POWER SYSTEM LAB MANUAL

Subject: Power System-1

Subject Code: ELPC 551

B.Tech - Vth Semester

Department of Electrical Engineering
J. C. Bose University of Science and Technology
YMCA, Faridabad-121006

DEPARTMENT OF ELECTRICAL ENGINEERING

VISION OF THE DEPARTMENT

Electrical Engineering Department congregates the challenges of new technological advancements to provide comprehensively trained, career-focused, morally strong accomplished graduates, cutting-edge researchers by experimental learning which contribute to ever-changing global society and serve as competent engineers.

MISSION OF THE DEPARTMENT

- To commit excellence in imparting knowledge through incubation and execution of high-quality innovative educational programs.
- To develop the Research-oriented culture to build national capabilities for excellent power management.
- To inculcate and harvest the moral values and ethical behavior in the students through exposure of self -discipline and personal integrity.
- To develop a Centre of Research and Education generating knowledge and technologies which lay ground work in shaping the future in the field of electrical engineering.

PROGRAM OUTCOMES (POs)

Graduates of the Electrical Engineering program at JCBUST, YMCA will be able to:

PO1. Apply knowledge of mathematics, science, engineering fundamentals, and electrical engineering specialization to the solution of engineering problems.

PO2. Identify, formulate, review literature, and analyze electrical engineering problems to design, conduct experiments, analyze data, and interpret data.

PO3. Design solutions for electrical engineering problems and design system components of processes that meet the desired needs with appropriate consideration for public health and safety and cultural, societal, and environmental considerations.

PO4. 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 in electrical engineering.

PO5. Create, select, and apply appropriate techniques, resources, and modern engineering and IT tools including prediction and modeling to electrical engineering activities with an understanding of the limitations.

PO6. Apply reasoning informed by contextual knowledge to assess societal, health, safety, legal, and cultural issues and the consequent responsibilities relevant to professional engineering practice.

PO7. Understand the impact of electrical engineering solutions in societal and environmental contexts, and demonstrate the knowledge and need for sustainable development.

PO8. Apply ethical principles and commit to professional ethics and responsibilities and norms of the engineering practice.

PO9. Function effectively as an individual, and as a member or leader in diverse teams, and in multidisciplinary settings.

PO10. Communicate effectively on complex engineering activities with the engineering committee and with society at large, such as being able to comprehend and write effective reports and design documentation, and make effective presentations in electrical engineering.

PO11. Demonstrate knowledge and understanding of the engineering principles 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. Recognize the need for, and the preparation and ability to engage in independent research and lifelong learning in the broadest context of technological changes in electrical engineering.

PROGRAM SPECIFIC OUTCOMES (PSOs)

PSO1. To apply state-of-the-art knowledge in analysis design and complex problem solving with effective implementation in the multidisciplinary area of Electrical Engineering with due regard to environmental and social concerns.

PSO2. To prepare graduates for continuous self-learning to apply technical knowledge and pursue research in advanced areas in the field of Electrical Engineering for a successful professional career to serve society ethically.

PROGRAM EDUCATIONAL OBJECTIVES (PEOs)

PEO1. To produce competent electrical engineering graduates with a strong foundation design, analytics and problem solving skills for successful professional careers in industry, research and public service.

PEO2. To provide a stimulating research environment so as to motivate the students for higher studies and innovation in the specific and allied domains of electrical engineering.

PEO3. To encourage the graduates to practice the profession following ethical codes, social responsibility and accountability.

PEO4. To train students to communicate effectively in multidisciplinary environment.

PEO5. To imbibe an attitude in the graduates for life-long learning process.

Syllabus

Power System Lab-1 (ELPC-551)

L-T-P **Internal Marks-15**
0-0-2 **ExternalMarks-35**
Total-50

List of Experiments

Experiment No. 1: To study Ferranti effect and determine A, B, C, D parameters of short and medium transmission line.

Experiment No. 2: To study the characteristics of microcontroller based over current relay.

Experiment No. 3: To perform symmetrical fault analysis in AC network analyser.

Experiment No. 4: To perform symmetrical fault analysis in DC network analyser & perform the experiment for unsymmetrical fault analysis on DC network.

Experiment No. 5: To study the characteristics of the operation of Buchholz relay.

Experiment No. 6: To study the characteristics of the microprocessor based DMT/IDMT over current relay and determines the time current characteristics.

Experiment No. 7: Testing of negative Sequence relay using the negative sequence kit against negative sequence current balanced and unbalanced load condition.

Experiment No. 8: To study the characteristics of Electromechanical over current relay.

Experiment No. 9: To study microcontroller base over/ under voltage relay.

Experiment No. 10: To study characteristics of microcontroller based earth fault relay.

Experiment No. 11: To study characteristics of electromechanical earth fault relay.

Experiment No. 12: To find out the string efficiency across the string of insulators.

Experiment 13: To study various effects on transmission line simulator

a) Ferranti effect simulation for an unloaded line

b) Shunt Reactor Compensation for Unloaded Line

c) Loading of Transmission line

d) Shunt capacitive compensation of transmission line (to improve voltage profile)

e) Parallel operation of transmission line

f) Simulation of 3-Phase fault

g) Simulation of SLG, LLG and LL fault

h) Effect of Parallel line on Fault Current

COURSE OBJECTIVES & OUTCOMES

Course objectives:

1. **Enhance analytical skills** to assess the Ferranti effect and calculations of the parameter of short and medium transmission lines and Symmetrical fault analysis.
2. **Gain practical expertise** in operation of various types of relay i.e operation of Buchholz relay, electromechanical over current relay, microcontroller base over/under voltage relay and electromechanical earth fault relay.
3. **Develop an in-depth understanding** of operation and working of various components of the power system and how the operation of various types of relay is carried out.
4. **Obtain hands-on experience** in the study of various effects on transmission lines by using transmission line simulator.

Course outcomes:

CO1. Students will be able to conduct performance tests on transmission lines to find out the parameters of the transmission line.

CO2. Students will be able to study various types of symmetrical faults and unsymmetrical faults. They will be able to calculate parameters related to faults.

CO3. Students will be able to study the characteristics of various types of relays.

CO4. Students will be able to study and understand effects of Ferranti effect on unloaded line, Shunt Reactor Compensation for Unloaded Line and Parallel operation of transmission line. They will also able to perform simulation of various types of faults also.

Mapping of Course Outcomes (COs) with POs and PSOs

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2
CO1	3	3	2	2	3	1	2	1	1	2	1	2	3	2
CO2	2	2	3	2	3	1	2	1	2	2	1	2	3	2
CO3	3	3	3	3	3	1	2	1	2	2	2	3	3	3
CO4	3	3	3	3	3	1	2	1	2	2	2	3	3	3

Justification:

1. **CO1** aligns strongly with fundamental knowledge and experimentation (PO1, PO2, PO5), while it moderately aligns with design and analysis (PO3, PO4). It supports PSO1 significantly through hands-on analysis, testing, and problem-solving in transmission line parameters calculations.

2. **CO2** contributes highly to the effects of symmetrical and unsymmetrical faults (PO3, PO5) and moderately to experimentation and analysis (PO2, PO4). The practical experience and performance analysis contribute to PSO1 and PSO2, reflecting real-world skills.
3. **CO3** involves both practical and theoretical knowledge of various types of relays, contributing significantly to all relevant POs, especially in experimentation and design (PO1, PO2, PO3, PO4, PO5) and advanced problem-solving (PSO1, PSO2).
4. **CO4** emphasizes the effects of shunt compensation on transmission line and simulation of various faults with research and experimentation (PO2, PO4), along with its application to real-world problems (PO3, PSO1). The course outcome also encourages continuous learning (PSO2, PO12).

||General Instructions||

1. Students should come well-prepared for the experiment they will be conducting.
2. Usage of mobile phones in the laboratory is strictly prohibited.
3. In the lab, wear shoes and avoid loose-fitting clothes.
4. Read and understand the experiment manual thoroughly before starting the experiment. Know the objectives, procedures, and safety precautions.
5. Before starting the experiment, check the condition of the equipment, wiring, and connections. Report any damaged or malfunctioning equipment to the lab instructor immediately.
6. Ensure all connections are made as per the circuit diagram. Double-check all connections before powering the equipment.
7. Do not switch on the power supply until the instructor has approved your setup. Always start with the minimum voltage/current required and gradually increase as needed.
8. Do not overload machines beyond their rated capacity. Overloading can damage the equipment and pose safety risks.
9. Familiarize yourself with the lab's emergency shutdown procedures, including the location of emergency switches and fire extinguishers.
10. Do not bring food or drinks into the lab to avoid accidental spills, which can lead to electrical hazards.
11. Stay attentive during the experiment. Avoid distractions like mobile phones, and do not engage in unnecessary conversation during lab work.
12. Accurately record all measurements and observations during the experiment. Ensure that all data is properly noted in your lab report.
13. If you are unsure about any procedure or face difficulties during the experiment, do not hesitate to ask the lab instructor for guidance.
14. After completing the experiment, switch off the power supply, disconnect the setup, and return all equipment to its proper place. Ensure the workspace is clean and organized.

Power System Lab-1
(ELPC-551)

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STUDY EXPERIMENTS

EXPERIMENT NO-1

AIM: To study Ferranti effect and determine A, B, C, D parameters of short and medium transmission line.

APPARATUS: -

S.no.	**Description**	**Quantity**
1	Transmission line sections (220V, 2A)	4
2	Continuous Power Supply	1
3	Digital Voltmeter	2
4	Digital Ammeters	2

THEORY:

Transmission line model consists of four sections and each section represents 50 Km long 400KV transmission line. Parameters of 50 Km long 400KV Transmission line are taken as:

Series Inductance = 80 mH

Series Resistance = 2 ohm

(In addition to resistance of inductance coil)

Shunt Capacitance = 0.4 microF

Leakage resistance or Shunt Conductance = 470 Kohm

For actual 400KV transmission lines range of parameter is:

I = Series Inductance = 1.0 to 2.0 Mh/Km

r = Series Resistance = 0.5 to 1.5 ohm/Km

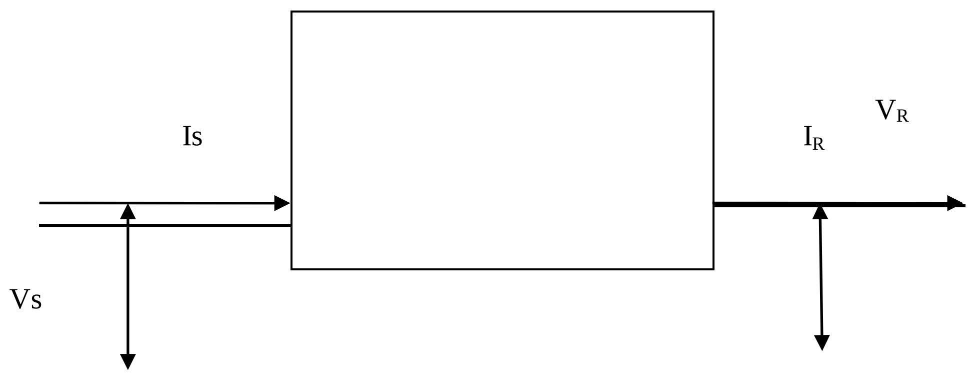
c = Shunt Capacitance = 0.008 to 0.010 microF/Km

g = Leakage resistance (Shunt Conductance) = 3 x 10^-8 to 5 x10^-8 mho/Km

ABCD parameters are widely used in analysis of power transmission engineering where they will be tuned as "Generalised Circuit Parameters" 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 parameters.

A long transmission line draws a substantial quantity of charging current. If such a line is open circuited for a very lightly loaded at the receiving end, the voltage at the receiving end may become higher than the voltage at the sending end. This is known as 'FERRANTI EFFECT' and is due to the voltage drop across the line inductance (due to the charging current) being in phase the sending end voltage. The both capacitance and inductance are necessary to produce this phenomenon. The capacitance and charging current is negligible in short line but significant in medium length lines and appreciable in long lines. Therefore, phenomenon occurs in medium and long lines.

ABCD parameters equations are given as:-



Assuming the receiving end open circuited, i.e. I_2=0.This

gives:-

A=VS/VR Reverse voltage ratio and is unit less

C= IS/VR Transfer admittance, unit is Mho

B= VS/IR Transfer impedance expressed in ohm

D= IS/IR Reverse current ratio and is unit less

In hybrid parameter representation both short circuit and open circuit terminal conditions are utilized hence this parameter representation is known as hybrid parameter representation.

Here:-

$$\begin{bmatrix} V_S \\ -I_R \end{bmatrix} = \begin{bmatrix} h_{11} & h_{12} \\ h_{21} & h_{22} \end{bmatrix} \begin{bmatrix} I_S \\ V_R \end{bmatrix}$$

If receiving end is short circuited, i.e. $V_R = 0$

$h_{11} = \frac{V_S}{I_S}$ Input impedance and unit is ohms

$h_{21} = \frac{I_R}{I_S}$ Forward current gain is a unit less quantity

In a similar way for the sending end open circuited i.e. $I_S = 0$

$h_{12} = \frac{V_S}{V_R}$ Reverse voltage gain and has no unit

$h_{22} = \frac{I_R}{V_R}$ Output admittance and is expresses in mho

In a transmission line, if the impedance at the sending end with Z_{i2} at receiving end be Z_{i1} at input port is Z_{i2} then Z_{i1} and Z_{i2} are termed as the IMAGE IMPEDANCE OF THE NETWORKS.

We can conveniently express the image impedance in terms of ABCD constant as:-

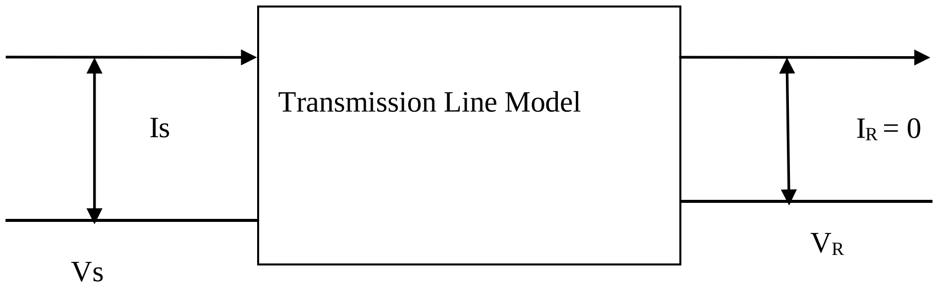
$Z_{i1} = \sqrt{\frac{AB}{CD}}$ and $Z_{i2} = \sqrt{\frac{BD}{AC}}$

However image impedance does not completely define a network. We need another parameter which we shall get from the voltage and current ratio known as image transfer constant and can be calculated as:-

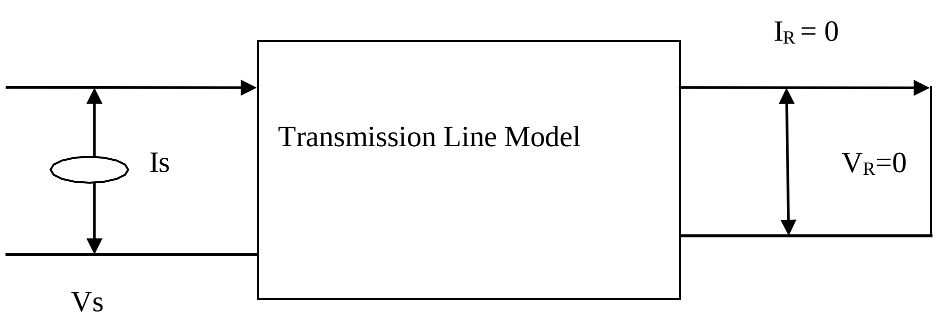
$$\sigma = \frac{1}{2} \ln \left(\frac{V_S I_S}{V_R I_R}\right) = \tanh^{-1} \sqrt{\frac{BC}{AD}}$$

CALCULATIONS & OBSERVATIONS

(i) ABCD Parameters

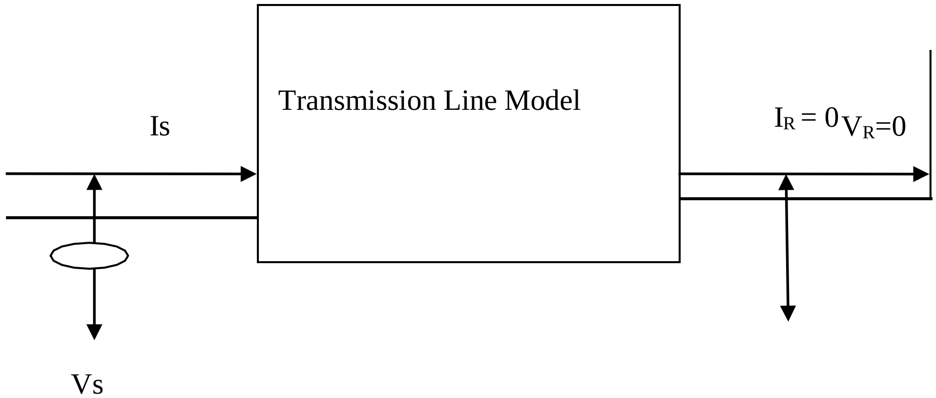


S.NO.	V_S	I_S	V_R	$A= V_1/V_2$	$C=I_1/V_2$



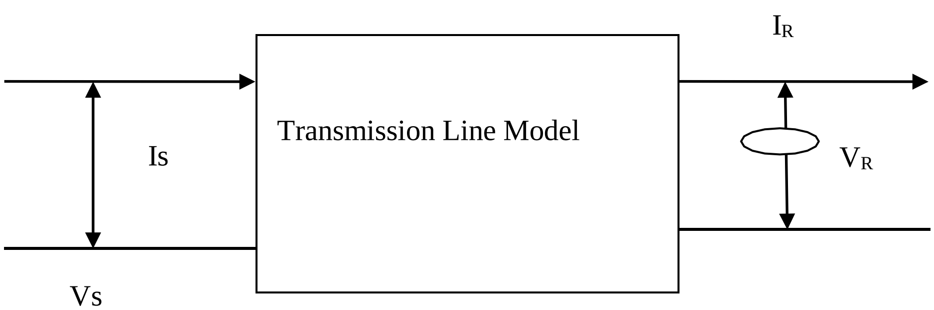
S.NO.	V_S	I_S	I_R	$B= V_S/I_R$	$D=I_S/I_R$

(ii) Hybrid Parameters:-



Calculation Table:-

S.NO.	V_S	I_S	I_R	$h_{11}= V_S/I_S$	$h_{21}=I_R/I_S$



S.NO.	V_R	I_R	V_S	$h_{12}= V_S/V_R$	$h_{22}=I_R/V_R$

(iii) Image Parameters:

$Z_{i1} = \sqrt{\frac{AB}{CD}}$

$Z_{i2} = \sqrt{\frac{BD}{AC}}$

$\sigma = tanh^{-1}\sqrt{\frac{BC}{AD}}$

PROCEDURE:

STEP 1:-

(i) To find out A and C parameters connected voltage supply of 220V to sending end (1-1’) and open circuit (5-5’) receiving end.

(ii) Observe the voltage of Vs, Is and V_R with the help of voltmeters and ammeters in the experimental kit.

STEP 2:-

(i) To find out B and D receiving end (5-5’) is short circuited and supply of 220V is given to sending end (1-1’).

(ii)Observe the voltage of Vs, Is and I_R.

STEP 3:-

(i) To find out the value of h_{11} and h_{21} take the reading of V_S, I_S and I_R from step No.2.

STEP 4:-

(i) To find out the value of h12 and h22 supply the 220V at receiving end terminal (5-5’) and open circuit the sending end terminal (1-1’).

(ii) Note down the value of Vs, V_R and L_R.

(ii) To find out the image parameters take the value of A, B, C and D from step No.1 & 2.

RESULT: ABCD parameters of medium transmission line (T and PI network) are computed.

EXPERIMENT NO- 2

AIM: To study micro controller based Over Current Relay

APPARATUS: -

S.no.	Description	Quantity
1	VPL-01 Module	1

THEORY:

The over current relays are used to sense the fault currents and over-load currents and trips off the system. Micro controller is used for the control operation. The programming is done in such a way that when the fault current value is above the set value the relay is closed/ opened (depends on connection) and it trips the circuit. The tripping of the relay is indicated by the LED. The LCD displays the set time, set current, fault current and tripping time. The following figure show front panel of VPL-01 module.

i. FRONT PANEL VIEW

Figure-1 Front Panel of VPL-01 Module

ii. FRONT PANEL DESCRIPTION

*LCD Display – Display the selection, set mode and relay status.

1 - Increment the Current and time settings.

2 – Decrement the Current and time settings.

3 – Cursor movement

4 –Enter the setting values & set to the processor.

*RST -Reset the all current setting values.

‘9’ PIN ‘D’ Connector – Its used to interface with PC.

*Power- Power N/OFF the Switch.

*LED (Indicate the relay tripping
action)

LED ‘ON’ – Relay Trip

LED ‘OFF’- Relay is normal condition (not Trip)

Current Sensing – Current sensing output = 5VAC

Banana Connector:

P & N (Current coil/input) – Apply input variable current (0-20A)

NO Contact – This terminal indicates the relay is normally in closed condition after relay tripped, this two terminal is closed with relay contacts.

NC Contact- This terminal indicates the relay is normally closed condition after relay tripped, this two terminal is opened with relay contacts.

PROCEDURE:

1. Current source is connected to across the banana connector L1 & L2 of VPL-01 module.
2. Power ON the VPL-01 module (Micro controller based Over Current relay). The LCD displays shows the following with a delay of few seconds between each display.

VI MICROSYSTEMS

VI MICROSYSTEMS PRESENTS

OVER CURRENT RELAY TRAINER

SELECT ANY ONE…

SELECT ANY ONE…
1.DMT…. 2.IDMT

The selection between type of relay of relay should be made by pressing the appropriate buttons in the display. The details of buttons in the display.

1- Selecting and incrementing

2- Selecting and decrementing

3- Cursor movement

4- Enter

RST- Reset the relay system

The type of operation to be carried out is displayed and is selected by the buttons 1 or 2.

Select buttons

1. DMT (Define Minimum Time)
2. IDMT (Inverse Definite Minimum Time)

Select IDMT

1. The IDMT operation can be selected by pressing 2.The set current I(s) has to be entered. The LCD displays the following.

ENTER AMP : 00.1A

………. [0.1-15A]……..

Set the current value by using 1, 2 &3 buttons

ENTER AMP :05.0A

………. [0.1-15A]……..

2. The button 4 is pressed. (All the set values are sent to the processor). Now the display shows.

ENTER TIME : 0.1s

………[0.1-2s]….

3. Set the Reset Time value by using 1, 2 & 3 buttons.

ENTER TIME : 0.7s

………[0.1-2s]….

The Time Multiplier Setting (TMS) value is to be entered. The range of TMS is 0.1 to 2s. This value is entered by pressing 4.

NOTE:

If the fault current < set Current the LCD displays the Current values by default as

SET CURRENT :5A

CURRENT: 3

Now press the RST button. Again set the same values and set the fault current is above the set Current.

4. If the fault current > set Current the LCD displays

OVER CURRENT
Time: 1s

The calculate time for relay tripping is obtained from the formula.

$$t = TMS \text{ X } \left[\frac{K}{\left(\frac{I}{I_S}\right)^{\alpha} - 1}\right] + C$$

The IDMT used is of normal inverse type. So the values of k, α, C are constant and are K=0.14, α=0.02 and

C=0. I is the fault Current and Is is the set Current of the relay unit.

5. The time starts to increase from 0.1S to until end of the calculated time in sec, then the relay coil is energized and trips the relay contacts. At the same time LED glows. After shows the LCD display.

Relay Tripped… Due to Over Current

6. Now LCD displays the following message one by one continuously until the relay system is reset and LED is glow.

Set AMP : 5A Tripped AMP : 10

Set TMS : 0.7S

Calc Time : ……s Trip Time:..........s

7. Press the RST button, Reset the processor and Relay tripping action.

i. SELECT DMT

1. The DMT operation can be selected by pressing 1. The LCD displays the following.

ENTER AMP : 00.1A ………. [0.1-15A]……..

Set the current value by using 1, 2 &3 buttons

ENTER AMP :05.0A ………. [0.1-15A]……..

2. The button 4 is pressed. (All the set values are sent to the processor). Now the display shows.

ENTER TIME : 000s ………[0-300s]….

Set the Reset Time value by using 1, 2 & 3 buttons

ENTER TIME : 007s ………[0-300s]….

3. Press the button 4.

4. The time starts to increase from 1S to until 007S. After 007S the relay coil is energized and trips the replay contacts. At the same time LED glows. After relay is tripped the LCD displays it as.

OVER Tripped……. SET : 7S T:7S

After the tripping of relay, the following messages are displayed one by one continuously until the system is reset.

Relay Tripped……. Due to Over Current

Set Current: 05.0 A Tripped Current : 10.0A

Set DMT TIME : 7s Tripped Time: 0.7

The relay system is reset by pressing RST button.

TABULATION:

IDMT

S.NO.	Set Current(A)	Fault Current(A)	Time Multiplier Setting(sec)	Calculated Relay tripping Time(sec)	Actual Relay Tripping Time(sec)

DMT:

S.NO.	Set Current (A)	Fault Current (A)	Set Time (sec)	Actual Relay Tripping Time(sec)

EXPERIMENT NO. 3

AIM: To perform symmetrical fault analysis in AC network analyzer.

APPARATUS USED:

S.no.	Description	Quantity
1	Network Analyzer	1
2	Ammeter (0-2A)	4
3	Voltmeter (0-2V)	1
4	1Mh, 2Mh, 3mH & 5mH Inductances	1

THEORY:

SYMMETRICAL FAULT

Fault involving all three phases is called a symmetrical fault (Balanced fault). Three phase short circuit is a symmetrical fault. When insulation of the system fails at one or more points or a conducting object comes in contact with live point, a fault occurs. The system must be protected against heavy flow of short circuit by means of protective equipment.

UNSYMMETRICAL FAULT:

The fault involving only one or two phases is called Unsymmetrical (Unbalanced fault). Single Line to Ground fault, Line-Line fault. Double line to ground fault are unsymmetrical faults. The majority of system fault are unsymmetrical fault. The system must be protected against these faults currents by mean of circuit breaker & relays. For the choice of protective equipment we must estimate the magnitude of current that would flow under fault condition. Unsymmetrical fault analyses require special tools like symmetrical components. Network analyzer can be for analysis of any type of unsymmetrical fault. First of all positive, negative and zero sequence networks are drawn of the system to be analyzed. Depending upon the type of unsymmetrical fault, these networks are interconnected on the Network analyzer.

For L-G fault, Positive, negative and zero sequence are connected in series.

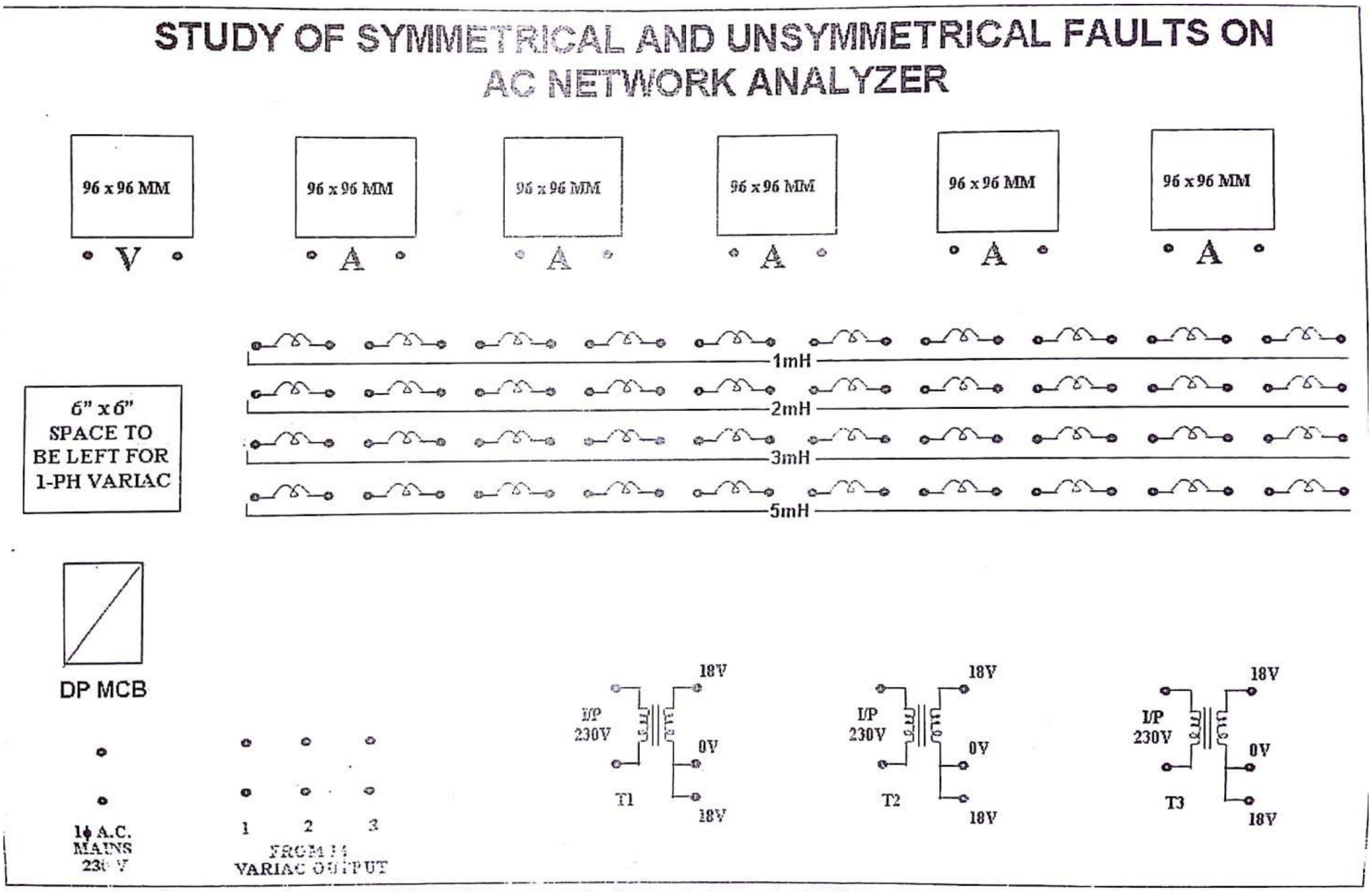
For L-L fault, positive & negative are connected in parallel.

For LL-G fault, positive sequence N/W is in series with the parallel combination of negative sequence network N/W & zero sequence N/W.

For symmetrical fault (L-L-L-G) only positive sequence network is required.

Symmetrical fault analysis is performed on the following sample problems.

PANEL VIEW



PROCEDURE:

1. Draw the single line diagram of the system indicating the fault point as per Figure-1.

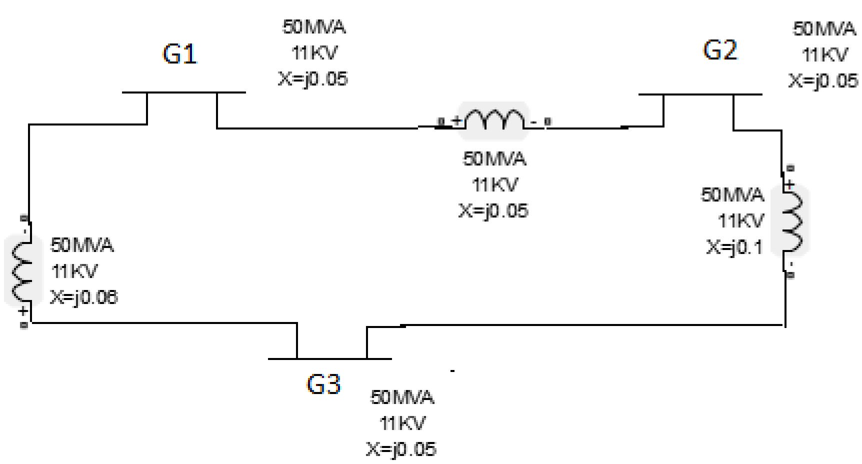


Figure 1

2. Draw the positive sequence network, negative sequence network and zero sequence network of the system

as the case may be.

In the present sample problem the negative sequence network is as shown in Figure-2

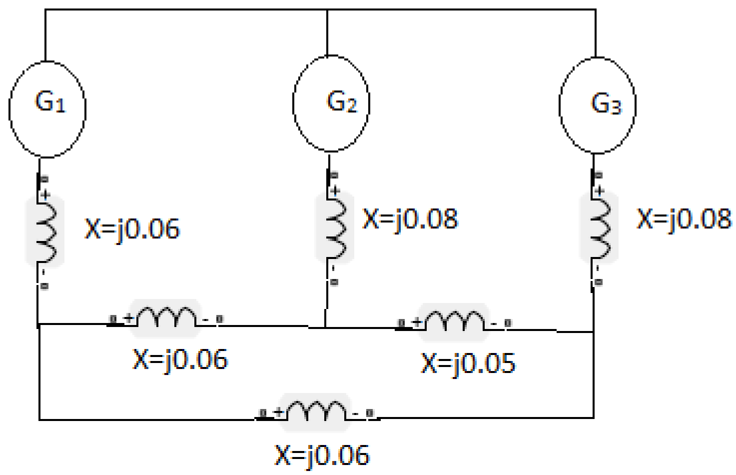


Figure 2

3. Redraw the positive sequence network by replacing the voltage source with per unit voltage source and by multiplying the inductances by a suitable factor so that sequence network can be simulated on the network analyzer. In the present case multiplication factor is as 31.4 (Reason for taking multiplication factor as 31.4 is that 0.05 Ohms reactance into 5mH inductance as shown below)

If $X_L=0.05$

$2\pi fL = 0.05$

$L = \frac{0.05}{314} * 100Mh = \frac{5}{31.4} mH$

And the positive sequence network is redrawn as shown in figure 3.

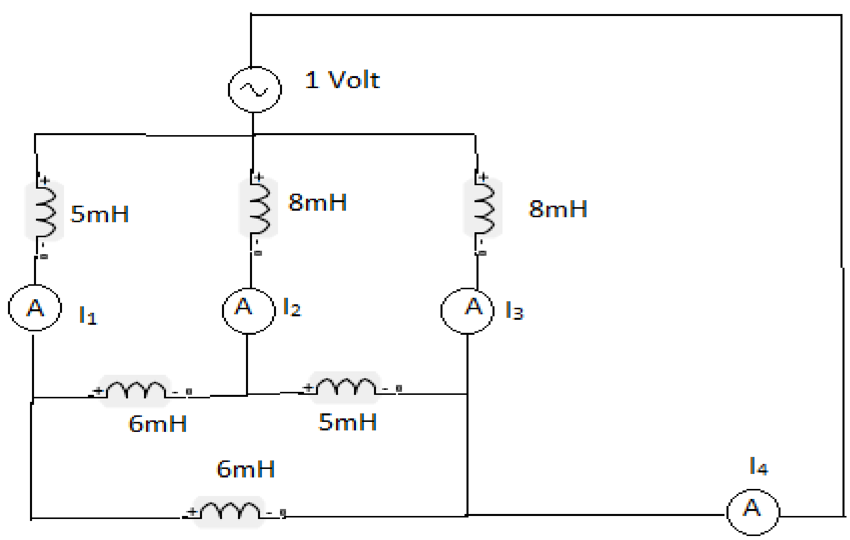


Figure 3

1. Simulate the system as shown in Figure-3 on the network analyzer (for the convenience of simulating the system on the network analyzer it preferred to mark positions of nodes on figure-3 and corresponding making shall be done with a marker on the front accordingly for different setups).
2. Keep the variac in the minimum position and switch on the supply of the network analyzer.
3. Adjust the voltage of the source as one volt with the help of variac.
4. Record the reading of the currents I_1, I_2, I_3 and I_4 as under:-

Source Voltage	I_1	I_2	I_3	I_4

5. Calculate the total fault current and fault current contributed by each generator. For the sample problem Current contributed by

Generator G_1= I_1 *multiplication factor * Base Current

Generator G_2= I_2 *multiplication factor * Base Current

Generator G_3= I_3 *multiplication factor * Base Current

Total Fault Current = I_4 * multiplication factor * Base Current

Base Current (in KA) = $\frac{Base\ MVA}{Base\ Voltage\ (KV)} = \frac{50}{\sqrt{3}*11}$= 2.62 KA

Results: Compare the result with the analytically calculated results.

EXPERIMENT NO. 4

<u>AIM</u>: To perform symmetrical fault analysis in DC network analyzer & to perform the experiment for unsymmetrical fault analysis on DC network.

APPARATUS USED:

S.no.	**Description**	**Quantity**
1	DC Network Analyzer	1
2	Ammeter (0-2A)	4
3	Voltmeter (110 V)	1
4	Resistance	1,2,3,4,5,1 0 ohm
	Dc Supply	1
	Connecting Wires	

<u>THEORY</u>:

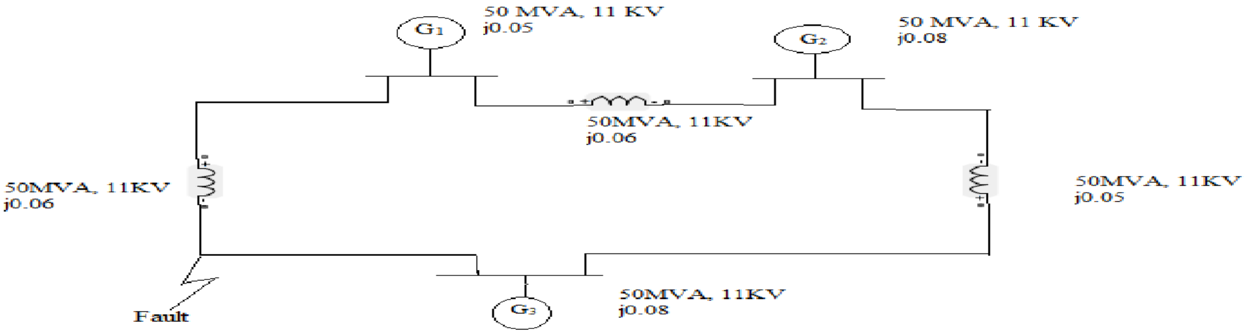
Case (i) <u>SYMMETRICAL FAULT</u>

Fault involving all the three phase (balance fault) is called symmetrical fault. Three phase short circuit is a symmetrical fault. Three phase short circuit is a symmetrical fault. When the insulation of the system fails at one or more point of a conduction object comes in contact with live point a fault occurs. The system must be protected again heavy flow of short circuit currents by means of protection equipments.

For the proper choice of the circuit breakers and protective equipment, we must estimate the magnitude of the current that would flow under short circuit condition.

For finding out the short circuit current, DC and AC Network analyzer are used. The circuit of the system to be analyzed is made on the network analyser. The problem to be solved is simulated on the analyzer. The fault is created and fault current is measured. This fault current when multiplied with base current gives the actual fault under fault conditions in the actual system.

<u>SAMPLE PROBLEM</u>



In case the generators and lines have different MVA values then for making calculations, the reactance are converted to some base MVA, normally the highest values is taken as base MVA.

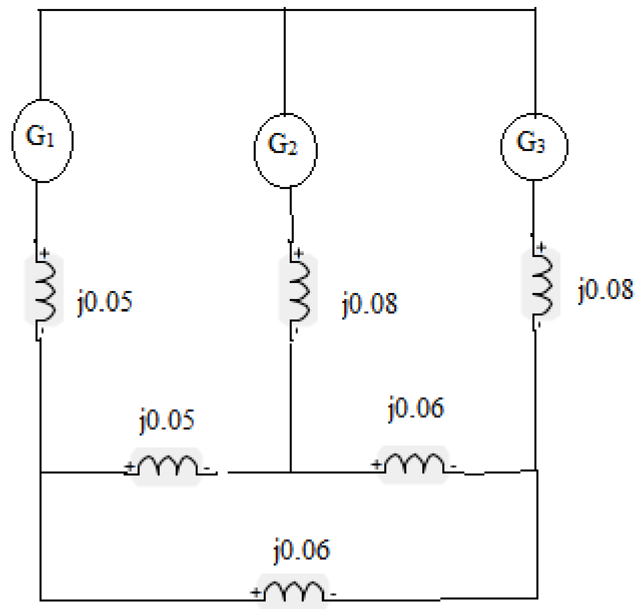
$Z_{new} = Z_{old} * NewMVA / OldMVA * (OldKV / NewKV)$^2

Base Current I_B = Base KV

In our problem:-

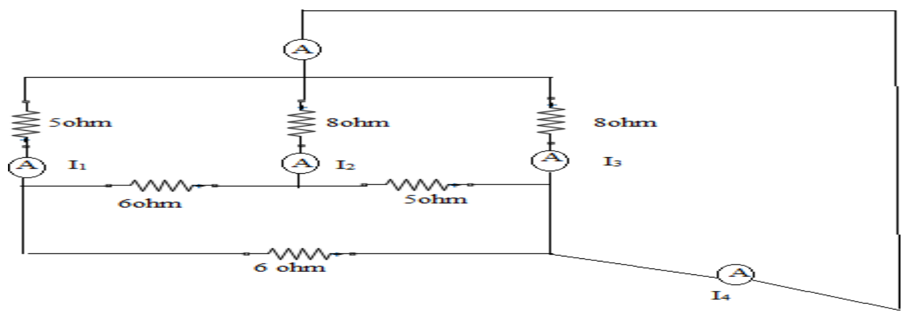
$I_B = \frac{(50/3)*10^6}{(11/\sqrt{3})*10^3}$A

Reactance diagram of the system is as under:

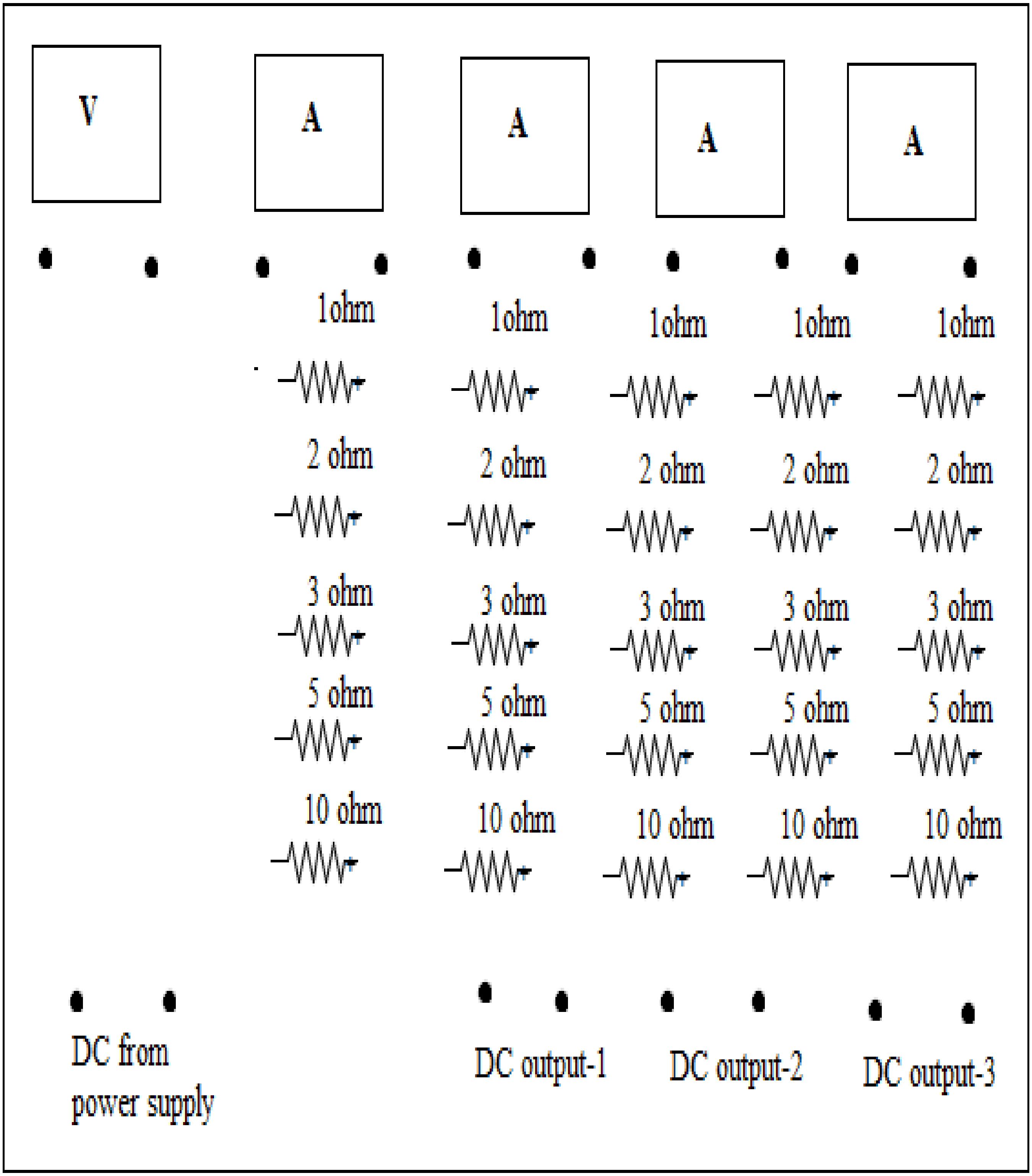


Replacing the generator with p.u. voltage source and further these voltage sources are in parallel so can be represented by a single voltage source of 1V DC. In case of DC network analyzer, the reactance of the generators and transmission lines are replaced with the resistance values.

Multiplying the resistance values with multiplying factor of 100, we get the circuit as under:-



Short circuit is created as F.



Panel View:

OBSERVATIONS:

V	I_1	I_2	I_3	I_4

Actual fault current = I_4 * Multiplying factor * Base Current

= 0.279*100*2.62

= 73.098 KA

Contribution of each generator

For generator G_1, fault current = $I_1 * M_F * I_B$

For generator G_2, fault current = $I_2 * M_F * I_B$

For generator G_3 fault current= $I_3 * M_F * I_B$

Case (ii) UNSYMMETRICAL FAULT

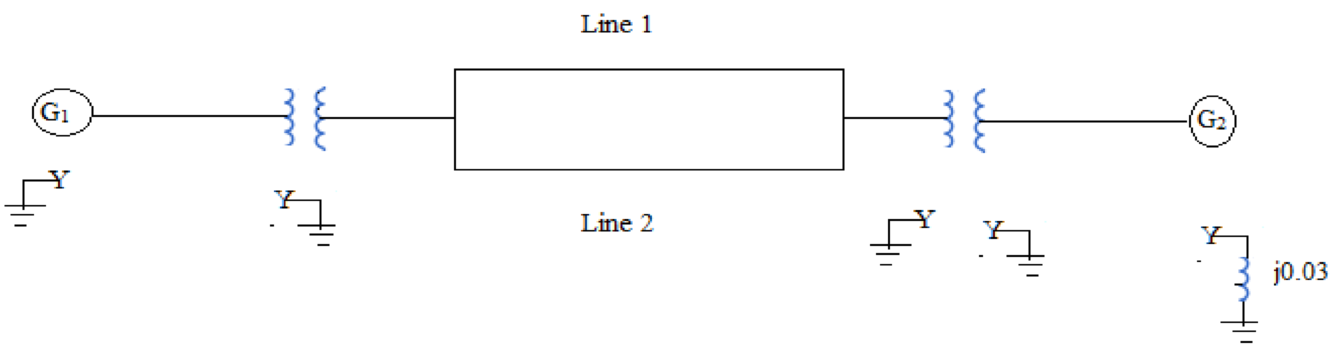
The fault involving only one or two phases is called Unsymmetrical (Unbalanced fault). Single Line to Ground fault, Line-Line fault, Double Line to Ground fault are unsymmetrical faults. The majority of system faults are unsymmetrical faults. The system must be protected against these fault current by means of circuit breakers & relays. For the choice of protective equipment we must estimate the magnitude of current that would flow under fault condition. Unsymmetrical fault analyses require special tools like symmetrical components. Network analyzer can be used for analysis of any type of unsymmetrical fault. First of all Positive, negative and Zero sequence networks are drawn of the system to be analysed. Depending upon the type of unsymmetrical fault, these networks are interconnected on the Network analyzer.

For L-G fault, Positive, negative and Zero Sequence networks are connected in series.

For L-L fault, Positive and negative Sequence networks are connected in parallel.

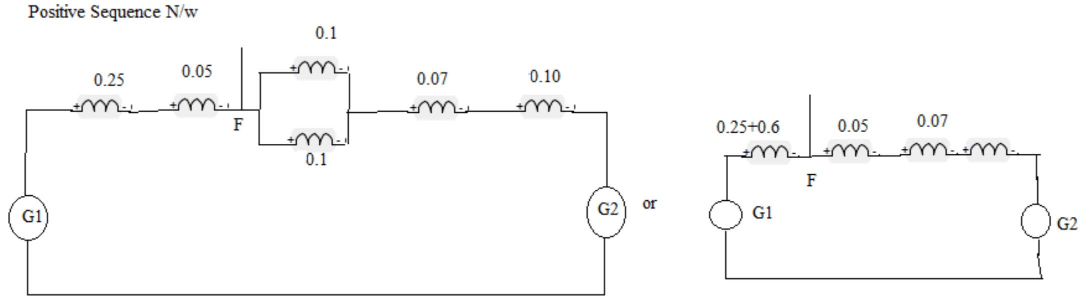
For LL-G fault, Positive Sequence networks is in series with the parallel combination of negative sequence N/W & Zero sequence N/W.

Here in the sample problem analysis of **Line to Line Ground fault** is done. The network to be analysed is shown in figure:

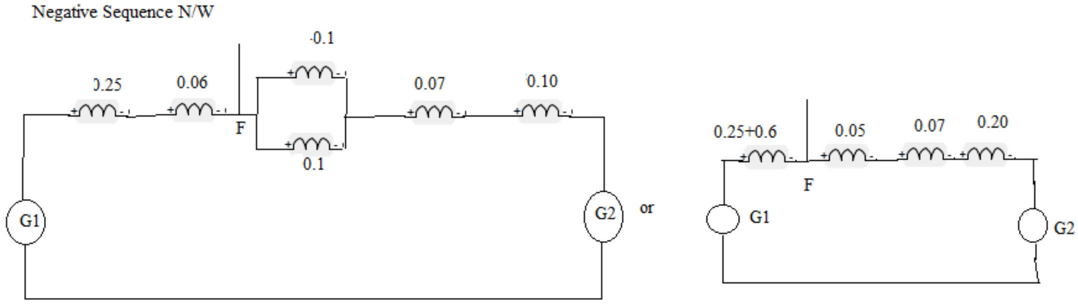


Equipment	MVA	KV	X_1	X_2	X_0
G_1	100	11	0.25	0.25	0.05
G_2	100	11	0.2	0.2	0.05
T_1	100	11/220	0.06	0.06	0.06
T_2	100	11/220	0.07	0.07	0.07
Line1	100	220	0.1	0.1	0.3
Line2	100	220	0.1	0.1	0.3

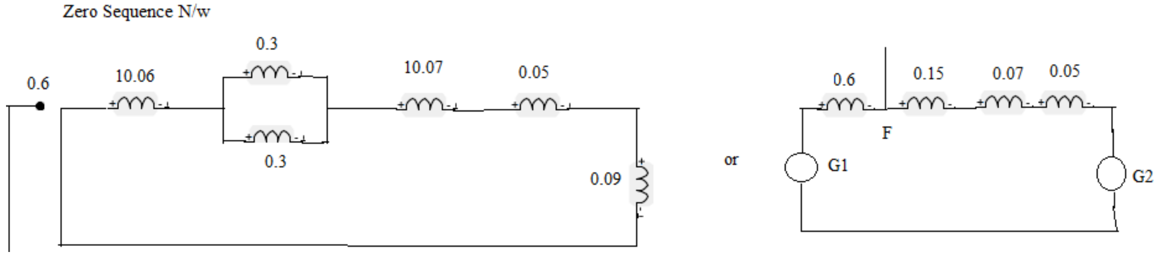
Positive Sequence N/w



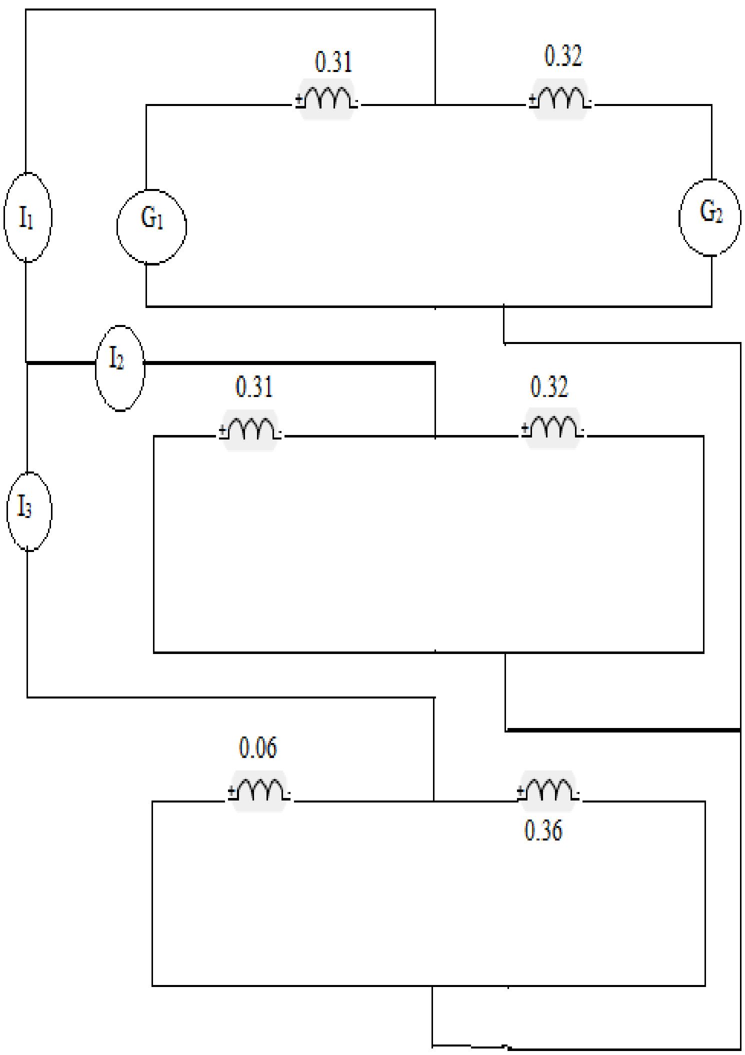
Negative Sequence N/W

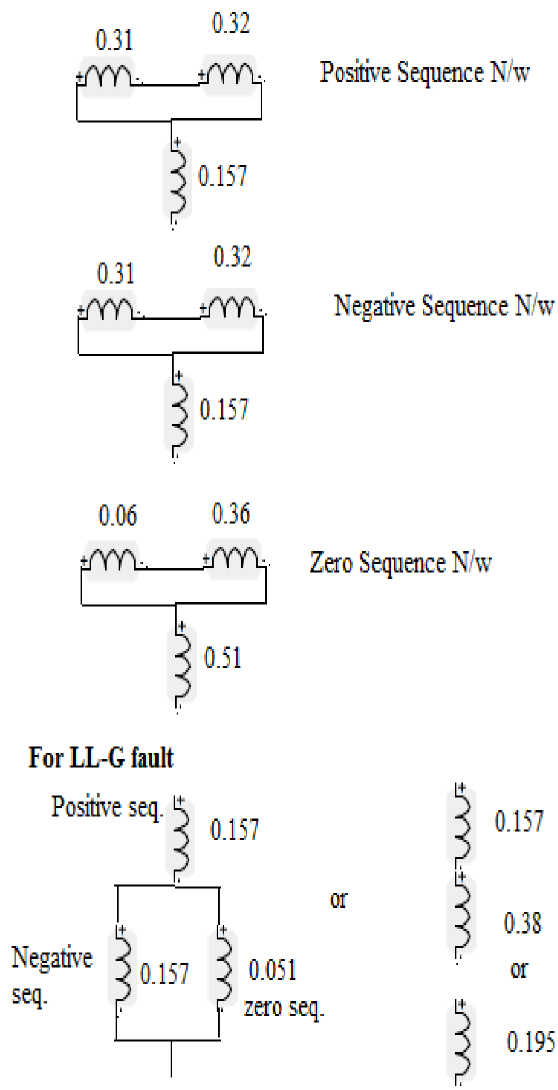


Zero Sequence N/w



Reducing the Sequence Networks with series parallel combination & Inter connecting we get





PROCEDURE:

i. Take multiplication factor of 100.

ii. Make the connections as shown in fig 3

iii. Connect the DC voltage Source.

iv. Note down the Ammeter readings.

v. It gives the fault current.

Calculation:

Calculations of theoretical fault Current:

Z_1=0.157

Z_2=0.157

Z_0=0.051

$I_F = E_a / Z_1 + (Z_2 Z_0 / Z_2 + Z_0)$

Actual fault current = I_F* Base MVA/Base Kv

Calculation of Observed fault Current:

Take multiplication factor 100.

V (Volts) I_1(A) I_2(A) I_3(A)

Observed fault current= I_1 * Base MVA/ Base KV

Formula Used:

$I_F = E_a / Z_1 + (Z_2 Z_0 / Z_2 + Z_0)$

Conclusion:

Theoretical fault current =

Practical fault Current =

% age error = $\frac{Theoritical\ fault\ Current - Practical\ fault\ current}{Theortical\ fault\ current} * 100$

EXPERIMENT NO.5

<u>AIM</u>: To study the operation of Buchholz relay.

<u>APPARATUS USED</u>:

S.no.	Description	Quantity
1	Buchholz relay testing apparatus	1

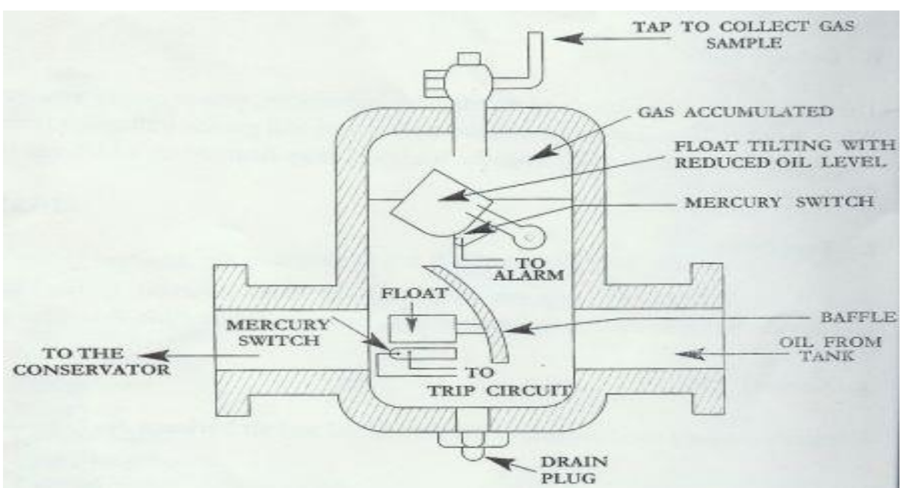
<u>THEORY</u>:

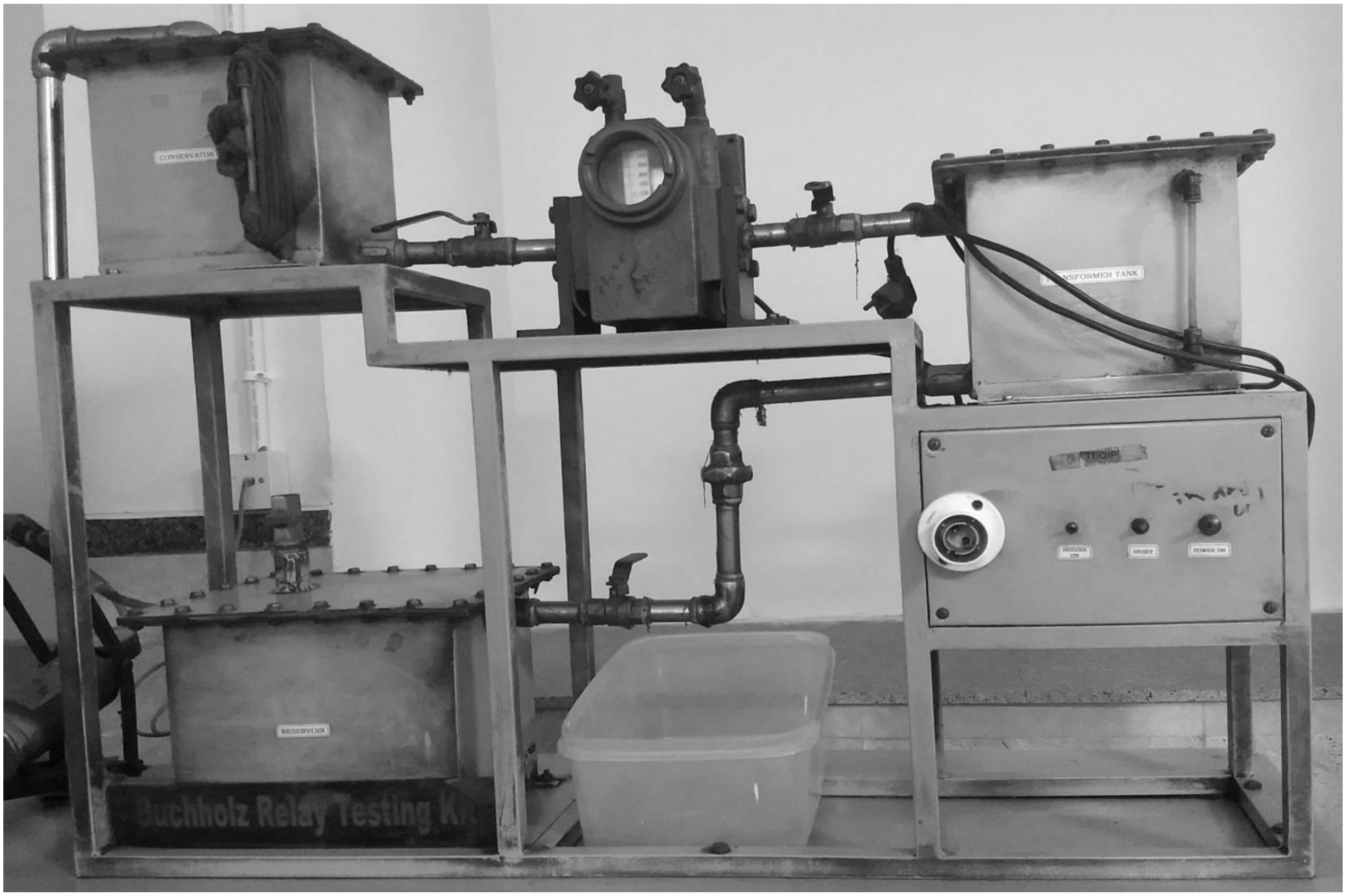
Buchholz relay function is based on very simple mechanical phenomenon. It is mechanically actuated. Whenever there will a minor internal fault in the transformer such as an insulation faults between turns, break down of core of transformer, core heating, the transformer insulating oil will be decomposed in different hydrocarbon gases, CO_2 and CO. The gases produced due to decomposition of transformer insulating oil will accumulate in the upper part the Buchholz container which causes fall of oil level in it.

Fall of oil level means lowering the position of float and thereby tilting the mercury switch. The contacts of this mercury switch are closed and an alarm circuit energized. Sometime due to oil leakage on the main tank air bubbles may be accumulated in the upper part of the Buchholz container which may also cause fall of oil level in it and alarm circuit will be energized. By collecting the accumulated gases from the gas release pockets on the top of the relay and by analyzing them one can predict the type of fault in the transformer.

More severe type of faults, such as short circuit between phases or the earth and faults in the tap changing environment, are accompanied by surge of oil which strikes the baffle plate and causes the mercury switch of the lower element to close. This switch energized the trip circuit of the circuit breakers associated with the transformer and immediately isolates the faulty transformer from the rest of the electrical power system by inter tripping breakers associated with both LV and HV sides of the transformer. This is how Buchholz relay functions.

<u>PICTORIAL VIEW OF BUCHHOLZ RELAY APPARATUS</u>:





<u>PROCEDURE</u>:

i. Close all the balls.
ii. Press the air compressor in order to increase the pressure.
iii. Immediately open the valve number 1.
iv. Oil from the tank rushes into the Buchholz relay & fill it completely.
v. Open the output valve of Buchholz relay.
vi. Oil will rush out from the Buchholz relay into tank.
vii. When the oil reaches at the half level, the buzzers starts ringing to show that the low recipient fault has occurred.

EXPERIMENT NO.6

AIM: To study the characteristics of microprocessor based DMT/IDMT over current relay and determines the time current characteristics.

APPARATUS USED:

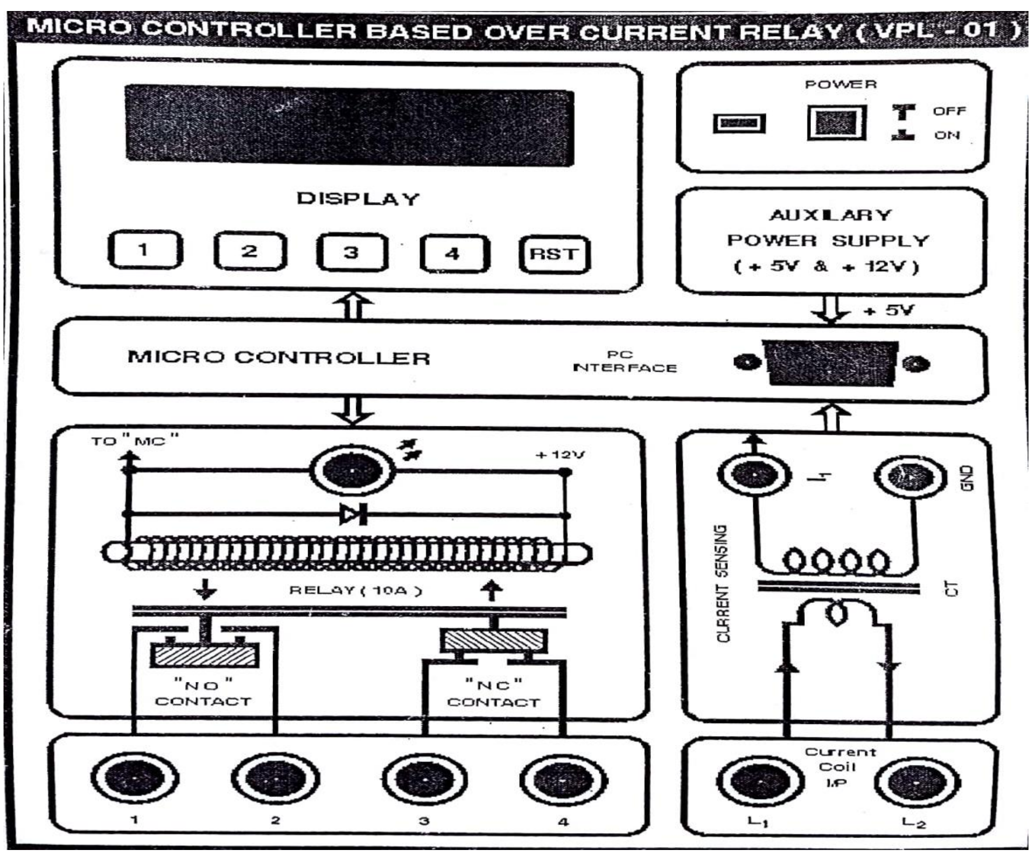
S.no.	Description	Quantity
1	DMT/IDMT over current relay Trainer Kit	1

THEORY:

There are several over current protection such as fuse, thermal relay & IDMT Relay. IDMT (Inverse Definite Minimum Time) Relay is high accuracy over current relay. The over current relay are used to sense the current and over-load currents and trips off the system. Micro controller is used for the control operation. The programming is done in such a way that when the fault current value is above the set value the relay is closed/ opened (depends on connection) and it trips the circuit. The tripping of the relay is indicated by the LED. The LCD displays the set time, set current, fault current and tripping time.

CIRCUIT DIAGRAM:

FRONT PANEL VIEW



PROCEDURE: MICRO CONTROLLER BASED OVER CURRENT RELAY

i. Current source is connected across the banana connector L1 & L2 of VPL-01 module.
ii. Power ON the VPL-01 module (Micro controller based Over Current relay). The LCD display shows the following with a delay of few seconds between each display.
iii.

VI MICROSYSTEMS

VI MICROSYSTEMS PRESENTS

OVER CURRENT RELAY TRAINER

SELECT ANY ONE…

SELECT ANY ONE 1. DMT…….. 2.IDMT………

The selection between types of relay should be made by pressing the appropriate buttons in the display. The details of buttons in the display.

1-Selecting and incrementing

2-Selecting and decrementing

3-Cursor movement

4-Enter RST-Reset the relay system.

The type of operation to be carried out is displayed and is selected by the buttons 1 or 2.

Select buttons

1. DMT (Definite Minimum Time)
2. IDMT(Inverse Definite Minimum Time)

I. SELECT IDMT

1. IDMT is selected by pressing 2, then the set Current (Is) of the relay unit is to be entered. The LCD displays,

ENTER AMP : 00.1 A

……………[0.1-15A]

Set the current value by using 1, 2 & 3 buttons

ENTER AMP : 00.1 A

……………[0.1-15A]

2. The button 4 is pressed. (All the set values are sent to the processor). Now the display shows.

ENTER TMS : 00.1 s

……………[0.1-2s]

3. Set the Relay reset time by using 1, 2 & 3 buttons.

ENTER TMS : 0.7

……………[0.1-2s]

The Time Multiplier Setting (TMS) value is to be entered. The range of TMS is 0.1 to 0.2s. This value is entered by pressing 4.
If the fault Current< Set current the LCD displays the current values by default as

SET CURRENT : 05.0A

CURRENT :3

Now press the RST button. Again set the same values and set the fault current is above the set Current.

4. If the fault Current > set Current then the LCD displays

OVER CURRENT Time: 01.0s

To calculate time for relay tripping is obtained from the formula.

$$t = TMS * \left[\frac{K}{\left(\frac{1}{Is}\right)^{\propto} - 1}\right] + C$$

5. The time starts to increase from 0.1s to until end of the calculated time in sec, then the relay coil is energized and tips the relay contacts. At the same time LED glows. After shows the LCD display.

Relay Tripped Due to Over Current

6. Now LCD displays the following one by one continuously until the relay system is reset and LED is glow.

SET AMP : 05.0A Tripped AMP: 10.0

Set TMS: 0.7S

Calc Time : ….. s Trip Time : ….. s

7. Press the RST button, reset the processor and relay tripping action.

II. SELECT DMT

1. The DMT operation tab is selected by pressing 1. The LCD displays the following.

ENTER AMP : 00.1 A ……………[0.1-15A]

Set the current value by using 1, 2 & 3 buttons

ENTER AMP : 00.1 A ……………[0.1-15A]

2. The button 4 is pressed. (All the set values are sent to the processor). Now the display shows.

ENTER TIME : 000 s ……………[0-300s]

Set the reset Time value by using 1, 2 & 3 buttons

ENTER TIME : 007S ……………[0-300s]

3. Press the button 4.
4. The time starts to increase from 1s to until 007s. After 007s the relay coil is energized and trips the relay contacts. At the same time LED glows. After relay is tripped the LCD displays it as

OVER Tripped Set : 7s T:7s

After the tripping of relay, the following messages are displayed one by one continuously until the system is reset.

Relay Tripped Due to Over Current

SET AMP : 05.0A Tripped AMP: 10.0A

Set DMT TIME: 7S Tripped Time: 7

The relay system is reset by pressing RST button.

OBSERVATION TABLE:

IDMT

S.NO.				

DMT

S.NO.				

RESULT: Characteristics of IDMT relay are drawn after performing the test.

EXPERIMENT- 7

AIM: Testing of negative sequence relay using the negative sequence kit against negative sequence current under balanced and unbalanced load condition.

APPARATUS USED:

S.no.	Description	Quantity
1	VPL-04mcl	2
2	3-Phase load	1
3	3-Phase Variac	1
4	Patch Chords	1

THEORY: The negative relays are also called unbalanced relays because these relays provide protection against negative sequence component of unbalanced currents existing due to unbalanced loads or phase-phase faults. The unbalanced currents are dangerous from generators and motors point of view as these currents can cause overheating. Negative sequence relays are generally used to give protection to generators and motors against unbalanced currents.

A negative sequence relay has a filter circuit which is operative only for negative sequence components. Low order of over current also causes dangerous situations hence a negative sequence relay has low current settings. The earth relay provides protection for phase to earth fault but not for phase to phase fault. A negative sequence relay provides protection against phase to phase faults which are responsible to produce negative sequence components.

PROCEDURE:

a) **Balanced Load Condition**

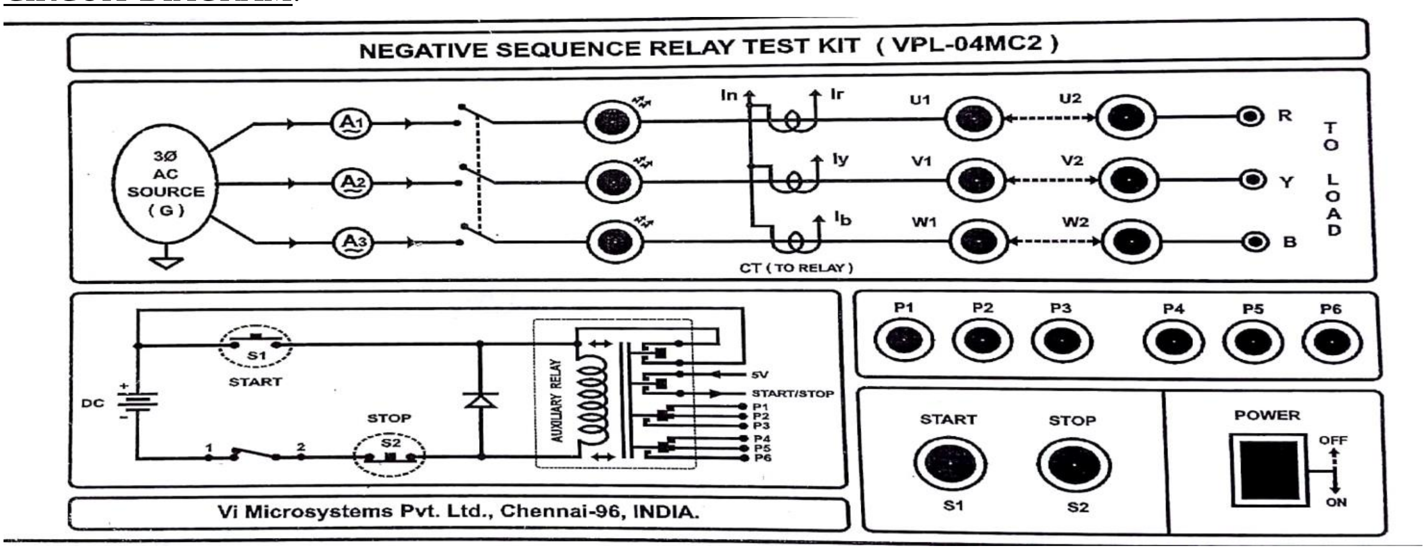
1. Initially keep the MCB and switches in the test kit in OFF condition.
2. Connect Power chord at the back of the module.
3. Give 3-Phase positive sequence supply to the input terminals of Variac.
4. Output of the variac should be connected to the R, Y, B and N terminals which is given along the side panel of the test kit.
5. Connect terminal U1 to U2, V1 and V2 and W1 &W2 as per the connection diagram.
6. Connect R, Y and B terminals which are given in the front panel of test kit to the 3-phase load terminal.
7. Now switch on the three phase mains.
8. Switch on the three phase MCB and ON/OFF switch in the front panel of the negative sequence test kit.
9. Switch on the 3-phase load.
10. Switch on the supply on the negative sequence panel.

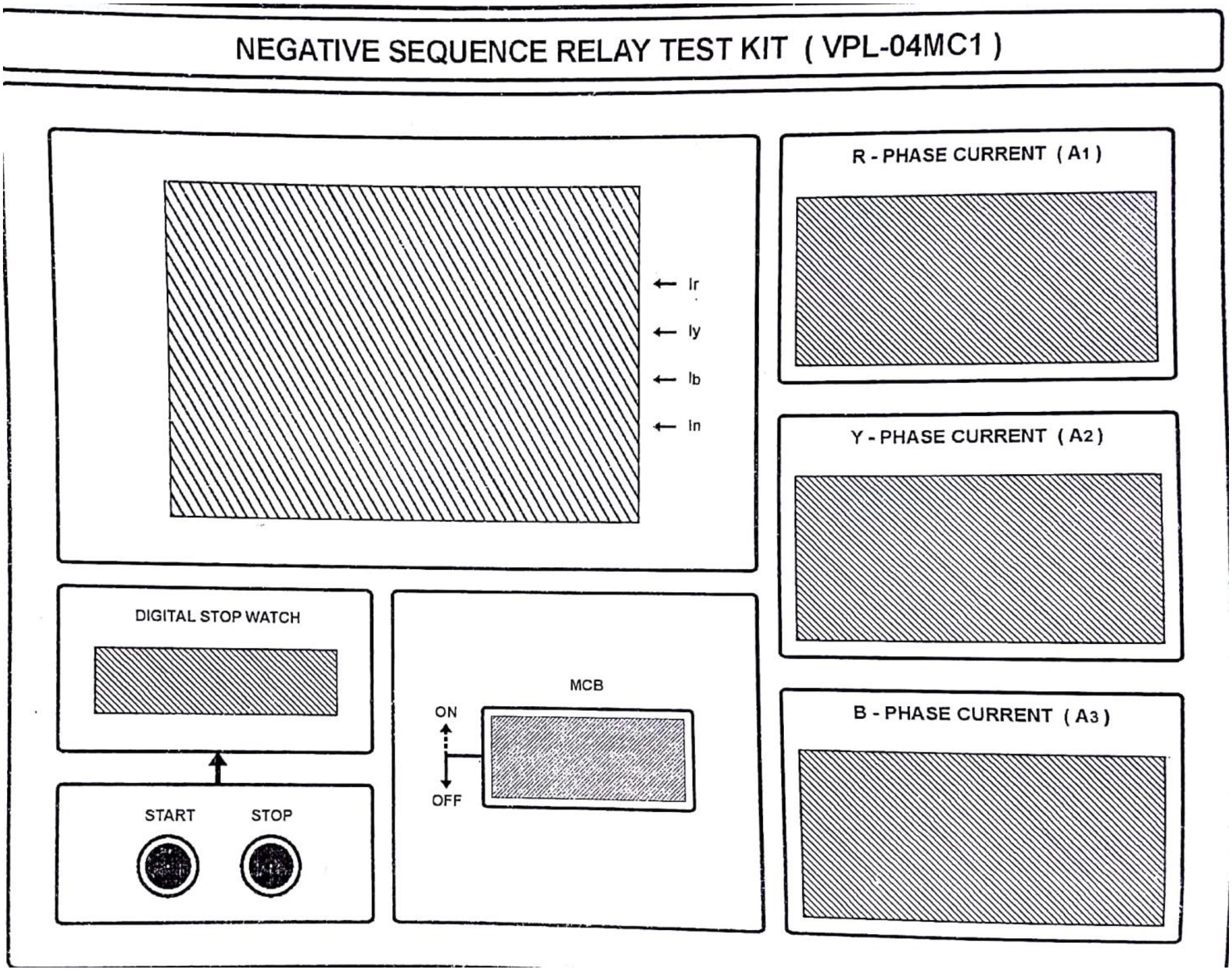
11. Reset the digital timer using the reset switch given in the front panel.
12. Now increase the 3-phase input voltage. So that the current through the relay should be more than the relay coil rating.
13. Measure the three phase current.
14. The negative sequence relay will trip according to internal time setting of the relay, when current through the relay coil reaches the coil current rating.
15. The similar experiment can be performed by reversing the input phase supply terminals fron RYB to RBY or BYR.

b) **Unbalanced Load Condition**

1. Switch on the three phase mains.
2. Switch on the three phases MCB and ON/OFF switch in the front panel of the negative sequence test kit.
3. Switch on the 3-phase load.
4. Switch on the supply on the negative sequence panel.
5. Reset the digital timer using the reset switch given in the front panel.
6. Now increase the 3-phase input voltage using the three phase variac and keep the variac in maximum position.
7. Measure the three phase current.
8. Now switch off the R-phase load by using the switch which is placed in three phase load.
9. Now ammeter shows the actual unbalanced current existing in the system.
10. Due to unbalanced load, negative sequence current will flow through the coil and the relay will trip after some time according to the internal time setting of the given relay.
11. The similar experiment can be performed by making unbalance condition on the other phases also.

CIRCUIT DIAGRAM:





RESULT:

Thus the testing of negative sequence relay using the negative sequence kit under both balanced and unbalanced load condition has been performed.

EXPERIMENT NO. 8

<u>AIM</u>: To study and test the Electromechanical Over Current Relay at different current setting in IDMT mode.

<u>APPARATUS USED</u>:

S.no.	Description	Quantity
1	VPL-102A Module	1
2	PC Power Chord	1
3	SP6 Patch Chords	1

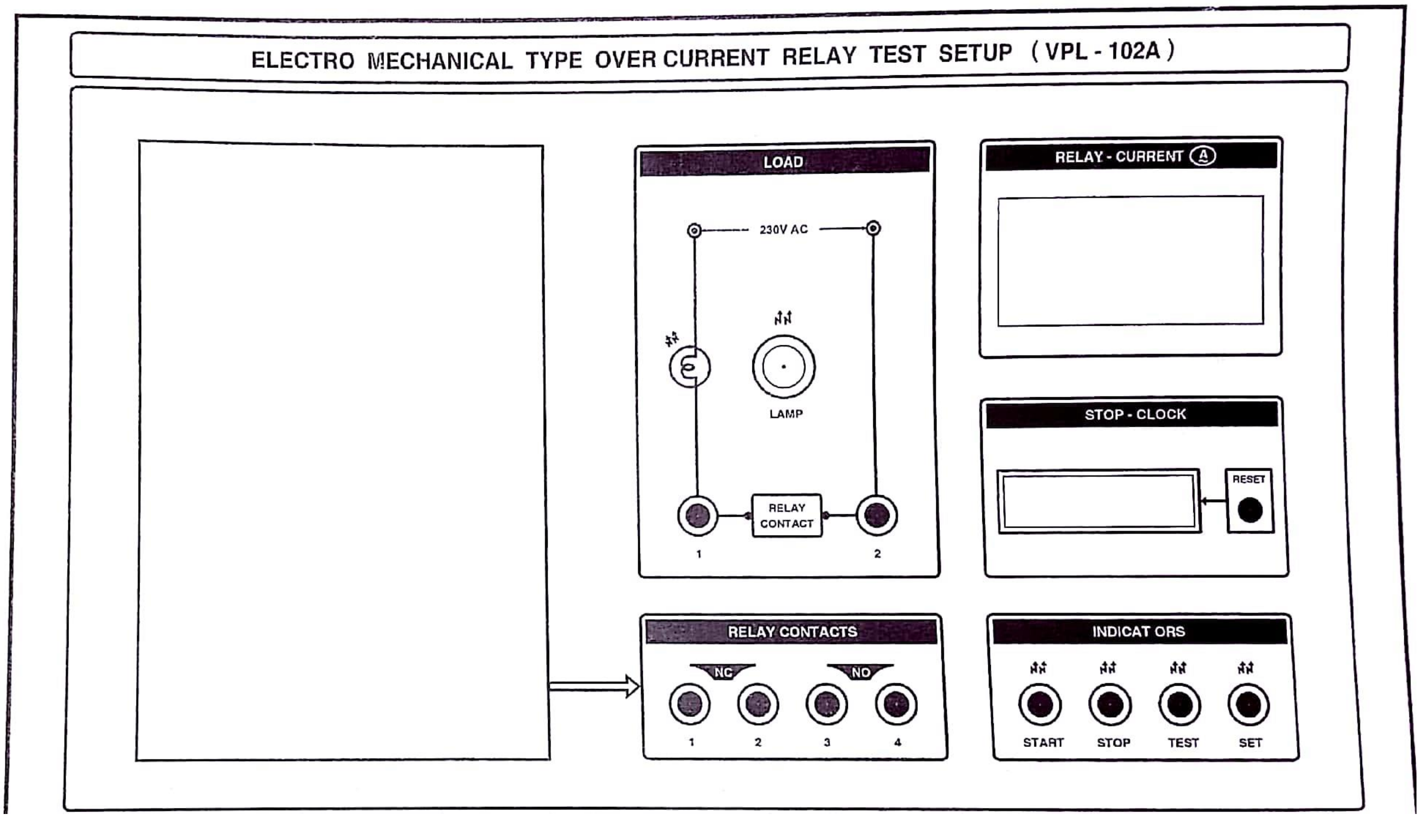
<u>THEORY</u>:

In a power system consisting of generators, transformers, transmission and distribution circuits, it is inevitable that some failure will occur somewhere in the system. When a failure occurs in any part of the system, it must be quickly detected and disconnected from the system. There are two principal reasons for it. Firstly, if the fault is not cleared quickly, it may cause unnecessary interruption of service to the customers. Secondly, rapid disconnection of faulted apparatus limits the amount of damage to it and prevents the effect of fault from spreading into the system.

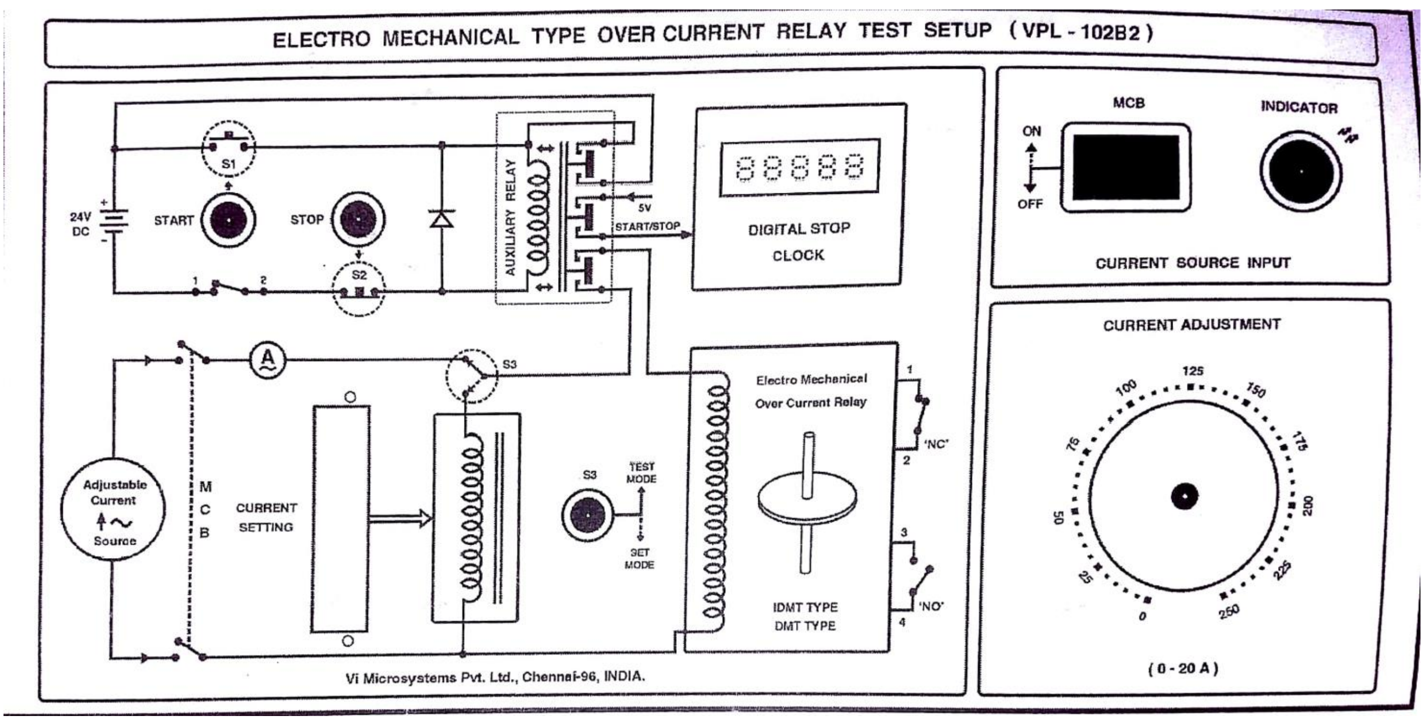
The detection of a fault and disconnection of a faulty section or apparatus can be achieved by using fuses or relays in conjunction with circuit breakers. A fuse performs both detection and interruption functions automatically but its use is limited for the protection of low-voltage circuits only. For high voltage circuits, relays and circuit breakers are employed to serve the desired function of automatic protective gear. The relays detect the fault and supply information to the circuit breaker, which performs the function of circuit interruption.

A Protective relay is a device that detects the fault and initiates the operation of the circuit breaker to isolate the defective element from the rest of the system. The relays detect the abnormal conditions in the electrical circuits by constantly measuring the electrical quantities, which are different under normal and fault conditions. The electrical quantities which may change under fault conditions are voltage, current, frequency and phase angle. The over current relay is a type of relay which operates when the current exceeds above the set value.

FIGURE



ELECTRO MECHANICAL TYPE OVER CURRENT RELAY TEST SETUP (VPL - 102A)
LOAD
230V AC
LAMP
RELAY CONTACT
1
2
RELAY - CURRENT (A)
STOP - CLOCK
RESET
RELAY CONTACTS
NC
NO
1
2
3
4
INDICATORS
START
STOP
TEST
SET



ELECTRO MECHANICAL TYPE OVER CURRENT RELAY TEST SETUP (VPL - 102B2)
24V DC
START
STOP
S1
S2
AUXILIARY RELAY
5V
START/STOP
DIGITAL STOP CLOCK
MCB
ON
OFF
INDICATOR
CURRENT SOURCE INPUT
Adjustable Current Source
M C B
CURRENT SETTING
S3
TEST MODE
SET MODE
Electro Mechanical Over Current Relay
'NC'
'NO'
IDMT TYPE
DMT TYPE
CURRENT ADJUSTMENT
(0 - 20 A)
Vi Microsystems Pvt. Ltd., Chennai-96, INDIA.

PROCEDURE:

Connection Procedure

1. Keep all the switches in OFF position.
2. Keep the current adjustment knob in minimum position.
3. Plug the plug setting at desired current value.
4. Connect desired relay contact that may be NO (or) NC Contact to the load terminal.

Experimental Procedure

1. Switch ON the power supply.
2. Switch ON the MCB ON/OFF switch.
3. Press the start button S1. Now start LED glows.
4. Set the fault current value using current adjustment knob provided on the front panel before the relay will trip. Now the stop clock also in running condition.
5. After setting the fault current then press the stop button S2 and also press the stop clock reset button to calculate the relay tripping time correctly.
6. Now press the start button S1. The stop clock starts counting and when relay trips, it stops counting. During the interval the disc in the relay will rotate.
7. When the relay coil trips, the disc returns to the normal (original) position. Note down the relay current from the RELAY-CURRENT meter and trip time from the stop clock.
8. To repeat the above experiment for the various fault current values do the above procedure.
9. Take the different readings by applying the different fault current values and tabulate all the readings and draw the graph between different fault current value and the corresponding actual tripping time.

S.NO.	Plug setting value	Fault current value	Theoretical tripping time	Actual tripping time

IDMT Characteristic curves:

An inverse-time relay is one in which the operating time is approximately inversely proportional to the magnitude of the actuating quantity. Figure 1 shows the time-current characteristics of an inverse current relay.

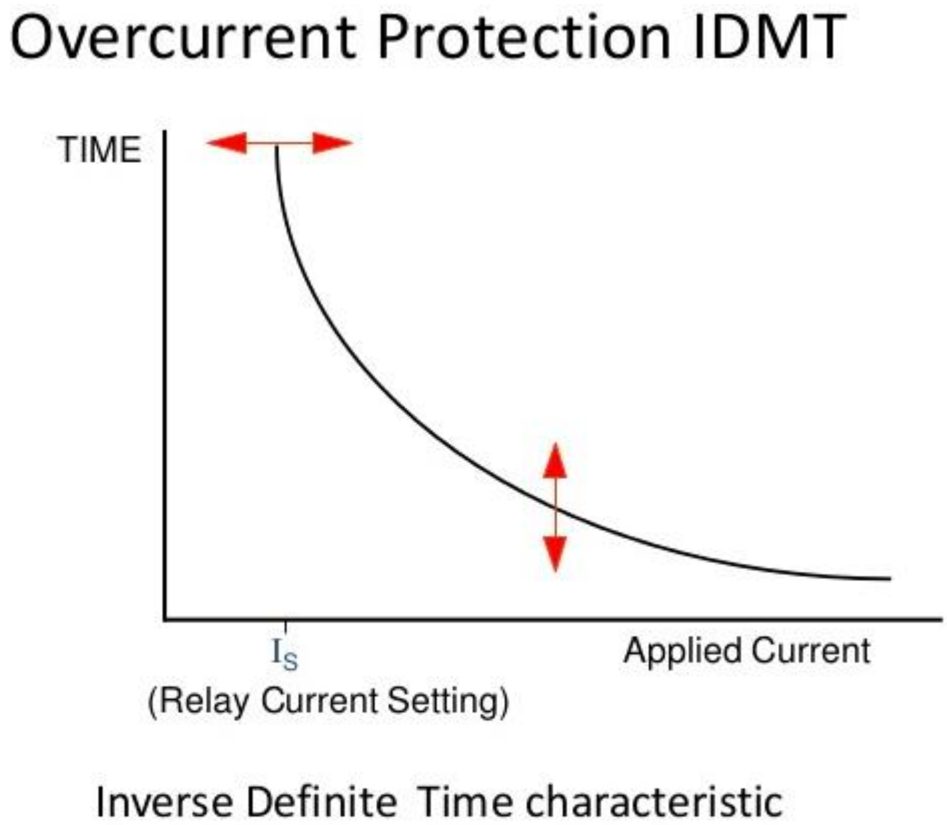


Figure 1, Inverse Time Characteristics of Electromechanical Type Over Current Relay

RESULT:

The Electromechanical Type Over Current Relay at different current setting in IDMT mode are studied.

EXPERIMENT NO. 9

<u>AIM</u>: To study Micro Controller Based Over/Under Voltage Relay

<u>APPARATUS:</u> -

S.no.	Description	Quantity
1	VPL-05 Module	1

<u>THEORY</u>:

Over/Under voltage relays are provided in AC circuits, bus bars, motors, rectifiers, and transformers etc., for voltage control and reactive power control of network buses and load buses. These relays can have instantaneous characteristics or inverse characteristics depending upon the construction and design. A define minimum time delay is provided in both types because the electrical apparatus must be capable of withstanding overload. Time delay is achieved by programming in the microcontroller which depends upon the amount of fault current.

i. FRONT PANEL VIEW

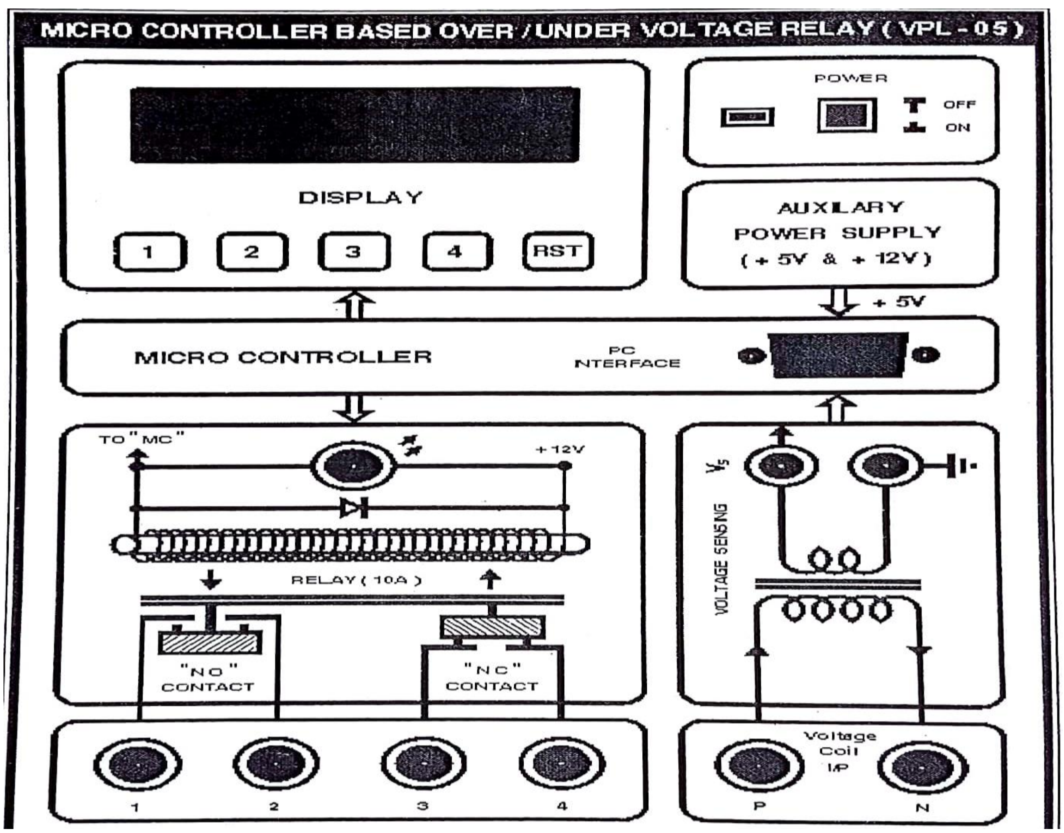


Figure-1 Front Panel of VPL-05 Module

ii. FRONT PANEL DESCRIPTION

Display

LCD – Display the selection, set mode and relay status.

1- Increment the Current and time settings.

2– Decrement the Current and time settings.

3– Cursor movement

4–Enter the setting values & set to the processor.

RST -Reset the all current setting values.

‘9’ PIN ‘D’ Connector – Its used to interface with PC.

Power- Power N/OFF the Switch.

LED (Indicate the relay tripping action)

LED ‘ON’ – Relay Trip

LED ‘OFF’- Relay is normal condition (not Trip)

Current Sensing – Current sensing output = 5VAC

Banana Connector

P & N (Voltage Coil) – Apply input Voltage(0-400V)

NO Contact – This terminal indicates the relay is normally in closed condition after relay tripped, this two terminal is closed with relay contacts.

NC Contact- This terminal indicates the relay is normally closed condition after relay tripped, this two terminal is opened with relay contacts.

PROCEDURE:

1. Initially auto transformer is in minimum position.
2. Connect Power card to auto transformer primary and secondary is connected to primary of step up transformer (230/400V).
3. Step up transformer secondary is connected to banana connector P & N (Voltage coil input) of VPL-05 module.
4. Power ON the Auto transformer.
5. Adjust the auto transformer at 50% of voltage.
6. Power ON the VPL-05 module. The LCD display shows the following with a delay of few seconds between each display.

VI MICROSYSTEMS PRESENTS

VOLTAGE RELAY TRAINER

SELECT ANY ONE…
1.DMT…. 2.IDMT

7. The selection between type of relay of relay should be made by pressing the appropriate buttons in the display.

The details of buttons in the display

1-Selecting and incrementing

2- Selecting and incrementing

3- Cursor movement

4-Enter

RST- Reset the relay system

8. The LCD display shows the two relay system. First select over voltage relay and then afterwards select under voltage relay.
9. Then select from DMT (Define Minimum Time) and IDMT (Inverse Definite Minimum Time)

OVER VOLTAGE RELAY

i. Select IDMT

1. The IDMT operation can be selected by pressing 2.The set Voltage V(s) has to be entered. The LCD displays the following.

ENTER VOLTAGE : 10V

………. [10-375V]……..

Set the voltage value by using 1, 2 &3 buttons

ENTER VOLTAGE :100V

………. [10-375V]……..

2. The button 4 is pressed. (All the set values are sent to the processor). Now the display shows.

ENTER TMS : 0.1s

………[0.1-2s]….

3. Set the Reset Time value by using 1, 2 & 3 buttons.

ENTER TMS : 0.7s

………[0.1-2s]….

The Time Multiplier Setting (TMS) value is to be entered. The range of TMS is 0.1 to 2s. This value is entered by pressing 4.

NOTE:

If the fault current < set Current the LCD displays the Current values by default as

SET VOLTAGE :100V

Voltage: 25 V

Now press the RST button. Again set the same values and set the fault voltage is the set Voltage.

4. If the fault voltage > set voltage the LCD displays

OVER VOLTAGE
Time: 1s

The calculate time for relay tripping is obtained from the formula.

$$t = TMS \times \left[\frac{K}{\frac{V}{V_S}^{\alpha} - 1}\right] + C$$

The IDMT used is of normal inverse type. So the values of k, α, C are constant and are K=0.14, α=0.02 and C=0. I is the fault Voltage and Vs is the set Voltage of the relay unit.

5. The time starts to increase from 0.1S to until end of the calculated time in sec, then the relay coil is energized and trips the relay contacts. At the same time LED glows. After shows the LCD display.

Relay Tripped…
Due to Over Voltage

6. Now LCD displays the following message one by one continuously until the relay system is reset and LED is glow.

Set VOLTAGE : 100V
Tripped VOLTAGE : 200

Set TMS : 0.7S

Calc Time : 4s
Trip Time: 4s

7. Press the RST button, Reset the processor and Relay tripping action.

ii. SELECT DMT

1. The DMT operation can be selected by pressing 1. The LCD displays the following.

ENTER VOLTAGE : 10V

………. [10-375V]……..

Set the current value by using 1, 2 &3 buttons

ENTER VOLTAGE :100V

………. [10-375V]……..

2. The button 4 is pressed. (All the set values are sent to the processor). Now the display shows.

ENTER TIME : 000s

………[0-300s]….

Set the Reset Time value by using 1, 2 & 3 buttons

ENTER TIME : 007s

………[0-300s]….

3. Press the button 4.

4. The time starts to increase from 1S to until 007S. After 007S the relay coil is energized and trips the replay contacts. At the same time LED glows. After relay is tripped the LCD displays it as.

OVER Tripped…….   SET : 7S T:7S

After the tripping of relay, the following messages are displayed one by one continuously until the system is reset.

Relay Tripped…….   Due to Over Voltage

Set voltage: 100V   Tripped VOLTAGE : 200

Set DMT TIME : 7s   Tripped Time: 0.7

5.The relay system is reset by pressing RST button.

TABULATION:

IDMT

S.NO.	Set Voltage (V)	Fault Voltage (V)	Time Multiplier Setting (sec)	Calculated Relay tripping Time (sec)	Actual Relay Tripping Time(sec)

DMT:

S.NO.	Set Voltage (V)	Fault Voltage (V)	Set Time (sec)	Actual Relay Tripping Time(sec)

UNDER VOLTAGE RELAY

i. **Select IDMT**

1. The IDMT operation can be selected by pressing 2.The set Voltage V(s) has to be entered. The LCD displays the following.

ENTER VOLTAGE : 10V ………. [10-375V]……..

Set the voltage value by using 1, 2 &3 buttons

ENTER VOLTAGE :100V ………. [10-375V]……..

2. The button 4 is pressed. (All the set values are sent to the processor). Now the display shows.

ENTER TMS : 0.1s ………[0.1-2s]….

3. Set the Reset Time value by using 1, 2 & 3 buttons.

ENTER TMS : 0.7s

………[0.1-2s]….

The Time Multiplier Setting (TMS) value is to be entered. The range of TMS is 0.1 to 2s. This value is entered by pressing 4.

NOTE:

If the fault current < set Current the LCD displays the Current values by default as

SET VOLTAGE : 100V

Voltage: 200 V

Now press the RST button. Again set the same values and set the fault voltage is the set Voltage.

4. If the fault voltage > set voltage the LCD displays

UNDER VOLTAGE
Time: 1s

The calculate time for relay tripping is obtained from the formula.

$$t = \text{TMS X} \left[\frac{K}{\frac{V}{V_S}^{\alpha} - 1}\right] + C$$

The IDMT used is of normal inverse type. So the values of k, α, C are constant and are K=0.14, α=0.02 and C=0. I is the fault Voltage and Vs is the set Voltage of the relay unit.

5. The time starts to increase from 0.1S to until end of the calculated time in sec, then the relay coil is energized and trips the relay contacts. At the same time LED glows. After shows the LCD display.

Relay Tripped…
Due to Under Voltage

6. Now LCD displays the following message one by one continuously until the relay system is reset and LED is glow.

Set VOLTAGE : 100V
Tripped VOLTAGE : 50

Set TMS : 0.7S

Calc Time : 4s
Trip Time: 4s

7. Press the RST button, Reset the processor and Relay tripping action.

ii. SELECT DMT

1. The DMT operation can be selected by pressing 1. The LCD displays the following.

ENTER VOLTAGE : 10V

………. [10-375V]……..

Set the current value by using 1, 2 &3 buttons

ENTER VOLTAGE :100V

………. [10-375V]……..

2. The button 4 is pressed. (All the set values are sent to the processor). Now the display shows.

ENTER TIME : 000s

………[0-300s]….

Set the Reset Time value by using 1, 2 & 3 buttons

ENTER TIME : 007s

………[0-300s]….

3. Press the button 4.

4. The time starts to increase from 1S to until 007S. After 007S the relay coil is energized and trips the replay contacts. At the same time LED glows. After relay is tripped the LCD displays it as.

OVER Tripped…….

SET : 7S T:7S

After the tripping of relay, the following messages are displayed one by one continuously until the system is reset.

Relay Tripped…….
Due to Over Voltage

Set voltage: 100V Tripped VOLTAGE : 200

Set DMT TIME : 7s Tripped Time: 7

5.The relay system is reset by pressing RST button.

TABULATION:

IDMT

S.NO.	Set Voltage (V)	Fault Voltage (V)	Time Multiplier Setting (sec)	Calculated Relay tripping Time (sec)	Actual Relay Tripping Time(sec)

DMT:

S.NO.	Set Voltage (A)	Fault Voltage (A)	Set Time (sec)	Actual Relay Tripping Time(sec)

RESULT: Microcontroller based over/under voltage relay has been studied.

EXPERIMENT NO. 10

<u>AIM</u>: To study Micro Controller Based Earth fault relay.

<u>APPARATUS:</u> -

S.no.	**Description**	**Quantity**
1	VPL-04 Module	1

<u>THEORY</u>:

The earth fault relay is used to provide protection against any earth fault in the windings of the transformer. The earth relay does not get actuated when there is a balanced flow of current in the windings of transformer. Hence no current spills into the earth fault relay. But, when there is an earth fault in the protected zone, (i.e. when phase is connected to earth) no longer the balanced current flows in the transformer windings. Now the earth fault relays is energized and the circuit breaker is opened. The earth fault is of two types.

1. Electro mechanical type relay

2. Static relay

iii. FRONT PANEL VIEW

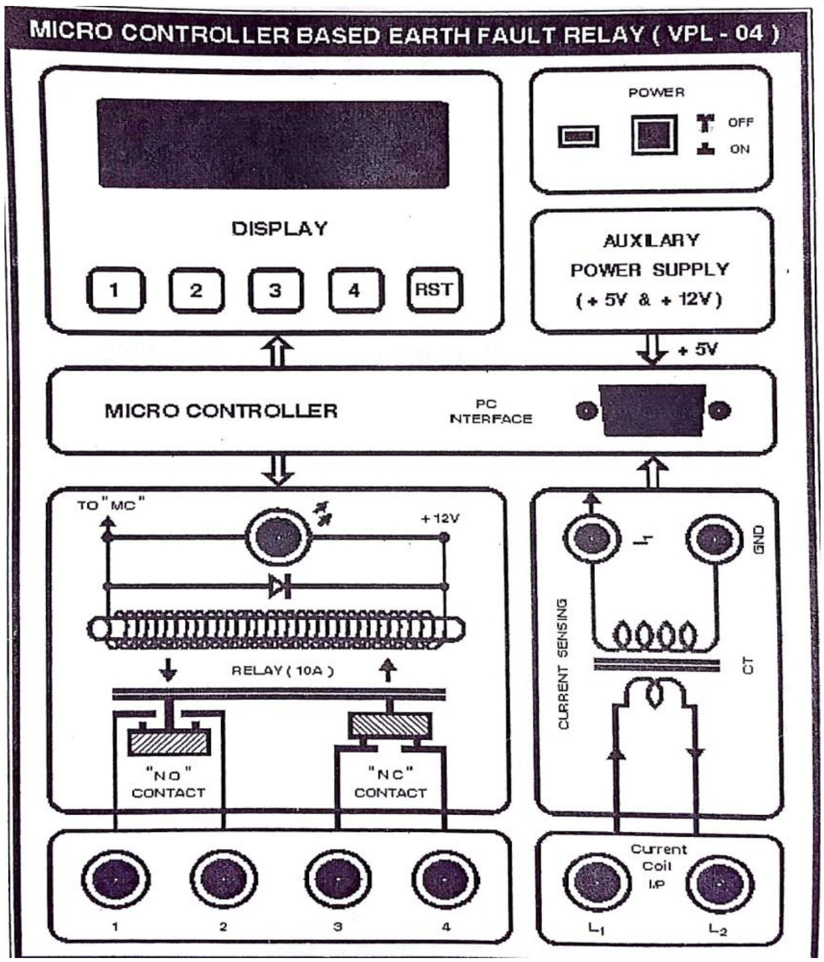


Figure-1 Front Panel of VPL-04 Module

iv. FRONT PANEL DESCRIPTION

Display

LCD – Display the selection, set mode and relay status.

1- Increment the Current and time settings.

2– Decrement the Current and time settings.

3– Cursor movement

4–Enter the setting values & set to the processor.

RST -Reset the all current setting values.

‘9’ PIN ‘D’ Connector – Its used to interface with PC.

Power- Power N/OFF the Switch.

LED (Indicate the relay tripping action)

LED ‘ON’ – Relay Trip

LED ‘OFF’- Relay is normal condition (not Trip)

Current Sensing – Current sensing output = 5VAC

Banana Connector

P & N (Voltage Coil) – Apply input variable current (0-20A)

NO Contact – This terminal indicates the relay is normally in closed condition after relay tripped, this two terminal is closed with relay contacts.

NC Contact- This terminal indicates the relay is normally closed condition after relay tripped, this two terminal is opened with relay contacts.

PROCEDURE:

1. Current source is connected to across the banana connector L1& L2 of VPL-04 module.
2. Power ON the VPL-04 module. The LCD display shows the following with a delay of few seconds between each display.

VI MICROSYSTEMS PRESENTS

OVER CURRENT RELAY TRAINER

SELECT ANY ONE… 1.DMT…. 2.IDMT

3. The selection between type of relay of relay should be made by pressing the appropriate buttons in the display.

The details of buttons in the display

1-Selecting and incrementing

2- Selecting and incrementing

3- Cursor movement

4-Enter

RST- Reset the relay system

The type of operation to be carried out is displayed and is selected by buttons 1 and 2. Select from DMT (Define Minimum Time) and IDMT (Inverse Definite Minimum Time)

i. Select IDMT

1. The IDMT operation can be selected by pressing 2.The set Current I(s) has to be entered. The LCD displays the following.

ENTER AMP : 0.01A ………. [0.01-1.5A]……..

Set the voltage value by using 1, 2 &3 buttons

ENTER AMP :0.5A ………. [0.01-1.5A]……..

2. The button 4 is pressed. (All the set values are sent to the processor). Now the display shows.

ENTER TMS : 0.1s ………[0.1-2s]….

3. Set the Reset Time value by using 1, 2 & 3 buttons.

ENTER TMS : 0.7s ………[0.1-2s]….

The Time Multiplier Setting (TMS) value is to be entered. The range of TMS is 0.1 to 2s. This value is entered by pressing 4.

NOTE:

If the fault current < set Current the LCD displays the Current values by default as

SET CURRENT :0.50A Current: 0.30

Now press the RST button. Again set the same values and set the fault current is the set Current.

4. If the fault current > set current the LCD displays

OVER CURRENT Time: 1s

The calculate time for relay tripping is obtained from the formula.

$$t = \text{TMS X} \left[\frac{K}{\frac{I}{I_S}^{\alpha} - 1} \right] + C$$

The IDMT used is of normal inverse type. So the values of k, α, C are constant and are K=0.14, α=0.02 and C=0. I is the fault Voltage and Vs is the set Voltage of the relay unit.

5. The time starts to increase from 0.1S to until end of the calculated time in sec, then the relay coil is energized and trips the relay contacts. At the same time LED glows. After shows the LCD display.

Relay Tripped… Due to Over Voltage

6. Now LCD displays the following message one by one continuously until the relay system is reset and LED is glow.

Set AMP : 0.50A Tripped AMP : 1

Set TMS : 0.7S

Calc Time : s Trip Time: s

7. Press the RST button, Reset the processor and Relay tripping action.

ii. SELECT DMT

1. The DMT operation can be selected by pressing 1. The LCD displays the following.

ENTER AMP : 0.01A ………. [0.1-1.5A]……..

Set the current value by using 1, 2 &3 buttons

ENTER AMP :0.50A ………. [0.1-1.5A]……..

2. The button 4 is pressed. (All the set values are sent to the processor). Now the display shows.

ENTER TIME : 000s ………[0-300s]….

Set the Reset Time value by using 1, 2 & 3 buttons

ENTER TIME : 007s ………[0-300s]….

3. Press the button 4.

4. The time starts to increase from 1S to until 007S. After 007S the relay coil is energized and trips the replay contacts. At the same time LED glows. After relay is tripped the LCD displays it as.

OVER Tripped……. SET : 7S T:7S

After the tripping of relay, the following messages are displayed one by one continuously until the system is reset.

Relay Tripped……. Due to Over Current

Set current: 0.50A Tripped CURRENT : 1

Set DMT TIME : 7s Tripped Time: 7

5.The relay system is reset by pressing RST button.

TABULATION:

IDMT

S.NO.	Set Current (A)	Fault Current (A)	Time Multiplier Setting (sec)	Calculated Relay tripping Time (sec)	Actual Relay Tripping Time(sec)

DMT:

S.NO.	Set Current (A)	Fault Current (A)	Set Time (sec)	Actual Relay Tripping Time(sec)

RESULT: Microcontroller based earth fault relay has been studied.

EXPERIMENT NO. 11

<u>AIM</u>: To study the Earth fault Relay for AC Motor Phase to Earth fault protection using Earth fault relay test setup trainer module (VPL-04A).

<u>APPARATUS:</u> -

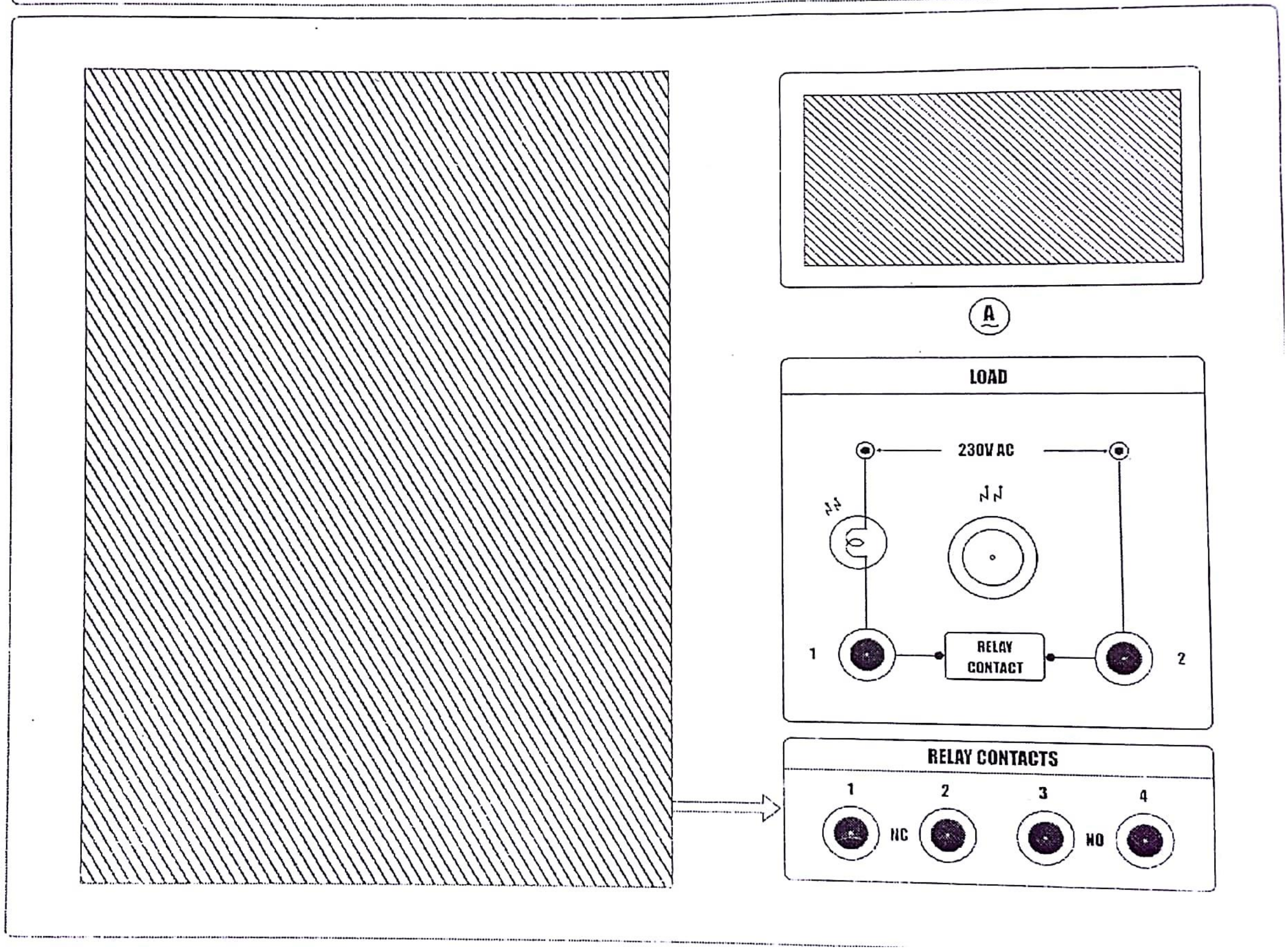
S.no.	Description	Quantity
1	VPL-04 Module	1
2	0.5 HP AC motor	1
3	Rheostat (330 ohm, 3A)	1
4	Portable Ammeter (0-10A)	1
5	Patch Chords	1

<u>THEORY</u>:

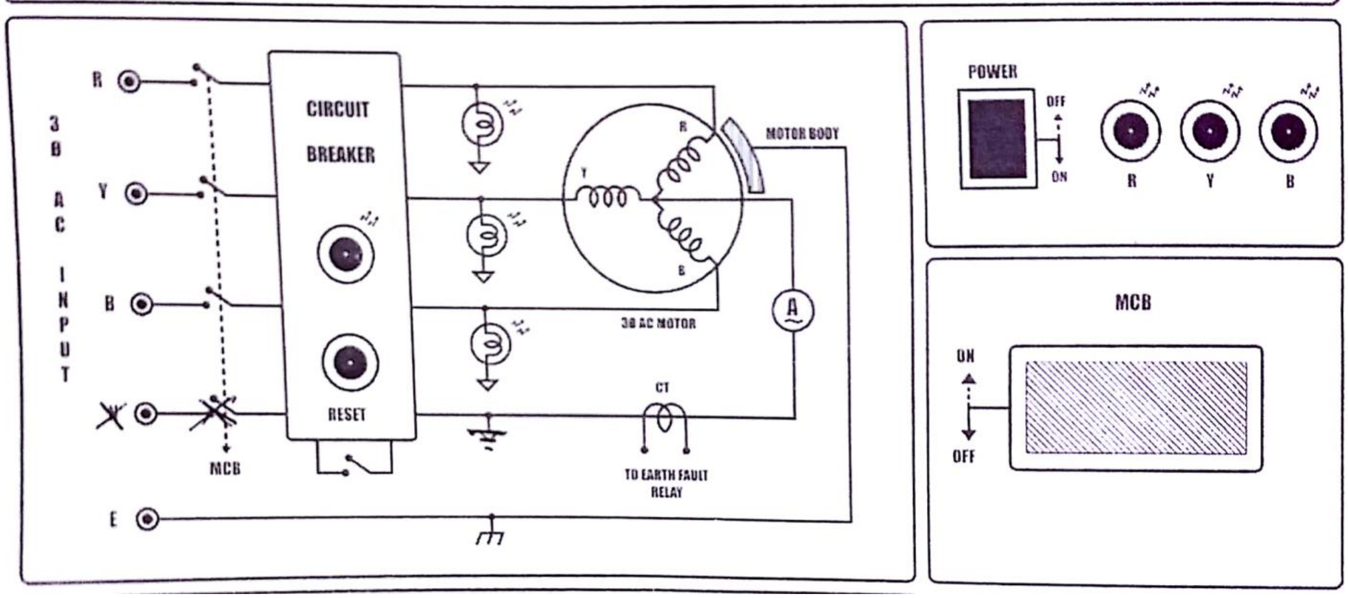
In electrical engineering, a protective relay is a relay device designed to trip a circuit breaker when a fault is detected. The first protective relays were electromagnetic devices, relying on coils operating on moving parts to provide detection of abnormal operating conditions such as over-current, over-voltage, reverse power flow, over-frequency, and under-frequency.

The relays detect the abnormal conditions in the electrical circuits by constantly measuring the electrical quantities, which are different under normal and fault conditions. The electrical quantities which may change under fault conditions are voltage, current, frequency and phase angle. The earth fault relay is a type of relay which operates when the earth current exceeds the set value.

ELECTRO MECHANICAL TYPE EARTH FAULT RELAY TEST SETUP (VPL-04A) ❶



ELECTRO MECHANICAL TYPE EARTH FAULT RELAY TEST SETUP (VPL-04A) ❷



CONNECTIONS:

1. Give 1ф supply to module setup, connect 3ф AC input supply R,Y and B to test setup through the terminals provided on the right side of the module. Black connector is the earth terminal.

2.Connect motor input R, Y, B and Neutral terminals to the 3 ф AC output terminals provided on the left side of the module (Black terminal is neutral).

3. Connect desired relay contact (may be NO or NC contacts) to the Load terminal.

4. Connect one of the phase terminal of the motor to the earth through rheostat and portable ammeter to the machine body. Machine body should be earthed.

PROCEDURE:

1. Set the earth fault relay plug setting value in any of the values.
2. Switch ON the power supply to the module.
3. Switch ON the power ON/OFF switch in the test set-up. And reset the circuit breaker.
4. Switch ON the 3ф power supply.
5. Switch ON the MCB ON/OFF switch.
6. Apply 3 ф AC voltage gradually to the module. The motor starts to rotate.
7. Digital Ammeter shows the neutral current of the motor which is the fault current for relay.
8. When the earth fault current reaches the set value the relay trips according to the fault current.
9. Ammeter displays the fault current at which the relay trips.
10. To apply the various fault current value adjust the rheostat and watch the current through the rheostat in the ammeter which should not exceed the rheostat current rating.
11. After the relay trip the circuit breaker will break the main supply. And the motor will stop rotate.
12. To repeat the above experiment for the various fault current values first switch of the MCB and make the rheostat at the maximum position. Then reset the Circuit Breaker.

RESULT:

The Earth fault relay for AC Motor Phase to earth fault protection using earth fault relay test setup trainer module (VPL-04A)

EXPERIMENT NO. 12

AIM: To determine the voltage distribution and string efficiency across the string of insulators with and without guard ring.

APPARATUS: -

S.no.	Description	Quantity
1	Trainer Kit with string of insulators with and without guard ring	1

THEORY:

Since the calculations of the voltage distribution across a 400KV string of insulators containing 20 discs is cumbersome, unless a digital computer program is used to handle a long ladder network, it is preferable to obtain the voltage distribution by simulation in a laboratory.

The voltage distribution across a string of disc insulator is a characteristic of the string and determines the maximum magnitude of the voltage appearing across the discs in the string. Because of the small capacitance between the pin and cap of each disc and the stray capacitance of each disc to ground, the voltage distribution across the string will be non-uniform. An equivalent circuit of a string is shown in figure 1. It is preferable that the voltage distribution be kept as near to linear distribution as possible. This is done by means of using guard rings which are specially shaped shields on the conductor end of the string.

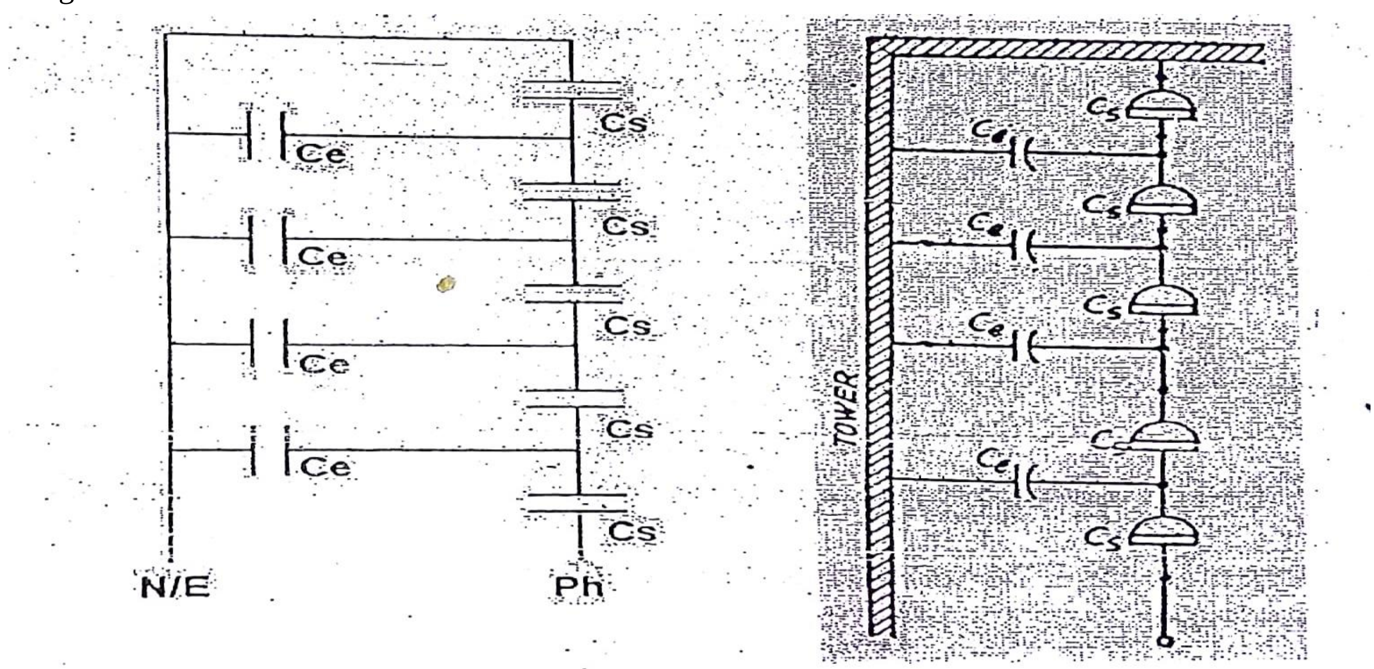


FIGURE 1

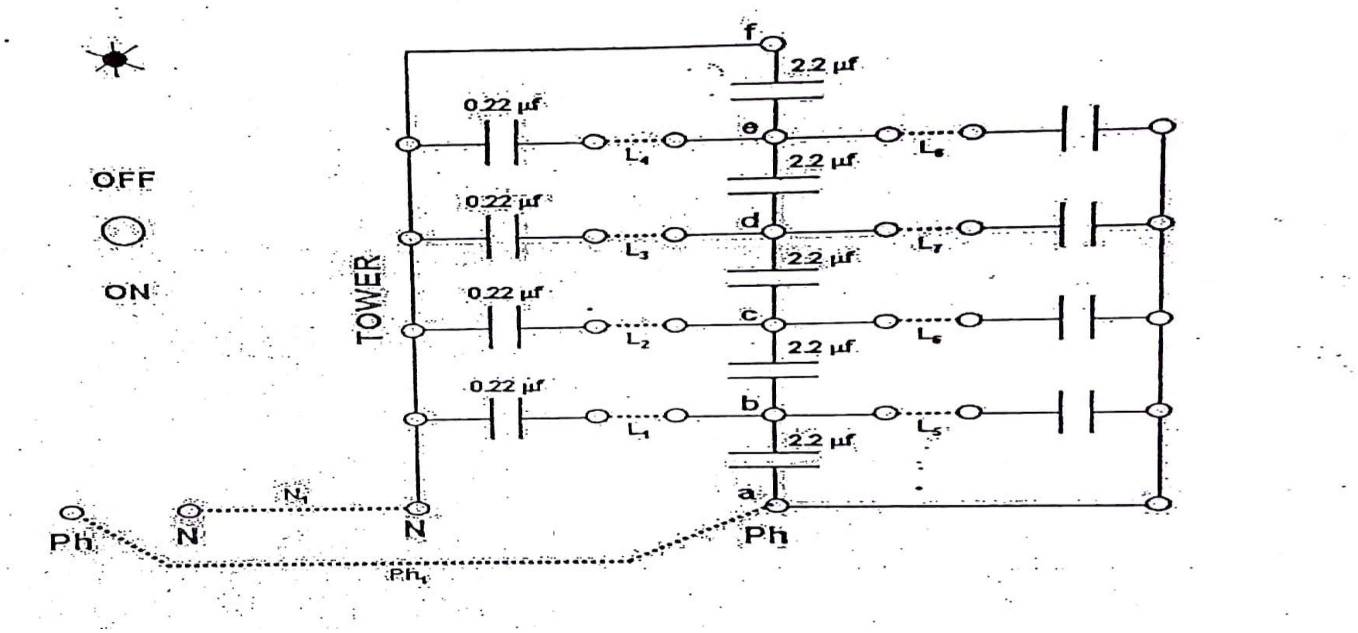


FIGURE 2

PROCEDURE:

1. Figure 2 represents the string of five suspension insulators and capacitance of each insulators Cs as 2.2microF and stray capacitance to ground/ tower Ce as 0.22 microF.
2. Connect link L1, L2, L3 & L4.
3. Connect link Ph1 & N1 and switch ON the supply.
4. Record the voltage between ab, bc, cd, de, ef and af in table 1.

Table1: Voltage distribution and string efficiency without guard ring

Vab	Vbc	Vcd	Vde	Vef	Vaf	String Efficiency=Vab/(5*Vaf)

5. Switch OFF the supply.
6. Connect the link L5, L6, L7 & L8 and switch ON the supply.
7. Record the readings of voltage between ab, bc, cd, de, ef & af in table 2.
8. Calculate the string efficiency without guard ring as indicated in table-1.
9. Calculate the string efficiency with guard ring as indicated in table-2.

Table2: Voltage distribution and string efficiency without guard ring

Vab	Vbc	Vcd	Vde	Vef	Vaf	String Efficiency= Vab/(5*Vaf)

RESULT: String efficiency without guard ring is ---------- and with guard ring is ----------.

EXPERIMRNT NO. 13

A) AIM: To demonstrate the concepts of Ferranti effect for a transmission line

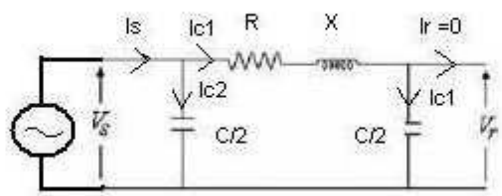
Apparatus Required:

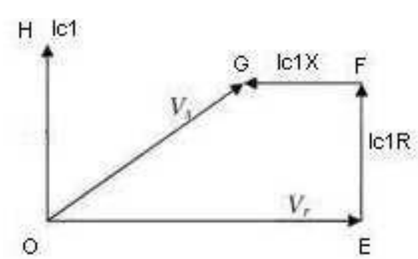
Sr. No.	Considerations/Equipment Required	Specification
	Type of conductor	Twin Moose
	Voltage level	110 V (simulating 400 kV line)
	Resistance R in ohm per km	0.009347
	Inductive reactance X in ohm per km	0.04488
	Half of capacitive susceptance B/2 in µ℧ per km	10.8968
	Line length in km	350
	Number of pi sections:	1

Theory

A long transmission line draws a substantial quantity of charging current. If such a line is open circuited or very lightly loaded at the receiving end the voltage at receiving end may become greater than voltage at sending end. This is known as Ferranti Effect and is due to the voltage drop across the line inductance being in phase with the sending end voltages. Therefore both capacitance and inductance is responsible to produce this phenomenon. The capacitance and charging current is negligible in short line but significant in medium line and appreciable in long line by equivalent π model. Due to high capacitance, the Ferranti effect is much more pronounced in underground cables, even in short lengths.

Figure below shows the equivalent pi modeling of transmission line used to demonstrate Ferranti effect and the phasor diagram showing relation between sending end and receiving





end voltage.

Procedure

1) Set up the TLS as explained in Ground Work 1.
2) Ensure that the load end contractor is off.
3) Switch on the main supply.
4) Switch on the line input supply.
5) Slowly increase and adjust the sending voltage to measure 110V, line to line.
6) Note down the sending end current.
7) Note down the terminal voltage.

Calculations:

1. Mainly two pi sections are there, which can be connected in series or parallel and hence accordingly R, L, and C parameter changes. The calculated parameters of each pi-section (for 350km) is as follows,

Resistance: 3.27 Ω

Inductance: 50 mH Capacitance

(C/2): 12.14 µF

2. Computing receiving end voltage

To compute the receiving end voltage of the entire line, equation 1 is used.

Vs = A*Vr + B*Ir ....(1)

Is = C*Vr + D*Ir .... (2)

Where Vs, Vr = sending and receiving end voltage

respectively Is, Ir = sending and receiving end current

respectively

A = D = (ZY/2) + 1 B

= Z

C = Y (1 + (ZY/4))

Considering unloaded line implies Ir = 0, hence we have Vr

= Vs/A

Using the calculated parameter of Z and Y/2 for pi-section, we have

Ztotal = 3.27+j15.7079 Ω

Y/2 total = j7.62776e-3 ℧

A = ((3.27+j15.7079)*(j7.62776e-3)/2)+1 =

0.94009+j0.01247 Vr = 110.52 / (0.9648+j6.2385e-3)

= 117.55 V

Results:

Results are tabulated as :.

Results of experiment on Ferranti effect simulation for an un-loaded line

Sr. No.	Ir (A)	Vs (V)	Vr (V)- TLS	Vr (V) - Calculated	Error (V)
1	0	110.52	118.95	117.552	1.398

B) **AIM :** To demonstrate the concepts of shunt reactor compensation as a solution for over voltage due to unloaded line.

Procedure:

1. Set up the TLS as explained in Ground Work 1.
2. Switch on the TLS as per steps given in Experiment 1.
3. Switch ON only inductive load
4. Increase inductive load till the receiving end voltage is equal to sending voltage.
5. Note down the sending end and receiving end current and power factor. Calculations:

As discussed in Ground Work 2, the receiving end voltage and current data from TLS is used to compute the sending end voltage and current so as to verify the TLS results.

After applying shunt

compensation Vr = 110.56 V, Ir

= 0.18 A, pf = 0.32

We have,

Vs = A*Vr + B*Ir Is

= C*Vr + D*Ir

A = D = 1 + (YZ/2) = 0.94009+j0.01247 B

= Z = 3.27145+j15.70796 ohm

C = Y [1+ (YZ/4)] = 0+j0.0076277 mho

Using the ABCD parameters equations and receiving end data,

we get Vs = 108.9207 V, Is = 0.3172 A

Results:

Results are tabulated as :

Results of shut reactor compensation of an unloaded line

SI No.	Description	TLS results	Calculated	Error
1	Sending end voltage (V)	110.48	108.9207	1.559
2	Sending end current (A)	0.26	0.3172	-0.0572

C) **AIM:** To determine the various electrical parameters at sending and receiving end for a loaded line

THEORY

When a transmission line is loaded, it either generates or absorbs reactive power based on the level of loading. A line which is loaded above its SIL will experience a drop is voltage at its receiving end. The sending end power factor depends on the load power factor and also the line parameters and loading level. Further owing to certain resistance present in the line, the sending end real power is a summation of the line losses and the load power. The aim of this experiment is to observe the changes in various electrical parameters at the two ends during various loading condition.

PROCEDURE

i. Set up the TLS as explained in Ground Work 1.
ii. Ensure that the load end contactor is off.
iii. Switch on the main supply.
iv. Switch on the line input supply.
v. Slowly increase and adjust the sending voltage to measure 110V, line to line.
vi. Switch on the load side contactor.
vii. Connect the resistive load.
viii. Connect the inductive load.
ix. Vary the load side dimmer to maintain load side to adjust the loading to the required power factor.
x. Record the various electrical parameters at the two ends.
xi. Take the reading at different loading values.

Calculations

1. Using the steps given in ground work 2, the calculated parameters of each pi-section is as follows

Resistance: 3.27 Ω

Inductance: 50 mH

Capacitance (C/2):

12.14 μF

2. Compute the sending end or receiving end voltage/currents

The relation between the sending end and receiving end voltage and currents is given by:

Vs =

A*Vr +

B*Ir Is =

C*Vr +

D*Ir

A = D = 1 + (YZ/2) =

0.94009+j0.01247 B = Z =

3.27145+j15.70796 ohm

C = Y [1+ (YZ/4)] = 0+j0.0076277 mho

The above equation is used to compute the voltage and currents at any one end, having the data of the other end.

%Vol drop = (Vs-Vr)*100/Vs

Results:

The results are tabulated as follows.

Results of experiment on transmission line loading

Case no	**loading**		**Vr**	**Ir**	**Vs (V)**		**Is (A)**		**%**	
	Amp	**pf**	**(V)**	**(A)**	**TLS**	**hand cal**	**TLS**	**hand cal**	**TLS**	**Hand Cal**
1	0	0	118.95	0	110.52	111.8338	0.46	0.5082	-7.6276	-6.3632
2	0.3	0.999	111.84	0.3	109.24	107.6207	0.5	0.5456	-2.3801	-3.9205
3	0.6	0.999	107.6	0.6	108.61	106.7244	0.69	0.7141	0.9299	-0.8204
4	0.9	0.999	102.51	0.9	106.46	105.6839	0.93	0.9379	3.7103	3.0032
5	0.3	0.96	109.31	0.3	108.34	107.0348	0.45	0.4750	-0.8953	-2.1257

6	0.6	0.95	102.58	0.6	107.96	105.9354	0.59	0.5992	4.9833	3.1674
7	0.88	0.95	95.95	0.88	107.08	104.8326	0.81	0.8032	10.3941	8.4732

Results of experiment on transmission line loading

Case no	loading		Ps (W)		Pr (W)		loss (W)		Qs (Var)		Qr (Var)	
	Amp	**pf**	**TLS**	**hand cal**	**TLS**	**hand cal**	**TLS**	**hand cal**	**TLS**	**hand cal**	**TLS**	**hand cal**
1	0	0	0.42	0.6733	0	0	0.42	0	-85.35	-98.4295	0	0
2	0.3	0.999	60.63	59.4693	58.68	58.0557	1.95	1.4137	-69.39	-82.4919	6.06	2.5983
3	0.6	0.999	115.77	115.6687	111.39	111.7094	4.38	3.9593	51.54	-63.5862	6.09	4.9995
4	0.9	0.999	167.85	167.9089	159.9	159.6375	7.95	8.2714	-24.24	-35.8151	5.85	7.1446
5	0.3	0.96	59.64	55.5822	55.86	54.5272	3.78	1.0550	-59.91	-68.2949	16.53	15.9038
6	0.6	0.95	105.99	104.4773	101.91	101.2740	4.08	3.2032	-24.57	-34.2651	33.78	33.2872
7	0.88	0.95	145.86	145.8339	139.08	138.9351	6.78	6.8988	15.39	1.7643	47.97	45.6657

D) **AIM**: Transmission line loading with load side shunt capacitive compensation to improve the voltage profile

Theory:

The transmission line loading depends on the quantum and power factor of the load, which directly impacts the system voltages. At surge impedance loading of the line, the receiving end voltage is equal to the sending end voltage for a loss less line. For the higher loadings, the receiving end voltage will be much less compared to the sending end voltage. The voltage drop in the EHV transmission line is negligible at unity power factor as the line resistance of the line is much less compared to series reactance value of the line. When the transmission line is loaded with reactive power or when the line is loaded beyond the surge impedance loading, the receiving end voltage drops. The receiving end voltage can be improved by shunt capacitive compensation at the load point which reduces the reactive power loading on the line and there by reduces the reactive drop.

Procedure

1) Set up the TLS as explained in Ground Work 1.
2) Ensure that the load end contactor is off.
3) Switch on the main supply.
4) Switch on the line input supply.
5) Slowly increase and adjust the sending end voltage to measure 110V, line to line.
6) Switch on the load side contactor.
7) Connect the resistive load.
8) Connect the inductive load.
9) Vary the load side dimmer to maintain load side power factor at 0.90
10) Take the reading at different loading values.
11) Switch on the shunt capacitor bank to bring back the receiving voltage to above 0.95 pu.
12) At each step, adjust the sending end voltage to be 110 V

Calculations:

1. Using the steps given in ground work 2, the calculated parameters of each pi-section is as follows

   Resistance: 3.27 Ω

   Inductance: 50 mH Capacitance

   (C/2): 12.14 µF

2. Compute the sending end or receiving end voltage/currents

The relation between the sending end and receiving end voltage and currents is given in equation 1 and 2.

Vs = A*Vr + B*Ir .... (1)

Is = C*Vr + D*Ir..(2)

From the given input, Z and Y/2 can be calculated: Ztotal

= 3.27+j15.7079 Ω

Y/2 total = j7.62776e-3 ℧ Hence

ABCD parameters are:

A = D = 1 + (YZ/2) = 0.94009+j0.01247 B = Z

= 3.27145+j15.70796 ohm

C = Y [1+ (YZ/4)] = 0+j0.0076277 mho

<u>Results:</u>

Readings can be taken up for various loadings as per the procedure and verified using given calculation steps. The readings can be noted down as

Case no	**loading**		**Vr**	**Ir**	**Compensation**	**Vs**		**Is**		**Loss**	
	Amp	**pf**	**(V)**	**(A)**	**(Var)**	**TLS**	**hand cal**	**TLS**	**hand cal**	**TLS**	**hand cal**
1											
2											

For verifying the results with hand calculation, the receiving end data from TLS is used to compute the expected sending end data. The loading current is the load current which is held constant during a particular case. The receiving end current (Ir) is the current at the receiving end of the line which comprises of effect of load current and current due to shunt compensation.

E) **AIM :** Simulation of parallel operation of transmission line.

Theory

The performance of transmission line depends on the current flowing through it. When a transmission line is operated in parallel, the performance of the line improves owing to the fact that the current now gets divided. Further a double circuit also provides redundancy in operation.

Procedure

1. Set up the TLS as explained in Ground Work 1.
2. Ensure that the load end contactor is off.
3. Switch on the main supply.
4. Switch on the line input supply.
5. Slowly increase and adjust the sending voltage to measure 110V, line to line.
6. Switch on the load side contactor.
7. Connect the resistive load.
8. Connect the inductive load.
9. Vary the load side dimmer to maintain load side to adjust the loading to the required power factor.
10. Record the various electrical parameters at the two ends.
11. Take the reading at different loading values.

Results:

The results are tabulated as given in Table below.These values can be verified using hand calculations.

Case no	loading		loss (W)		% Vol drop	
	Amp	pf	Parallel circuit (2x350 km)	Single circuit (1x350 km)	Parallel circuit (2x350 km)	Single circuit (1x350 km)
1	0.6	0.999	3.87	4.38	-2.8148	0.9299
2	0.9	0.999	12.66	7.95	-0.5723	3.7103
3	0.6	0.95	3.81	4.08	-0.4181	4.9833
4	0.9	0.95	4.89	6.78	2.6338	10.3941

F) AIM:Simulation of 3-Phase fault

Procedure

1. Set up the TLS as explained in Ground Work 1.
2. Set the relay to the following setting. Procedure to set relay is provided in the relay catalogue.

   Phase Hi-set pick up = 1.5A. Phase Hi-set operating time = 0.1s. Earth

   Hi-set pick up = 1.5A. Earth Hi-set operating time = 0.1s.
3. Ensure that the load end contactor is off.
4. Switch on the main supply.
5. Switch on the line input supply.
6. Slowly increase and adjust the sending end voltage to measure 110V, line to line.
7. Switch on the load.
8. Create three phase fault at end of pi-section and note down the fault current from the relay.
9. Different readings can be taken up by using combinations of pi sections; either single or series or parallel combination.

Result

Table below shows the results of simulation of three phase fault at different locations.

Initially only one pi section is considered and three phase fault is created at the end of line that is at 350 km. Corresponding readings are:

Fault current, If = 4.2 A, fault voltage, Vf = 64.1 V, and reactance, X = 15 Ohm

Secondly, two pi sections are connected in series and three phase fault is created at the end of line that is at 700 km. Corresponding readings are:

Fault current, If = 1.8 A, fault voltage, Vf = 65.3. V, and reactance, X = 36.3 Ohm

Finally two pi sections are connected in series and three phase fault is created at the center of line that is at 350 km. Corresponding readings are:

Fault current, If = 4.3 A, fault voltage, Vf = 64.1 V, and reactance, X = 14.9 Ohm

Fault Type	Fault Distance (km)	Fault Current (A)	Fault Voltage (V)
3-Phase Fault	350 (One pi Section)	4.2	64.1
	350 (Two pi Sections in series)	4.3	64.1
	700 (Two pi Sections in series)	1.8	65.3

Table Simulation of three phase fault

G) AIM: Simulation of SLG, LLG, LL fault

Procedure

:

1. Set up the TLS as explained in Ground Work 1.
2. Set the relay to the following setting. Procedure to set relay is provided in the relay catalogue.

   Phase Hi-set pick up = 1.5 A. Phase Hi-set operating time = 0.1s. Earth

   Hi-set pick up = 1.5 A. Earth Hi-set operating time = 0.1s.
3. Ensure that the load end contactor is off.
4. Switch on the main supply.
5. Switch on the line input supply.
6. Slowly increase and adjust the sending end voltage to measure 110V, line to line.
7. Switch on the load.
8. Create R-N fault at end of each pi-section and note down the fault current (Ir-n) from the relay.
9. Reset the relay after each fault creation.

Result

Similar to simulation of three phase fault, other type of faults can be created and corresponding readings can be noted.

All the unsymmetrical types of faults can be created here; SLG fault can be on R or Y or B phase; similarly LLG can be RYG or YBG or BRG, and LL can be RY or YB or BR. Hence total nine types of faults can be created.

The results can be tabulated as per the table below

Simulation of three phase fault

Fault Type	Fault Distance (km)	Fault Current (A)	Fault Voltage (V)
SLG	350 (One pi Section)		
	350 (Two pi Sections in series)		
	700 (Two pi Sections in series)		

LLG	350 (One pi Section)		
	350 (Two pi Sections in series)		
	700 (Two pi Sections in series)		
LL	350 (One pi Section)		
	350 (Two pi Sections in series)		
	700 (Two pi Sections in series)		

H) **AIM**: Effect of parallel line on fault current

Procedure:

1. Set up the TLS as explained in Ground Work 1.
2. Set the relay to the following setting. Procedure to set relay is provided in the relay catalogue.

   Phase Hi-set pick up = 1.5 A. Phase Hi-set operating time = 0.1s. Earth

   Hi-set pick up = 1.5 A. Earth Hi-set operating time = 0.1s.
3. Determine the simulator pi section R, L and C values, as explained in ground work 2.
4. Connect the two circuits in parallel.
5. Ensure that the load end contactor is off.
6. Switch on the main supply.
7. Switch on the line input supply.
8. Slowly increase and adjust the sending end voltage to measure 110V, line to line.
9. Switch on the load.
10. Create R-Y and R-N fault at end of the line and note down the fault current from the relay.
11. Reset the relay after each fault creation.

Results

As per the procedure explained, different types of faults can be created and its effect can be compared for both single and parallel line.

The results are tabulated in table below

Results for fault on parallel line

Fault Distance 350 km		
Fault type	Single circuit (A)	Parallel circuit (A)

APPENDIX

Ground Work 1: PU modeling of the given transmission line on given base and computation of TLS values

AIM: To demonstrate the procedure of pu calculation from actual value and to arrive at the simulator impedance values to model the transmission line.

Input data:

The Table 5.1 shows the input details for 400 kV Twin Moose, 110 kV Zebra and 11 kV Dog conductors.

Table : Input data for different conductor types

Type of conductor	Twin Moose	Zebra	Dog
Voltage level (kV)	400	110	11
Resistance R in Ω per km	0.05887	0.06626	0.2572
Inductive reactance X in Ω per km	0.28266	0.38815	0.34482
Half of capacitive susceptance (B/2) in µ℧ per km	1.7292	1.49686	18.137
Line length in km	350	150	10

Theoretical background:

A per-unit system is the expression of system quantities as fractions of a defined base unit quantity, which normalize the various electrical parameters resulting in ease of computation. The main idea for per unit system is to absorb large difference in absolute values into base relationships. Thus, representation of elements in the system with per unit values becomes more uniform. The ohmic value referred to one side of the transformer is not same, when it is referred to other side of the transformer; however when referred in pu, the values remain same and thus have a significant advantage in power system analysis.

In the pu value computation, the base MVA and the base voltage are defined. Three phase line to line voltage is selected as base kV. Here for the simplifying the calculation base MVA is taken as 400 MVA for 400 kV, 110 MVA for 110 kV and 11 MVA for 11 kV.

Once these two base quantities are defined, the current and impedance base values are computed as per the procedure given below.

In the simulator, the given transmission line voltage is mapped to 110V, as the rated voltage of the simulator is 110V. Further, the power base is selected close to rated power of the line.

For 400 kV line, rated power can be taken as 400 MVA.

Rated current of 400 kV line with 400 MVA power

works out to Rated current = (400*1000)/ (1.732*400)

= 577.350527 A.

This rated current is mapped to 1 A in the

simulator.

Procedure:

1. Connect the TLS set up as per the following instructions:
   - For connecting one pi section: Connect one side of pi section to source panel by 4 probes (R, Y, B, and N) and similarly to load side from other end.
   - For connecting two pi sections: First connect two pi sections either in series or in parallel as per the requirement. And then connect the equivalent pi section to source side and load side panel as discussed above.
2. Determine the pi section the R, X and B/2 by multiplying the per km values by the line length.
3. Fix the base voltage same as the line voltage.
4. Fix the base power as the rated power of the line; say for 400 kV, 400 MVA;

for 110 kV, 110 MVA and so on.

5. Determine the PU impedance and susceptance values on the selected base voltage (kV) and selected MVA, the procedure to calculate the pu values is as follows

Base impedance= (kV*kV)/MVA

PU impedance is computed as actual impedance divided by base

impedance. PU resistance = Actual resistance/ Base impedance

PU reactance = Actual reactance/Base impedance

PU susceptance = Actual susceptance * Base impedance

6. Convert the pu impedance computed in step 5 to actual value referred to simulator base, the procedure to calculate the actual value is as follows

Compute simulator base power = √3 * Simulator base voltage * Simulator

base current

Compute simulator base impedance = (simulator base voltage * simulator base voltage)/ simulator base power

Determine the simulator base admittance as reciprocal of the simulator base impedance

Simulator resistance in ohm = PU resistance * Simulator Base

impedance Simulator reactance in ohm = PU reactance * Simulator

Base impedance Simulator susceptance in mho = PU susceptance *

Simulator base admittance

7. Determine the simulator capacitance value to be used in the pi model as Capacitance = susceptance / (2.0*pi*50), where 50 is the system frequency in Hz

Determine the simulator inductor value to be used in the pi model as Inductance = Reactance / (2.0*pi*50), where 50 is the system frequency in Hz

Calculations

Similar calculations can be done for other types of conductor by using above formulations and actual values given in Table 1. Table 2 gives the calculated base and respective pu values for all the conductor types.

Description	Units	Calculated value		
		400 kV Twin Moose	110 kV Zebra	11 kV Dog
Per pi section length	km	350	150	10
Per pi section R	Ω	20.6048	9.9396	2.5721
Per pi section X	Ω	98.932	58.2229	3.44821
Per pi section B/2	℧	6.0525e-4	2.2453e-4	1.8137e-4
Base Voltage	kV	400	110	11
Base Power	MVA	400	110	11
Base Current	A	577.3502	577.3502	577.3502
Base Z	Ω	400	110	11
Base Y	℧	0.0025	9.0909e-3	0.0909
Pi section R	pu	0.051512	0.09036	0.23382

Description	Units	Calculated value		
		400 kV Twin Moose	110 kV Zebra	11 kV Dog
Pi section X	pu	0.24733	0.52929	0.31347
Pi section B/2	pu	0.2421	0.02469	1.1995e-3
Simulator base Voltage	V	110	110	110
Simulator base current	A	1	1	1
Simulator base power	VA	190.5255	190.5255	190.5255
Simulator base impedance	Ω	63.5085	63.5085	63.5085
Simulator base admittance	℧	0.01574	0.01574	0.01574
Simulator pi section R	Ω	3.27145	5.739	14.85

Simulator pi section X	Ω	15.7079	33.615	19.90827
Simulator pi section B/2	℧	0.003813	0.0003889	3.14159e-5
Simulator pi section C/2	μF	12.14	1.238	0.001
Simulator pi section L	mH	50	107	63.37

Ground Work 2: Long hand calculation to verify TLS results

Aim: To demonstrate the procedure to be adopted while performing hand calculation using ABCD parameters.

Input data:

- R, X and B/2 of line referred to TLS base
- Receiving end voltage and current
- Stray resistance (R_s)

Theoretical background:

The sending end or receiving end voltage and current can be computed using ABCD parameters provided the other end voltage and current data is available. The equation used in ABCD parameters is given in (1) and (2).

Vs = A*Vr + B*Ir....................... (5.1)

Is = C*Vr + D*Ir ....(5.2)

Where Vs, Vr = sending and receiving end voltage

respectively (phase voltage) Is, Ir = sending and receiving end

current respectively

A = D = (ZY/2) + 1 (Z and Y

are for total line) B = Z

C = Y (1 + (ZY/4))

As assumed, additional source resistance should also be considered in the theoretical model of the transmission line. Thus the total Z to be considered in equation of ABCD parameter is

Z = (R + Rs) + j X

After solving (1) and (2), the complex sending and receiving end voltage and currents are known. Compute

φs = difference between sending end voltage angle and sending end current angle.

φr = difference between sending end voltage angle and sending end current angle.

Thus

$$Ps = \sqrt{3} * Vr * Ir * \cos \varphi s$$

$$Qs = \sqrt{3} * Vrl * Ir * \sin \varphi s$$

$$Pr = \sqrt{3} * Vrl * Ir * \cos \varphi r$$

$$Qr = \sqrt{3} * Vrl * Ir * \sin \varphi r$$

Where Vrl and Vsl is the receiving end and sending end line to line voltage.

$$\% \text{Loss} = (Ps - Pr)*100/Ps$$

$$\% \text{voltage drop} = (Vs-Vr)*100/Vs$$

In the ABCD parameter method both voltage and current known must be of the same end, if one end voltage and the other end current is known the solution must be obtained by iterative methods. Hence for the purpose of verifying the TLS results, it is suggested that Vr and Ir values obtained from the TLS meter is taken and then calculate the expected Vs and Is for the considered case.