F. meter	10A, 75V	UPF	1
2.	Voltmeter	(0-30V)	MI	1
3.	Ammeter	(0-10A)	MI	1

#### Theory:

For a given transmission line, the relationship between the sending end voltage and current to the receiving end voltage and current is expressed as

$$V_s = AV_r + BI_r$$

$$I_s = CV_r + DI_r$$

Where the constants are measured by conducting the OC & SC tests at the two ends of the line.

Impedance measurement on the Sending End (SE) side: SE impedance with Receiving End (RE) open circuit is

$$Z_{so} = \frac{V_s}{I_s} = \frac{A}{C} (I_r = 0)$$

SE impedance with RE short circuited,

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

Measurement of impedance on RE side using equations

$$V_r = DV_s - BI_s$$

$$I_r = -CV_s + AI_s$$

While performing test, the current leaves the Network

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

$$V_r = DV_s - BI_s$$

$$-I_r = -CV_s - AI_s$$

$$I_r = CV_s + AI_s$$

RE impedance with SE open circuited,  $Z_{ro}$

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

RE impedance with SE short circuited,  $Z_{rs}$

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

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

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

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

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

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

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

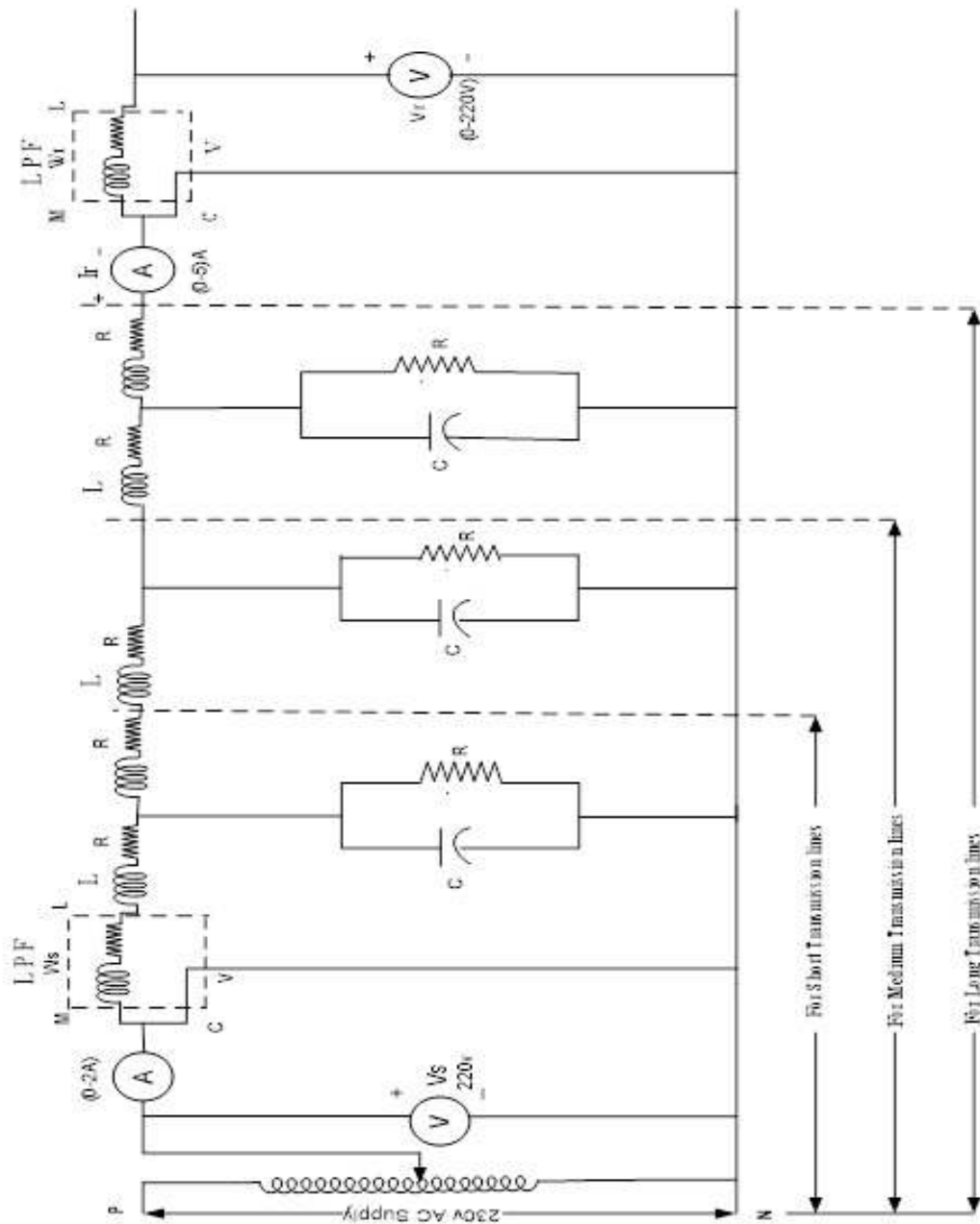
$$Z_{ro} = \frac{D}{C}$$

$$D = CZ_{r_o} = \frac{Z_{r_o}}{Z_{s_o}} \sqrt{\frac{Z_{s_o}}{(Z_{r_o} - Z_{r_s})}} (Z_{r_o} = Z_{s_o})$$

$$D = A$$

**Circuit Diagram:**

Panel circuit diagram for O.C and S.C test on both sending and receiving end side is shown in fig.1 and fig. 2



**Fig. 1**

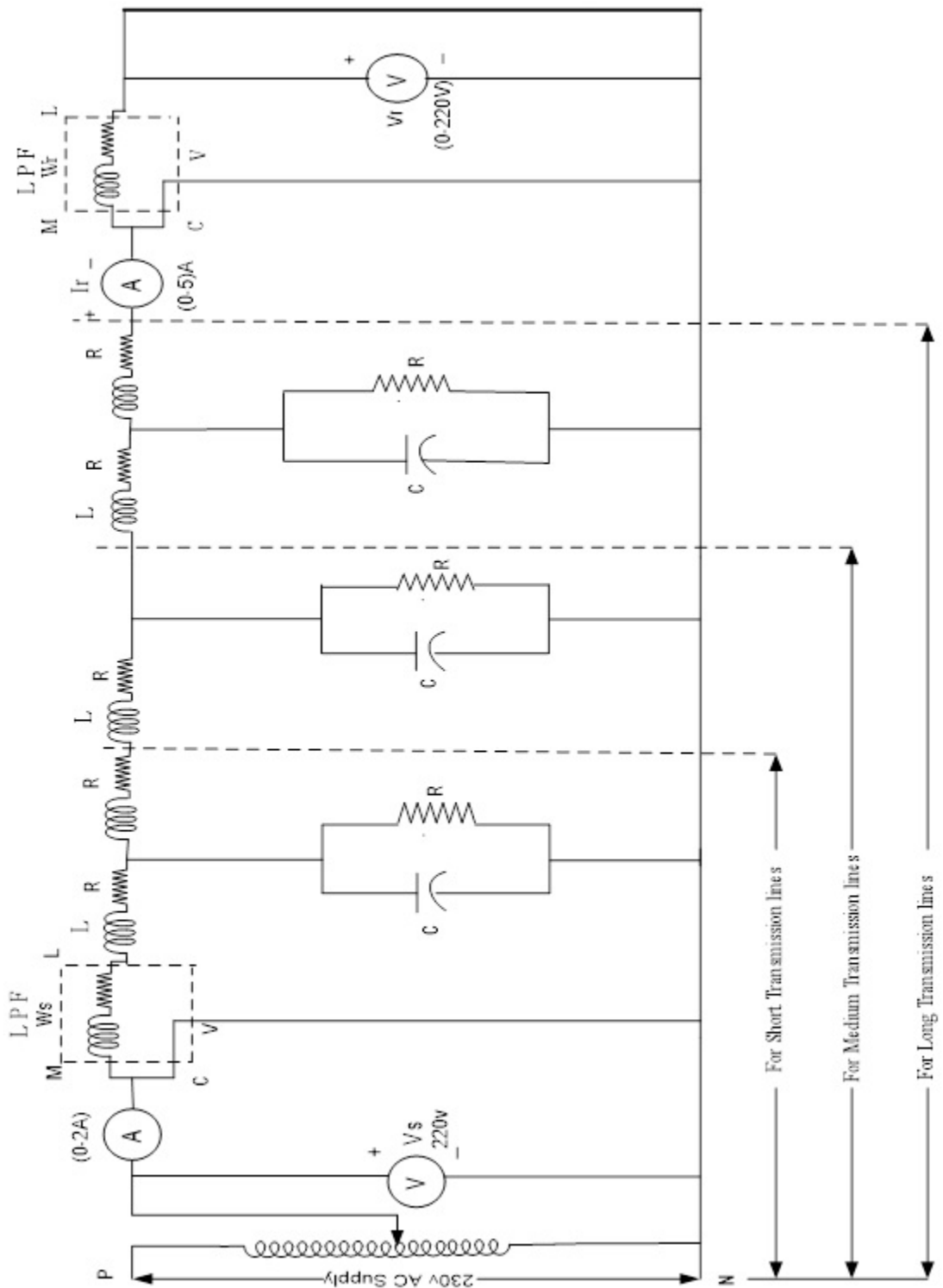
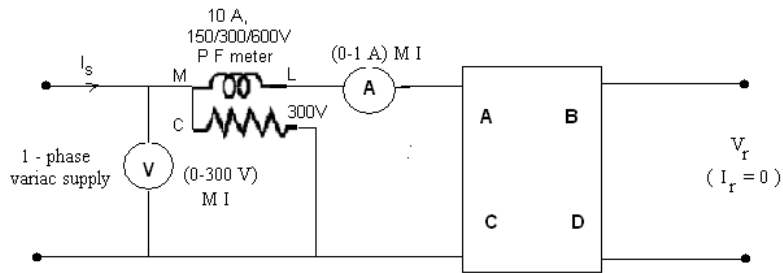
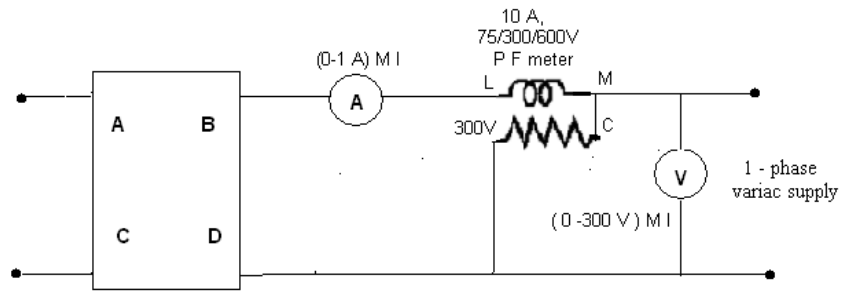


Fig. 2

**OC Test:**

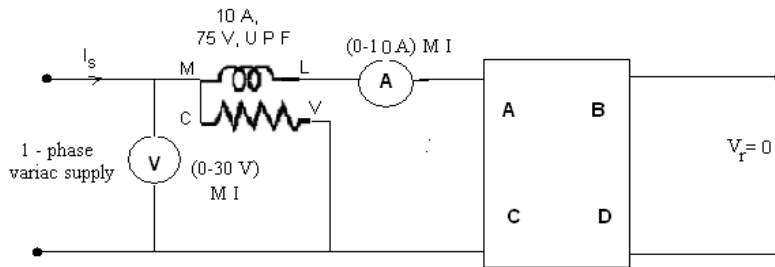


**Fig-3 (OC test on RE side)**

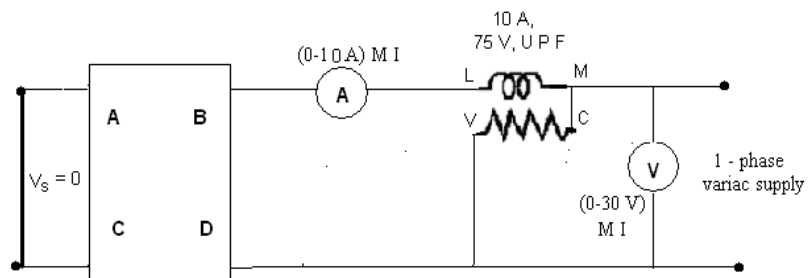


**Fig-4 (OC test on SE side)**

**SC Test:**



**Fig-5 (SC test on RE side)**



**Fig-6 (SC test on SE side)**

**Procedure:**

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

- 1) Connect the circuit as per fig.(3) for O.C. test on RE side.
- 2) Set 230V on Voltmeter using variac and note  $V_s$ ,  $I_s$  and p.f. meter reading.
- 3) Connect the circuit as per fig (5) for S.C. test on RE side .
- 4) Set 8A on Ammeter and note  $V_s$ ,  $I_s$  and wattmeter readings.

**O.C. & SC tests of SE side:**

- 1) Connect the circuit as per fig.(4) for O.C test on SE side
- 2) Set 230V in Voltmeter & note  $V_r$ ,  $I_r$ &p.f meter reading.
- 3) Connect the circuit as per fig (6) for SC test on SE side
- 4) Set 8A in Ammeter & note  $V_r$ ,  $I_r$ & Wattmeter reading.

**Tabular Form:**

Sending end test		
Tests		
O.C		
S.C		
Receiving end test		
Tests		
O.C		
S.C		

**Result:**

**Viva questions:**

- 1) What are A, B, C, D constants for short, medium and long transmission lines?
- 2) What are the uses of A, B, C and D constants?
- 3) Prove  $AD - BC = 1$ .
- 4) Give the different models of medium transmission line?
- 5) What is the purpose of power circle diagram.



## Expt. No. 4. Differential Protection of Transformer

### Aim:

To determine the characteristics of the given differential relay and to apply the relay for the protection against internal faults.

### Apparatus:

- 1) A panel consisting of one differential relay
- 2) Digital ammeters : (0-5A) -----3 No's
- 3) Barrel rheostats : 0-100 Ohms----- 2 No's
- 4) Variac : (0-260 V), Single phase
- 5) Connecting wires : As per requirement

### Theory:

A Differential relay responds to vector difference between two or more similar electrical quantities, hence the Differential relay has at least two actuating quantities of same nature.

Ex: Current / Current.

The Relay responds to vector difference between actuating quantities such as magnitude and/or Phase angle difference.

Differential protection is generally used as a unit protection. Most differential relays are Current operated Differential relays in which vector difference between current entering the winding & current leaving the winding is used for relay operation.

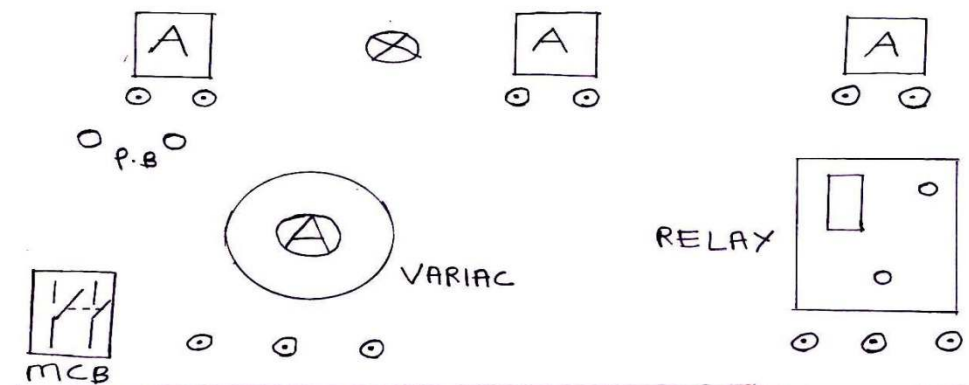
The positive way of protecting a circuit against internal faults is to arrange relays to compare the currents entering and leaving it, which will be same under normal conditions and even under an external fault. Any difference in currents must be due to currents flowing in to a fault within the protected circuit. When this system is applied to any electrical equipment, it is called differential current protection and affords protection against only internal faults.

Differential protection can be applied to generators, motors, transformers and transmission lines. When applied to transformers, the ratio of transformation and the phase shift in the three phase transformer must be taken in to account. In order to avoid undesirable operation, on heavy external faults due to errors in current transformers, restraining windings are provided which are energized by the through current and have fewer turns than the operating winding.

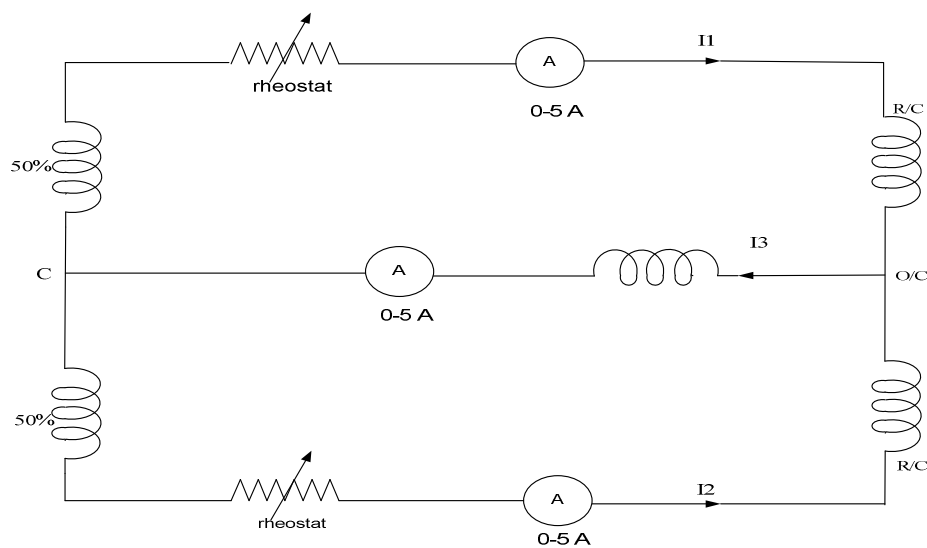
When used for protecting a transformer the transformation ratio must be taken into account and suitable current transformers must be employed for the relay, such that the through current is approximately same in both the restraining windings. When the difference between the restraining windings exceeds a certain set amount, the operating winding must act, because the difference of currents would flow in the operating winding.

**Circuit Diagram:**

Panel circuit is shown in fig.1



**Fig. 1**



**Fig. 2**

**Procedure:**

- 1) Connect the relays as shown in fig. 2
- 2) By removing the top lid cover of relay, adjust the bias tap on both sides, either for 30% or 50%
- 3) Keep the variac almost in mid position.
- 4) Switch on the MCB and push GREEN button, now adjust I<sub>1</sub> and I<sub>2</sub>, each to be equal by adjusting one of the rheostats or by the variac, such that the current in the operating coil is very close to zero as shown by the ammeter.
- 5) Keep I<sub>1</sub> constant at this value and create a difference in the currents I<sub>1</sub> and I<sub>2</sub>, by using rheostats until circuit trips. Take the reading of I<sub>1</sub>, I<sub>2</sub> and I<sub>3</sub>.
- 6) Repeat this process until the current reaches the rated value of the relay.[here it is 2 Amps].
- 7) Repeat the above steps keeping I<sub>2</sub> to a constant value and adjust I<sub>1</sub> until the circuit trips. Record every time all the currents shown by the ammeters.

**Tabular Form:**

**50% bias setting**

S.No	Through current (A)		Differential current (A)	Percent bias by calculation	% Error
	I <sub>1</sub>	I <sub>2</sub>	I <sub>3</sub> .		

**30% bias setting**

S.No	Through current (A)		Differential current (A)	Percent bias by calculation	% Error
	I <sub>1</sub>	I <sub>2</sub>	I <sub>3</sub> .		

$$\% \text{ Bias} = \frac{\text{Differential current}}{\text{Average current}} * 100$$

**Result:**

**Viva questions:**

- 1) Which of the electrical quantities are normally used in this sort of protection?
- 2) What is meant by unit type and non-unit type of protection?
- 3) What do you understand by through fault?
- 4) What kind of equipment can be protected by this type of protective system?
- 5) What is biasing?
- 6) What is a percentage differential protection? Why is this required and Where is it used?
- 7) Draw the schematic diagram of this type of arrangement for a a) Star / Delta Transformer and b) a Star connected Generator and explain the functioning?
- 8) Is this a current operated or voltage operated protective system?
- 9) How are the C.Ts connected for protection under this scheme?

## Expt. No. 5. Sequence Impedance of three-phase Alternator

### Aim:

To determine the Positive, Negative and Zero sequence impedance of the given three phase alternator

### Apparatus:

S.No	Name Of The Equipment	Range	Type	Quantity
1.	Auto-Transformer	( 0—230V)		1 No
2.	Ammeter	(0 –2.5 A)	MC	1 No
3.	Ammeter	(0 –10A)	MI	1 No
4.	Wattmeter	( 10 A 75/150/600V)		1 No

### Theory:

The positive, negative and zero sequence impedances of rotating machines are generally different.

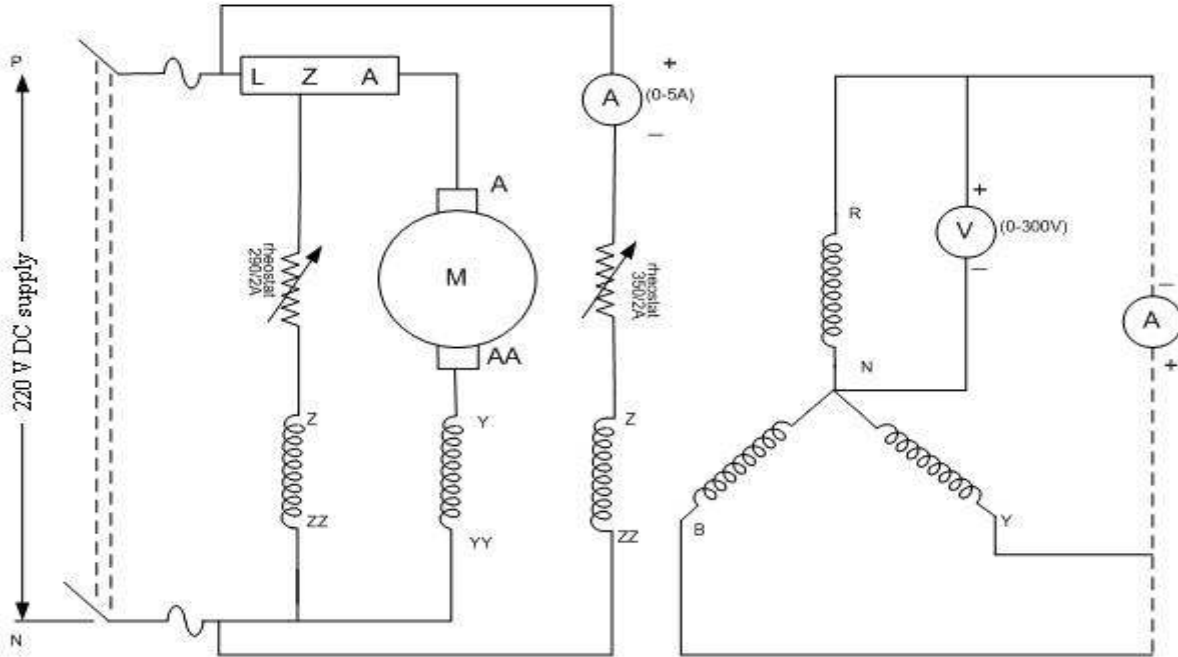
The positive sequence impedance of synchronous generator depends upon the working of the machine, whether it is working under sub transient, transient or steady state condition. The impedance under steady state condition is known as synchronous impedance of the machine. We can say that positive sequence impedance is equal to the synchronous impedance of the machine. Synchronous impedance can be obtained by performing O.C.C and S.C.C tests on the given alternator.

The negative sequence impedance of a machine is the impedance offered to the flow of negative sequence current. The negative sequence impedance is much less than positive Sequence impedance.

The zero sequence impedance is the impedance offered to the flow of zero sequence current. This impedance is quite variable and depends on the distribution of windings, i.e. the winding factors. Zero sequence impedance is much smaller than positive and negative sequence impedance.

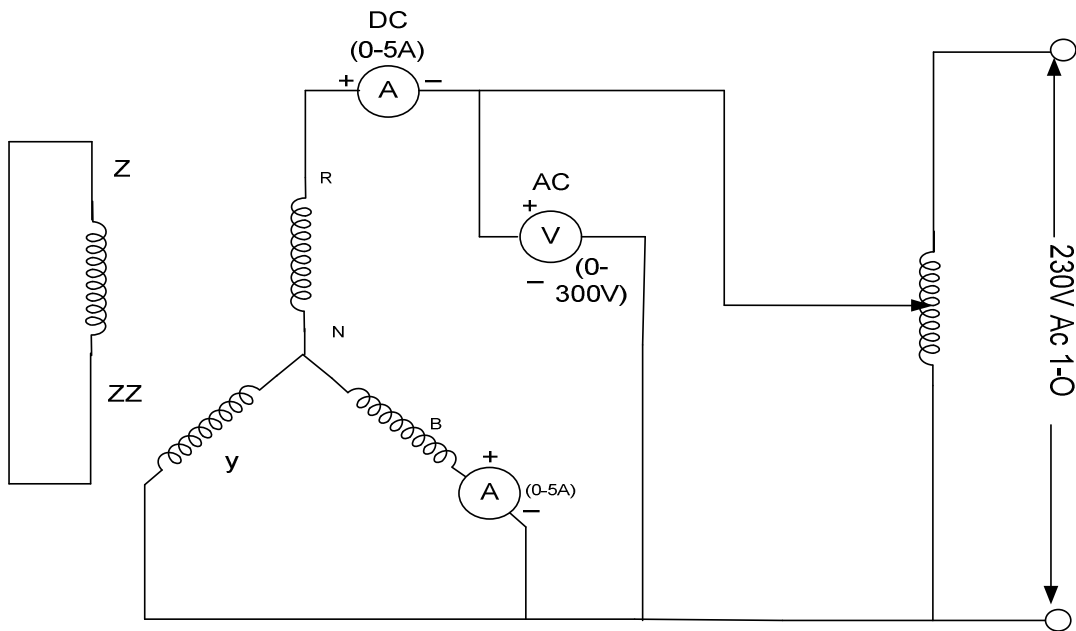
**Circuit Diagram:**

**(A) Positive Sequence Impedance:**



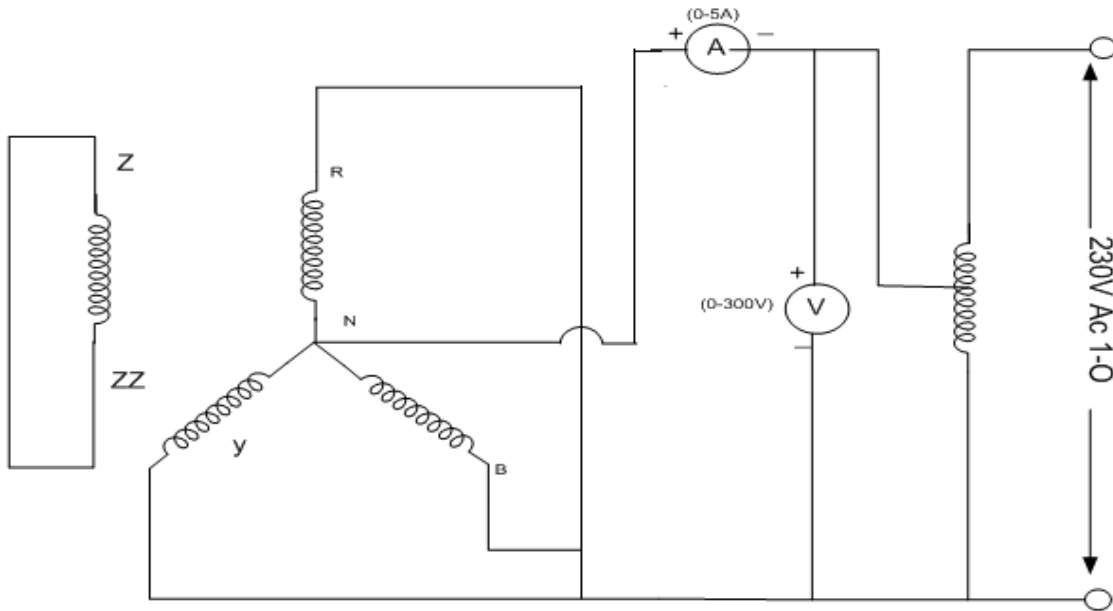
**Fig.1**

**(B) Negative Sequence Impedance:**



**Fig.2**

**(c) Zero-Sequence Impedance:**



**Fig. 3**

**Procedure:**

**Positive sequence impedance:**

- 1) Obtain the O.C.C of the Alternator by connecting the Alternator as in fig .1.
- 2) Obtain the S.C.C of the Alternator by connecting the Alternator as in fig .2.
- 3) Determine the stator resistance / phase by connecting as shown in fig.3.

$$Z_s = \frac{E_{OC}}{I_{SC}} \quad (\text{At a same value of field current})$$

**Negative sequence impedance:**

- 1) Connect the Circuit as shown in the fig.2.
- 2) Run the machine at rated speed with low excitation to the field of the Alternator.
- 3) The lines B and C shorted and the meters are connected as shown

$$\cos(\phi) = \frac{W}{(V * I)}$$

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

**Zero sequence impedance:**

- 1) Connect the circuit as shown in the fig. 3.
- 2) Three phase winding are connected in series.
- 3) Apply low voltage to the Armature, so that rated full load current flow in the series field winding

$$Z_0 = \frac{V_{a0}}{I_{a0}} = \frac{3E}{I}$$

**Tabular Form:**

**Positive sequence:**

**O.C.C:**

S.no	Voltage	Current
1		
2		
3		
4		

**S.C.C:**

S.no	Voltage	Current

**Negative sequence**

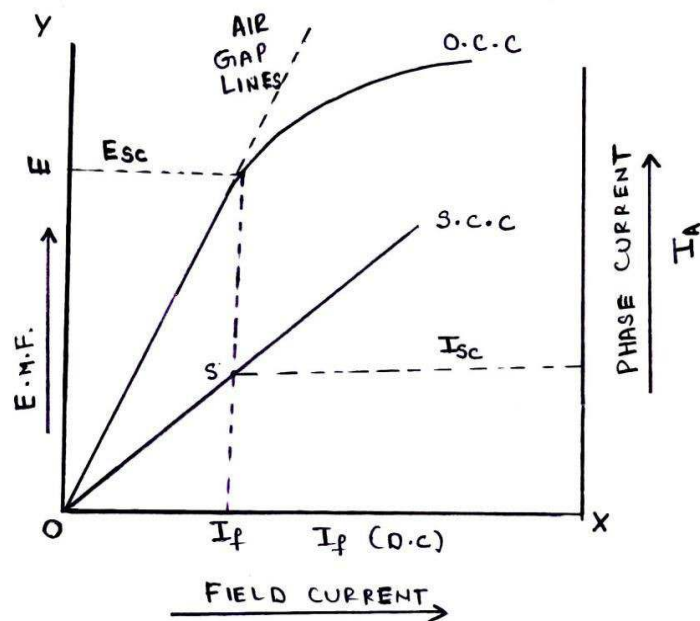
S.no	Voltage	Current

**Zero sequence**

S.no	Voltage	Current



### Expected Graph:



### Results:

### Viva questions:

- 1) What do you understand by the sequence impedances?
- 2) Which of the sequence impedance is high? Arrange the sequence impedances of a given machine in a) ascending , b) descending order
- 3) If the alternator is not grounded, will there be any zero sequence current exist?

**Expt. No. 6. Determination of positive, negative and zero-sequence reactance of 3-phase transformers using sequence current excitation fault calculation.**

**Aim:**

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

**Apparatus:**

S.No	Name Of The Equipment	Range	Type	Quantity
1.	Voltmeter	( 0—60V)	MI	1 No
2.	Ammeter	(0 –5A)	MI	1 No

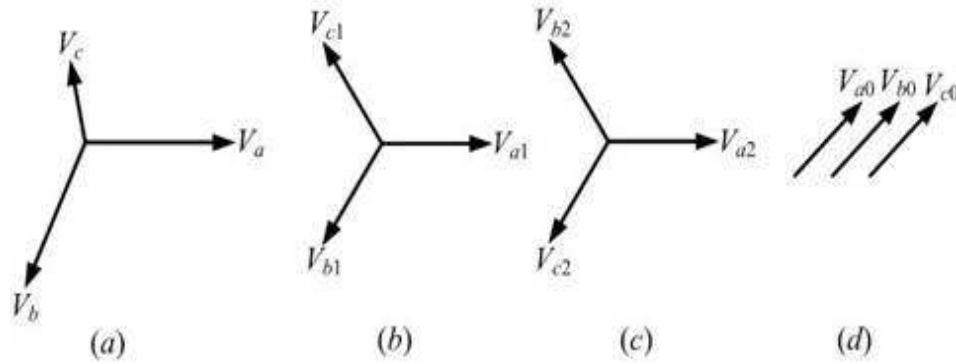
**Theory:**

**Symmetrical Components**

A system of three unbalanced phasors can be resolved in the following three symmetrical components:

- Positive Sequence: A balanced three-phase system with the same phase sequence as the original sequence.
- Negative sequence: A balanced three-phase system with the opposite phase sequence as the original sequence.
- Zero Sequence : Three equal phases with no phase difference between them .

Fig :1 depicts a set of three unbalanced phasors that are resolved into the three sequence components mentioned above. In this the original set of three phasors are denoted by  $V_a$  ,  $V_b$  and  $V_c$  , while their positive, negative and zero sequence components are denoted by the subscripts 1, 2 and 0 respectively. This implies that the positive, negative and zero sequence components of phase-a are denoted by  $V_{a1}$  ,  $V_{a2}$  and  $V_{a0}$  respectively. Note that just like the voltage phasors given in Fig:1 we can also resolve three unbalanced current phasors into three symmetrical components.



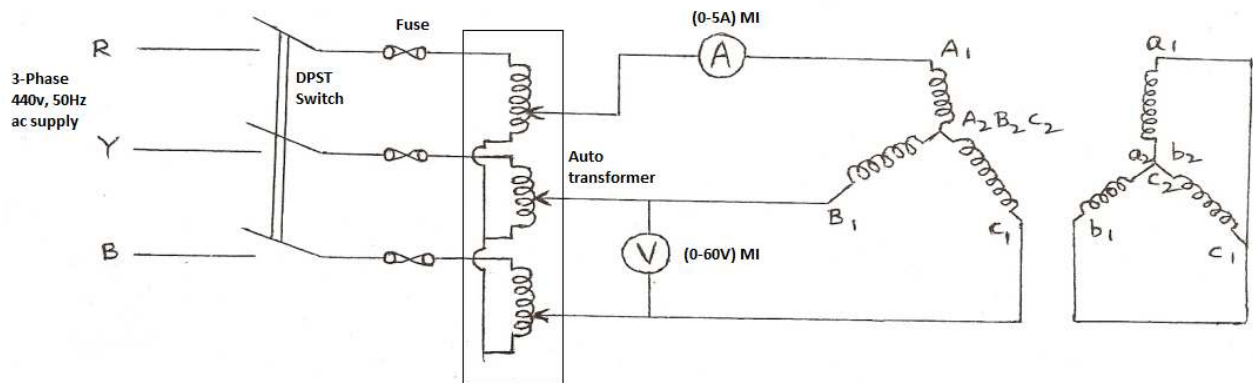
**Fig.1 Representation of (a) an unbalanced network, its (b) positive sequence, (c) negative sequence and (d) zero sequence.**

The sequence circuits developed in the previous sections are combined to form the sequence networks. The sequence networks for the positive, negative and zero sequences are formed separately by combining the sequence circuits of all the individual elements. Certain assumptions are made while forming the sequence networks. These are listed below

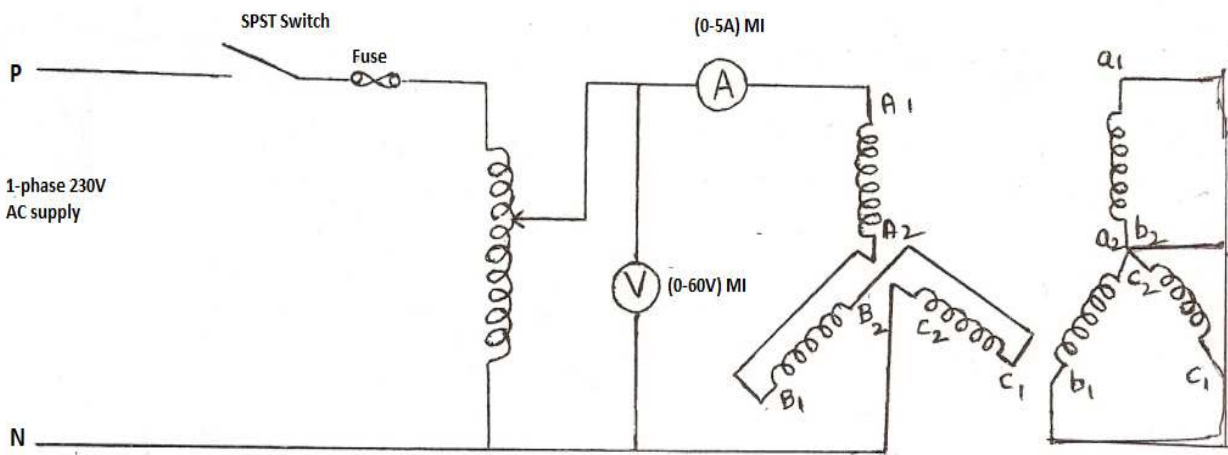
1. Apart from synchronous machines, the network is made of static elements.
2. The voltage drop caused by the current in a particular sequence depends only on the impedance of that part of the network.
3. The positive and negative sequence impedances are equal for all static circuit components, while the zero sequence component need not be the same as them. Furthermore sub-transient positive and negative sequence impedances of a synchronous machine are equal.
4. Voltage sources are connected to the positive sequence circuits of the rotating machines.
5. No positive or negative sequence current flows between neutral and ground.

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.

## Circuit Diagram:



**Fig.2**



**Fig.3**

## Procedure:-

### **(a) Positive sequence:**

- 1) Connect the given three phase transformer as shown in the fig. 2.
- 2) After short-circuiting the secondary side adjust the voltage on primary side with the help of the autotransformer such that the rated current flows in the windings..
- 3) Note down the voltage and current. From these readings determine the transformer positive sequence Impedance which is also equal to negative sequence impedance.

**(b) Zero sequence:**

- 1) Connect the given three phase transformer as shown in fig. 3
- 2) After short-circuiting the secondary side adjust the voltage on primary side which is a single phase voltage with the help of the autotransformer such that the rated current flows in the windings.
- 3) Note down the voltage and current. From these readings determine the transformer zero sequence impedance

**Tabular Form:**

**Positive sequence:**

v	I	$Z_1=Z_2=$ $V / (1.732 * I)$

**Zero sequence:**

v	I	$Z_0=V / (3 * I)$

Where,

$Z_1$  = Positive sequence impedance

$Z_2$  = Negative sequence impedance

$Z_0$  = Zero sequence impedance

$V$  = Voltage applied

$I$  = Rated current

Positive sequence Impedance:  $Z_1 = V/1.732 I$

Negative sequence Impedance:  $Z_2 = Z_1$

Zero sequence Impedance:  $Z_0 = V/3I$

**Results :**

**Viva questions:**

- 1) Define Sequence Impedances.
- 2) Explain symmetrical components method.
- 3) Why +ve, -ve sequence impedances same for a transformer?
- 4) Express the line voltages in terms of symmetrical components .

## Expt. No. 7. Characteristics of Static Relays: Under voltage and Over voltage relay

### Aim:

To Study characteristics of solid state under voltage and over voltage relays

### Apparatus:

S.No	Name Of The Equipment	Range	Type	Quantity
1.	Static under & over voltages Relays	-	-	1 No's Each
2.	Auto Transformer	(0-230V)	Single phase	1Nos
3.	Voltmeter	(0- 300V)	MI	1Nos
4.	Timer	-	-	1 No
5.	Connecting wires	As per requirement		
6.	Stop watch	-	-	1 No

### **Details of the Undervoltage relay:**

Differential 0 – 20 volts

Off delay 0 – 15 sec

On delay 0 – 15 sec.

### **Details of the Overvoltage relay:**

Voltage 220 – 280 volts

Time delay 0 – 15 sec

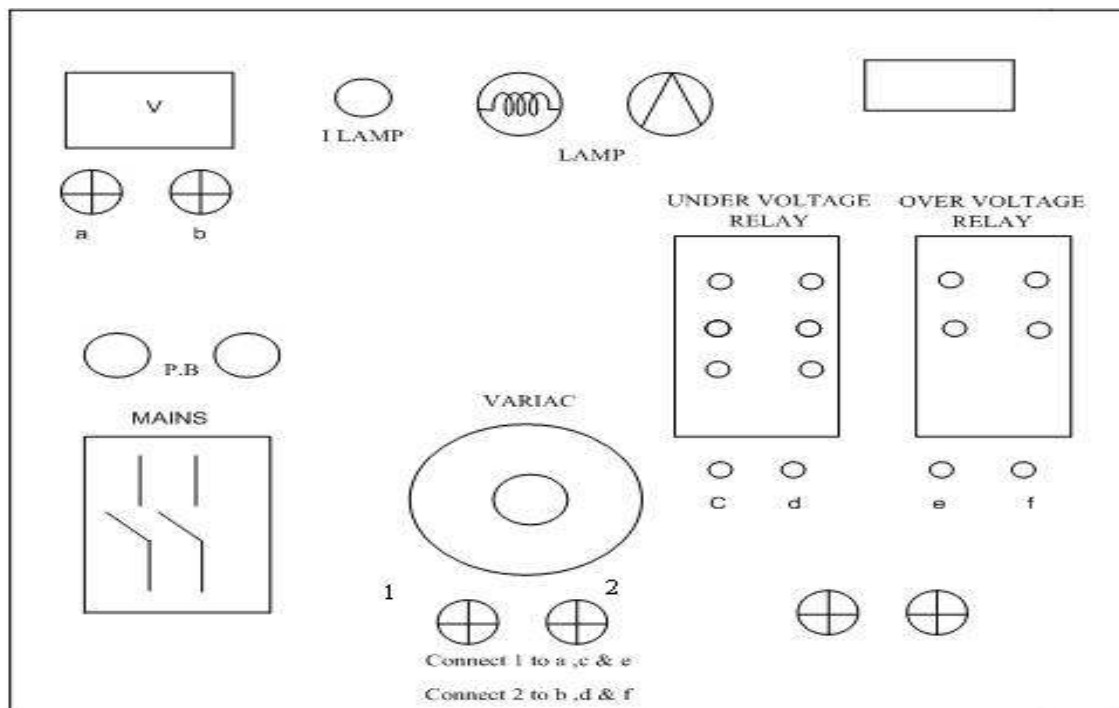
Differential fixed 3 volts.

### **Theory:**

The voltage comparison type solid state voltage relays, normally uses a rectifier bridge with smoothing filters, having a common source taken from the supply to which the equipment to be protected is connected. A comparator circuit compares with the set voltage, for verifying whether the voltage sensed is below or above the set value. If the difference exceeds a certain amount it is processed further for actuating a relay, which in turn cuts off the circuit through a contactor in the circuit, there by disconnecting the equipment from the main supply.

Time delay is incorporated by using 555 timer and resistance – capacitor (RC) circuit. The resistor is in the form of potentiometer, so that the required time delay can be adjusted. The setting knobs are placed in easily accessible front plate. The given panel is representative of 3 phase circuit and uses a single phase 230 Volts circuit. The main supply is single phase 230 volts, 50 Hz. In this panel the under voltage and overvoltage relays are provided with a variable single phase supply and a digital voltmeter to read the set voltage.

### Circuit Diagram:



**Fig. 1**

### Procedure:-

- 1) Give connections as per the circuit shown in fig. 1.
- 2) Set the under voltage relay at 180 volts with a time some time delay [say 10secs]
- 3) Switch on the mains, press green push button and set the voltage about 210 volts.
- 4) Now slowly reduce the voltage to 180 volts and start the stop watch at the same time
- 5) When the circuit would trip stop the watch and record the time.
- 6) Change the time setting for the same voltage on the relay and repeat the process till it



trips. Record the timing.

- 7) Now change the voltage setting on the relay and repeat the process as above to record the time for tripping.
- 8) For over voltage set the overvoltage relay setting at 210 volts. Also set the required time setting on the relay
- 9) Increase the voltage using variac to 215 volts and note the time required for tripping
- 10) Similarly, set the voltages at different levels and record tripping times

**Tabular Form:**

**Under voltage relay:**

<b>S.no</b>	<b>Voltage (V)</b>	<b>Time (S)</b>

**Over voltage relay:**

<b>S.no</b>	<b>Voltage (V)</b>	<b>Time (S)</b>

**Result:**

**Viva Questions:**

- 1) What is the need for this type of static relay?
- 2) What do you understand by a static relay?
- 3) How will you protect a transmission line of 132kv line from over voltage or under voltage?
- 4) How will you know that a relay has operated?
- 5) What is current graded system?

## Expt. No. 8(a). Determination of Dielectric strength of oil and study of Megger

**Aim:** To find the dielectric strength of transformer oil.

**Apparatus:**

- 1) Oil testing kit for transformer.
- 2) Circuit-breaker oils

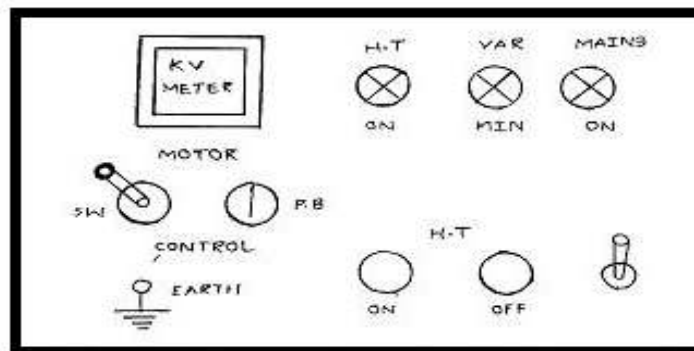
**Theory:**

Transformer oil (also known as insulating oil) is a special type of oil which has excellent electrical insulating properties and is stable at high temperatures. Transformer oil is used in oil-filled electrical power transformers to insulate, reduce arcing and corona discharge, and to dissipate the heat of the transformer (i.e. act as a coolant). Transformer oil is also used to preserve the transformer's core and windings – as these are fully immersed inside the oil.

The dielectric strength of transformer oil is also known as the breakdown voltage (BDV) of transformer oil. Breakdown voltage is measured by observing at which voltage, sparking starts between two electrodes immersed in the oil (which is shown in fig. 2), separated by a specified gap.

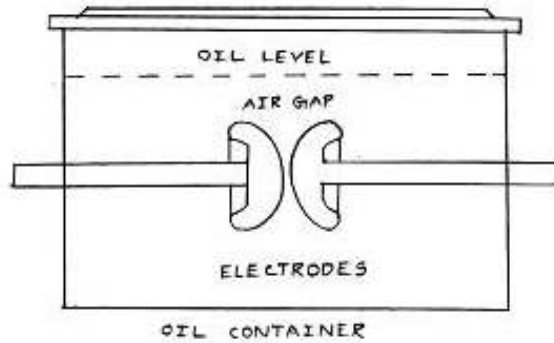
A low value of BDV indicates presence of moisture content and conducting substances in the oil.

**Circuit Diagram:**



**Oil Testing Kit**

**Fig.1**



**Fig. 2**

**Procedure:-**

- 1) Clean the test cell which is placed in the oil testing kit (model circuit is as shown in fig. 1).
- 2) Pour oil to be tested, in this cell and stir it well.
- 3) Place it in the test compartment and close the lid by screwing down the knob.
- 4) Record the temperature of room if the oil is not hot. If hot, record oil temperature before pouring into the cell. It should lie between 15 to 35 degrees.
- 5) Switch on the supply and increase the voltage by the device fitted on panel. The rate of rise should be 2kV/second. (Usually this is taken care by the automatic control provided in the kit.)
- 6) Note and record the voltage at breakdown, i.e when spark over occurs. [It is in most of cases the kit makers provide an interlocking to switch off automatically the mains.] Otherwise switch off at once.
- 7) After a brief pause, repeat six times the procedure from starting to sixth step.
- 8) Tabulate these results. Average of 4-5 readings is taken as the breakdown voltage.

**Tabular Form:**

S.No	Voltage(kV)
<b>Average</b>	

**Result:**

**Viva Questions:**

- 1) If we change the distance between electrodes, do we need to apply more or less voltage for flashover?
- 2) What is the Breakdown strength of Air?
- 3) Why flashover occurs at a less voltage if we repeat the experiment with a brief time gap for the same distance between electrodes?
- 4) Why is transformer oil used in a transformer?
- 5) Is it necessary that this oil should have very good insulating properties?
- 6) Why does the transformer oil's insulating property deteriorate?

## Expt. No. 8(b). study of Megger

### Aim:

To study the operation of Megger

### Apparatus Required:

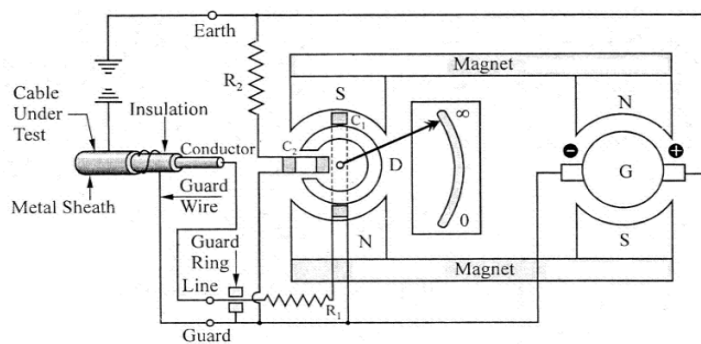
- Megger Kit

### Theory:

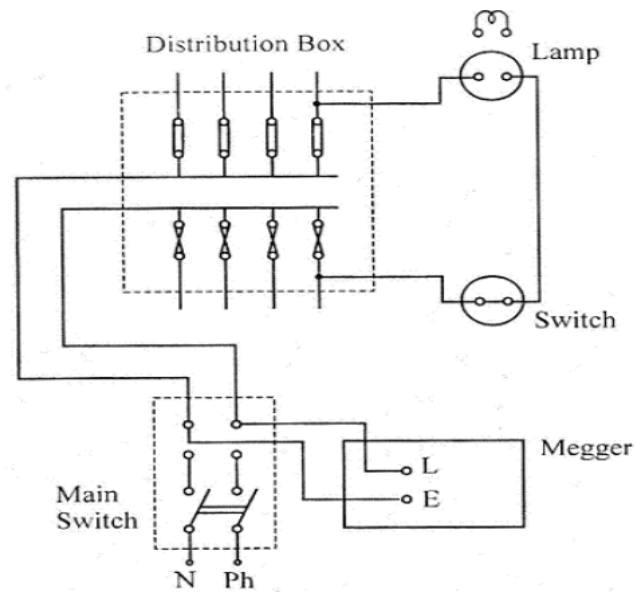
Megger is a very useful instrument for the measurement of high resistance and insulation resistance of cables, bushing, electrical installations and machines.

Figure. 1 shows the constructional diagram of a megger. It consists of two primary elements, a direct reading ohm-meter and a small hand driven (through gearing) permanent magnet type D.C. generator G which supplies the testing voltage such as 500, 1000 or 2500V depending upon the instrument. The moving system of the ohmmeter consists primarily of two coils C1 and C2. These coils are mounted rigidly at an angle to one another and move in the air gap of a permanent magnet. Coil C1, called the current coil or deflecting coil is connected between the negative brush of the generator and the line terminal along with the resistance R1 in series with it. Coil C2, called the potential coil or control coil, is in series with the resistance R2 and connected across the supply of the generator. This coil is narrower than coil C1 and encircles a part of the C- shaped iron core D during the course of its movement. Thin flexible ligaments exerting negligible tension on the moving system make connections to the coil. The whole moving system is supported between the two jewel bearings. The insulating bushing of the line terminal is mounted on a metal ring, known as a guard, which is connected, back to the negative line or the guard terminal.

### Circuit Diagram:



**Fig. 1**



**Fig. 2**

**Procedure:**

**Insulation Resistance between Conductors:**

- 1) Connect the circuit as shown in fig. 2
- 2) With all fuse links in position, all switches ON (except main switch which should be off) and all lamps and appliance out, megger terminals are connected between the two conductors as shown in Fig. 2.
- 3) Reading of the megger under this condition gives the insulation resistance between the two conductors under test.

**Result:**

**Viva questions:**

- 1) What are the applications of megger?
- 2) Give the classification of resistance from measurement point of view

## Expt. No. 9. Measurement of capacitance of three core cable

**Aim:** To measure core to core and, core to earth capacitance of a given three core cable

**Apparatus:**

- 1) Three core cable
- 2) LCR Meter

**Theory:**

An underground cable essentially consists of one or more conductors covered with suitable insulation and surrounded by a protecting cover.

**(i) Cores or Conductors:** A cable may have one or more than one core (conductor) depending upon the type of service for which it is intended to . For instance, the 3-conductor cable shown in Fig. 1 is used for 3-phase service. The conductors are made of tinned copper or aluminium and are usually stranded in order to provide flexibility to the cable.

**(ii) Insulation:** Each core or conductor is provided with a suitable thickness of insulation, the thickness of layer depending upon the voltage to be withstood by the cable. The commonly used materials for insulation are impregnated paper, varnished cambric or rubber mineral compound.

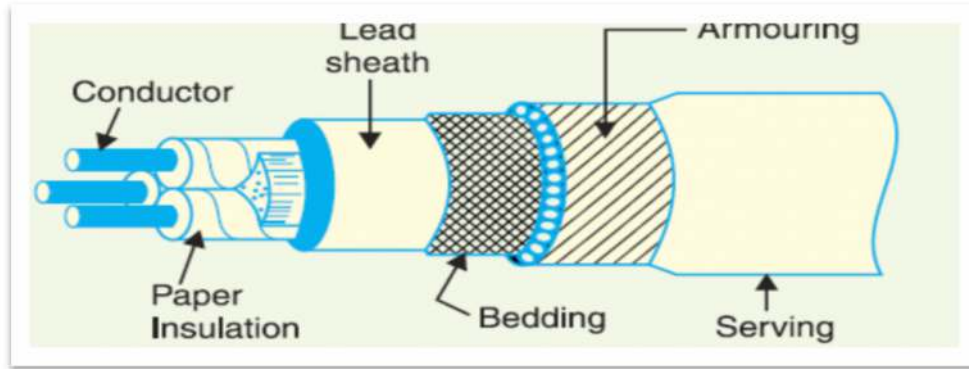
**(iii) Metallic sheath:** In order to protect the cable from moisture, gases or other damaging liquids (acids or alkalis) in the soil and atmosphere, a metallic sheath of lead or aluminium is provided over the insulation as shown in Fig. 1

**(iv) Bedding:** Over the metallic sheath is applied a layer of bedding which consists of a fibrous material like jute or hessian tape. The purpose of bedding is to protect the metallic sheath against corrosion and from mechanical injury due to armouring.

**(v) Armouring:** Over the bedding, armouring is provided which consists of one or two layers of galvanised steel wire or steel tape. Its purpose is to protect the cable from mechanical injury while laying it and during the course of handling. Armouring may not be done in the case of some cables.

**(vi) Serving:** In order to protect armouring from atmospheric conditions, a layer of fibrous material (like jute) similar to bedding is provided over the armouring. This is known as serving.





**Fig. 1**

The Capacitance of 3 Core Cables is much more important than that of overhead line because in cables

- (i) conductors are nearer to each other and to the earthed sheath
- (ii) they are separated by a dielectric of permittivity much greater than that of air.

Fig. 2 shows a system of capacitances in a 3-core belted cable used for 3-phase system. Since potential difference exists between pairs of conductors and between each conductor and the sheath, electrostatic fields are set up in the cable as shown in Fig. 2 (i). These electrostatic fields give rise to core-core capacitances  $C_c$  and conductor-earth capacitances  $C_e$  as shown in Fig. 2(ii). The three  $C_c$  are delta connected whereas the three  $C_e$  are star connected, the sheath forming the star point [See Fig. 2(iii)].

The lay of a belted cable makes it reasonable to assume equality of each  $C_c$  and each  $C_e$ . The three delta connected capacitances  $C_c$  [See Fig.2(iv)] can be converted into equivalent star connected Capacitance of 3 Core Cables as shown in Fig. 2(v). It can be easily shown that equivalent star capacitance  $C_{eq}$  is equal to three times the delta-capacitance  $C_c$  i.e.  $C_{eq}=3C_c$ .

The system of Capacitance of 3 Core Cables shown in Fig.2(iii) reduces to the equivalent circuit shown in Fig. 2(vi)

Therefore, the whole cable is equivalent to three star-connected capacitors each of Capacitance of 3 Core Cables [See Fig. 2(vii)],

$$\begin{aligned}
 C_N &= C_e + C_{eq} \\
 &= C_e + 3C_c
 \end{aligned}$$

If,  $V_{ph}$  is the phase voltage, then charging current  $I_c$  is given by ;

$$\begin{aligned}
 I_C &= \frac{V_{ph}}{\text{Capacitive reactance per phase}} \\
 &= 2\pi f V_{ph} C_N \\
 &= 2\pi f V_{ph} (C_e + 3C_c)
 \end{aligned}$$

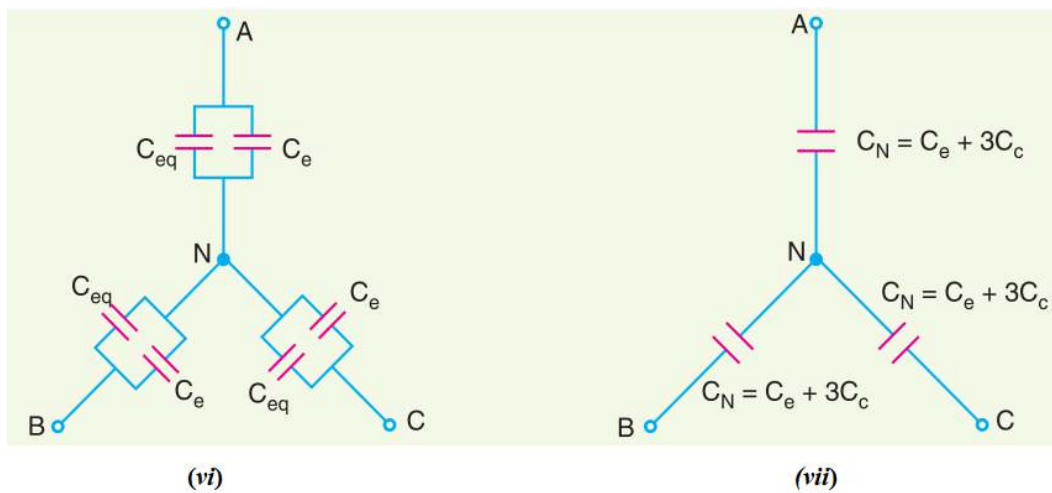
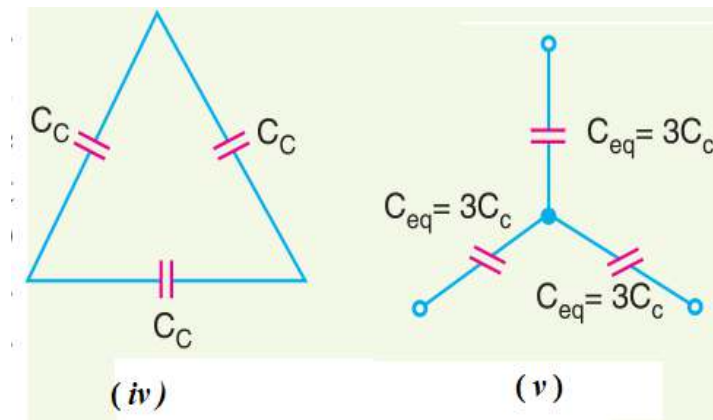
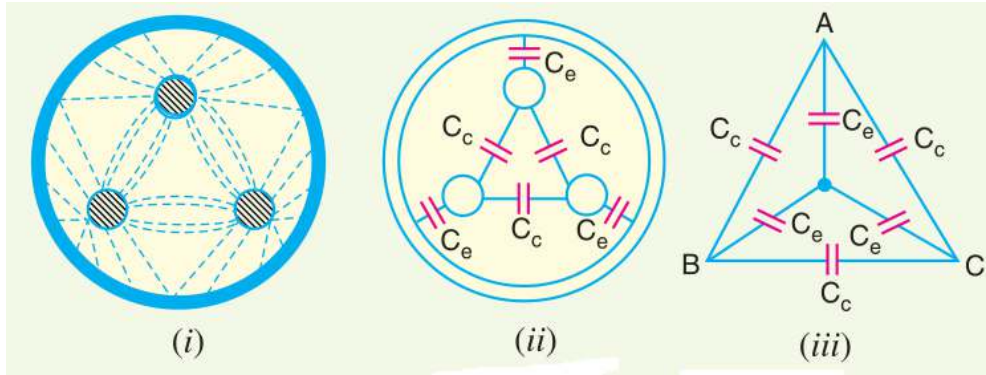


Fig. 2

### Circuit Diagram:

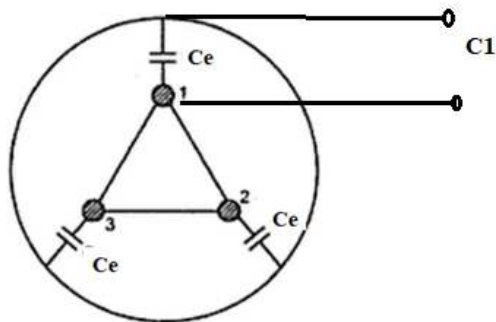
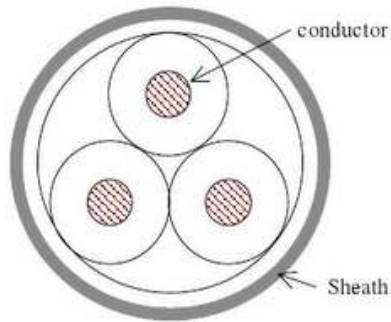


Fig. 3

Fig. 4

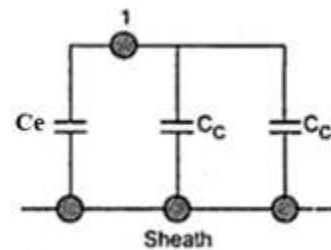
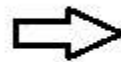
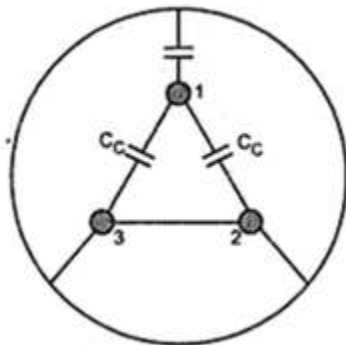


Fig. 5

### Procedure:

#### Measurement of $C_E$ :

- 1) Three cores are bunched together and the capacitance  $C_1$  is measured between the bunched cores and the sheath (ref. fig. 4).
- 2) The bunching eliminates all the three capacitance  $C_c$ , leaving the three capacitors  $C_e$  in parallel.

$$C_E = C_1/3$$

**(b) Measurement of  $C_c$**

- 1) Two cores are bunched with the sheath and capacitance  $C_2$  is measured between them and the third core (ref. fig. 5)

$$C_c = (C_2 - C_E)/2$$

**(c) Measurement of  $C_N$**

- 1) Measure capacitance  $C_3$  between two cores with the third core left free.

$$C_N = 2C_3 \quad (\text{or}) \quad C_N = C_E + 3 * C_c$$

**Result:**

**Viva Questions:**

- 1) What are the different layers present in cable and why are they used ?
- 2) What are the advantages of under ground cables compared to Overhead lines.?
- 3) What are the different types of cables based on voltage levels.?
- 4) What is meant by Capacitance grading ?
- 5) What are the different methods for capacitance grading?

**Expt. No. 10. Simulation of String of Insulators for Determination of Voltage  
Distribution and String Efficiency**

**Aim:**

To determine voltage distribution and string efficiency of suspension insulator with and without guard ring.

**Apparatus:**

- 1) -Panel for simulation fitted with capacitors
- 2) -Capacitor ----- 4  $\mu$ f----- 3
- 3) -Capacitor -----2.5  $\mu$ f----- 4
- 4) -Variac, single phase -----230V, 50Hz
- 5) -Voltmeter or multimeter -----(0-230v)
- 6) -Connecting wires as per requirement.

**Theory:**

Suspension types of insulators are used on transmission lines of 33KV and above. A thumb rule is that each disc is for 11 KV. To find the number of insulators of any voltage is to have one disc for every 11 KV. This does not mean that voltage across the discs of the string is uniformly distributed. This is because of the capacitance formed between the metal parts of the insulators and the tower structure and the capacitance affects the voltage distribution across the string. The capacitance of each unit is known as mutual capacitance.

- To improve string efficiency the following methods are used.
  - a. Selection of ratio of mutual capacitance to Capacitance to ground. A larger value of m is preferred.
  - b. Grading of units
  - c. **Static shielding by using a Guard ring or grading ring.**

A string of suspension insulators are shown in fig.1.

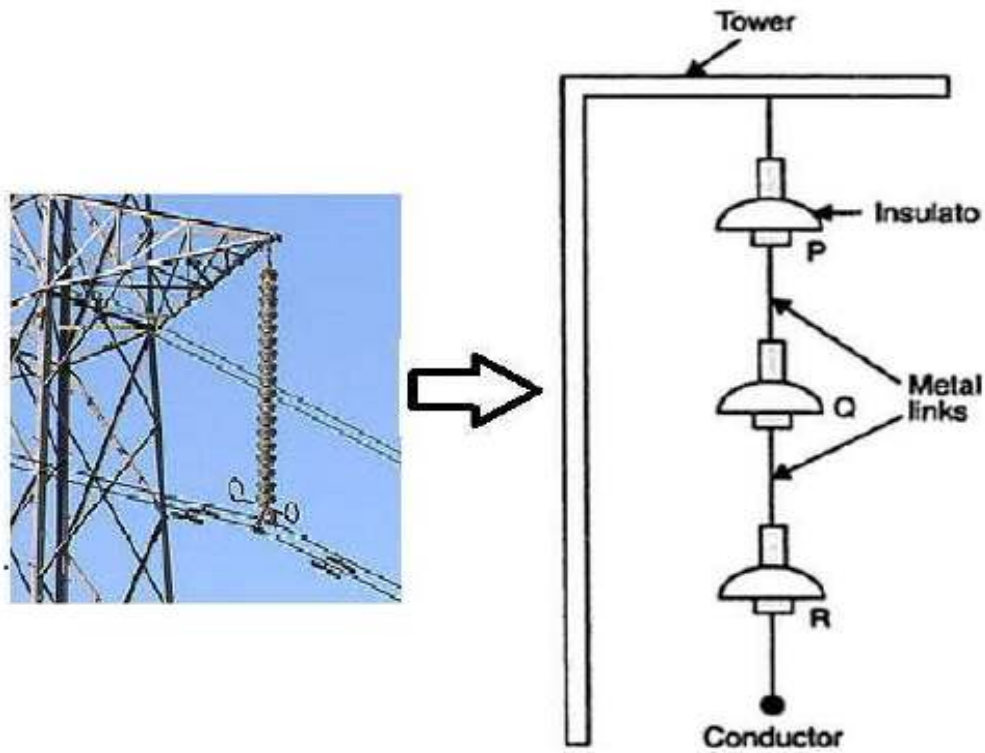


Fig. 1

**Circuit Diagram:**

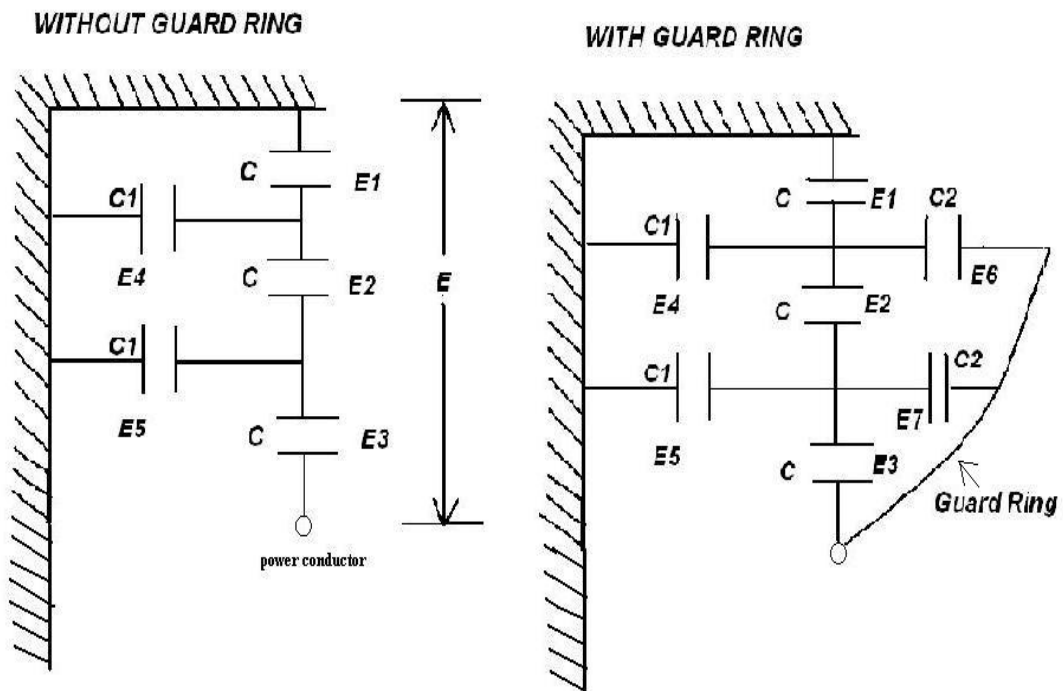


Fig. 2

**Procedure:**

- 1) Connect the circuit as per fig :2 (without guard ring)
- 2) Increase the voltage slowly using variac to the desired value say 80 V
- 3) Read the voltage across each disc, with multi meter and record the voltages in tabular form.
- 4) Repeat this procedure for conductor voltages of 120 and 160 V tabulate the readings.
- 5) Now connect the circuit as per fig : 2 (with guard ring)
- 6) Repeat the above steps i.e. same procedure as in case of without guard ring tabulate the reading for 80, 120 and 160 V
- 7) Calculate the string efficiency in each case.

**Tabular Form:**

S.No	Applied Voltage	Without Guard ring				With Guard ring			
		Voltages at			% String Efficiency	Voltages at			% String Efficiency
		E <sub>1</sub>	E <sub>2</sub>	E <sub>3</sub>		E <sub>1</sub>	E <sub>2</sub>	E <sub>3</sub>	

$$\text{String efficiency} = \frac{\text{Total Voltage across the string}(E)}{N * \text{Voltage across the unit near the power conductor}(E_3)}$$

Where N = number of units in a string

**Result:**

**Viva Questions:**

- 1) What is String Efficiency?
- 2) What are the methods of improving Voltage Distribution?
- 3) What is the importance of guard ring?
- 4) Describe the types of insulators.
- 5) What are the different materials used in the manufacture of insulators.



## **Expt. No. 11. Simulation of Load frequency control**

### **Aim:**

To become familiar with modeling and analysis of the frequency and tie-line flow dynamics of a power system with and without load frequency controllers (LFC).

### **Apparatus:**

MATLAB/SIMULINK software

### **Theory:**

Active power control is one of the important control actions to be performed for the normal operation of the system to match the system generation with the continuously changing system load in order to maintain the constancy of system frequency to a fine tolerance level. This is one of the foremost requirements in providing quality power supply. A change in system load causes a change in the speed of all rotating masses (Turbine – generator rotor systems) of the system leading to change in system frequency. The speed change from synchronous speed initiates the governor control (primary control) action resulting in the entire participating generator – turbine units taking up the change in load, stabilizing system frequency. Restoration of frequency to nominal value requires secondary control action which adjusts the load - reference set points of selected (regulating) generator – turbine units.

The primary objectives of automatic generation control (AGC) are to regulate system frequency to the set nominal value and also to regulate the net interchange of each area to the scheduled value by adjusting the outputs of the regulating units. This function is referred to as load frequency control (LFC).

### Circuit Diagram:

#### (a) Without Integral Controller

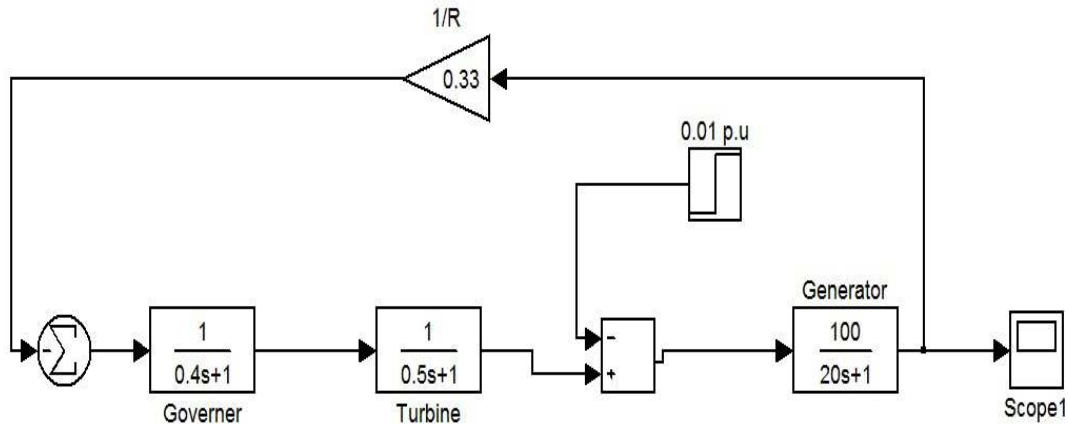


Fig. 1

#### (b) With Integral Controller

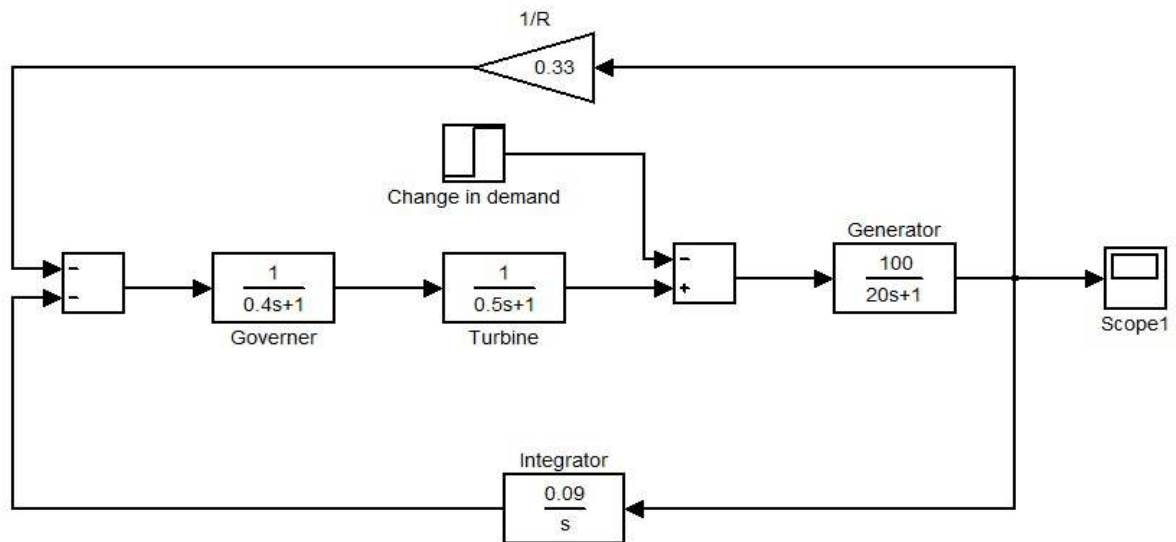


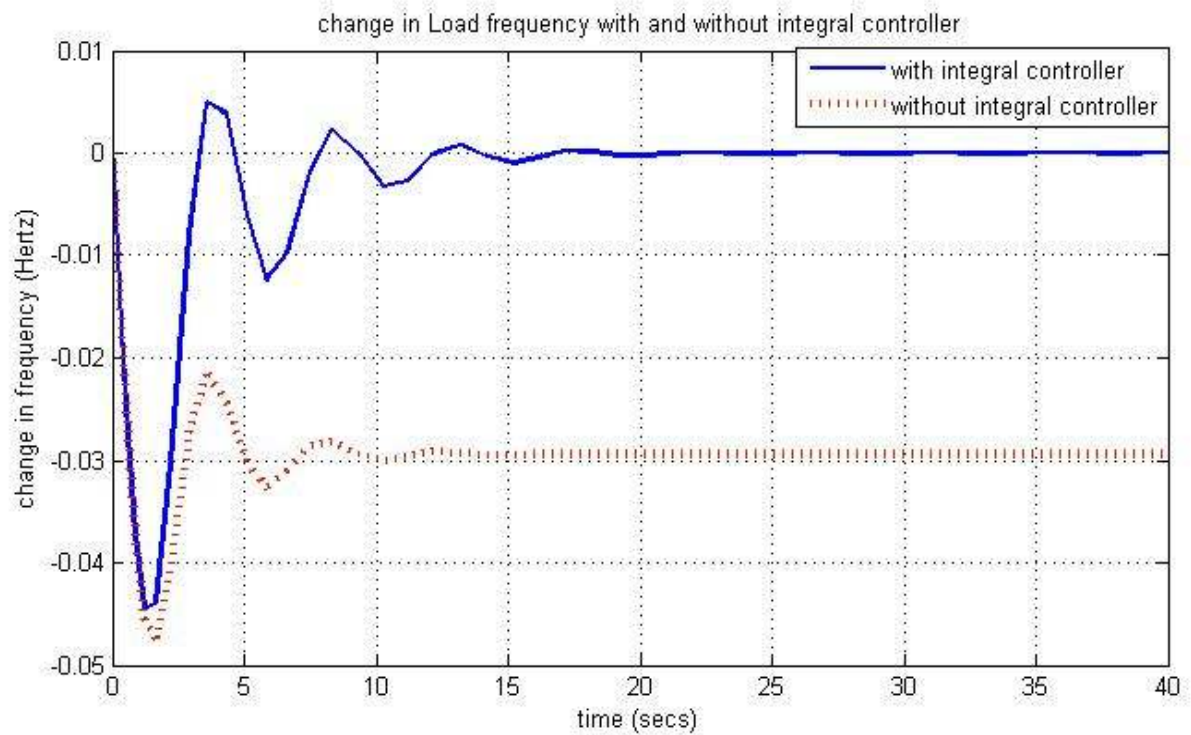
Fig. 2

### Procedure:

1. Enter the command window of the MATLAB.
2. Create a new Model by selecting File - New – Model.
3. Pick up the blocks from the Simulink library browser and form a block diagram as per fig. 1 and fig. 2
4. After forming the block diagram, save the block diagram and run the Simulink circuit

5. Double click the scope and view the result.

**Expected waveforms:**



**Result:**

**Viva Questions:**

- 1) How frequency is controlled at the power generating station.?
- 2) What is integral controller?
- 3) What is closed loop control?
- 4) What is single area and two area control?
- 5) Define P, I, PI and PID controllers.

## **Expt. No. 12. Study of fault analysis on alternator**

### **Aim:**

To find the fault currents and fault voltages when a single line to ground (L-G) fault and line to line (L-L) faults occur on unloaded alternator.

### **Apparatus required:**

S.No	Apparatus	Type	Range	Quantity
1	Ammeter			
2	Voltmeter			
3	Rheostat			
4	Static Exciter			
5	Tachometer			
6	Connecting Wires			

### **Theory:**

A fault is any abnormal condition in a power system. The steady state operating mode of a power system is balanced 3-phase a.c. However, due to sudden external or internal changes in the system, this condition is disrupted.

#### **Causes of Power System Faults:**

Lightning  
Heavy winds  
Trees falling across lines  
Vehicles colliding with towers or poles  
Birds shorting lines  
Aircraft colliding with lines  
Vandalism  
Small animals entering switchgear  
Line breaks due to excessive loading

#### **Common Power System Faults:**

Power system faults may be categorized as one of four types; in order of frequency of occurrence, they are:

Single line to ground fault

Line to line fault

Double line to ground fault

Balanced three phase faults

The first three types constitute severe unbalanced operating conditions which involves only one or two phases hence referred to as unsymmetrical faults. In the fourth type, a fault involving all the three phases occurs therefore referred to as symmetrical (balanced) fault.

### Symmetrical components:

The majority of faults in power systems are asymmetrical. To analyse an asymmetrical fault, an unbalanced 3- phase circuit has to be solved. Since the direct solution of such a circuit is very difficult, the solution can be more easily obtained by using symmetrical components since this yields three (fictitious) single phase networks, only one of which contains a driving emf. Since the system reactances are balanced the three fictitious networks have no mutual coupling between them, a fact that is making this method of analysis quite simple.

Unbalanced three phase systems can be split into three balanced components, namely Positive Sequence (balanced and having the same phase sequence as the unbalanced supply), Negative Sequence (balanced and having the opposite phase sequence to the unbalanced supply) and Zero Sequence (balanced but having the same phase and hence no phase sequence). These are known as the Symmetrical Components or the Sequence Components and are shown in fig. 1

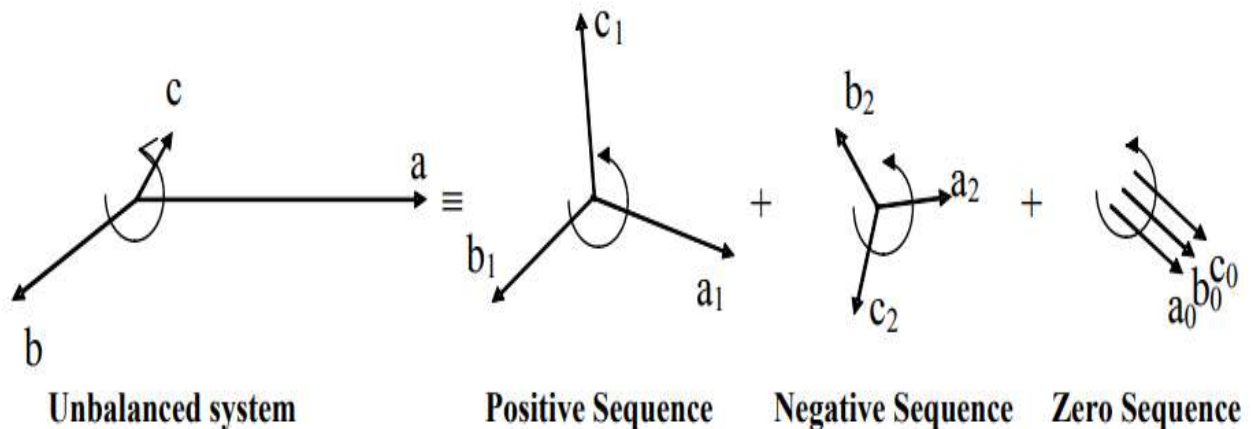
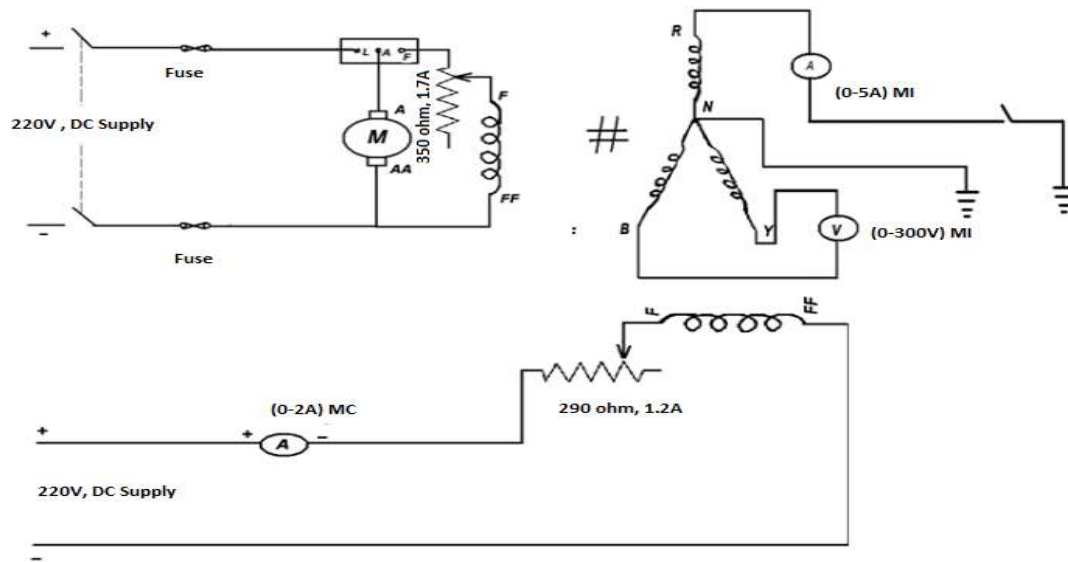


Fig. 1

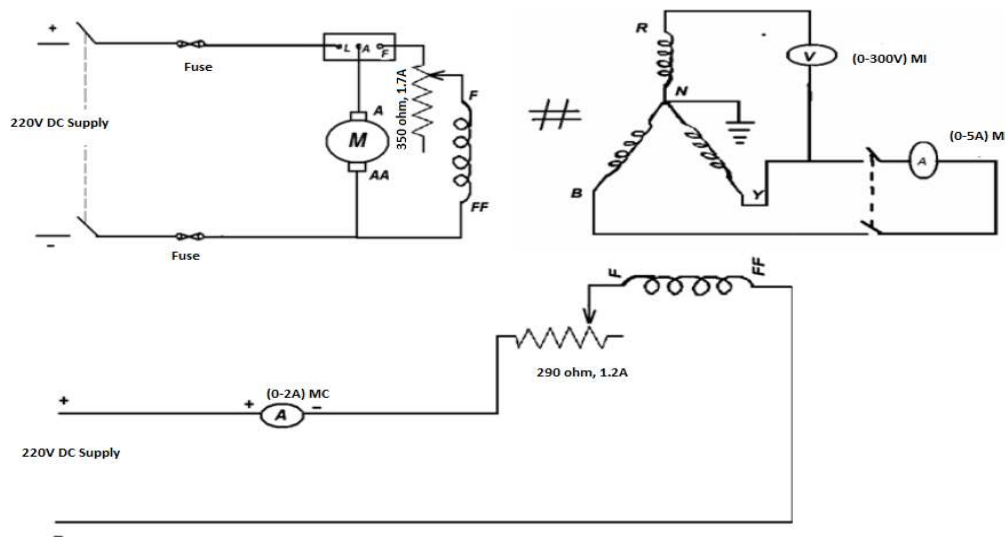
A positive sequence set of three symmetrical voltages (i.e. all numerically equal and all displaced from each other by  $120^\circ$ ) having the same phase sequence abc as the original set and denoted by  $V_{a1}, V_{b1}, V_{c1}$  as shown in the fig.1

In this the original set of three phasors are denoted by  $V_a$ ,  $V_b$  and  $V_c$ , while their positive, negative and zero sequence components are denoted by the subscripts 1, 2 and 0 respectively. This implies that the positive, negative and zero sequence components of phase-a are denoted by  $V_{a1}$ ,  $V_{a2}$  and  $V_{a0}$  respectively. Note that just like the voltage phasors given in fig. 1 we can also resolve three unbalanced current phasors into three symmetrical components.

**Circuit diagram:**



**Fig. 2**



**Fig. 3**

**Procedure:**

**(a) LG Fault:-**

- 1) Connect the circuit as per fig. 2.
- 2) Ensure that the filed rheostat is kept in minimum resistance position and DPST switch in off position and give the supply to DC motor and then by varying field rheostat. Let, the motor runs at rated speed.
- 3) By varying the rheostat rated voltage in the voltmeter connected between the phase into be obtained with DPST switch in open stator.
- 4) At this instant note down all the voltmeter and ammeter readings.
- 5) Now close the DPST switch under fault condition. Note down the fault currents and fault voltages.

**(b) LL Fault:-**

- 1) Connect the circuit as per fig. 3.
- 2) Ensure that the filed rheostat is kept in minimum resistance position and DPST switch in off position and give the supply to DC motor and then by varying field rheostat. Let, the motor runs at rated speed.
- 3) Vary the rated speed up to rated voltage in the voltmeter connected between the phasor with DPST Switch in open position.
- 4) Now create a fault between the phasor Y and B, take readings of voltmeter and Ammeter.
- 5) Calculate Fault current using sequence impedance method

**Tabular Form:**

**(a) LG Fault:-**

$V_{RN}$ (V)	$V_{YN}$ (V)	$V_{BN}$ (V)	$I_R$ (A)	$V_{RY}$ (V)	$V_{YB}$ (V)	$V_{BR}$ (V)	$I_F$ (A)

**(b) LL Fault:-**

$V_{RN}$ (V)	$V_{YN}$ (V)	$V_{BN}$ (V)	$I_R$ (A)	$V_{RY}$ (V)	$V_{YB}$ (V)	$V_{BR}$ (V)	$I_F$ (A)

### Calculations:

$$\alpha = 1\angle 120^\circ$$

$$\alpha^2 = 1\angle 240^\circ \text{ or } 1\angle -120^\circ$$

$$\alpha^3 = 1\angle 360^\circ \text{ or } 1$$

$$\begin{bmatrix} V_{a0} \\ V_{a1} \\ V_{a2} \end{bmatrix} = \frac{1}{3} \begin{bmatrix} 1 & 1 & 1 \\ 1 & \lambda & \lambda^2 \\ 1 & \lambda^2 & \lambda \end{bmatrix} \begin{bmatrix} V_a \\ V_b \\ V_c \end{bmatrix}$$

### For LG-fault:

$$\begin{bmatrix} I_{a0} \\ I_{a1} \\ I_{a2} \end{bmatrix} = \frac{1}{3} \begin{bmatrix} 1 & 1 & 1 \\ 1 & \lambda & \lambda^2 \\ 1 & \lambda^2 & \lambda \end{bmatrix} \begin{bmatrix} I_a \\ I_b \\ I_c \end{bmatrix}$$

$$I_{a0} = I_{a1} = I_{a2} = \frac{I_a}{3}$$

$$Z_0 = \frac{-V_{a0}}{I_{a0}}$$

$$Z_1 = \frac{E_a - V_{a1}}{I_{a1}}$$

$$Z_2 = \frac{-V_{a2}}{I_{a2}}$$

$$Z_f = \frac{V_{RN}}{I_R}$$

$$I_{fault} = \frac{3E_a}{Z_1 + Z_2 + Z_0 + 3Z_f}$$



### For LL Fault

$$I_a = 0, \quad I_b + I_c = 0$$

$$I_c = -I_b$$

$$V_b = V_c$$

$$\begin{bmatrix} I_{a0} \\ I_{a1} \\ I_{a2} \end{bmatrix} = \frac{1}{3} \begin{bmatrix} 1 & 1 & 1 \\ 1 & \lambda & \lambda^2 \\ 1 & \lambda^2 & \lambda \end{bmatrix} \begin{bmatrix} I_a \\ I_b \\ I_c \end{bmatrix}$$

$$I_{a0} = 0$$

$$I_{a1} = \frac{1}{3} [\lambda I_b - \lambda^2 I_c]$$

$$I_{a2} = \frac{1}{3} [\lambda^2 I_b - \lambda I_c]$$

$$Z_f = 0$$

$$Z_1 + Z_2 = \frac{E}{I_{a1}}$$

$$I_{fault} = \frac{-j\sqrt{3}E}{Z_1 + Z_2}$$

### Results:

**Viva questions:**

- 1) What are the different faults in power system?
- 2) Which fault is least severe?
- 3) What are the causes for faults?
- 4) Which fault is most severe?
- 5) What is meant by fault in power system?
- 6) What are symmetrical components?
- 7) Define positive sequence, negative sequence and zero sequence components.
- 8) Arrange the faults in the increasing order of severity.