POWER SYSTEMS AND PROTECTION LAB

LAB MANUAL

Course Code	:	AEE112
Regulations	:	IARE -R16
Class	:	VII Semester

DEPARTMENT OF ELECTRICAL AND ELECTRONICS ENGINEERING

INSTITUTE OF AERONAUTICAL ENGINEERING

(Autonomous)

Dundigal – 500 043, Hyderabad

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Dundigal, Hyderabad - 500 043

Department of Electrical and Electronics Engineering

Program Outcomes	
PO1	**Engineering Knowledge**: Apply the knowledge of mathematics, science, engineering fundamentals, and an engineering specialization to the solution of complex engineering problems.
PO2	**Problem Analysis**: Identify, formulate, review research literature, and analyze complex engineering problems reaching substantiated conclusions using first principles of mathematics, natural sciences, and engineering sciences.
PO3	**Design / Development of Solutions**: Design solutions for complex 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, APPRATUS, and modern engineering and IT tools including prediction and modeling to complex 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 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.
PO8	**Ethics**: Apply ethical principles and commit to professional ethics and responsibilities and norms of the 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	
PSO1	**Professional Skills:** Able to utilize the knowledge of high voltage engineering in collaboration with power systems in innovative, dynamic and challenging environment, for the research based team work.
PSO2	**Problem - Solving Skills:** Can explore the scientific theories, ideas, methodologies and the new cutting edge technologies in renewable energy engineering, and use this erudition in their professional development and gain sufficient competence to solve the current and future energy problems universally.
PSO3	**Successful Career and Entrepreneurship:** The understanding of technologies like PLC, PMC, process controllers, transducers and HMI one can analyze, design electrical and electronics principles to install, test , maintain power system and applications.

INDEX

ATTAINMENT OF PROGRAM OUTCOMES & PROGRAM SPECIFIC OUTCOMES

Exp. No.	Experiment	Program Outcomes Attained	Program Specific Outcomes Attained
1	Characteristics of an MCB	PO1, PO3	PSO1
2	Characteristics of fuse and thermal overload protection	PO1, PO2	PSO1
3	ABCD parameters of transmission line	PO1, PO3,PO4	PSO1
4	Ferranti effect in a transmission line	PO1, PO3,PO4	PSO1
5	Surge impedance loading	PO1, PO3,PO4	PSO1
6	Effect of shunt compensation	PO1, PO4	PSO1
7	Voltage profile improvement using tap changing transformer	PO1, PO3	PSO1
8	Efficiency and regulation of a transmission line	PO1, PO3,PO4	PSO3
9	Performance of impedance relay	PO2, PO3	PSO3
10	Performance of over current relay	PO1, PO3	PSO3
11	Earth fault protection	PO1, PO3,PO4	PSO3
12	Feeder protection	PO 3,PO 4	PSO3
13	Measurement of sequence impedances of synchronous machine	PO3,PO4	PSO3
14	String efficiency of insulators	PO1, PO3,PO4	PSO3

POWER SYSTEMS AND PROTECTION LABORATORY

OBJECTIVE:

I. Understand the importance of protection and plotting the characteristics of MCB and Fuse.
II. Determine the parameters, surge impedance loading and reactive power compensation of transmission lines.
III. Understand the concept of Ferranti effect of a transmission lines.
IV. Calculate positive, negative and zero sequence impedances of synchronous machine.

OUTCOMES:

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

1. Examine the functioning of miniature circuit breaker(MCB).
2. Understand internal circuit of high rupturing capacity and tripping of bimetallic thermal overload protection.
3. Record of ABCD Parameters of transmission line.
4. Analyze Ferranti effect in a transmission line.
5. Calculate surge impedence loading (SIL) of a transmission line.
6. Explain the concept of shunt compensation to counteract the voltage rise on no load and zero-regulation at different loads in a transmission line.
7. Understand the concept of voltage improvement by reactive power control using tap changing Transformer.
8. Determine the performance of a transmission line by calculating its efficiency and regulation.
9. Understand the working principle of impedance relay and its effect during faults in a transmission line.
10. Understand the working principle of over current relay and its effect during faults in a transmission line.
11. Analyze earth fault detection methods and various earth fault protection schemes
12. Analyze various protection schemes in radial feeder under various fault conditions.
13. Calculate positive, negative and zero sequence impedances of synchronous machine by using direct method and fault analysis method.
14. Determine of string efficiency in a string of insulators.

EXPERIMENT - 1

CHARACTERISTICS OF AN MCB

1.1 AIM:

To plot the characteristics of miniature circuit breaker (MCB).

1.2 APPARATUS:

S. No.	Equipments	Range	Quantity
1	Ammeter	0.5-10A	1
2	Voltmeter	250-500V	1
3	Miniature circuit breaker	240-415V	1
4	Variable load	-	1
5	Connecting wires	-	As Required

1.3 THEORY:

MCB is high fault capacity, thermal /magnetic current limiting trip free automatic switching device with fast magnetic tripping. Thermal operation with inverse time current characteristics for overload protection. Hammer trip assisted magnetic operation for short circuit protection. Thermal operation is achieved with a bimetallic strip which deflected when heated by any over current flowing through it. In doing so releases the later mechanism and causes the contact to open. Inverse time current characteristic result greater the overload current short the time required to operate the MCB. When short circuit Fault occurs the rising current energizes the solenoid opening the plunger to strike the trip level causing immediate release of the latch mechanism. Rapidity of the magnetic solenoid operation causes instantaneous opening of contacts.

MCB or Miniature Circuit Breaker is an electromechanical device which protects an electric circuit from an overcurrent. The overcurrent in an electrical circuit may result from short circuit, overload or faulty design.

In short, MCB is a device for overload and short circuit protection. They are used in residential & commercial areas. Just like we spend the time to make a thorough check before buying appliances like washing machines or refrigerators, we must also research about MCBs.

An MCB is a better alternative to a Fuse since it does not require replacement once an overload is detected. Unlike a fuse, an MCB can be easily operated and thus offers improved operational safety and greater convenience without incurring a large operating cost. They are used to protect lower current circuits and have the following specifications

- Current rating – Amperes
- Short Circuit Rating – Kilo Amperes (kA)
- Operating Characteristics – B, C or D Curves.

Miniature Circuit Breakers are switchgear which is usually available in the range of 0.5A to 100A. Their Short circuit rating is given in Kiloamps (kA), and this indicates the level of its ability to work. For example, a domestic MCB would normally have a 6kA fault level, whereas one used in an industrial application may need a unit with a 10kA fault capability.

WORKING PRINCIPLE OF MCB

MCB's are protective devices that are made to break the circuit in case of overload or Short circuit.

- For Overload protection, they have Bi-metallic strip which causes the circuit to open.
- For short circuit, it has an electromagnetic kind of thing.

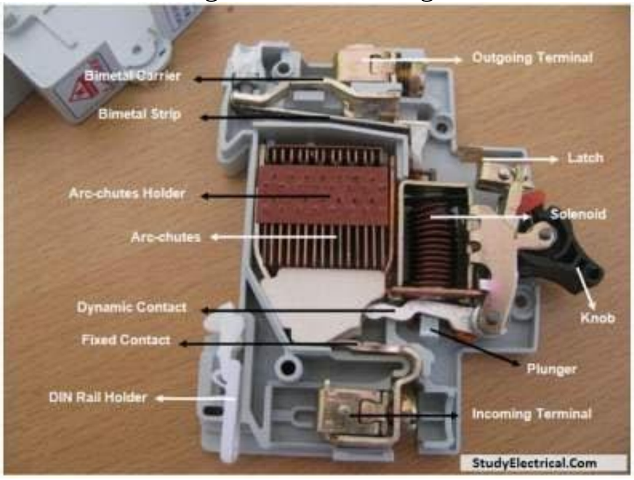


Fig. 1.1 Construction of Miniature Circuit Breaker

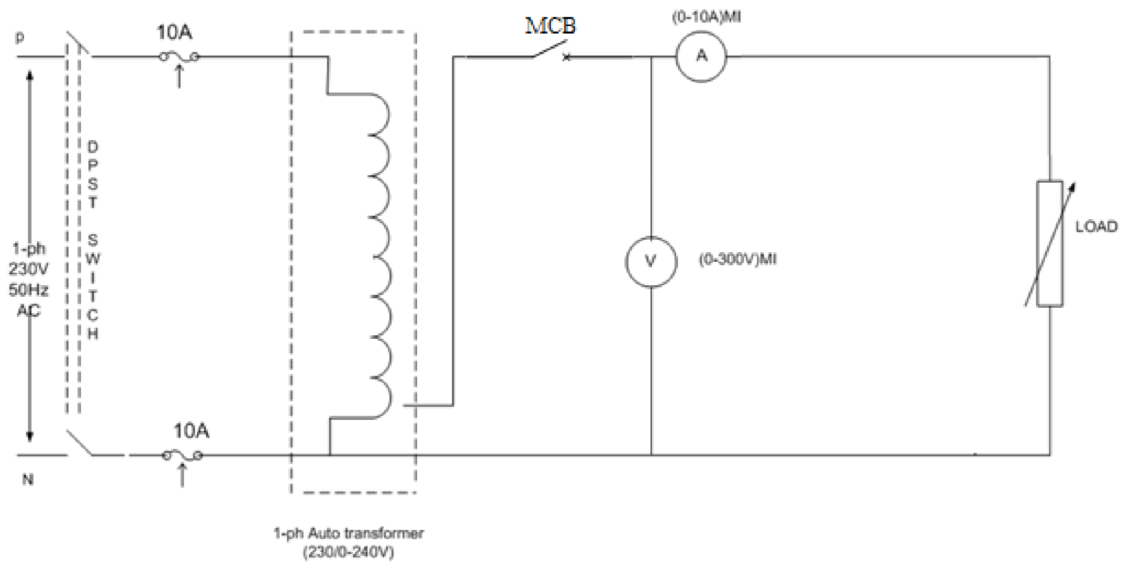
There is two arrangement of operation of a miniature circuit breaker.

1. Due to the thermal effect of over electric current
2. Due to the electromagnetic effect of over current.

The thermal operation of the miniature circuit breaker is achieved with a bimetallic strip. Whenever continuous over electric current flows through MCB, the bimetallic strip is heated and deflects by bending.

This deflection of bimetallic strip releases the mechanical latch. As this mechanical latch is attached with the operating mechanism, it causes to open the miniature circuit breaker contacts.

1.4 CIRCUIT DIAGRAM:



1.5 PROCEDURE:

1. Make the connections as shown in circuit diagram
2. Now vary the load gradually till the rated current of MCB flows in the circuit. The rating of ammeter & voltmeter and note the time at which MCB blows
3. Now increase the load in small steps. Record the reading of voltmeter and ammeter
4. Repeat the above step.
5. Plot the graph between time and current.

1.6 TABULAR COLUMN:

S.No.	Voltage	Current	Time (In Sec.)

1.7 MODEL GRAPH

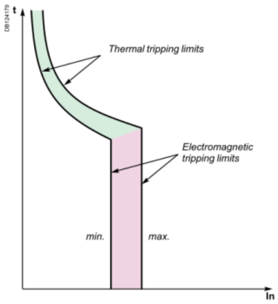


Fig.1.2. Time Vs Current

1.8 RESULT:

1.9 PRE LAB VIVA QUESTIONS:

1. What is the function of MCB?
2. State difference between MCB & MCCB?
3. What are the duties of Circuit Breakers?
4. What is the difference between Isolator and Circuit Breaker?
5. What are the different types of circuit breakers?

1.10 POST LAB VIVA QUESTIONS:

1. State difference between MCB & MCCB, Where it is used?
1. How does a circuit breaker different from switch?
2. What is difference between fuse and breaker?
3. What is the difference between Isolator and Circuit Breaker?
4. Explain the working principal of the circuit breaker?

EXPERIMENT - 2

CHARACTERISTICS OF FUSE AND THERMAL OVERLOAD PROTECTION

2.1 AIM:

To Study of characteristics of High Rupturing Capacity (HRC) fuse and tripping of bimetallic thermal overload protection and its characteristics.

2.2 APPARATUS:

S. No.	Equipments	Range	Quantity
1	Fuse	5A, 10A,16A	1
2	Ammeter	0-10A	1
3	Voltmeter	0-300V	1
4	Connecting wires	-	As Required

2.3 THEORY:

A current limiting protective device cuts off a short circuit in less than one half cycle and that too before it reaches its total prospective highly destructive value fuses are current limiting time. By maintaining a minimum ratio of fuse – ampere rating between upstream and downstream fuse selective coordination is assured which prevents the power failure caused over current conditions.

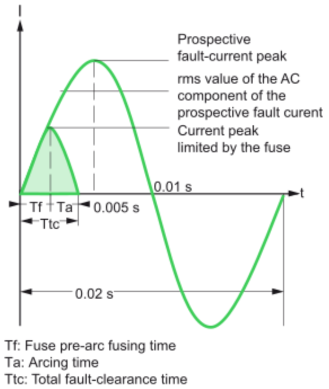
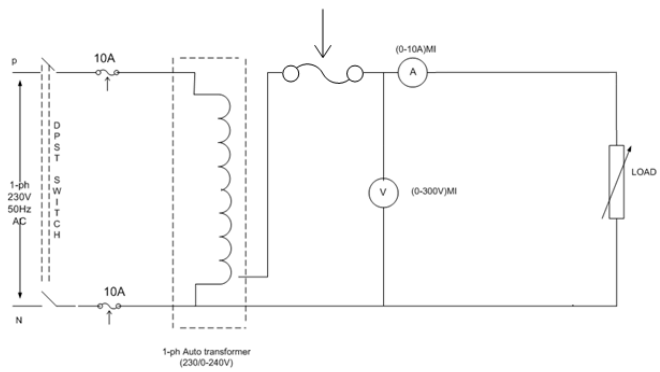


Fig. 2.1 Characteristics of FUSE

2.4 CIRCUIT DIAGRAM:



2.5 PROCEDURE:

1. Make the connections as shown in circuit diagram
2. Now vary the load gradually till the rated current of fuse flows in the circuit. The rating of ammeter & voltmeter and note the time at which fuse blows
3. Now increase the load in small steps. Record the reading of voltmeter and ammeter
4. Repeat the above step.
5. Plot the graph between time and current.

2.6 TABULAR COLUMN:

S.No.	Voltage	Current	Time (In Sec.)

2.7 MODEL GRAPH

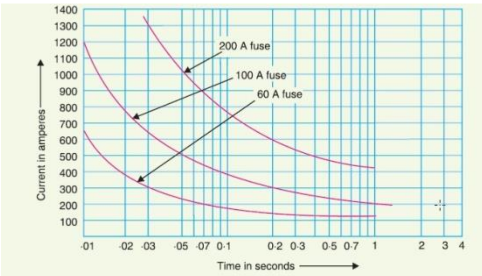


Fig.2.2. Time Vs Current

2.8. RESULT:

2.9 PRE LAB POST VIVA QUESTIONS:

1. Define fuse and give its working principle?
2. Why do we require Fuse?
3. What are various types of fuse?
4. Advantages of Fuse?

2.10 POST LAB POST VIVA QUESTIONS:

1. Define fusing factor?
2. What is the maximum current up to which fuses can be used?
3. What is the advantage of HRC fuses?
4. In a HRC fuse what is the time between the cut off and the final current zero called?

EXPERIMENT - 3

ABCD PARAMETERS OF TRANSMISSION LINE

3.1 AIM:

To study the performance of a transmission line. Also compute its ABCD parameters.

3.2 APPARATUS:

Sl. No.	Apparatus	Range
1.	Transmission Line Model	Different π sections
2.	Power Analyzer	-
3.	Voltmeter	0–750V AC
4.	Ammeter	0–20A AC
5.	Variac	1ϕ 0-230V AC
7.	Patch Cords/Connecting wires	As required

3.3 THEORY:

ABCD Parameter are widely used in analysis of power transmission engineering where they will be turned as "Generalized circuit parameter" ABCD parameters are also called as Transmission parameter. It is conventional to designate the input port as sending end and the output port as receiving end while representing ABCD parameter.

We know that,

$$V_S = A\,V_R + B\,I_R \quad \text{---------------------} \quad (1)$$

$$I_S = C\,V_R + D\,I_R \quad \text{---------------------} \quad (2)$$

At open circuit conditions, we get

$$A = \frac{V_S}{V_R}, \text{when } I_R = 0 \quad \text{---------------------} \quad (3)$$

$$C = \frac{I_S}{V_R}, \text{when } I_R = 0 \quad \text{---------------------} \quad (4)$$

At short circuit conditions, we get

$$B = \frac{V_S}{I_R}, \text{when } V_R = 0 \text{---------------------} \quad (5)$$

$$B = \frac{I_S}{I_R}, \text{when } V_R = 0 \text{---------------------} \quad (6)$$

And Also,

$$AD\text{–}BC = 1 \quad \text{---------------------} \quad (7)$$

The above method can be used for short transmission line.

For medium or long transmission line,

Open circuiting the receiving end of the line, the open circuit impedance Z_{oc} is measured at the sending end as

$$Z_{OC} = \frac{A}{C} \text{ ---------------------- } (8)$$

Short circuiting the load end of the line, the short circuit impedance Z_{sc} is measured at the sending end as

$$Z_{SC} = \frac{B}{A} \text{ ---------------------- } (9)$$

For a symmetrical network,

$$\boldsymbol{A = D}, \text{ ---------------------- } (10)$$

For a passive network,

$$\boldsymbol{AD - BC = 1} \text{ ---------------------- } (11)$$

Substituting equation (10) in equation (11),

$$\boldsymbol{A^2 - BC = 1} \text{ ---------------------- } (12)$$

3.3 PROCEDURE:

1. To find out A and C parameters connect voltage supply of 220V to sending end and open circuit receiving end.
2. Observe the voltage of V_s, I_s and V_r with the help of voltmeter and ammeters in the experimental kit.
3. To find out B and D receiving end is short circuited and supply of 220V is given to sending end.
4. Observe the voltage of V_s, I_s and I_r .

The Calculated A, B, C, D Parameters are

A=

B=

C=

D=

3.4 CIRCUIT DIAGRAM:

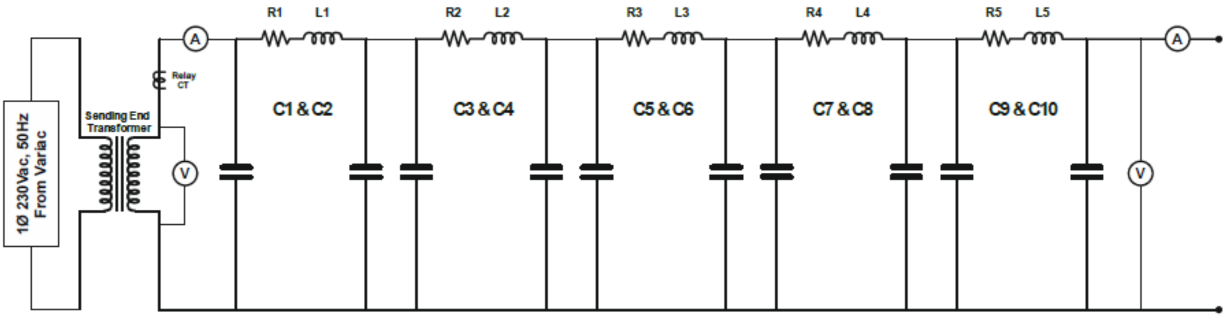


Fig.3.1 Circuit for open circuit test for calculating A and C values

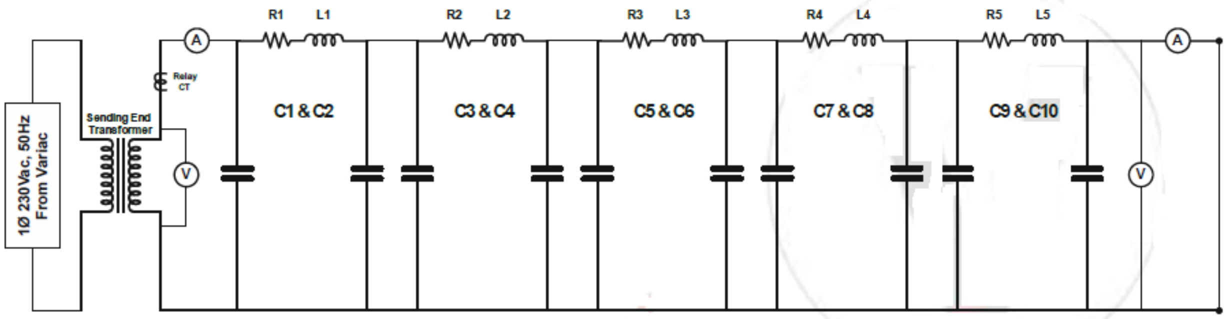


Fig.3.1 Circuit for short circuit test calculating B and D values

3.4 TABULAR COLUMN:

Open Circuit:-

S.No	V_S	I_S	V_R	$A=V_S/V_R$	$C=I_S/V_R$

Short Circuit:-

S.No	V_S	I_S	V_R	$B=V_S/I_R$	$D=I_S/I_R$

3.5 RESULT:

3.6 PRE LAB VIVA QUESTIONS:

1. Determine the overall ABCD parameters when 2 two port network?
2. Write few applications of ABCD parameters?
3. Why ABCD parameters are called as transmission parameter?

3.7 PRE LAB VIVA QUESTIONS:

1. Determine ABCD parameters of a 2 two port network?

2. Write few applications of ABCD parameters?

EXPERIMENT - 4

FERRANTI EFFECT IN A TRANSMISSION LINE

4.1 AIM:

To observe the Ferranti effect in a model of transmission line.

4.2 APPARATUS:

S. No.	Equipments	Quantity
1	Three phase alternator rating: 400V, 5kVA, and 1500 rpm.	1
2	Ammeter	1
3	Voltmeter	1
4	Rheostat	1

4.3 THEORY:

Ferranti Effect:

Long transmission line/cables draws a substantial quantity of charging current. If such a line/cable is open circuited or very lightly loaded at the receiving end, the voltage at receiving end may become greater than voltage at sending end due to capacitive reactance. This is known as Ferranti Effect. Both capacitance and inductance is responsible to produce this effect. The capacitance (which is responsible for charging current) is negligible in short line but significant in medium line and appreciable in long line. Hence, this phenomenon occurs in medium and long lines. The figure shown below is representing a transmission line by an equivalent pi (π)-model. The voltage rise is proportional to the square of the line length.

In general practice we know, that for all electrical systems current flows from the region of higher potential to the region of lower potential, to compensate for the electrical potential difference that exists in the system. In all practical cases the sending end voltage is higher than the receiving end, so current flows from the source or the supply end to the load. But Sir S.Z.Ferranti, in the year 1890, came up with an astonishing theory about medium and long distance transmission line suggesting that in case of light loading or no load operation of transmission system, the receiving end voltage often increases beyond the sending end voltage, leading to a phenomena known as Ferranti Effect in Power System.

A long transmission line can be considered to compose a considerably high amount of capacitance and inductor distributed across the entire length of the line. Ferranti Effect occurs when current drawn by the distributed capacitance of the line itself is greater than the current associated with the load at the receiving end of the line (during light or no load). This capacitor charging current leads to voltage drop across the line inductor of the transmission system which is in phase with the sending end voltages. This voltage drop keeps on increasing additively as we move towards the load end of the line and subsequently the receiving end voltage tends to get larger than applied voltage leading to the phenomena called Ferranti Effect.

4.4 CIRCUIT DIAGRAM:

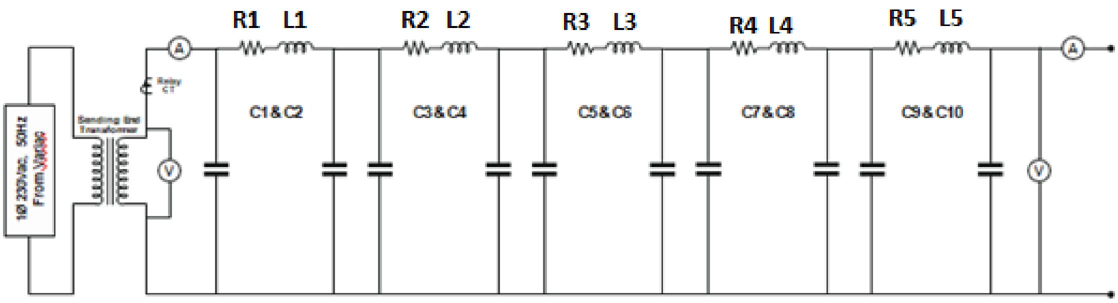


Fig.4.Circuit for study of Ferrenti effect

4.5. PROCEDURE:

1. Connect mains cable to 230VAC, Single phase supply with proper earth connection.
2. Keep MAINS MCB in OFF position and the variac in Zero position.
3. Make the connection as per circuit diagram shown in fig (3). Now the connection is for receiving end open condition.
4. Switch on MAINS+CONTROL MCB. All the meters will glow.
5. Put both the relays to UNHEALTHY state.
6. Select the values of line inductance and capacitance as required.
7. Set the voltage of sending end to required level by varying the variac-1.
8. Note down the reading for all parameters i.e., sending end voltage and receiving end voltage.
9. You can observe that the receiving end voltage will be higher than sending end voltage.
10. Note down the value for different sending end voltage readings.
11. The receiving end voltage will be higher than sending end.

4.6. TABULAR COLUMN:

Sl. No.	Sending End Voltage		Receiving End Voltage	
1.				
2.				
3.				

4.7 RESULT:

4.8. PRE LAB VIVA QUESTIONS:

1. What is a Ferranti Effect?
2. How to Reduce Ferranti Effect in Transmission Line?
3. Why Ferranti Effect occurs in a Transmission Line?
4. What happens during the Ferranti effect?

4.8. POST LAB VIVA QUESTIONS:

1. A transmission line of 200 Km is supplying at 50Hz frequency. What is the percentage rise in voltage at receiving end?
2. When does the Ferranti effect happen on the transmission line?
3. When is the Ferranti effect on the long transmission lines experienced?

EXPERIMENT - 5

SURGE IMPEDANCE LOADING

5.1 AIM:

To study of Surge Impedance Loading (SIL) of a transmission line.

5.2 APPARATUS:

Sl. No.	Apparatus	Range
1.	Transmission Line Model	Different π sections
2.	Power Analyzer	
3.	Voltmeter	0-750V AC
4.	Ammeter	0-20A AC
5.	Variac	1ϕ , 0-230V AC
7.	Patch Cords/Connecting wires	As required

5.3 THEORY:

Surge Impedance loading of a line is the power transmitted when it is transmitted through a resistance equal to surge impedance.

$$I^2\omega L = V^2\omega C$$

$$\frac{V}{I} = \sqrt{\frac{L}{C}} = Z_n$$

Z_n is natural impedance and surge impedance of the line

$$P_0 = \frac{V^2}{Z_n}$$

5.4 CIRCUIT DIAGRAM:

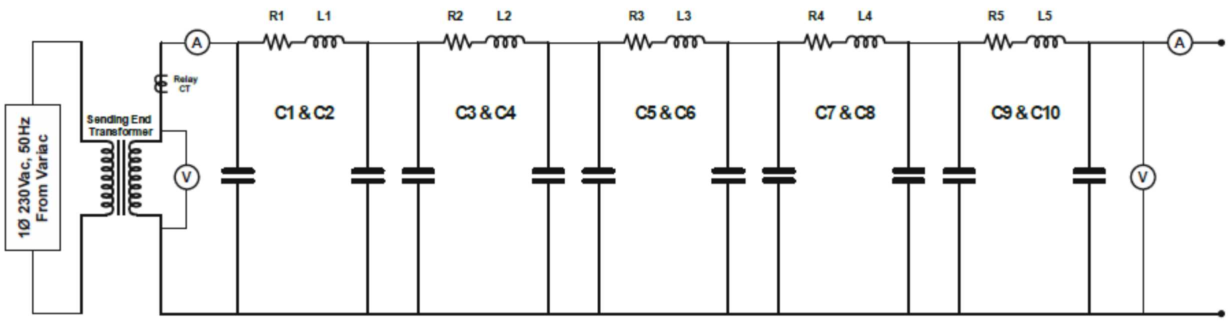


Fig.5.1 Circuit for open circuit test

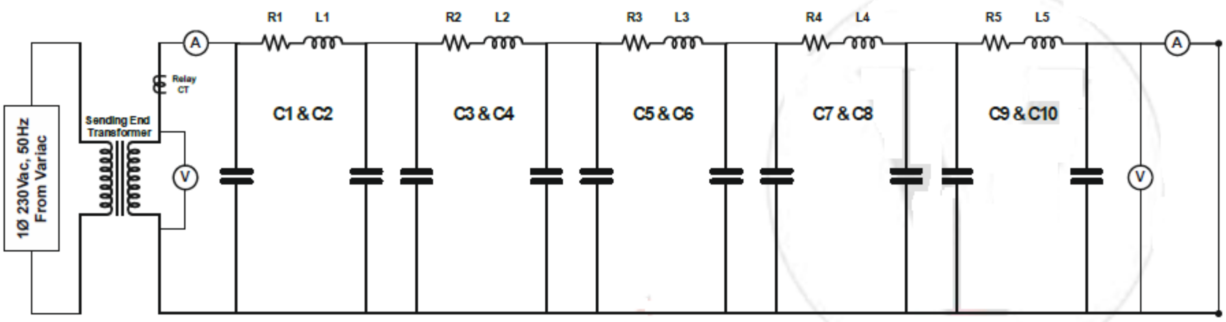


Fig.5.1 Circuit for short circuit test

5.4 PROCEDURE:

1. To find SIL, keep the receiving side open and note down sending end voltage (V_{OC}) and current (I_{SC}).
2. Now, short the receiving end and note down sending end voltage (V_{OC}) and current (I_{SC}).Find impedance in open circuit and short circuit condition.

$$Z_{OC} = \frac{V_{OC}}{I_{OC}}, Z_{SC} = \frac{V_{SC}}{I_{SC}}$$

3. Find core or natural impedence, Z_0 or Z_n =$\sqrt{ZOC.ZSC}$
4. SIL=$\frac{V^2}{Z_C}$

5.5. TABULAR COLUMN

Open circuit test:

S. No.	Sending End		Receiving End	
	Voltage (V_S)	Current (I_S)	Voltage (V_R)	Current (I_R)
1.				
2.				
3.				

Short circuit test:

S. No.	Sending End		Receiving End	
	Voltage (V_S)	Current (I_S)	Voltage (V_R)	Current (I_R)
1.				
2.				
3.				

5.7 RESULT:

5.8. PRE LAB VIVA QUESTIONS:

1. What is surge impedance loading?
2. Define surge impedance?
3. Give equation for surge impedance?

5.9. PRE LAB VIVA QUESTIONS:

1. Define surge impedance loading?
2. Derive expression for surge impedance?

EXPERIMENT – 06

EFFECT OF SHUNT COMPENSATION

6.1 AIM

To determine shunt compensation to counteract the voltage rise on no load and zero regulation at different loads in a transmission line.

6.2 APPARATUS

Sl. No.	Apparatus	Range
1.	Transmission line model	Different π sections
2.	Power analyzer	
3.	Voltmeter	0-750V AC
4.	Ammeter	0-20A AC
5.	Variac	1ϕ 0-230V AC
6.	Patch Cords/Connecting wires	As required

6.3 THEORY

In shunt compensation, power system is connected in shunt (parallel) with the FACTS. It works as a controllable current source. Shunt compensation is of two types:

Shunt capacitive compensation

This method is used to improve the power factor. Whenever an inductive load is connected to the transmission line, power factor lags because of lagging load current. To compensate, a shunt capacitor is connected which draws current leading the source voltage. The net result is improvement in power factor.

Shunt inductive compensation

This method is used either when charging the transmission line, or, when there is very low load at the receiving end. Due to very low, or no load – very low current flows through the transmission line. Shunt capacitance in the transmission line causes voltage amplification (Ferranti effect). The receiving end voltage may become double the sending end voltage (generally in case of very long transmission lines). To compensate, shunt inductors are connected across the transmission line.

6.4 CIRCUIT DIAGRAM:

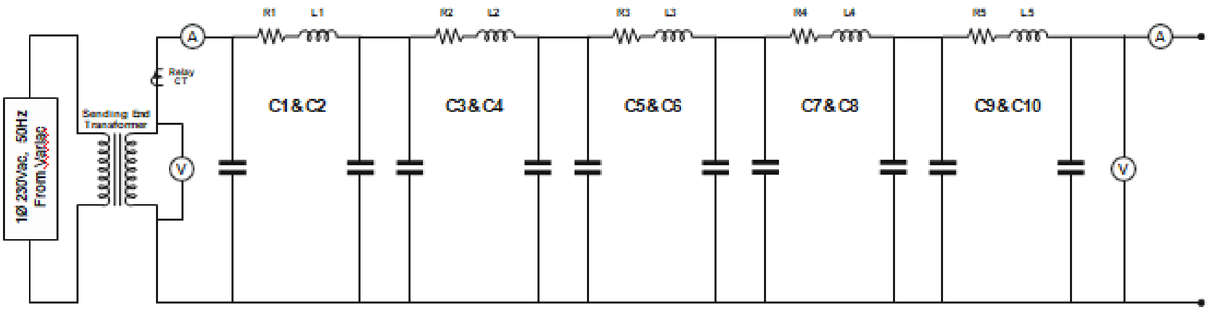


Figure 6.1: Circuit for receiving end open

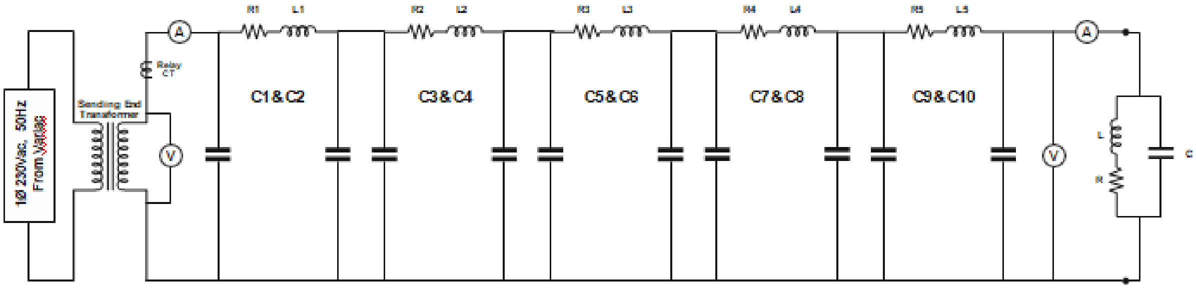


Figure 6.2: Circuit with compensation connected

6.5 PROCEDURE:

1. Connect mains cable to 230VAC, Single phase supply with proper earth connection.
2. Keep MAINS MCB in OFF position and the variac in Zero position.
3. Make the connection as per circuit diagram shown in fig (6.1). Now the connection is for receiving end open condition.
4. Switch on MAINS+CONTROL MCB. All the meters will glow.
5. Put both the relays to UNHEALTHY state.
6. Select the values of line inductance and capacitance as required.
7. Press CB-1 ON push button
8. Set the voltage of sending end to required level by varying the variac-1.
9. Note down the reading of sending end voltage and receiving end voltage.
10. You can observe that the receiving end voltage will be higher than sending end voltage.
11. Press CB-1 OFF and introduce the compensation unit. (Here RLC Unit-1 or 2 can be used)
12. Connect as in fig(6.2).

6.6 TABULAR COLUMN:

S. No.	Sending End		Receiving End	
	Voltage (V_S)	Current (I_S)	Voltage (V_R)	Current (I_R)
1.				
2.				
3.				

S. No.	Before Compensation		After Compensation		VAR Loaded
	SE (Vs)	RE (Vr)	SE (Vs)	RE (Vr)	
1.					
2.					
3.					

6.7. RESULT:

6.8. PRE LAB VIVA QUESTIONS

1. What is shunt compensation?
2. Give methods of shunt compensation?

6.8. PRE LAB VIVA QUESTIONS:

1. Explain the concept of shunt compensation?
2. Difference between shunt and series compensation?

EXPERIMENT – 07

VOLTAGE PROFILE IMPROVEMENT USING TAP CHANGING TRANSFORMER

7.1. AIM

To study of voltage improvement by reactive power control using tap changing transformer.

7.2 APPARATUS

Sl. No.	Apparatus	Range
1.	Transmission line model	Different π sections
2.	Power analyzer	
3.	Voltmeter	0-750V AC
4.	Ammeter	0-20A AC
5.	Variac	1ϕ 0-230V AC
6.	Patch Cords/Connecting wires	As required

7.3 THEORY

Tap changing in Transformers is a normal fact that increases in load lead to decrease in the supply voltage. Hence the voltage supplied by the transformer to the load must be maintained within the prescribed limits. This can be done by changing the transformer turns ratio. The taps are leads or connections provided at various points on the winding. The turns ratio differ from one tap to another and hence different voltages can be obtained at each tap.

Need for system voltage control

- System voltage control is essential for:
- Adjusting the terminal voltage of consumer within the prescribed limits
- Adjustment of voltage based on change in load.
- In order to control the real and reactive power.
- For varying the secondary voltage based on the requirement.

Types of taps

Taps may be principal, positive or negative. Principal tap is one at which rated secondary voltage can be obtained for the rated primary voltage. As the name states positive and negative taps are those at which secondary voltage is more or less than the principle tap.

7.4 CIRCUIT DIAGRAM:

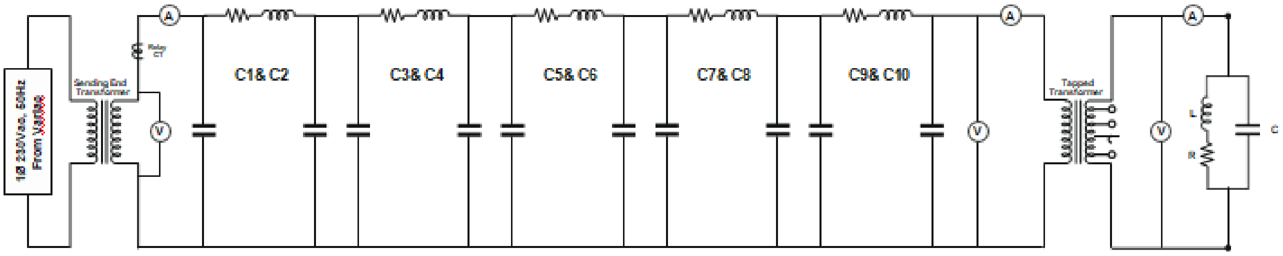


Fig.7. Circuit for receiving end open

7.5 PROCEDURE:

1. Connect mains cable to 230VAC, Single phase supply with proper earth connection.
2. Keep MAINS MCB in OFF position and the variac in Zero position.
3. Make the connection as per circuit diagram shown in fig (9). Recevind is connected through the meter to tap changing transformer and to the load. (if required use variac-2 to have control over input to the tap changing transformer)
4. Switch on MAINS+CONTROL MCB. All the meters will glow.
5. Put both the relays to UNHEALTHY state.
6. Select the values of line inductance and capacitance as required.
7. Press CB-1 ON push button.
8. Set the voltage of sending end such that the receiving end voltage is 220V
9. Press CB-2 ON and CB-3 ON push button.
10. Apply load using the RLC Unit provided.
11. Observe the voltage at the load end. If V<220V increase it by changing the position of tap or V>220V then decrease it by reduce the value of tapped output.

7.6 TABULAR COLUMN:

S. No.	Sending End		Receiving End		
	Voltage (V_S)	Current (I_S)	Voltage (V_R)	Current (I_R)	Reactive power
1.					
2.					
3.					

7.7 RESULT

7.8. PRE LAB VIVA QUESTIONS

1. What is the need for voltage control?
2. What are different types of voltage tappings?
3. What are two fundamental features of a tap changer?

7.9. PRE LAB VIVA QUESTIONS:

1. Give various types of tap changer?
2. What are the basic requirements for regulating voltage of transformer?

EXPERIMENT - 8

EFFICIENCY AND REGULATION OF A TRANSMISSION LINE

8.1 AIM:

To determine the performance of the transmission line by calculating its efficiency and regulation

8.2 APPARATUS:

Sl. No.	Apparatus	Range
1.	Transmission line model	Different π sections
2.	Power analyzer	
3.	Voltmeter	0-750V AC
4.	Ammeter	0-20A AC
5.	Variac	1ϕ 0-230V AC
6.	Patch Cords/Connecting wires	As required

8.3 THEORY

The performance of a power system is mainly dependent on the performance of the transmission lines in the system. It is necessary to calculate the voltage, current and power at any point on a transmission line provided the values at one point are known.
The transmission line performance is governed by its four parameters - series resistance and inductance, shunt capacitance and conductance. All these parameters are distributed over the length of the line. The insulation of a line is seldom perfect and leakage currents flow over the surface of insulators especially during bad weather. This leakage is simulated by shunt conductance. The shunt conductance is in parallel with the system capacitance. Generally the leakage currents are small and the shunt conductance is ignored in calculations.
Performance of transmission lines is meant the determination of efficiency and regulation of lines. The efficiency of transmission lines is defined as

$$\% \text{ efficiency } (\eta) \; \frac{\text{Power delivered at the receiving end}}{\text{Power sent from the sending end}} * 100$$

The end of the line where load is connected is called the receiving end and where source of supply is connected is called the sending end.

$$\% \text{ regulation} = \frac{|V_{r(No\ Load)}| - |V_{r(Load)}|}{|V_{r(Load)}|} * 100$$

The Regulation of a line is defined as the change in the receiving end voltage, expressed in percent of full load voltage, from no load to full load, keeping the sending end voltage and frequency constant.

8.4 CIRCUIT DIAGRAM:

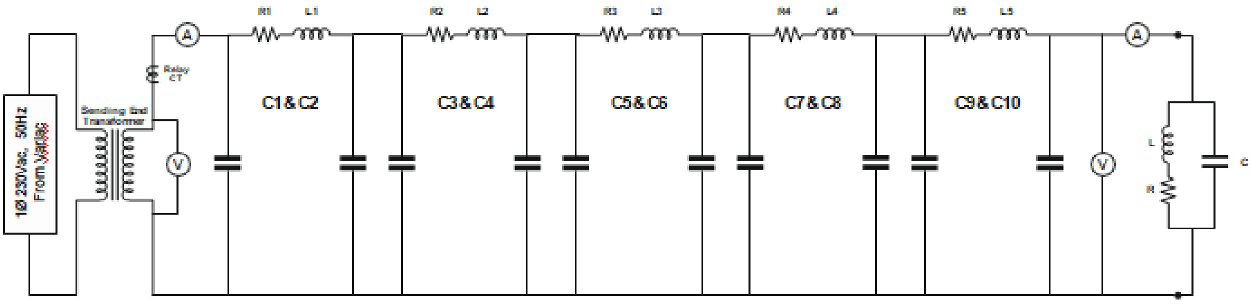


Fig – 8. Circuit for loading at receiving end

8.5 PROCEDURE:

1. Connect mains cable to 230VAC, Single phase supply with proper earth connection.
2. Keep MAINS MCB in OFF position and the variac in Zero position.
3. Make the connection as per circuit diagram shown in fig (8).
4. Switch on MAINS+CONTROL MCB. All the meters will glow.
5. Put both the relays to UNHEALTHY state.
6. Select the values of line inductance and capacitance as required.
7. Initially keep all the loads to OFF state
8. Press CB-1 ON and CB-2 ON push button
9. Set the voltage of sending end to required level (say 220V) by varying variac-1.
10. Note down the reading of sending end and receiving end voltage, current, and power.
11. Apply loads gradually and note down the readings.
12. Tabulate the readings and calculate efficiency and regulation of the line.
13. Repeat the same for different values of line parameters.

8.6 TABULAR COLUMN:

S. No.	Sending End			Receiving End			Efficiency	Regulation
	Voltage (V_S)	Current (I_S)	Power(P)	Voltage (V_R)	Current (I_R)	Power		
1.								
2.								
3.								

8.7 RESULT:

8.8. PRE LAB VIVA QUESTIONS:

1. Give expression for efficiency of transmission line?
2. Give formula for efficiency of transmission line?
3. Give types of transmission lines?

4. What is transmission line voltage regulation?

8.9. PRE LAB VIVA QUESTIONS:

1. Give transmission line parameters?
2. Effect of leakage currents in transmission line?
3. Effect of load power factor on regulation of transmission line?
4. What is End Condenser Method in Medium Transmission Line?
5. Give expression for efficiency and regulation of a transformer

EXPERIMENT – 09

PERFORMANCE OF IMPEDANCE RELAY

9.1 AIM

To study the working principle of impedance relay and its effect during faults in a transmission line.

APPARATUS

Sl. No.	Apparatus	Range
1.	Transmission line model	Different π sections
2.	Power analyzer	
3.	Voltmeter	0-750V AC
4.	Ammeter	0-20A AC
5.	Variac	1ϕ 0-230V AC
6.	Patch Cords/Connecting wires	As required

9.2 THEORY

There is one type of relay which functions depending upon the distance of fault in the line. More specifically, the relay operates depending upon the impedance between the point of fault and the point where relay is installed. These relays are known as distance relay or impedance relay.

The working principle of distance relay or impedance relay is very simple. There is one voltage element from potential transformer and a current element fed from current transformer of the system. The deflecting torque is produced by secondary current of CT and restoring torque is produced by voltage of potential transformer. In normal operating condition, restoring torque is more than deflecting torque. Hence relay will not operate. But in faulty condition, the current becomes quite large whereas voltage becomes less. Consequently, deflecting torque becomes more than restoring torque and dynamic parts of the relay starts moving which ultimately close the No contact of relay. Hence clearly operation or working principle of distance relay, depends upon the ratio of system voltage and current. As the ratio of voltage to current is nothing but impedance a distance relay is also known as impedance relay.

The operation of such relay depends upon the predetermined value of voltage to current ratio. This ratio is nothing but impedance. The relay will only operate when this voltage to current ratio becomes less than its predetermined value. Hence, it can be said that the relay will only operate when the impedance of the line becomes less than predetermined impedance (voltage / current). As the impedance of a transmission line is directly proportional to its length, it can easily be concluded that a distance relay can only operate if fault is occurred within a predetermined distance or length of line.

9.3 CIRCUIT DIAGRAM:

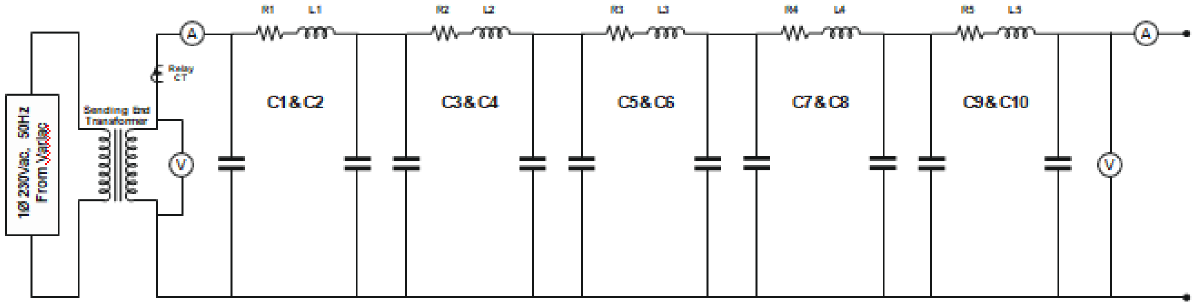


Figure 9.1. Circuit for receiving open end

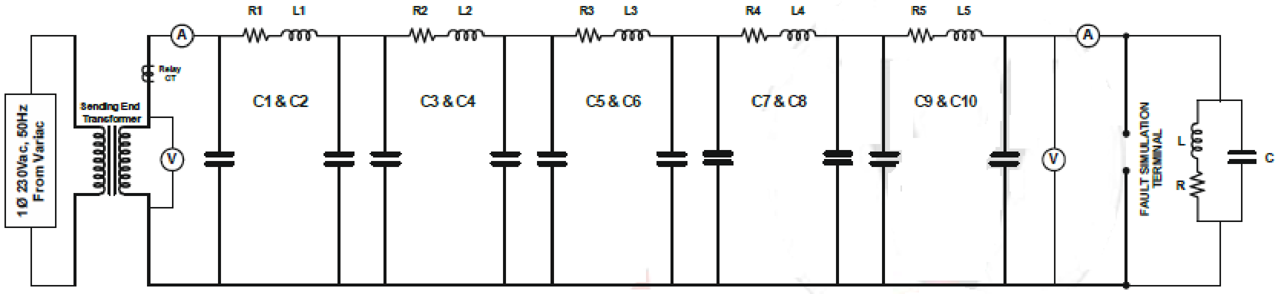


Fig 9.2. Circuit with RLC load

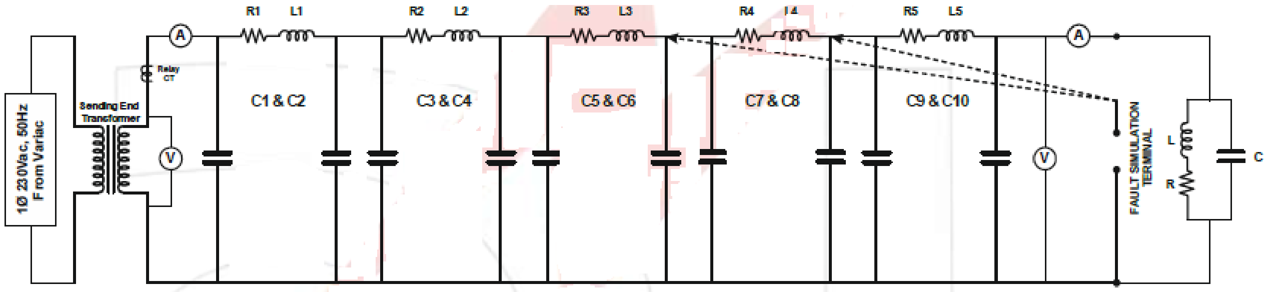


Fig 9.3. Circuit with RLC load

9.4 PROCEDURE:

1. Connect mains cable to 230VAC, Single phase supply with proper earth connection.
2. Keep MAINS MCB in OFF position and the variac in Zero position.
3. Make the connection as per circuit diagram shown in fig (9.1). Now the connection is for receiving end open condition.
4. Switch on MAINS+CONTROL MCB. All the meters will glow.
5. Put the impedance relay to HEALTHY state and Over current relay to UNHEALTHY state.
6. Program the Impedance relay if required.

a. Press SET on the relay and select the %IMPEDANCE value using HIGH/LOW key (1% to 200%) and press SET twice to confirm

b. Now select the value of K=100 (Range: 10-100) and press SET twice to confirm

c. Set Impedance as 100%

7. Select the values of line inductance and capacitance as required.
8. Keep the fault simulation switch in POSITION-1
9. Change the connection as shown in fig. (9.2)
10. Apply a load of say 100W.
11. Press CB-1 ON and CB-2 ON push button
12. Set the voltage of sending end to 220V by varying the variac-1.
13. Press the ENTER key on impedance relay.
14. Put the Fault Simulation Switch to POSITION-2. Time Interval meter starts counting,

the relay may read around 98% to 100%. The relay may not trip or may take a long time to trip.
15. Now switch off CB-1 and put the fault simulation switch to POSITION-1.
16. Change the connection to around 240/320kms i.e., after 3rd or 4th π section as shown in fig(9.3)
17. Press CB-1 ON Push button and press ENTER key on the relay.
18. Put the Fault Simulation Switch to POSITION-2. Time Interval meter starts counting, the relay will be active and tripped after few seconds.
19. Display will show Impedance, voltage, current, trip time and distance of tripping. Note down the values.
20. Repeat the same at different distance of fault.

9.5 TABULAR COLUMN

S.No	%Z	Impedence realy voltage	Impedence relay current	Trip time	Fault at km (from sending end)

9.6 Calculations:

$$Z_0 = Z_{Set}$$

$$T_d = \frac{k}{Z_{Set} - Z_{actual}}$$

K= T.M.S(10-100)

9.7 RESULT:

9.8. PRE LAB VIVA QUESTIONS:

1. What is relay and give its importance in protection systems?
2. What are various types of relays?
3. Advantages of impedance relay?

9.9. PRE LAB VIVA QUESTIONS:

1. Explain working of impedance relay?
2. Give various applications of impedance relays?

EXPERIMENT – 10

PERFORMANCE OF OVER CURRENT RELAY

10.1 AIM

To study the working principle of over-current relay and its effect during faults in a transmission line.

10.2 APPARATUS

Sl. No.	Apparatus	Range
1.	Transmission line model	Different π sections
2.	Power analyzer	
3.	Voltmeter	0-750V AC
4.	Ammeter	0-20A AC
5.	Variac	1ϕ 0-230V AC
6.	Patch Cords/Connecting wires	As required

10.3 THEORY

Lines are protected by overcurrent-, distance-, or pilot-relaying equipment, depending on the requirements. Overcurrent relaying is the simplest and cheapest, the most difficult to apply, and the quickest to need readjustment or even replacement as a system changes. It is generally used for phase- and ground-fault protection on station-service and distribution circuits in electric utility and in industrial systems, and on some sub-transmission lines where the cost of distance relaying cannot be justified. It is used for primary ground-fault protection on most transmission lines where distance relays are used for phase faults, and for ground back-up protection on most lines having pilot relaying for primary protection. However, distance relaying for ground-fault primary and back-up protection of transmission lines is slowly replacing overcurrent relaying. Overcurrent relaying is used extensively also at power transformer locations for external-fault back-up protection, but here, also, there is a trend toward replacing overcurrent with distance relays. It is generally the practice to use a set of two or three overcurrent relays for protection against interphase faults and a separate overcurrent relay for single-phase-to ground faults. Separate ground relays are generally favoured because they can be adjusted to provide faster and more sensitive protection for single-phase-to-ground faults than the phase relays can provide. However, the phase relays alone are sometimes relied on for protection against all types of faults. On the other hand, the phase relays must sometimes be made to be inoperative on the zero-phase-sequence component of ground-fault current.
Overcurrent relaying is well suited to distribution-system protection for several reasons. Not only is overcurrent relaying basically simple and inexpensive but also these advantages are realized in the greatest degree in many distribution circuits.

10.4 CIRCUIT DIAGRAM:

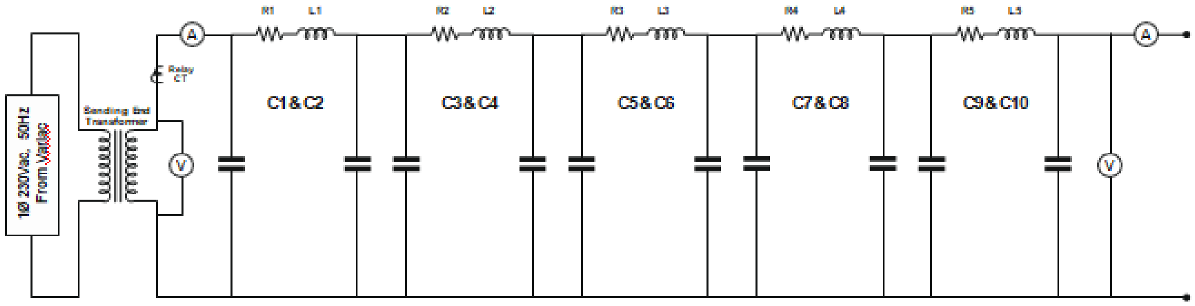


Figure 10.1. Circuit for receiving open end

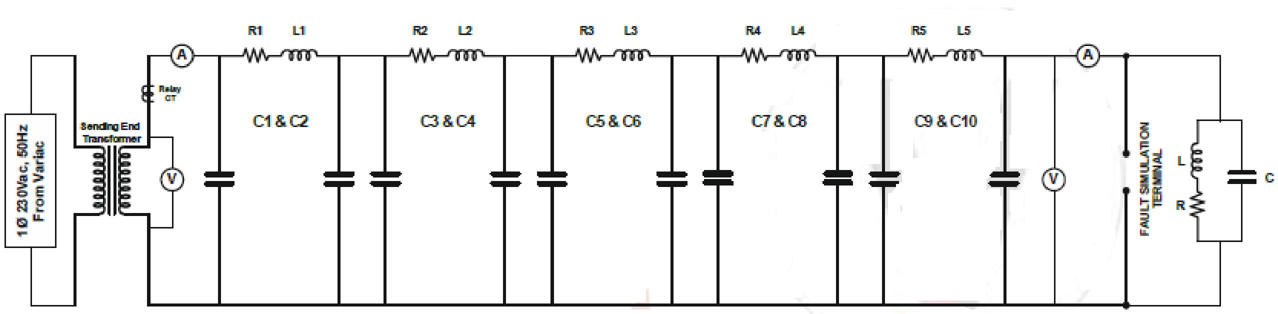


Fig 10.2. Circuit for loading at receiving end

10.5 PROCEDURE:

1. Connect mains cable to 230VAC, Single phase supply with proper earth connection.
2. Keep MAINS MCB in OFF position and the variac in Zero position.
3. Make the connection as per circuit diagram shown in fig (10.2). Now the connection is for receiving end open condition.
4. Switch on MAINS+CONTROL MCB. All the meters will glow.
5. Put the impedance relay to UNHEALTHY state and over current relay to HEALTHY state.
6. Program the over current relay as required.

a. Using DIP switches provided select the input current range and the type of characteristics required. (Refer DIP switch settings chart in table 1)

b. Select the required current limit for tripping. Also select the high-set feature if required.

c. Set the TMS value in range of 0.1 to 1.6

7. Select the values of line inductance and capacitance as required.
8. Keep the fault simulation switch in POSITION-2
9. Change the connection as shown in fig. (10.2) with connection RLC load
10. Press CB-1 ON and CB-2 ON push button
11. Set the voltage of sending end to 220V by varying the variac-1.
12. Increase the load gradually, when the current exceeds the set limit in over current relay, the relay starts blinking and trips according to the TMS value and characteristics selected.
13. Note down the readings of current and trip time.

10.6 TABULAR COLUMN:

S.No	Relay set current	TMS	Fault current	PMS	Trip time

10.7 RESULT:

10.8. PRE LAB VIVA QUESTIONS:

1. What is relay?
2. Give importance of over current realay?
2. What are various types of over current relays?

10.9. PRE LAB VIVA QUESTIONS:

1. Explain working of over current relay?
2. Give various applications of over current relays?
3. Define inverse and definite over current relay?

EXPERIMENT – 11

EARTH FAULT PROTECTION

11.1 AIM

To study of earth fault detection methods and various earth fault protection schemes.

11.2 APPARATUS

S. No.	Equipments	Quantity
1	Earth fault relay unit	1
2	Patch Cords	As required

11.3 THEORY:

In the electrical systems always exists the possibility of having shutdowns due to over currents or short circuits produced by operation mistakes, ambient conditions, lack of maintenance or atmospheric discharges. In the case of short circuit, this can be classified in the next types:
1. Bolted Faults. It occurs when the conductors (phase, neutral or ground) are solidly connected, having an impedance equal to cero on this connection and because this, a maximum current condition is present.
2. Ground Fault It occurs when one of the system phases get on direct contact to ground or to any metallic part that is grounded.
3. Arcing Fault It happens between two close conductors but are not in direct contact. Any of these faults is really dangerous for both equipment and personnel. In this document we will discuss more in detail the ground fault.

Why protect against Ground Fault:

The ground fault has its origin on different ways but the more common are reduced insulation, physical damages to insulation system or excessive transient or steady-state voltage stresses on insulation. These problems can be produced due to moisture, atmospheric contamination, insulation deterioration, mechanical stresses, etc. Although the situations mentioned before can be avoided following a good maintenance Schedule, always exists the latent risk of a fault, commonly during the installation or major maintenance to equipment.

Grounding Methods

Nowadays the interest on the using of ground fault Protection systems has been increasing due to this Protection is required for in some equipment and feeders, besides the interest of improving safety for personnel. The intention of grounding systems is to control the voltage with respect to ground and provide a current path that allows us to detect the unwanted connection between line and phase conductors and then be able to send a signal to trip the protection devices to remove the voltage on these conductors. There are several devices for Ground Fault protection on the market and they have their use depending on the grounding method used in our system. Whenever working on the design of an electrical system the question of how to ground the system came up. Grounding electrical systems is generally recommended, however there are exceptions. There are several methods and criteria for grounding systems and each has its own purpose.

Listed below are some of the existing methods and which are their advantages and disadvantages: -

Ungrounded System

This system is defined as one who does not have an intentional connection to ground. However, there is always a capacitive coupling between the line conductors and ground. This system is also known as grounded by capacitance.

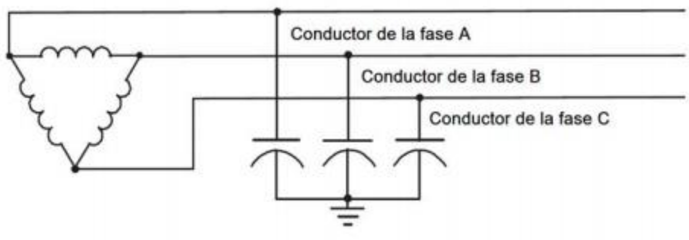


Fig 11.1

When the system is operating normally, capacitive currents and phase to ground voltages are equal and displaced 120 ° C of each other so that a vector system is fully balanced. If any of the phases is in contact with ground, the current flow through this phase to ground will stop because there will be no potential difference between conductors. At the same time in the remaining phases the current flow is increased by root 3 and will be moved only 60°C each other. Therefore, the vector sum of these currents is increased by 3 times the current Ico. Each time that a fault is presented in this configuration, it generates an over-voltage that can be many times greater in magnitude than the nominal (6 to 8 times) which is a result of resonance between the inductive reactance of the system and the distributed capacitance to ground. These over voltages can cause failure of the insulation system.

Resistance Grounding

A system grounded through resistance is defined as one in which the neutral of a transformer or generator is grounded through a resistor.

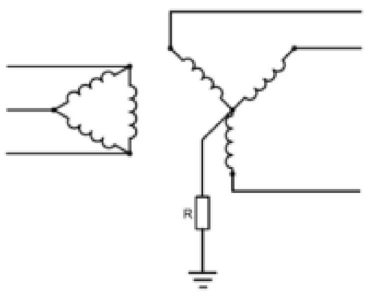


Fig 11.2

The reasons for limiting the current using a resistor are:

1. To reduce damage during a fault of electrical equipment such as panels, transformers, motors, cable, etc.
2. To reduce mechanical stresses in circuits and devices leading fault currents.
3. To reduce the risk of electrocution to personnel.
4. To reduce the risk of arc flash to personnel that could accidentally cause a failure or that is near to the fault location.
5. To reduce momentary voltage drop that occurs when a fault is present.
6. To secure control of transient voltages while at the same time avoiding shutdown of a faulted on the occurrence of the first ground fault (High Resistance Grounding) Grounding through resistance

can be 2 types High Resistance or Low Resistance which are distinguished by the amount of current permitted to flow.

High Resistance Grounding

High resistance grounding employs a neutral resistor of high ohmic value. The Resistor is used to limit the ground fault current (Ig) and typically is limited to 10A or less. When you have a system like this, does not require an immediate release of the fault as the current is limited to a very low level. Protective devices associated with a High Resistance system allows the system to continue working with the presence of a ground fault and send an alarm instead of tripping and open the associated protection. A typical scheme for detecting a ground fault in a high resistance grounding system is shown in the figure below, where under normal operation the neutral point of transformer is at zero potential, but when a line to ground fault occurs, phase voltage at the neutral is raised to almost the value of the line-to-neutral voltage which is detected by a relay. This relay activates a visual and / or sound alarm to notify to maintenance personnel and then attend, locate and repair the fault.

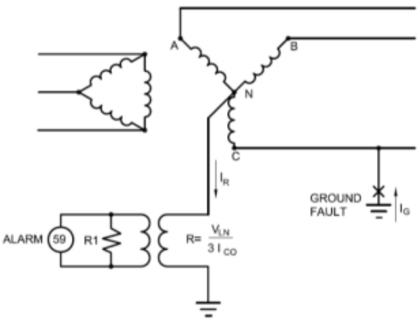


Fig:11.3

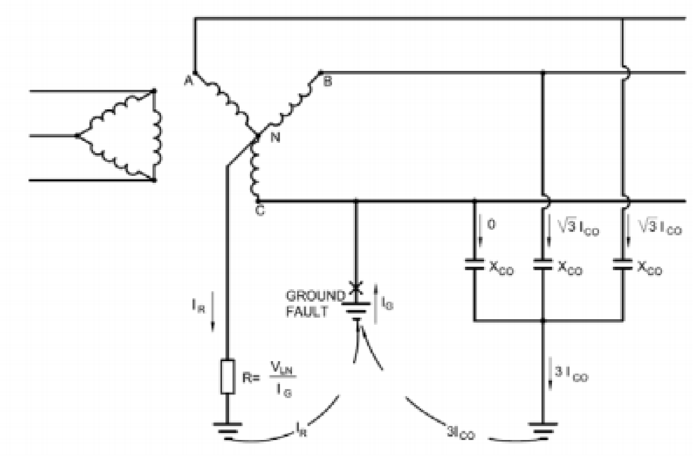
The advantages of using system could be listed as follows:

1. Service continuity. The first ground fault does not require equipment to be shutdown.
2. Transient over voltages due to re-striking are reduced.
3. A pulse system can help to locate the fault.
4. The need of coordinated ground fault relaying is eliminated. Typically this system can be used in low voltage systems where single-phase loads are not present, in MV where continuity of service is required and the capacitive current is not very high, and in retrofits where they had previously ungrounded system.

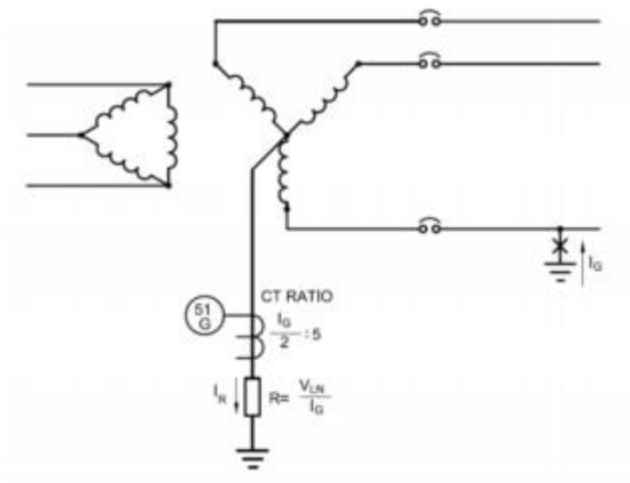
Low Resistance Grounding

This system limits the ground fault current to a value between 100A and 1000A, being the most common value 400A. The value of this resistance is calculated as R = Vln / Ig, where Vln is the line to neutral voltage of the system and fault current Ig is the ground fault current desired.

This system has the advantage of facilitating the immediate release and selectively to ground fault. The method used to detect this fault is to use an overcurrent relay 51G. At the moment of a fault the neutral voltage rises almost to the line to neutral voltage and a current begins to flow through the resistance.

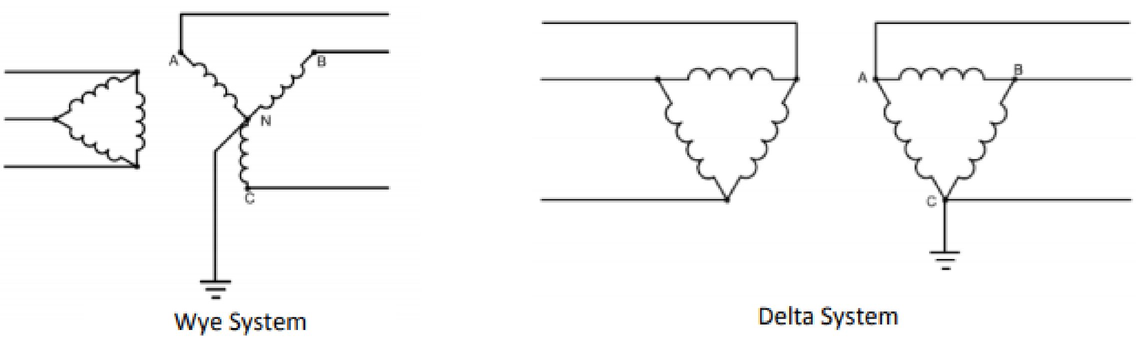


Once the relay detects this current sends the signal to open the associated low-voltage switch. Grounding through a low resistance is used in medium voltage systems of 15KV and lower, particularly where large rotating machines are used and where is wanted to reduce ground fault to hundreds rather than thousands of amperes



Solid grounding

Solid grounding refers to the connection of the neutral conductor directly to ground.



This configuration can be suitably protected against voltage surges and ground faults. This system allows flexibility and allows the connection of line to neutral loads. When using this configuration in systems of 600V or higher, will have to use residual or zero sequence protective relays. The circuit breakers are normally provided with current transformers that provide the signal from each of the phases for over current relay and ground fault relay takes the signal from the star that forms from the current transformers to increase the sensitivity of ground faults. The methods of detection as zero-sequence and residual will be discussed later. One disadvantage of the solidly grounded system is that the ground fault magnitudes reached may be so large that they could completely destroy the equipment. However, if these faults are quickly released the damage to equipment would be within "acceptable" levels.

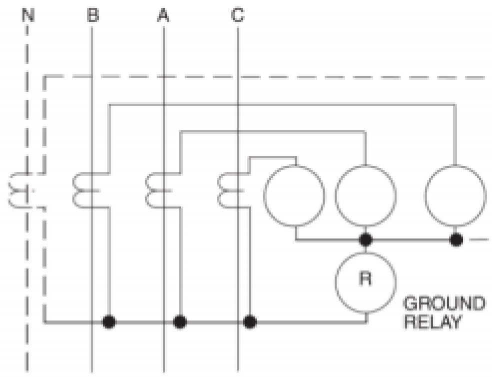
Reactance Grounded System

Reactance Grounded System In this configuration a reactor between the neutral and earth is installed. The levels of ground fault current when grounding through a reactor are considerably higher than desirable levels in systems grounded through resistance, because this grounding through a reactor is not commonly used as an alternative of grounding by low resistance.

Ground Fault Detection Methods:
The ground fault current can be monitored in different ways, could be monitored either as it flows out of the fault or returning to the neutral point of the source transformer or a generator. When monitoring the current coming out from the fault all the conductors of the system are monitored individually and when monitoring the return to neutral point only neutral is monitored. To perform this monitoring power transformers are used either in all the line conductors or in the neutral depending on the method being used. Protection devices that receive signals from the current transformers must have the ability to adjust the values of pick-up and the ability to adjust the time delays.

Residual Ground Fault Protection

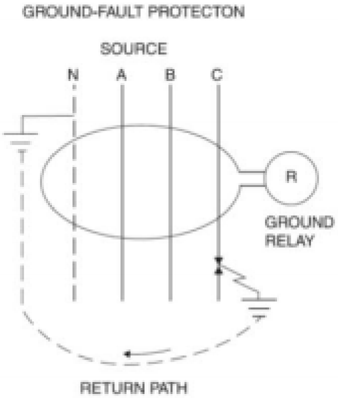
Residual protection is commonly used in medium voltage systems. This system consists of the use of 3 interconnected current transformers which send a signal proportional to the flow of ground fault current to the protection relay or device to trip. This system is not often used in low voltage equipment, but there are available low-voltage systems with 3 current transformers connected on a residual basis.



In 3-phase 3-wires systems the resulting from the vector sum of phase currents is zero even if a fault is present between phases. When one of the phases get in contact to ground short circuit current flows through the earth and not anymore by the line faulted line producing an imbalance in the circuit generating a residual current that is detected by the protective device. When you have systems of 3 phase 4 wire where they feed single phase loads, you should add a fourth current transformer to monitor the current consumed by such loads as well as single-phase zero sequence harmonic currents produced by nonlinear loads such as fluorescent lighting. If this fourth sensor is not used the protection device would see the imbalance between phases as a ground fault and will open the circuit.
The selectivity of the residual protection scheme depends on the ratio of the CTs which should be sufficient capacity for normal loads of the circuit. In this system instantaneous trip is not used because when starting some loads such as motors can generate a "normal" imbalance between

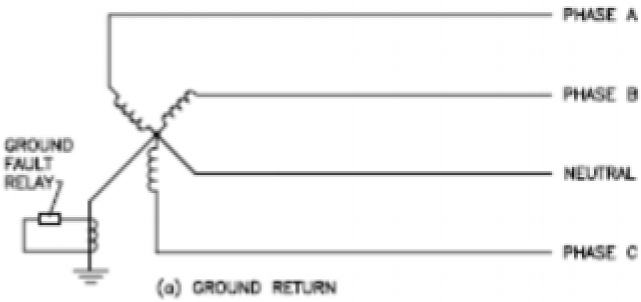
phases which could generate a protective device tripping. If more selectivity is required, the Balanced Core scheme must be used.

Core Balance (Zero sequence sensor): The core balance method is based on the flux summation. This method uses only one current transformer which monitors the three phases of the system (and neutral if exists) at the same time. Unlike the method residual current transformer is less amperage capacity and only monitors a possible imbalance and no load current of each line, it helps to have a better selectivity. In normal operating conditions (balanced, unbalanced, single phase loads or short circuits between phases) the flux summation of the currents flowing through the CT is zero. When a ground fault current flows through the ground wire it creates an imbalance in the CT output which generates the operation of the protection.



Ground Return

Ground Return Placing a current transformer on the grounded neutral and using a related protection relay, provides a ground fault detection method of low cost. Because only will monitor the ground fault current, adjustments can be set at very low current values.



In low-resistance grounded systems at 5 and 15KV this method is often used where ground fault currents are relatively low. It is also used in solidly grounded 480V, 3 phase 3 wire or 3 phase 4 wire. To provide adequate protection, the relay must be wired to trip the main circuit breaker at secondary side of the transformer and set a time delay to allow the circuit breaker to trip and if once the circuit breaker is tripped the fault is still sensed the relay must send a signal to that protection on the primary side to operate.

11.4 PROCEDURE:

OPERATION OF PANEL

1. Switch ON the MCB, the Voltmeter will show the line voltage.
2. Initially Rotary Switch should be in Amp Adjust Position.
3. Now to set the desired fault current we will be using current source. For that switch ON the Rotary switch and move the current source till the desired fault current is indicated on the Ammeter, it is quit possible that while adjusting the fault current the FLAG of the Relay might trip for that you have to RESET the

FLAG by moving the marked shaft UPWARD denoted by (RELAY FLAG RESET) for resetting the FLAG the Toggle switch must be brought in OFF position and the marked shaft move UPWARD.

4. Now the desire Fault Current is SET and relay FLAG RESET – Only when the disk has move fully anti clockwise. Now move the Rotary Switch in Relay Test and press the green push button and timer counting will START and counting will STOP once the relay is operated. Note down the time in seconds.

5. Now for various T.M.S. (Time Multiplier Setting) and P.S.M. (Plug Setting Multiplier), the time taken by the relay to operate at various fault current may be noted down.

6. Now plot the graph between time take for the relay to operate Vs Plug Setting Multiplier at various T.M.S.

11.5 TABULAR COLUMN:

TMS = 1.00, PS = 1.0 Amp

S.No	Current(a)	Time(measured)	Time (std)	PSM

11.7 RESULT:

EXPERIMENT – 12

FEEDER PROTECTION

12.1 AIM

To study the various protection schemes in radial feeder under various fault conditions.

12.2 APPARATUS

S. No.	Equipments	Quantity
1	Alternator coupled to Motor	1
2	Motor Drive	1
3	Power Analyzer	1
4	RPM meter	1
5	Variac(1-ph)	1
6	Rheostat(150Ω/3A)	1
7	Patch Cords	As required

12.3 THEORY

The word feeder here means the connecting link between two circuits. The feeder could be in the form of a transmission line, short, medium of long, or this could be a distribution circuit. The various methods of protecting the feeders are:

1. Over current protection.
2. Distance protection.
3. Pilot relaying protection.

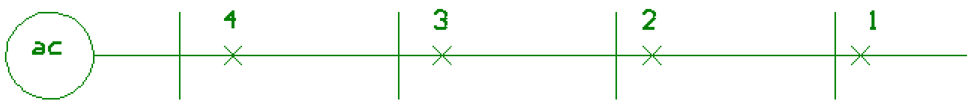
Of these, over current protection is the simplest and cheapest form of protection. It is most difficult to apply and needs readjustment, should a change in the circuit occur. This may even have to be replaced depending upon the circuit conditions. Over current relaying for distribution circuits besides being simple and cheap provides the following advantages:

1. Very often the relays need not be directional and hence no A.C. voltage source is required.
2. Two phase and one earth fault relay or three element, earth fault relay can be used.

The over current protection is normally used as back up protection where the primary protection is provided with distance schemes.

The discrimination using over current protection is achieved in the following ways.

1. Time graded system.
2. Current graded system.
3. Time – current graded system.



A radial feeder with relays

TIME GRADED SYSTEM

The selectivity is achieved based on the time of operation of the relays. Consider a radial feeder in fig.1 the feeder is being fed form one source and has four substations indicated by vertical lines. The crosses represent the location of the relays. The relays used are simple over current protection relays. The time of operation the relays at various locations is so adjusted that the relay farthest from the source will have minimum time of operation and as it is approached towards the source the operating time increases. This is the main drawback of grading the relays in this way because it is required that the more severs a fault is lesser should be the operating time of the relays whereas in this scheme of operating time increases. The main application of such a grading is done on systems where the fault current does not vary much with the location of the fault and hence the inverse characteristic is not used.

CURRENT GRADED SYSTEM

This type of grading is done on a system where the fault current varies appreciably with the location of the fault. This means as we go towards the source the fault current increases. With this if the relays are set to pick at progressively higher current towards the source, then the disadvantages of the long-time delay that occurs in cars of time graded systems can be partially overcome. This is known as current grading. Since it is difficult to determine the magnitude of the current accurately and also the accuracy of the relays under transient conditions is likely to suffer, current grading alone cannot be used. Usually a combination of the two grading i.e., current time grading is used.

TIME – CURRENT GRADING.

This type of grading is achieved with the help of inverse time over current relays and the most widely used is the IDMT relay. The other inverse characteristics. E.g. Very inverse or extremely inverse are also employed depending upon the system requirements. If the IDMT relays are slow at low values of overloads, extremely inverse relays are used and if the fault current reduces substantially as the fault location moves away from the source, very inverse type of relays are used.

12.4 CIRCUIT DIAGRAM:

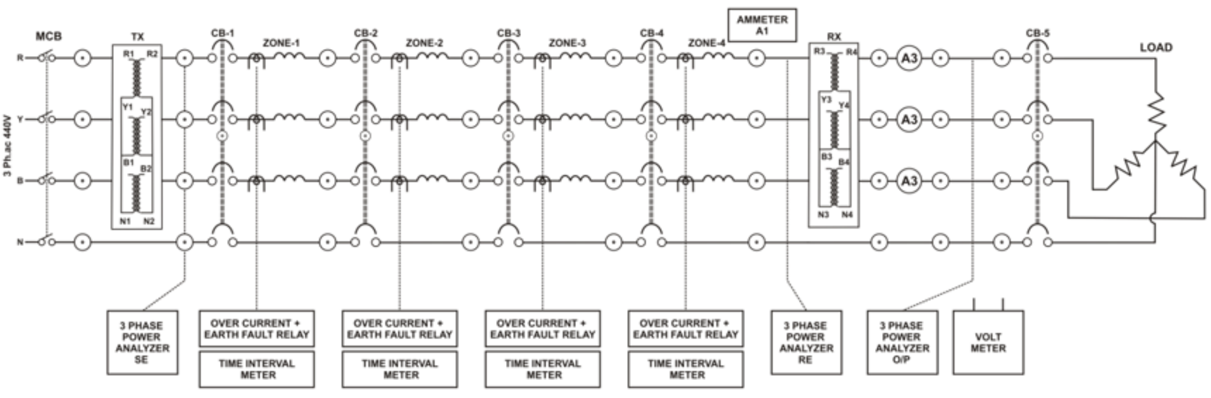


Figure 1: Circuit for radial feeder protection system

12.5 PROCEDURE:

SELECTION OF CURRENT SETTING:

1. For proper coordination between various relays on a radial feeder, the pickup of the relay should be such that it will operate for all short circuits in its own line and should provide backup protection for short circuits in immediately adjoining line.
2. For back up protection setting, it should be equal to the value of the current when the fault is at the far end of the adjoining section with minimum generation connected to the system.
3. A 3-phase fault under maximum generation gives the maximum fault current and line to line fault under minimum generation gives the minimum fault current.
4. The relay must respond between these two extreme limits.. On a radial system the current setting of the relay farthest from the source should be minimum and it goes on increasing as we go towards the source. According to Indian Standard Specification the operating value should exceed 1.3 times the setting, i.e., Min short circuit current ≥ 1.3 I setting

SELECTION OF TIME SETTING:

1. For proper coordination between various relays on a radial feeder the operating time of the relay farthest from the source should be minimum and it should increase as we go towards the source.
2. Referring to fig 11.1 if the time of operation of relays 1 is say T1, that of the relay 2 say T2 the T2=T1+t where t is the time step between successive relays and consists of the time of operation of C.B at 1 over travel of relay at 2 and factor of safety time.
3. Here over travel of relay at 2 means, the travel of the relay at 2 due to inertial of the moving system of the relay even after the fault at location 1 is removed.
4. A suitable value of over-travel is 0.1sec. Similarly factor of safety time is taken as 0.1sec, the time grading should be done at the maximum fault currents because at lower values it will automatically have a higher selectivity as the curves are more inverse in that range.

12.6 TABULAR COLUMN

S.No	Voltage(V_R)	Voltage(V_Y)	Voltage(V_B)	Current(I_R)	Current(I_Y)	Current(I_B)

12.9 RESULT:

12.7 PRE LAB POST VIVA QUESTIONS:

1. Give various types feeder protection methods?
2. Give various distance schemes?

12.8 POST LAB POST VIVA QUESTIONS:

1. What are main requirements for feeder protection?
2. Explain the procedure for feeder protection of ring main systems?
3. Discuss the advantages of feeder protection?

EXPERIMENT – 13

MEASUREMENT OF SEQUENCE IMPEDANCE OF SYNCHRONOUS MACHINE

13.1(a) AIM

To Measure the Sequence Impedance i.e., positive sequence, negative sequence and zero sequence of Synchronous Machine by direct method and fault protection devices.

13.2 APPARATUS

S. No.	Equipments	Quantity
1	Alternator coupled to Motor	1
2	Motor Drive	1
3	Power Analyzer	1
4	RPM meter	1
5	Variac(1-ph)	1
6	Patch Cords	As required

13.3 THEORY

The sequence impedances of an alternator have differing values. This is because of the difference in the effect of the armature m.m.f on the DC field m.m.f for different sequences. They may be defined as:

1. Positive Sequence Impedance
It is the ratio of the fundamental component of armature voltage, due to the fundamental positive sequence component of armature current, to this component of armature current at rated frequency. This is the usual impedance (either synchronous or transient or sub-transient) of alternator.
2. Negative Sequence Impedance
It is the ratio of fundamental component of armature voltage, due to the fundamental negative sequence component of armature current, to this component of armature current at rated frequency
3. Zero Sequence Impedance
It is the ratio of fundamental component of armature voltage, due to the fundamental zero sequence component of armature current, to this component of armature current at rated frequency.

13.4 CIRCUIT DIAGRAM:

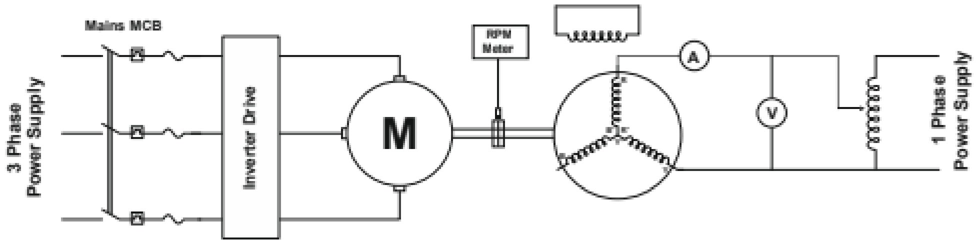


Figure 13.1: Circuit for Positive Sequence Impedance

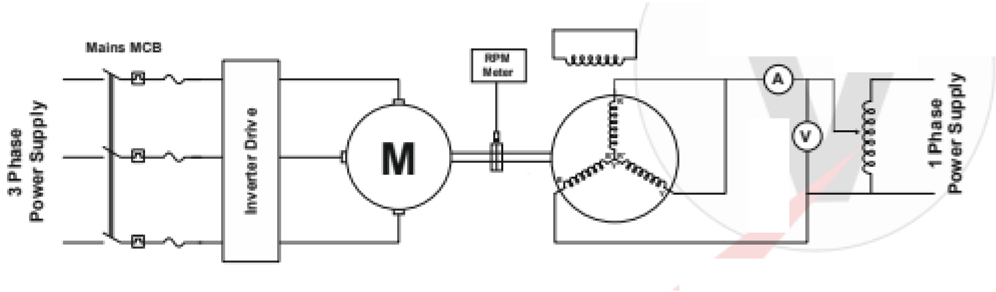


Figure 13.2: Circuit for Negative Sequence Impedance

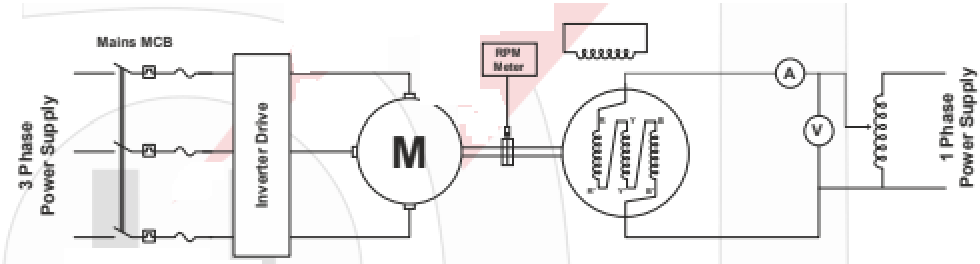


Figure 13.3: Circuit for Zero Sequence Impedance

13.5 PROCEDURE

Positive Sequence Impedance

1. Connect as shown in figure (13.1).
2. Initially keep the variac at zero position.
3. Switch on the supply and run the Motor at synchronous speed using the speed control knob provided in the panel.
4. Gradually apply single phase voltage using the variac across any two winding(R-Y) of the alternator. (near rated current)
5. Note down the values of voltage and current.
6. Similarly do for Y-B and R-B and calculate the positive sequence impedance.

Negative Sequence Impedance

1. Connect as shown in figure (13.2).
2. Initially keep the variac at zero position.
3. Switch on the supply and run the Motor at synchronous speed using the speed control knob provided in the panel.
4. Short any two terminals of the alternator and connect single phase variac to the other terminal as shown.
5. Gradually apply single phase voltage using the variac across the two terminals (shorted and open end) of the alternator. (near rated current)
6. Note down the values of voltage and current.
7. Calculate the value of Negative Sequence Impedance.

Zero Sequence Impedance

1. Connect as shown in figure (13.3).
2. Initially keep the variac at zero position.
3. Switch on the supply and run the Motor at a speed close to the synchronous speed using the speed control knob provided in the panel.

4. With all the three phases of the alternator in series connection, gradually apply single phase voltage using the variac across the ends of the alternator. (near rated current)
5. Note down the values of voltage and current.
6. Calculate the value of Zero sequence Impedance.

13.6 TABULAR COLUMN

Positive Sequence Impedance

	Voltage(V_1)	Current(I_1)	Z_1
R-Y			
Y-B			
B-R			

$$Z1 = V_1/2I_1$$

Average value of z_1=____Ω

Negative Sequence Impedance

Voltage(V_2)	Current(I_2)	Z_2

$$Z_2 = \frac{V_2}{\sqrt{3}I_2}$$

Value of Z_2=____Ω

Zero Sequence Impedance

Voltage(V_0)	Current(I_0)	Z_0

$$Z_0 = \frac{V_0}{3I_0}$$

Value of Z_0=____Ω

13.7. RESULT:

13.1 (b) FAULT ANALYSIS METHOD

AIM

To measurement of positive, negative and zero sequence impedances of synchronous machine by using direct method and fault analysis method.

APPARATUS

S. No.	Equipments	Quantity
1	Alternator coupled to Motor	1
2	Motor Drive	1
3	Power Analyzer	1

4	RPM meter	1
5	Variac(1-ph)	1
6	Rheostat(150Ω/3A)	1
7	Patch Cords	As required

PROCEDURE

Line to Ground Fault

1. Connect the Rheostat between line & ground initially by keeping the Rheostat at max position.
2. Switch on the supply and run the Motor at synchronous speed using the speed control knob provided in the panel.
3. Gradually apply DC voltage to the field using the variac such that the alternator provides its rated voltage.
4. Note down the values of voltage and current.
5. Now gradually decrease Rheostat t till the rated current.
6. Similarly do for L-L and L-N etc.

TABULAR COLUMN

S.No	Voltage(V_R)	Voltage(V_Y)	Voltage(V_B)	Current(I_R)	Current(I_Y)	Current(I_B)

RESULT:

13.8 PRE LAB POST VIVA QUESTIONS:

1. Define positive, negative and zero sequence impedances and their expressions respectively?
2. What are the various faults that occurs in alternator?

13.9 POST LAB POST VIVA QUESTIONS:

1. Define sequence impedance, types and phasor diagrams respectively?
2 .Explain the procedure for finding sequence impedances using fault analysis method?

EXPERIMENT – 14

STRING EFFICIENCY OF INSULATORS

14.1 AIM

To determine string efficiency in a string of insulators.

14.2 APPARATUS

S. No.	Equipments	Quantity
1	Alternator coupled to Motor	1
2	Motor Drive	1
3	Power Analyzer	1
4	RPM meter	1
5	Variac(1-ph)	1
6	Rheostat(150Ω/3A)	1
7	Patch Cords	As required

14.3 THEORY

Power transmission by overhead lines ia the by means of transportation of electrical energy from source to load centers. This energy transfer requires higher system voltages in EHV/UHV ac and dc on order to reduce the line loss and increases the power handling capacity. As the system voltage increases, the design of external insulation for both line and station insulation depends on the pollution performance.

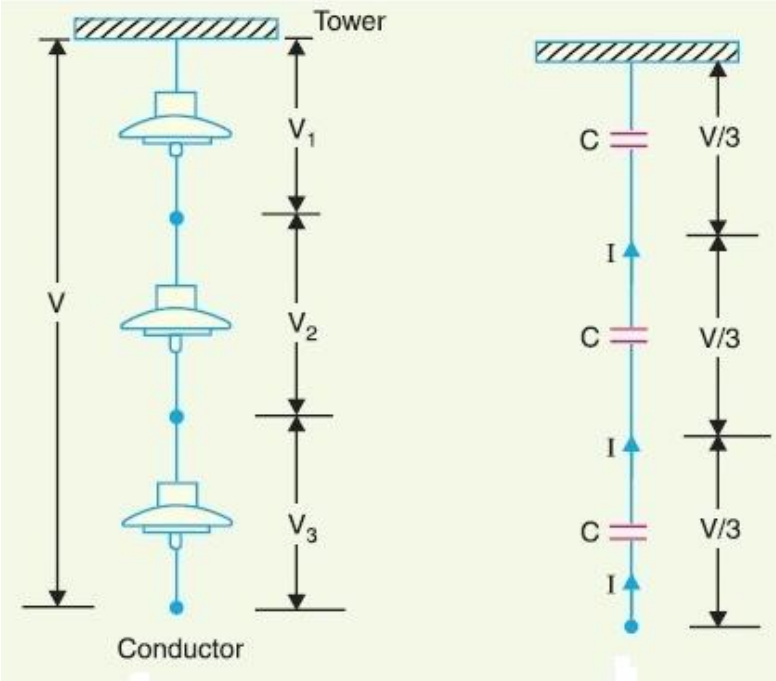
PROPERTIES:

1. It has large resistance and specific resistance.
2. Large di-electric strength.
3. High Mechanical strength
4. Resisting high temperature.
5. May not get change in nature due to temperature.
6. It should not absorb water
7. Can be made to any shape.
8. Cannot get fire simply.

Normally any one of the following methods is adopted for measurement of AC voltage distribution of string insulator in dry conditions and also to find efficiency of insulator in dry conditions and to find the efficiency of insulators.

1. Sphere gap method.
2. Capacitive voltage divider method.

14.4 CIRCUIT DIAGRAM:



14.5 PROCEDURE

1. Suspend the set of string insulator vertically and connect the top part of the string to the earth.
2. Connect the test jig across the last insulator.
3. Apply high voltage to the pin of the lowest insulator of the string.
4. Gradually increase the voltage until spark occurs.
5. Note down the breakdown voltage and the total voltage applied across the string.
6. Repeat the process for all the insulators in the string.
7. Tabulate the results and calculate efficiency.

14.6 CALCULATION:

%voltage shared by the insulator is given by,

$$\%V = \frac{SPARK\ OVER\ VOLTAGE\ OF\ THE\ GAP}{VOLTAGE\ APPLIED\ TO\ THE\ STRING\ TO\ CAUSE\ BREAKDOWN} * 100$$

$$\text{String efficiency} = \frac{voltage\ across\ string}{n * voltage\ across\ unit\ adjacent\ to\ line} * 100$$

THEORITICAL CALCULATIONS:

Let , $m = \frac{CAPACITANCE\ PER\ INSULATOR}{CAPACITANCE\ PER\ GROUND} = \frac{C'}{C}$

Let V be the operating voltage (line to ground)

V=V1+V2+V3+V4+V5

I2=I1+IC1

14.7 TABULAR COLUMN

S.No	Voltage across insulators	Breakdown Voltage	%Flash Voltage

14.8 PRE LAB POST VIVA QUESTIONS:

1. Define string efficiency?
2. Give various methods of improving string efficiency?
3. Why it is necessary to find string efficiency of insulators?
4. Derive mathematical expression for string efficiency of 3-disc string?

14.9 POST LAB POST VIVA QUESTIONS:

1. Define string efficiency and its importance?
2. Explain the procedure to calculate efficiency for 5 –disc system?
3. Give mathematical expression for string efficiency and percentage voltage distribution?

14.10 RESULT: