POORNIMA
COLLEGE OF ENGINEERING

Department of Electrical Engineering

Power System Protection Lab Manual

Year: -3rd Yr. /VI SEM

Lab Code: - 6EE4-23

INDEX

POORNIMA COLLEGE OF ENGINEERING, JAIPUR

DEPARTMENT OF ELECTRICAL ENGINEERING

VISION

To be a model of excellence in Professional Education and Research by creating electrical engineers who are prepared for lifelong engagement in the rapidly changing fields and technologies with the ability to work in team.

MISSION

- ✓ To provide a dynamic environment of technical education wherein students learn in collaboration with others to develop knowledge of basic and engineering sciences.
- ✓ To identify and strengthen current thrust areas based upon informed perception of global societal issues in the electrical and allied branches.
- ✓ To develop human potential with intellectual capability who can become a good professional, researcher and lifelong learner.

POORNIMA COLLEGE OF ENGINEERING, JAIPUR
DEPARTMENT OF ELECTRICAL ENGINEERING

PROGRAM EDUCATIONAL OBJECTIVES (PEO's)

PEO 1: Graduates will have the ability to formulate, analyze and apply design process using the basic knowledge of engineering and sciences to solve complex electrical engineering problems.

PEO 2: Graduates will exhibit quality of leadership, teamwork, time management, with a commitment towards addressing societal issues of equity, public and environmental safety using modern engineering tools.

PEO 3: Graduates will possess dynamic communication and have successful transition into a broad range of multi-disciplinary career options in industry, government and research as lifelong learner.

PROGRAM OUTCOMES (PO's)

Engineering Graduates will be able to:

1. **Engineering knowledge**: Apply the knowledge of mathematics, science, engineering fundamentals, and an engineering specialization to the solution of complex engineering problems.
2. **Problem analysis**: Identify, formulate, review research literature, and analyze complex engineering problems reaching substantiated conclusions using first principles of mathematics, natural sciences, and engineering sciences.
3. **Design/development of solutions**: Design solutions for complex engineering problems and design system components or processes that meet the specified needs with appropriate consideration for the public health and safety, and the cultural, societal, and environmental considerations.
4. **Conduct investigations of complex problems**: Use research-based knowledge and research methods including design of experiments, analysis and interpretation of data, and synthesis of the information to provide valid conclusions.

5. **Modern tool usage**: Create, select, and apply appropriate techniques, resources, and modern engineering and IT tools including prediction and modeling to complex engineering activities with an understanding of the limitations.
6. **The engineer and society**: Apply reasoning informed by the contextual knowledge to assess societal, health, safety, legal and cultural issues and the consequent responsibilities relevant to the professional engineering practice.
7. **Environment and sustainability**: Understand the impact of the professional engineering solutions in societal and environmental contexts, and demonstrate the knowledge of, and need for sustainable development.
8. **Ethics**: Apply ethical principles and commit to professional ethics and responsibilities and norms of the engineering practice.
9. **Individual and team work**: Function effectively as an individual, and as a member or leader in diverse teams, and in multidisciplinary settings.
10. **Communication**: Communicate effectively on complex engineering activities with the engineering community and with society at large, such as, being able to comprehend and write effective reports and design documentation, make effective presentations, and give and receive clear instructions.
11. **Project management and finance**: Demonstrate knowledge and understanding of the engineering and management principles and apply these to one's own work, as a member and leader in a team, to manage projects and in multidisciplinary environments.
12. **Life-long learning**: Recognize the need for, and have the preparation and ability to engage in independent and life-long learning in the broadest context of technological change.

PROGRAM SPECIFIC OUTCOMES (PSO's)

PSO1: Graduate possesses the ability to apply fundamental knowledge of basic sciences, mathematics and computation to solve the problems in the field of electrical engineering for the benefit of society.

PSO2: Graduate possesses the ability to professionally communicate and ethically solve complex electrical engineering problems using modern engineering tools.

PSO3: Graduate possesses sound fundamental knowledge to be either employable or develop entrepreneurship in the emerging areas of renewable and green energy, electric and hybrid vehicles and smart grids and shall be susceptive to life- long learning.

LAB OUTCOMES

LO1: Verify the operation of microprocessor based differential, distance, under/over voltage relays.**[Apply]**

LO2: Analyze the various dynamic characteristics of digital relays for transmission line and transformer protection.**[Analyze]**

LO3: Assess single phase and three phase power system faults.**[Evaluate]**

LO4: Assemble the microcontroller based directional DMT and IDMT type relays in over current conditions.**[Create]**

MAPPING OF LO WITH PO

LO	LAB OUTCOME	PO											
		1	2	3	4	5	6	7	8	9	10	11	12
1	Student will able to **Verify** the operation of microprocessor based differential, distance, under/over voltage relays.**[Apply]**	-	3	-	-	-	-	-	-	-	-	-	-
2	Student will able to **Analyze** the various dynamic characteristics of digital relays for transmission line and transformer protection.**[Analyze]**	-	-	-	-	3	-	-	-	-	-	-	-
3	Student will able to **Assess** single phase and three phase power system faults.**[Evaluate]**	-	-	-	-	-	-	-	-	3	-	-	-
4	Student will able to **Assemble** the microcontroller based directional DMT and IDMT type relays in over current conditions.**[Create]**	-	-	-	-	2	-	-	-	-	-	-	-

MAPPING OF LO WITH PSO

LO	LAB OUTCOME	PSO1	PSO2	PSO3
1	Student will able to **Verify** the operation of microprocessor based differential, distance, under/over voltage relays.**[Apply]**	2	-	-
2	Student will able to **Analyze** the various dynamic characteristics of digital relays for transmission line and transformer protection.**[Analyze]**	-	2	-
3	Student will able to **Assess** single phase and three phase power system faults.**[Evaluate]**	-	-	1
4	Student will able to **Assemble** the microcontroller based directional DMT and IDMT type relays in over current conditions.**[Create]**	-	2	-

LAB RULES

ALWAYS:

- Enter into the lab on time and leave at proper time.
- Wait for the previous class to leave before the next class enters.
- Keep the bag outside in the respective racks.
- Utilize lab hours in the corresponding.
- Turn off the pc before leaving the lab unless a member of lab staff has specifically told you not to do so.
- Leave the labs at least as nice as you found them.
- If you notice a problem with a piece of equipment or the room in general (e.g. cooling, heating, lighting) please report it to lab staff immediately. Do not attempt to fix the problem yourself.

NEVER:

- No food or drink is allowed in the lab or near any of the equipment. Don't bring any external material in the lab, except your lab record, copy and books.
- Don't bring the mobile phones in the lab. If necessary then keep them in silence mode.
- Please be considerate of those around you, especially in terms of noise level. While labs are a natural place for conversations of all types, kindly keep the volume turned down.
- If you are having problems or questions, please go to either the faculty, lab in-charge or the lab supporting staff. They will help you. We need your full support and cooperation for smooth functioning of the lab.

SAFETY MEASURES / INSTRUCTIONS

BEFORE ENTERING IN THE LAB

- All the students are supposed to prepare the theory regarding the next experiment/ Program.
- Students are supposed to bring their lab records as per their lab schedule.
- Previous experiment/program should be written in the lab record.
- If applicable trace paper/graph paper must be pasted in lab record with proper labeling.
- All the students must follow the instructions, failing which he/she may not be allowed in the lab.

WHILE WORKING IN THE LAB

- Adhere to experimental schedule as instructed by the lab in-charge/faculty.
- Get the previously performed experiment/ program signed by the faculty/ lab in charge.
- Get the output of current experiment/program checked by the faculty/ lab in charge in the lab copy.
- Each student should work on his/her assigned computer at each turn of the lab.
- Take responsibility of valuable accessories.

LIST OF EXPERIMENTS

Max. Marks=50

1. To determine fault type, fault impedance and fault location during single line to ground fault.
2. To determine fault type, fault impedance and fault location during single line-to-line fault.
3. To determine fault type, fault impedance and fault location during double line to ground fault.
4. To study the operation of micro-controller based over current relay in DMT type and IDMT type.
5. To analyse the operation of micro-controller based directional over current relay in DMT type and IDMT type.
6. To study the micro-controller based under voltage relay.
7. To study the micro-controller based over voltage relay.
8. To study the operation of micro-controller based un-biased single-phase differential relay.
9. To study the operation of micro-controller based biased single-phase differential relay.
10. To study the operation of micro-controller un-based biased three phase differential relay.
11. To study the operation of micro-controller based biased three phase differential relay.

EVALUATION SCHEME

Name Of Exam	Conducted By	Experiment Marks	Viva Marks	Total
I Mid Term	PCE	15	5	20
II Mid Term	PCE	15	5	20
End Term	RTU	15	5	20

Name Of Exam	Conducted By	Performance Marks	Attendance Marks	Total
Sessional	PCE	15	5	20

DISTRIBUTION OF LAB RECORD MARKS PER EXPERIMENT

Attendance	Record	Performance	Total
2	3	5	10

LAB PLAN

Total number of experiment: 13

Total number of turns required: 14

NUMBER OF TURNS REQUIRED FOR

Experiment Number	Turns	Scheduled Day
Zero Lab	1	Turn 1
Exp. 1	1	Turn 2
Exp. 2	1	Turn 3
Exp. 3	1	Turn 4
Exp. 4	1	Turn 5
Exp. 5	1	Turn 6
Exp. 6	1	Turn 7
Exp. 7	1	Turn 8
Exp. 8	1	Turn 9
Exp. 9	1	Turn 10
Exp. 10	1	Turn 11
Exp. 11	1	Turn 12
Exp. 12	1	Turn 13
Exp. 13	1	Turn 14

DISTRIBUTION OF LAB HOURS

- Explanation of Experiment & Logic : 20 Minutes
- Performing the Experiment : 40 Minutes
- File Checking : 30 Minutes
- Viva/Quiz : 20 Minutes
- Solving of Queries : 10 Minutes

ROTOR PLAN

ROTOR-I

1. To determine fault type, fault impedance and fault location during single line to ground fault.

2. To determine fault type, fault impedance and fault location during single line-to-line fault.

3. To determine fault type, fault impedance and fault location during double line to ground fault.

4. To study the operation of micro-controller based over current relay in DMT type and IDMT type.

5. To analyze the operation of micro-controller based directional over current relay in DMT type and IDMT type.

6. To study the micro-controller based under voltage relay.

ROTOR-II

7. To study the micro-controller based over voltage relay.

8. To study the operation of micro-controller based un-biased single-phase differential relay.

9. To study the operation of micro-controller based biased single-phase differential relay.

10. To study the operation of micro-controller un-based biased three phase differential relay.

11. To study the operation of micro-controller based biased three phase differential relay.

12. Study gas actuated Buchholz relay. [BEYOND SYLLABUS]

13. To study the protection of bus-bars by differential protection. [BEYOND SYLLABUS]

ZERO LAB

Introduction to Lab:

a) Relevance to Branch:-

Power system protection is a branch of electrical engineering that deals with the protection of electrical power systems from faults through the isolation of faulted parts from the rest of the electrical network. The objective of a protection scheme is to keep the power system stable by isolating only the components that are under fault, whilst leaving as much of the network as possible still in operation.

b). Relevance to Society: -

As we all know the without electrical power we are helpless and most of the work needs continuous supply of electricity. For the overall development and daily needs of society, a lot of machines run in the various industries, and to operate them properly uninterrupted supply is the only requirement. So we can say that it is directly relevant to the society.

c). Relevance to Self: -

This subject has its own importance, for the personal growth this is must to have the knowledge the protection system because every core companies required knowledgeable electrical engineers. Right now this is the only sector which is touching sky-heights. There are many more projects in which students can be imparted and in spite of that many research projects are going on to make the protection of electrical network economically.

d). Pre- Requisites (Connection with previous year): -

In previous semester Transmission and Distribution of Electrical Power which partially related to this subject, because topics like machine protection, helps to generate the concept of protection of equipments. For further study good concept of this subject, will be very helpful in switch gear and protection which will come in next year.

EXPERIMENT NO: 1

OBJECT: -. To determine fault type, fault impedance and fault location during single line to ground fault.

THEORY:-

Fault Analysis in Power Systems

In general, a fault is any event, unbalanced situation or any asymmetrical situation that interferes with the normal current flow in a power system and forces voltages and currents to differ from each other.

It is important to distinguish between series and shunt faults in order to make an accurate fault analysis of an asymmetrical three-phase system. When the fault is caused by an unbalance in the line impedance and does not involve a ground, or any type of inter-connection between phase conductors it is known as a series fault. On the other hand, when the fault occurs and there is an inter-connection between phase-conductors or between conductor(s) and ground and/or neutral it is known as a shunt fault

Statistically, series faults do not occur as often as shunt faults does. Because of this fact only the shunt faults are explained here in detail since the emphasis in this project is on analysis of a power system under shunt faults.

Single Line-to-Ground Fault

The single line-to-ground fault is usually referred as “short circuit” fault and occurs when one conductor falls to ground or makes contact with the neutral wire.

general representation of a single line-to-ground fault is shown in Figure 3.10 where F is the fault point with impedances Z_f. Figure 3.11 shows the sequences network diagram. Phase a is usually assumed to be the faulted phase, this is for simplicity in the fault analysis calculations

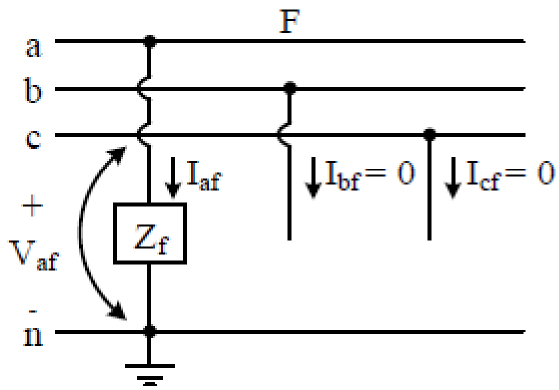

Figure 1**:** General representation of a single line-to-ground fault

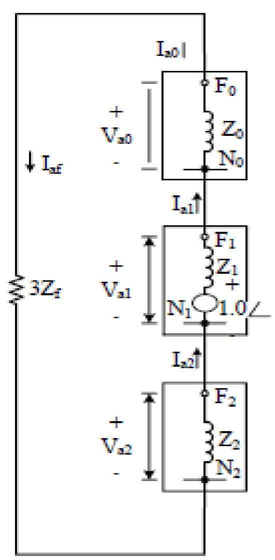

Figure 2 : Sequence network diagram of a single line-to-ground fault.

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Since the zero-, positive-, and negative-sequence currents are equals as it can be observed in Figure 2. Therefore,

$$I_{a0} = I_{a1} = I_{a2} = \frac{1.0\angle 0^{\circ}}{Z_0 + Z_1 + Z_2 + 3Z_f}$$

Since

$$\begin{bmatrix} I_{af} \\ I_{bf} \\ I_{cf} \end{bmatrix} = \begin{bmatrix} 1 & 1 & 1 \\ 1 & a^2 & a \\ 1 & a & a^2 \end{bmatrix} \begin{bmatrix} I_{a0} \\ I_{a1} \\ I_{a2} \end{bmatrix} \quad (1)$$

Solving Equation the fault current for phase a is

$$I_{af} = I_{a0} + I_{a1} + I_{a2} \quad (2)$$

it can also be

$$I_{af} = 3I_{a0} = 3I_{a1} = 3I_{a2} \quad (3)$$

From Figure 1 it can be observed that,

$$V_{af} = Z_f I_{af} \quad (4)$$

The voltage at faulted phase a can be obtained by substituting, Equation (1) into Equation (5). Therefore

$$V_{af} = 3Z_f I_{a1} \quad (5)$$

but

$$V_{af} = V_{a0} + V_{a1} + V_{a2} \quad (6)$$

therefore,

$$V_{a0} + V_{a1} + V_{a2} = 3Z_f I_{a1} \quad (7)$$

With the results obtained for sequence currents, the sequence voltages can be obtained from

$$\begin{bmatrix} V_{a0} \\ V_{b1} \\ V_{c2} \end{bmatrix} = \begin{bmatrix} 0 \\ 1.0\angle 0° \\ 0 \end{bmatrix} - \begin{bmatrix} 1 & 1 & 1 \\ 1 & a^2 & a \\ 1 & a & a^2 \end{bmatrix} \begin{bmatrix} I_{a0} \\ I_{a1} \\ I_{a2} \end{bmatrix} \quad (8)$$

By solving Equation

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

$$V_{a1} = 1.0 - Z_1 I_{a1} \quad (9)$$

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

If the single line-to-ground fault occurs on phase b or c, the voltages can be found by the relation that exists to the known phase voltage components

$$\begin{bmatrix} V_{af} \\ V_{bf} \\ V_{cf} \end{bmatrix} = \begin{bmatrix} 1 & 1 & 1 \\ 1 & a^2 & a \\ 1 & a & a^2 \end{bmatrix} \begin{bmatrix} V_{a0} \\ V_{a1} \\ V_{a2} \end{bmatrix}$$

as

$$V_{bf} = V_{a0} + a^2 V_{a1} + a V_{a2}$$
$$V_{cf} = V_{a0} + a V_{a1} + a^2 V_{a2}$$

RESULT - Determination of various parameters of L-G has been done

VIVA QUESTIONS:

1.What is the objective of the experiment on determining fault type, fault impedance, and fault location during a single line to ground fault?

2.How is a single line to ground fault different from other types of faults in a power system?

3.What are the common methods used to determine fault type in a power system?

4.Explain the principle behind fault impedance measurement in the context of single line to ground faults.

5.What are the factors that can affect fault impedance measurement accuracy?

6.How does fault impedance help in locating faults in a power system?

7.Discuss the significance of fault location determination in power system operation and maintenance.

8.What are the different techniques available for fault location determination during a single line to ground fault?

9.How does the fault type affect the approach to fault location determination?

10.What are the challenges associated with accurately determining fault location in a complex power system network?

11.Explain how time-domain reflectometry (TDR) is used in fault location during single line to ground faults.

12.What are the advantages and limitations of TDR in fault location compared to other methods?

13.Describe the procedure involved in conducting the experiment to determine fault type, fault impedance, and fault location.

14.How do you ensure safety measures are followed during the experiment, considering the involvement of power systems?

15.What are the potential applications of the results obtained from this experiment in real-world power system operations and maintenance?

EXPERIMENT NO: 2

OBJECT: - To determine fault type, fault impedance and fault location during single line-to-line fault

THEORY:-

Fault Analysis in Power Systems

In general, a fault is any event, unbalanced situation or any asymmetrical situation that interferes with the normal current flow in a power system and forces voltages and currents to differ from each other.

It is important to distinguish between series and shunt faults in order to make an accurate fault analysis of an asymmetrical three-phase system. When the fault is caused by an unbalance in the line impedance and does not involve a ground, or any type of inter-connection between phase conductors it is known as a series fault. On the other hand, when the fault occurs and there is an inter-connection between phase-conductors or between conductor(s) and ground and/or neutral it is known as a shunt fault

Statistically, series faults do not occur as often as shunt faults does. Because of this fact only the shunt faults are explained here in detail since the emphasis in this project is on analysis of a power system under shunt faults.

Single Line-to-Line Fault

A line-to-line fault may take place either on an overhead and/or underground transmission system and occurs when two conductors are short-circuited. One of the characteristic of this type of fault is that its fault impedance magnitude could vary over a wide range making very hard to predict its upper and lower limits. It is when the fault impedance is zero that the highest asymmetry at the line-to-line fault occurs .

The general representation of a line-to-line fault is shown in Figure 1 where F is the fault point with impedances Zf. Figure 2 shows the sequences network diagram. Phase b and c are usually assumed to be the faulted phases; this is for simplicity in the fault analysis calculations .

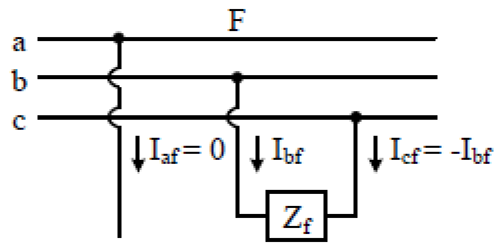


Figure 1- Sequence network diagram of a line-to-line fault

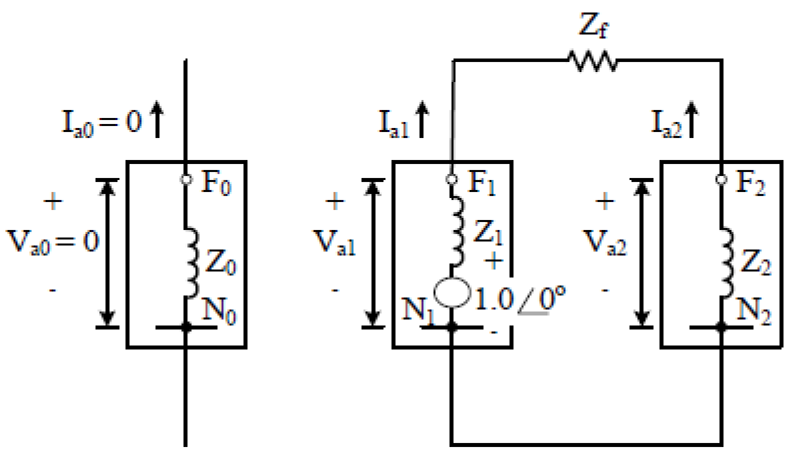


Figure 2 Sequence network diagram of a single line-to-ground fault.

From Figure 2 it can be noticed that

$$I_{af} = 0$$
$$I_{bf} = -I_{cf}$$
$$V_{bc} = Z_f I_{bf}$$ **(1)**

Since

$$\begin{bmatrix} I_{af} \\ I_{bf} \\ I_{cf} \end{bmatrix} = \begin{bmatrix} 1 & 1 & 1 \\ 1 & a^2 & a \\ 1 & a & a^2 \end{bmatrix} \begin{bmatrix} I_{a0} \\ I_{a1} \\ I_{a2} \end{bmatrix}$$ **(2)**

And the sequence currents can be obtained as

$$I_{a0} = 0$$ **(3)**

$$I_{a1} = -I_{a2} = \frac{1.0\angle 0^{\circ}}{Z_1 + Z_2 + Z_f} \qquad \textbf{(4)}$$

If $Z_f = 0$,

$$I_{a1} = -I_{a2} = \frac{1.0\angle 0^{\circ}}{Z_1 + Z_2} \qquad \textbf{(5)}$$

The fault currents for phase b and c can be obtained by substituting Equations 3 and 4 into Equation 2

$$I_{bf} = -I_{cf} = \sqrt{3}\ I_{a1}\angle -90^{\circ} \qquad \textbf{(6)}$$

With the results obtained for sequence currents, the sequence voltages can be obtained from

$$\begin{bmatrix} V_{a0} \\ V_{b1} \\ V_{c2} \end{bmatrix} = \begin{bmatrix} 0 \\ 1.0\angle 0^{\circ} \\ 0 \end{bmatrix} - \begin{bmatrix} 1 & 1 & 1 \\ 1 & a^2 & a \\ 1 & a & a^2 \end{bmatrix} \begin{bmatrix} I_{a0} \\ I_{a1} \\ I_{a2} \end{bmatrix} \qquad \textbf{(7)}$$

The sequence voltages can be found similarly by substituting Equations 3 and 4 into Equation 7

$$\begin{aligned} V_{a0} &= 0 \\ V_{a1} &= 1.0 - Z_1 I_{a1} \\ V_{a2} &= -Z_2 I_{a2} - Z_2 I_{a1} \end{aligned} \qquad \textbf{(8)}$$

$$\begin{bmatrix} V_{af} \\ V_{bf} \\ V_{cf} \end{bmatrix} = \begin{bmatrix} 1 & 1 & 1 \\ 1 & a^2 & a \\ 1 & a & a^2 \end{bmatrix} \begin{bmatrix} V_{a0} \\ V_{a1} \\ V_{a2} \end{bmatrix} \qquad \textbf{(8a)}$$

Also substituting Equation 8 into Equation 8a

$$\begin{aligned} V_{af} &= V_{a1} + V_{a2} = 1.0 + I_{a1}(Z_2 - Z_1) \\ V_{bf} &= a^2 V_{a1} + a V_{a2} = a^2 + I_{a1}(aZ_2 - a^2 Z_1) \\ V_{cf} &= a V_{a1} + a^2 V_{a2} = a + I_{a1}(a^2 Z_2 - a Z_1) \end{aligned} \qquad \textbf{(9)}$$

Finally, the line-to-line voltages for a line-to-line fault can be expressed as Finally, the line-to-line voltages for a line-to-line fault can be expressed as

$$\begin{aligned} V_{ab} &= V_{af} - V_{bf} \\ V_{bc} &= V_{bf} - V_{cf} \\ V_{ca} &= V_{cf} - V_{af} \end{aligned}$$

RESULT - Determination of various parameters of L-L has been done

VIVA QUESTIONS:

1. Can you explain the significance of determining fault type, fault impedance, and fault location in power systems?
2. What are the different types of faults that can occur in a power system?
3. How does a single line-to-line fault differ from other types of faults?
4. Describe the experimental setup used to determine fault type, fault impedance, and fault location during a single line-to-line fault.
5. What instruments or equipment are typically employed in such experiments?
6. How is fault impedance measured during a single line-to-line fault?
7. What are the main challenges in accurately determining fault impedance?
8. Explain the method used to determine the fault location during a single line-to-line fault.
9. How does the fault location technique vary for different types of power system configurations?
10. What are the key assumptions made in fault location calculations?
11. How do variations in fault resistance and reactance affect fault location accuracy?
12. What strategies can be employed to enhance the accuracy of fault location determination?
13. Discuss the role of signal processing techniques in analyzing fault data during experiments.
14. How do you validate the results obtained from experimental fault analysis?
15. What are the practical implications of knowing fault type, fault impedance, and fault location in power system operation and maintenance?

EXPERIMENT NO 3

OBJECT: - To determine fault type, fault impedance and fault location during double line to ground fault

THEORY:-

Fault Analysis in Power Systems

In general, a fault is any event, unbalanced situation or any asymmetrical situation that interferes with the normal current flow in a power system and forces voltages and currents to differ from each other.

It is important to distinguish between series and shunt faults in order to make an accurate fault analysis of an asymmetrical three-phase system. When the fault is caused by an unbalance in the line impedance and does not involve a ground, or any type of inter-connection between phase conductors it is known as a series fault. On the other hand, when the fault occurs and there is an inter-connection between phase-conductors or between conductor(s) and ground and/or neutral it is known as a shunt fault

Statistically, series faults do not occur as often as shunt faults does. Because of this fact only the shunt faults are explained here in detail since the emphasis in this project is on analysis of a power system under shunt faults.

Double Line-to-Ground Fault

A double line-to-ground fault represents a serious event that causes a significant asymmetry in a three-phase symmetrical system and it may spread into a three-phase fault when not clear in appropriate time. The major problem when analyzing this type of fault is the assumption of the fault impedance Z_f , and the value of the impedance towards the ground Z_g

The general representation of a double line-to-ground fault is shown in Figure

1 where F is the fault point with impedances Z_f and the impedance from line to ground Z_g . Figure 2 shows the sequences network diagram. Phase b and c are assumed to be the faulted phases, this is for simplicity in the fault analysis calculations

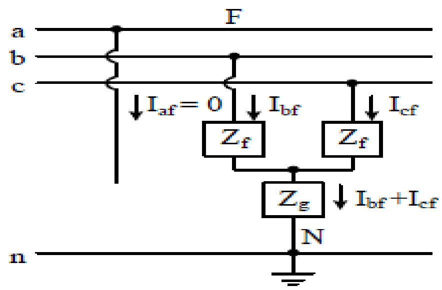


Figure 1 General representation of a double line-to-ground fault.

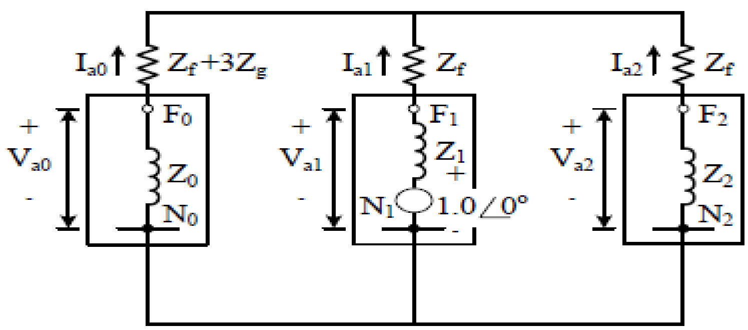


Figure 2 Sequence network diagram of a double line-to-ground fault.

$$\begin{bmatrix} I_{af} \\ I_{bf} \\ I_{cf} \end{bmatrix} = \begin{bmatrix} 1 & 1 & 1 \\ 1 & a^2 & a \\ 1 & a & a^2 \end{bmatrix} \begin{bmatrix} I_{a0} \\ I_{a1} \\ I_{a2} \end{bmatrix} \quad (1A)$$

$$I_{af} = 3I_{a0} = 3I_{a1} = 3I_{a2} \quad (1B)$$

From Figure 2 it can be observed that

$$I_{af} = 0$$
$$V_{bf} = (Z_f + Z_g)I_{bf} + Z_g I_{cf} \quad (1)$$
$$V_{cf} = (Z_f + Z_g)I_{cf} + Z_g I_{bf}$$

Based on Figure 2, the positive-sequence currents can be found as

$$I_{a1} = \frac{1.0\angle 0^{\circ}}{(Z_1 + Z_f) + \frac{(Z_2 + Z_f)(Z_0 + Z_f + 3Z_g)}{(Z_2 + Z_f) + (Z_0 + Z_f + 3Z_g)}}$$

$$I_{a2} = -[\frac{(Z_0 + Z_f + 3Z_g)}{(Z_2 + Z_f) + (Z_0 + Z_f + 3Z_g)}]I_{a1}$$

$$I_{a0} = -[\frac{(Z_2 + Z_f)}{(Z_2 + Z_f) + (Z_0 + Z_f + 3Z_g)}]I_{a1} \quad (2)$$

An alternative method is,

$$I_{af} = 0 = I_{a0} + I_{a1} + I_{a2}$$

$$I_{a0} = -(I_{a1} + I_{a2}) \quad (3)$$

If Z_f and Z_g are both equal to zero, then the positive-, negative-, and zero-sequences can be obtained from

$$I_{a1} = \frac{1.0\angle 0^{\circ}}{(Z_1) + \frac{(Z_2)(Z_0)}{(Z_2 + Z_0)}}$$

$$I_{a2} = -[\frac{(Z_0)}{(Z_2 + Z_0)}]I_{a1}$$

$$I_{a0} = -[\frac{(Z_2)}{(Z_2 + Z_0)}]I_{a1} \quad (4)$$

From Figure 2 the current for phase a is

$$I_{af} = 0$$

Now, substituting Equations (4) into Equation (1A) to obtain phase b and c fault currents

$$I_{bf} = I_{a0} + a^2 I_{a1} + aI_{a2}$$

$$I_{cf} = I_{a0} + aI_{a1} + a^2 I_{a2} \quad (5)$$

The total fault current flowing into the neutral is

$$I_n = 3I_{a0} = I_{bf} + I_{cf} \quad (6)$$

And the sequences voltages can be obtained by using Equation (1B)

$$\begin{aligned} V_{0a} &= -Z_0 I_{a0} \\ V_{a1} &= 1.0 - Z_1 I_{a1} \\ V_{a2} &= -Z_2 I_{a2} \end{aligned} \quad (7)$$

The phase voltages are equal to

$$\begin{aligned} V_{af} &= V_{a0} + V_{a1} + V_{a2} \\ V_{bf} &= V_{a0} + a^2 V_{a1} + aV_{a2} \\ V_{cf} &= V_{a0} + aV_{a1} + a^2 V_{a2} \end{aligned} \quad (8)$$

The line-to-line voltages can be obtained from

$$\begin{aligned} V_{ab} &= V_{af} - V_{bf} \\ V_{bc} &= V_{bf} - V_{cf} \\ V_{ca} &= V_{cf} - V_{af} \end{aligned} \quad (9)$$

If $Z_f = 0$ and $Z_g = 0$ then the sequence voltages become, and the positive-sequence current is found by using Equation (4).

$$V_{a0} = V_{a1} = V_{a2} = 1.0 - Z_1 I_{a1} \quad (10)$$

Now the negative- and zero-sequence currents can be obtained from

$$\begin{aligned} I_{a2} &= -\frac{V_{a2}}{Z_2} \\ I_{a0} &= -\frac{V_{a0}}{Z_0} \end{aligned} \quad (11)$$

The resultant phase voltages from the relationship given in Equation (10) can be expressed as

$$\begin{aligned} V_{af} &= V_{a0} + V_{a1} + V_{a2} = 3V_{a1} \\ V_{bf} &= V_{cf} = 0 \end{aligned} \quad (12)$$

And the line-to-line voltages are

$$
\begin{aligned}
V_{abf} &= V_{af} - V_{bf} = V_{af} \\
V_{bcf} &= V_{bf} - V_{cf} = 0 \\
V_{caf} &= V_{cf} - V_{af} = -V_{af}
\end{aligned}
\tag{13}
$$

RESULT - Determination of various parameters of LL-G has been done

VIVA QUESTIONS:

1. What is the primary objective of the experiment on determining fault type, fault impedance, and fault location during a double line to ground fault?
2. How does a double line to ground fault differ from other types of faults in power systems?
3. Explain the significance of determining fault type in power system operation and protection.
4. What are the common methods used to detect and locate faults in power systems?
5. Describe the experimental setup required to conduct the double line to ground fault analysis.
6. How do fault impedance and fault location influence the operation of protective relays in power systems?
7. What are the factors that affect fault impedance and how are they measured in the experiment?
8. Discuss the role of voltage and current measurements in determining fault characteristics during the experiment.
9. What types of sensors and measuring instruments are typically employed in fault analysis experiments?
10. How is fault location calculated based on the measured impedance and other parameters?

11. Explain the concept of symmetrical components and its relevance to fault analysis in power systems.
12. What are the potential challenges or limitations encountered in accurately determining fault type and location?
13. How does the presence of system grounding configurations affect fault analysis outcomes?
14. Discuss the importance of coordination between protective relays and fault analysis techniques in ensuring reliable power system operation.
15. Can the results obtained from the experiment be extrapolated to real-world power systems? If so, what considerations need to be taken into account?

EXPERIMENT NO 4

OBJECT: - To study the operation of micro-controller based over current relay in DMT type

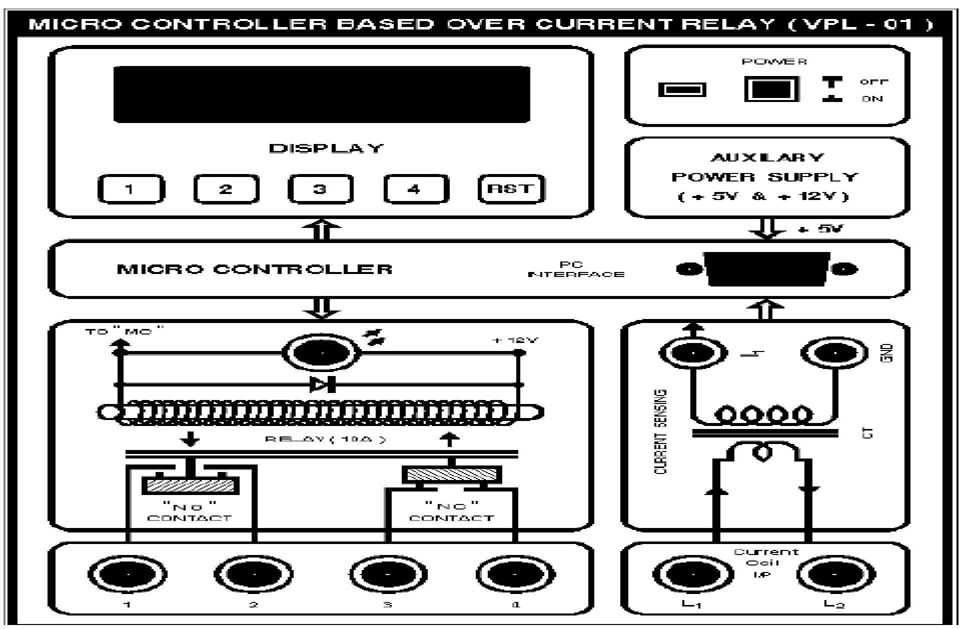
APPARATUS:

1) Microcontroller based overcurrent relay set up

2) Connecting wires

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.



FRONT PANEL VIEW DIAGRAM Of Microcontroller Based Over Current Relay

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 display shows the following with a delay of few seconds between each display.

The selection between type 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).

SELECT DMT

1.The DMT operation can be selected by pressing 1 Set the Relay reset time by using 1,2 & 3 buttons

2.The button 4 is pressed. (All the set values are sent to the processor). Set the current value by using 1,2 & 3 buttons

3. Press the button 4.

4. The time starts to increase from 00.01S to until the calculated time. 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. Time = 00.01

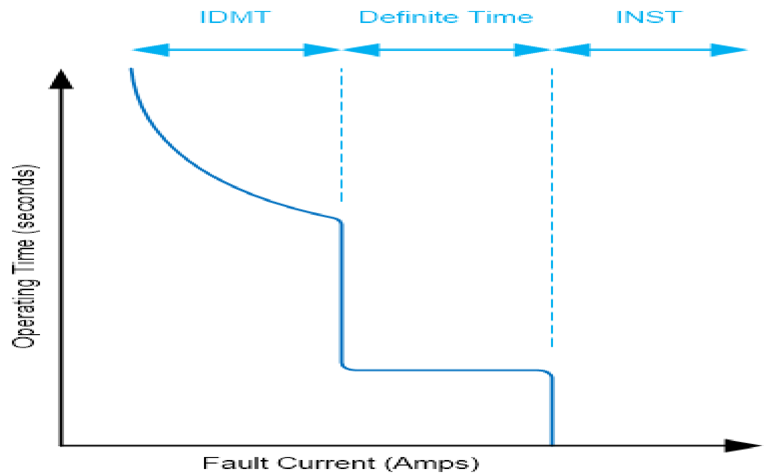
After the tripping of relay, the following messages are displayed one by one continuously until the system is reset. Set time = 00.105 SC = 00.60 TC = 1.07

The relay system is reset by pressing RST button.

TABULAR COLUMN

DMT:

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



Result: Hence the DMT characteristics of microcontroller based overcurrent relay are studied.

VIVA QUESTIONS:

1. Can you explain the basic principle behind the operation of a micro-controller based overcurrent relay in a DMT type configuration?
2. What are the main components involved in a micro-controller based overcurrent relay system?
3. How does the micro-controller in the relay determine overcurrent conditions?
4. What are the advantages of using a micro-controller based overcurrent relay compared to traditional relay systems?
5. How does the micro-controller handle various fault conditions in the system?
6. What parameters can be programmed and adjusted in a micro-controller based overcurrent relay?
7. How does the relay communicate with other devices or systems in the network?
8. Can you explain the process of setting up and calibrating a micro-controller based overcurrent relay?
9. What are the typical applications of a DMT type overcurrent relay in power systems?
10. How does the micro-controller handle coordination with other protective devices in the network?

11. What measures are taken to ensure reliability and accuracy in the operation of a micro-controller based overcurrent relay?
12. How does the micro-controller based overcurrent relay respond to transient conditions in the system?
13. What are the challenges associated with implementing micro-controller based protection systems in real-world applications?
14. How does the micro-controller based overcurrent relay handle different fault types, such as phase-to-phase, phase-to-ground, or three-phase faults?
15. Can you discuss any specific case studies or real-world examples where micro-controller based overcurrent relays have been effectively utilized in power systems?

EXPERIMENT NO 5

OBJECT: - To study the operation of micro-controller based over current relay in IDMT type

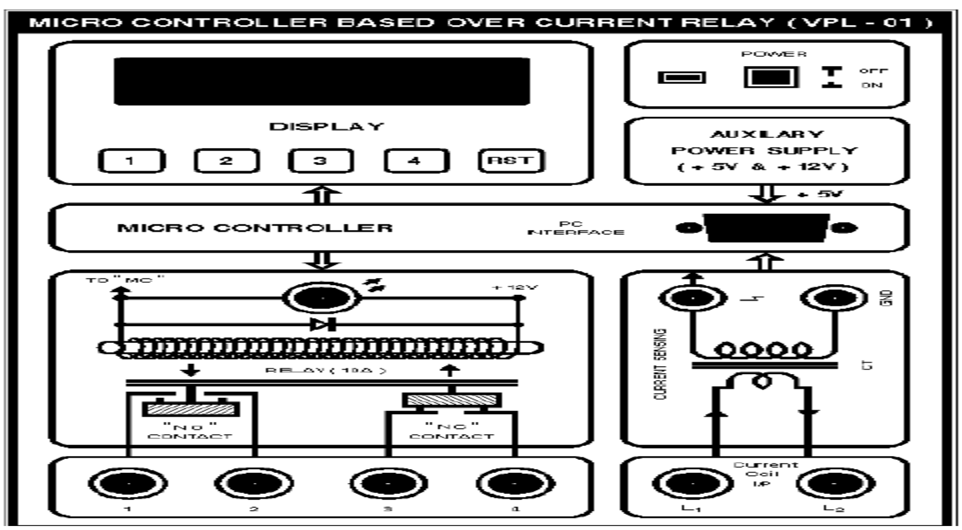
APPARATUS:

1) Microcontroller based overcurrent relay set up

2) Connecting wires

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.



FRONT PANEL VIEW DIAGRAM Of Microcontroller Based Over Current Relay

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 display shows the following with a delay of few seconds between each display.

The selection between type 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,

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

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

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.

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

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

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

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

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

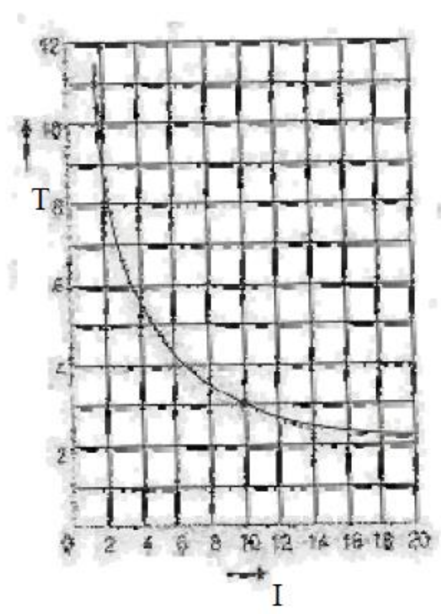
7. Press the RST button, Reset the processor and Relay tripping action.

TABULAR COLUMN

IDMT

S NO	Set Current (A)	Fault Current (A) Trip Current	Time Multiplier Setting(sec) (or)Set Time	Calculated Relay Tripping Time (Sec)	Actual Relay Tripping Time (Sec)

Expected Graph: IDMT



Result: Hence the IDMT characteristics of microcontroller based overcurrent relay are studied.

VIVA QUESTIONS:

1. What is the basic principle behind the operation of a micro-controller based overcurrent relay in IDMT (Inverse Definite Minimum Time) type?
2. How does a micro-controller based overcurrent relay differ from traditional electromechanical relays in terms of functionality and operation?
3. Can you explain the concept of IDMT (Inverse Definite Minimum Time) characteristic and its significance in overcurrent protection?
4. What are the key components involved in a micro-controller based overcurrent relay system?
5. How does the micro-controller monitor and analyze the current flowing through the circuit in real-time?
6. What factors influence the time-delay characteristic of the IDMT relay? How does the micro-controller adjust these factors?
7. What measures are taken to ensure the accuracy and reliability of the overcurrent protection provided by the micro-controller based relay?
8. Can you describe the calibration process of a micro-controller based overcurrent relay in IDMT type?
9. How does the relay detect and distinguish between various fault conditions such as overload, short circuit, and earth fault?
10. What are the advantages of using a micro-controller based overcurrent relay compared to conventional relay systems?
11. How does the micro-controller handle communication interfaces for remote monitoring and control purposes?
12. What safety features are implemented in the micro-controller based overcurrent relay to prevent false tripping or malfunction?
13. Can you explain the role of software algorithms in optimizing the performance of the relay in different operating conditions?
14. How does the micro-controller based overcurrent relay respond to transient currents and disturbances in the system?
15. What are the future prospects and potential advancements in micro-controller based overcurrent relay technology for enhanced protection and efficiency?

EXPERIMENT NO 6

OBJECT: - . To study the micro-controller based under voltage relay

Apparatus required:

S.No	Apparatus	Type	Quantity
01	UV/OV Relay	µP based	01No
02	Voltage Source Unit (230/110-230V)		01No
03	Connecting Wires		As Required
04	Voltmeter (0-500V AC)	Digital	01No

Theory: Over Voltage/Under Voltage Relay is an electronic microcontroller based single- phase voltage relay. It is suitable for over voltage/under voltage protection schemes in LV, MV and HV power distribution systems. It is also suitable for over voltage protection of AC circuits, capacitors, machines such as generators, synchronous motor and under voltage protection of AC circuits, Induction motors, automatic change over schemes etc

The microcontroller-based design offers a wide range of Trip-Time characteristics, under voltage or over voltage mode and PT rating (110V, 240V, 415V), which can all be selected in the field at the time of commissioning. It accepts very wide auxiliary supply range.Relay is designed for flush mounting. It is very compact in size, which results in saving of panel space. Its draw-out construction makes installation and maintenance very easy.

Details of L&T Under voltage relay:

Fig 1: Under Voltage Relay

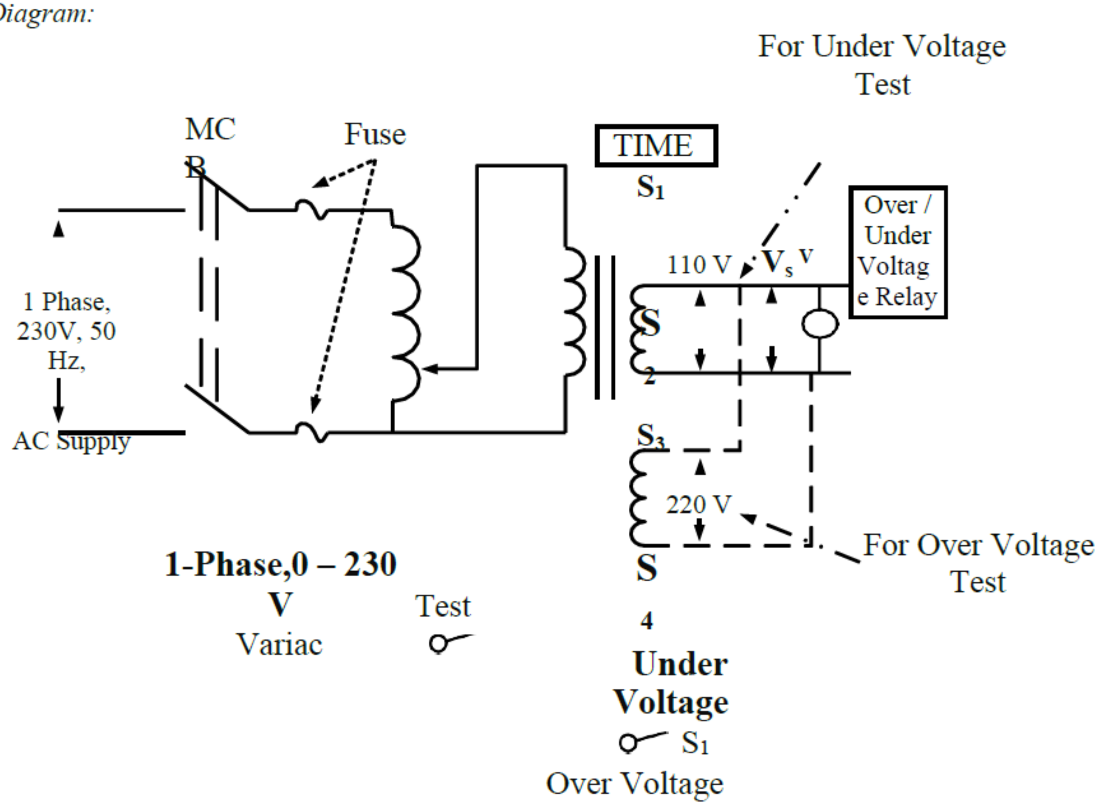
Technical Specifications of the relay are:

1.0	Rated Voltage (Vn)	110V
2.0	Rated Frequency	50Hz
3.0	Auxiliary Power Supply	230VAC

4.0 Relay Settings:

Pick up voltage(Vs)	
Over Voltage Mode	105% to 180% of Vn in steps of 5% Under
Voltage mode	95% to 20% of Vn in steps of 5%
Time Multiplier TMS	0.1 to 1.6 in steps of0.1

Circuit Diagram:



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Calculations:

The following are the calculations for voltage and TMS settings:

Voltage setting on the secondary side of the transformer:

The calculated voltage Vs is given by equation

Vs *[1 ± (0.05 Σ a)]Vn …………………………………………..(1)

+ is for over voltage

-is for under voltage

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

Vn is P.T. rating i.e. 110V. T.M.S:

Trip time $T = K\,(0.1 + \Sigma t)$…………………………………………..(2)

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

K = 3.5 for over voltage

K = 5.7 for under voltage

PROCEDURE FOR UNDER VOLTAGE TESTING:

UNDER VOLTAGE TESTING:

1. Connect circuit as per the circuit diagram. Switch ON MCB.
2. Calculate Vs from equations (1) and (2) for different values of ‘a’ and ‘t’ and tabulate the values in table 1 and table 2.

Table 1

a	Vs
0.05	99V
0.1	94V
0.2	83V
0.4	61V

Table 2 (value of K=5.7)

t	Vs
0.1	
0.2	
0.4	
0.8	

3. Ensure that the switch S1 in the circuit diagram is in ‘Under Voltage condition’, variac is in zero position and the switch ‘TEST’ is OFF position.
4. Now apply a voltage from variac which is less than the calculated setting voltageVsfor a=0.05 in order to test the operating condition of relay. Observe the relay indication and tripping. The setup will be in OFF condition.
5. Switch ON the ‘TEST’ mode, reset the timer
6. Switch ON the green button and note down the time in timer circuit for the applied under voltage Vs after tripping.
7. Repeat steps from 3 to 6 for three under voltage values.

Tabular Columns:

UNDER VOLTAGE TESTING:

Vs =			Weight (a) =	
S.No	**T.M.S**	**Voltage Setting**	**Applied Voltage**	**Operating time**

RESULT:

We have successfully studied about the micro-controller based under voltage relay

VIVA QUESTIONS:

1. What is the purpose of a micro-controller based under voltage relay?
2. How does a micro-controller based under voltage relay differ from traditional relay systems?
3. Can you explain the basic working principle of a micro-controller based under voltage relay?
4. What are the key components involved in designing a micro-controller based under voltage relay?
5. How do you program the micro-controller to detect and respond to under voltage conditions?
6. What are the advantages of using a micro-controller in under voltage protection compared to analog methods?
7. How does the sensitivity of a micro-controller based under voltage relay impact its performance?
8. Can you describe the process of calibrating a micro-controller based under voltage relay?
9. What safety considerations should be taken into account when designing and implementing a micro-controller based under voltage relay system?

10. How does the response time of a micro-controller based under voltage relay affect its effectiveness in protecting electrical systems?
11. What are the typical applications where a micro-controller based under voltage relay is used?
12. How can the performance of a micro-controller based under voltage relay be optimized for specific industrial or commercial settings?
13. What measures can be implemented to ensure the reliability and durability of a micro-controller based under voltage relay in harsh environments?
14. Can you explain the role of feedback mechanisms in enhancing the performance of a micro-controller based under voltage relay?
15. What are the limitations or challenges associated with using micro-controller based under voltage relays, and how can they be mitigated?

EXPERIMENT NO 7

OBJECT: - . To study the micro-controller based over voltage relay

Apparatus required:

S.No	Apparatus	Type	Quantity
01	UV/OV Relay	µP based	01No
02	Voltage Source Unit (230/110-230V)		01No
03	Connecting Wires		As Required
04	Voltmeter (0-500V AC)	Digital	01No

Theory: Over Voltage/Under Voltage Relay is an electronic microcontroller based single- phase voltage relay. It is suitable for over voltage/under voltage protection schemes in LV, MV and HV power distribution systems. It is also suitable for over voltage protection of AC circuits, capacitors, machines such as generators, synchronous motor and under voltage protection of AC circuits, Induction motors, automatic change over schemes etc

The microcontroller-based design offers a wide range of Trip-Time characteristics, under voltage or over voltage mode and PT rating (110V, 240V, 415V), which can all be selected in the field at the time of commissioning. It accepts very wide auxiliary supply range.Relay is designed for flush mounting. It is very compact in size, which results in saving of panel space. Its draw-out construction makes installation and maintenance very easy.

Details of L&T Over voltage relay:

Fig 1: Over voltage Relay

Technical Specifications of the relay are:

1.0	Rated Voltage (Vn)	110V
2.0	Rated Frequency	50Hz
3.0	Auxiliary Power Supply	230VAC
4.0	Relay Settings:	

Pick up voltage(Vs)

Over Voltage Mode	105% to 180% of Vn in steps of 5%
	Under
Voltage mode	95% to 20% of Vn in steps of 5%
Time Multiplier TMS	0.1 to 1.6 in steps of0.1

Calculations:

The following are the calculations for voltage and TMS settings:

Voltage setting on the secondary side of the transformer:

The calculated voltage Vs is given by equation

Vs *[1 ± (0.05 Σ *a*)]*Vn* ……………………………………………..(1)

+ is for over voltage

-is for under voltage

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

Vn is P.T. rating i.e. 110V. T.M.S:

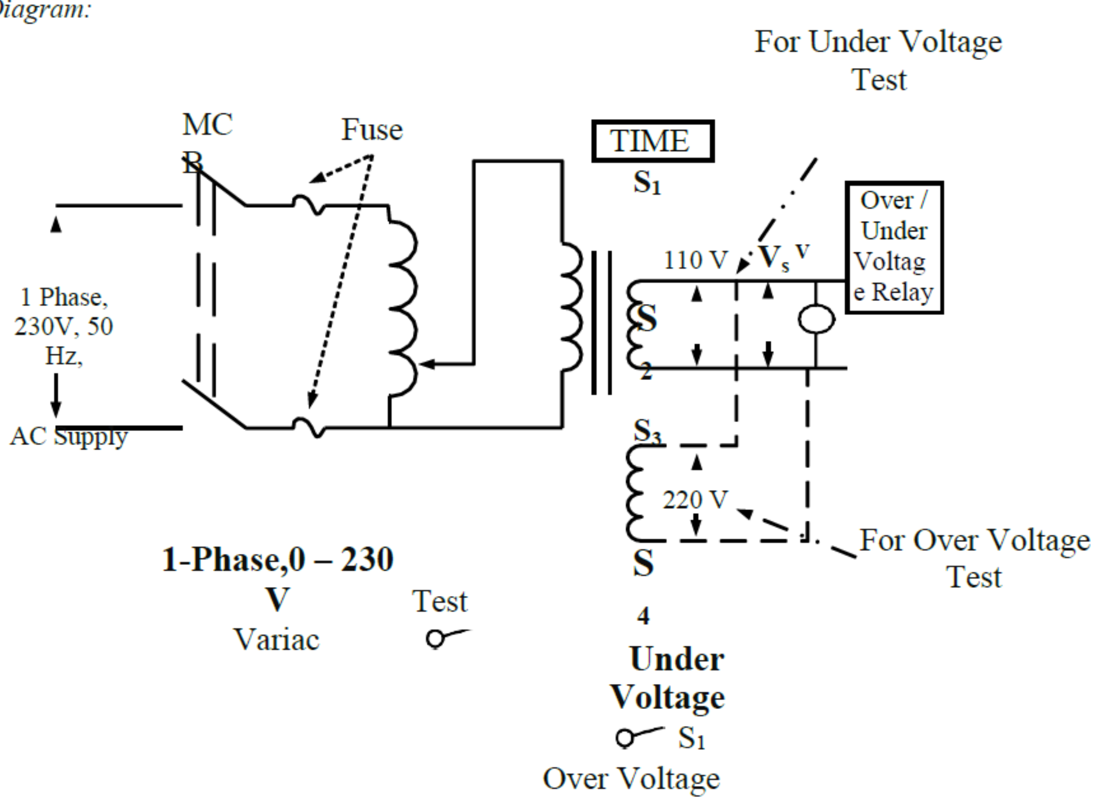
Trip time *T*= *K* (0.1 + Σ*t*)……………………………………………..(2)

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

K = 3.5 for over voltage

K = 5.7 for under voltage

Circuit Diagram:



PROCEDURE FOR OVER VOLTAGE TESTING:

1. Connect circuit as per the connection diagram. For over voltage condition, connect the relay to the terminals S3 and S4which are present on the secondary side of the transformer. Switch ON MCB.

2. Calculate Vsfrom equations (1) and (2) for different values of ‘a’ and ‘t’ and tabulate the values in table 3 and table 5.

Table 1

a	***Vs***
0.05	121V
0.1	126V
0.2	138V
0.4	140V

Table 2 (value of K=3.5)

t	***T***
0.1	
0.2	
0.4	
0.8	

3. Ensure that the switch S1 in the circuit diagram is in ‘Over Voltage condition’, variac is in zero positon and the switch ‘TEST’ is OFF position.

4. Now apply a voltage from variac which is greater than the calculated setting voltage Vs for a=0.05 in order to test the operating condition of relay. Observe the relay indication and tripping. The setup will be in OFF condition.

5. Switch ON the ‘TEST’ mode, reset the timer

6. Switch ON the green button and note down the time in timer circuit for the applied under voltage Vs after tripping.

7. Repeat steps from 3 to 6 for three over voltage values.

Tabular Columns:

OVER VOLTAGE TESTING :

Vs =			Weight (a) =	
S.No	**T.M.S**	**Voltage Setting**	**Applied Voltage**	**Operating time**

RESULTS

We have successfully studied about the micro-controller based over voltage relay

VIVA QUESTIONS:

1. What is the purpose of using a micro-controller in an overvoltage relay system?
2. How does the overvoltage relay protect electrical equipment?
3. What are the key components required to build a micro-controller based overvoltage relay?
4. Can you explain the working principle of the micro-controller based overvoltage relay system?
5. How does the micro-controller detect overvoltage conditions?
6. What measures are taken by the micro-controller when an overvoltage is detected?
7. How does the micro-controller ensure timely response to overvoltage events?
8. What are the advantages of using a micro-controller in comparison to traditional overvoltage protection methods?
9. What factors should be considered when selecting a micro-controller for overvoltage protection applications?
10. Can you discuss the role of programming in configuring the micro-controller for overvoltage protection?
11. How does the micro-controller communicate the status of overvoltage events to external devices or systems?

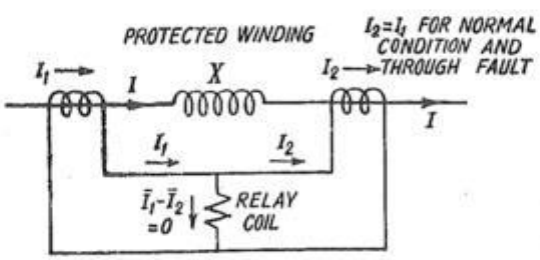
12. What testing procedures are employed to validate the performance of a micro-controller based overvoltage relay?
13. How do environmental factors such as temperature and humidity affect the operation of the micro-controller based overvoltage relay?
14. Can the micro-controller based overvoltage relay be integrated with other protective devices in a power system? If yes, how?
15. What are the potential challenges or limitations associated with the implementation of a micro-controller based overvoltage relay?

EXPERIMENT NO: 8

Object: **To study the operation of micro-controller based unbiased single phase differential relay..**

APPARATUS- digital ammeter,load differential relay and control circuit, tapping terminal of different ratio.

Theory:-A simple rule of thumb is that the CT's on any wyes winding of a power transformer should be connected in delta, and the CT's on any delta winding should be connected in wyes. This rule may be broken, but it rarely is; for the moment let us assume that it is inviolate. Later, we shall learn the basis for this rule. The remaining problem is how to make the required interconnection between the CT's and the differential relay. Two basic requirements that the differential-relay connections must satisfy are: (1) the differential relay must not operate for load or external faults; and (2) the relay must operate for severe enough internal faults. If one does not know what the proper connections are, the procedure is first to make the connections that will satisfy the requirement of not tripping for external faults. Then, one can test the connections for their ability to provide tripping for internal faults. As an example, let us take the wye-delta power transformer of Fig. The first step is arbitrarily to assume currents flowing in the power-transformer windings in whichever directions one wishes, but to observe the requirements imposed by the polarity marks that the currents flow in opposite directions in the windings on the same core, as shown in Fig. We shall also assume that all the windings have the same number of turns so that the current magnitudes are equal, neglecting the very small exciting-current component. (Once the proper connections have been determined, the actual turn ratios can very easily be taken into account.)



For Through Fault

Fig. 1 (a). Principle of circulating current relay of generators, transformers.

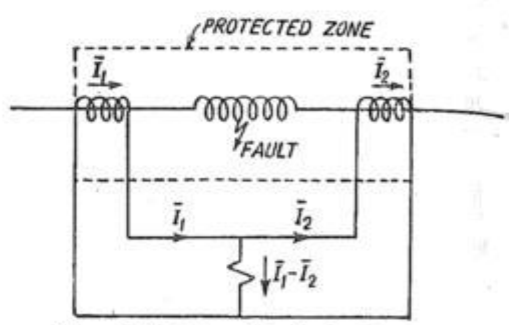


Fig. 1 (b). Internal Fault : $I_1 - I_2 \neq 0$.

On the basis of the foregoing, Fig.shows the currents that flow in the power-transformer
Leads and the CT primaries for the general external-fault case for which the relay must not trip. We are assuming that no current flows into the ground from the neutral of the wyes winding; in other words, we are assuming that the three-phase currents add vector ally to zero.

The next step is to connect one of the sets of CT's in delta or in wyes, according to the rule of thumb already discussed; it does not matter how the connection is made, i.e., whether one way or reversed Then, the other set of CT's must be connected also according to the rule, but, since the connections of the first set of CT's have been chosen, it does matter how the second set is connected; this connection must be made so that the secondary currents will circulate between the CT's as required for the external-fault case. A completed connection diagram that meets the requirements is shown in Fig. The connections would still be correct if the connections of both sets of CT's were reversed.

Proof that the relay will tend to operate for internal faults will not be given here, but the reader can easily satisfy himself by drawing current-flow diagrams for assumed faults. It will be found that protection is provided for turn-to-turn faults as well as for faults between phases or to ground if the fault current is high enough.

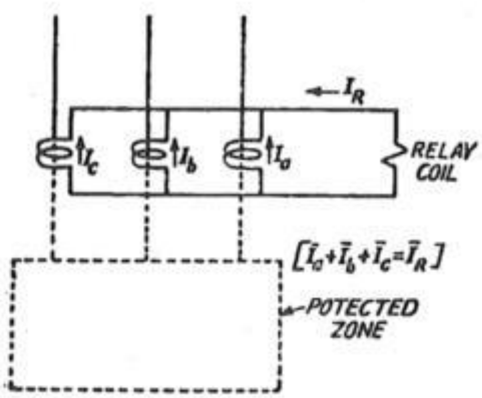
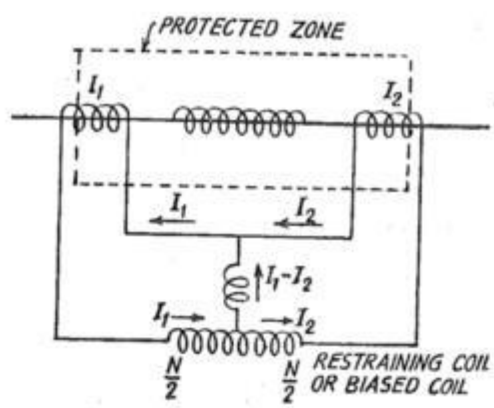


Fig. 2. Differential Protection of 3-phase circuit.



$$A.T. = \left(\frac{I_1 + I_2}{2}\right)N$$

Fig. 3. Per cent Differential Relay. (Biased Differential Relay.)

We shall now examine the rule of thumb that tells us whether to connect the CT's in wyes or in delta. Actually, for the assumption made in arriving at Fig., namely, that the three phase currents add vector ally to zero, we could have used wyes-connected CT's on the wyes side and delta-connected CT's on the delta side. In other words, for all external-fault conditions except ground faults on the wyes side of the bank, it would not matter which pair of CT combinations was used. Or, if the neutral of the power transformer was not grounded, it would not matter. The significant point is that, when ground current can flow in the wyes windings for an external fault, we must use the delta connection (or resort to a Zero-phase-sequence-current-shunt that will be discussed later). The delta CT connection circulates the zero-phase-sequence components of the currents inside the delta and thereby keeps them out of the external connections to the relay. This is necessary because there are no zero-phase-sequence components of current on the delta side of the power transformer for a ground fault on the wyes side; therefore, there is no possibility of the zero-phase-sequence currents simply circulating between the sets of CT's and, if the CT's on the wyes side were not delta connected, the zero-phase-sequence components would flow in the operating coils and cause the relay to operate undesirably for external ground faults.

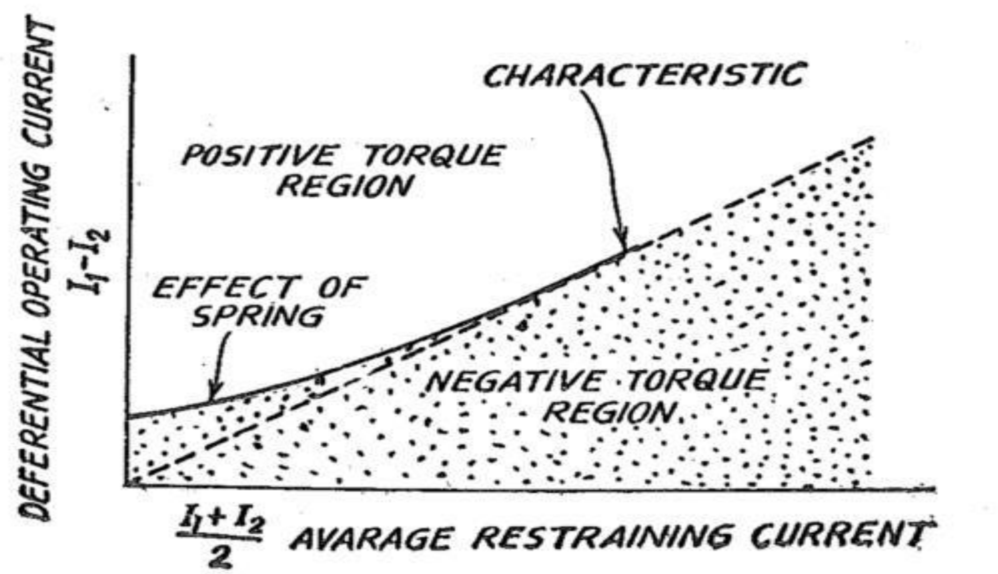


Fig. 4. Operating characteristic of differential relay.

Observation Table:-

Result:-We have successfully Study percentage bias differential relay & Plot the characteristics of a percentage bias differential relay for 20%, 30% and 40% biasing.

VIVA QUESTIONS:

1. What is the primary function of a micro-controller based unbiased single phase differential relay?
2. How does the unbiased single phase differential relay differ from other types of relays?
3. Can you explain the basic principle of operation behind the unbiased single phase differential relay?
4. What are the key components of the micro-controller based unbiased single phase differential relay circuit?
5. How does the micro-controller enhance the performance of the differential relay compared to traditional relay designs?
6. What are the advantages of using a micro-controller in relay circuits?
7. How does the relay detect faults in the single phase system?
8. Can you describe the algorithm used by the micro-controller to determine whether a fault has occurred?
9. What measures are taken to ensure the reliability and accuracy of the relay's operation?
10. How does the relay respond to different types and magnitudes of faults in the system?
11. What factors might affect the sensitivity of the unbiased single phase differential relay?
12. How is the relay calibrated and tested to ensure proper functioning?
13. What are the limitations of the micro-controller based unbiased single phase differential relay?
14. Can you discuss any potential challenges or difficulties encountered during the implementation of the relay experiment?
15. How does the relay contribute to the overall protection and safety of the electrical system?

EXPERIMENT NO: 9

Object:To study the operation of micro-controller based biased single phase differential relay
Apparatus required:
1) Differential Relay - Type MIB202
2) Single phase transformer
3) Single phase Variac
4) Ammeters 0 – 10A, 0 – 20A
5) Current Transformers 10/5 – 2Nos
6) Connecting wires.

THEORY: The differential relay is one that operates when the vector difference of two or more similar electrical quantities exceed a pre – determined value. This means for a differential relay it should have two or more similar electrical quantities and these quantities should have phase displacement for the operating of the relay. The name is not due to particular construction of the relay but is due to the way in which the relay is connected in the circuit.

The percentage differential protection relay consists of an Operating coil and a Restraining coil. The operating coil is connected to the midpoint of the restraining coil. Normally no current flows through the operating coil under normal conditions. The operating coil under through fault condition, but to the dissimilarities in C-T’s. The differential current through the operating coil is (I1-I2) and equivalent developed by the operating coil is proportional to the ampere turns. i.e., TO (I1-i2) NR, where NR is number of turns in the restraining coil at balance, (I1-I2) No=1/2(I1-I2) NR.

From the above characteristics it is clear that expect of control spring at low currents, the ratio of the differential operating coil current to the average restraining coil current is a fixed percentage that is why it is known as percentage differential, since the relay has a using operating characteristics relay i.e., The pickup value T’s the magnitude of through current increases. The relay is restrained or biased against operating in accurately due to this the relay is known as biased relay.

Biasing is required to allow the transformer to be operated at different input voltages by changing the tap position to obtain the constant voltage output. This will make primary & secondary ratio currents will not match the voltage ratio of transformer, which will not allow the differential relay to trip under unwanted condition. It is very important protection for transformer which identifies internal problems such as Earth Fault, phase to phase fault and inter turn short. When this relay operates; we should see that the transformer is isolated from both HV and LV side of the transformer.

Differential relay is used for major 3 phase transformers such as 10MVA and above as it is costly and needs Class PS type current transformers to avoid nuisance tripping due to through faults. It requires interposing CTs to compensate mismatch of CTs and to make the currents through differential relay equal in magnitude and opposite in direction. This requires CT secondary's to be connected in star when transformer winding is in delta and they will be connected in Delta for the transformer connected in star.

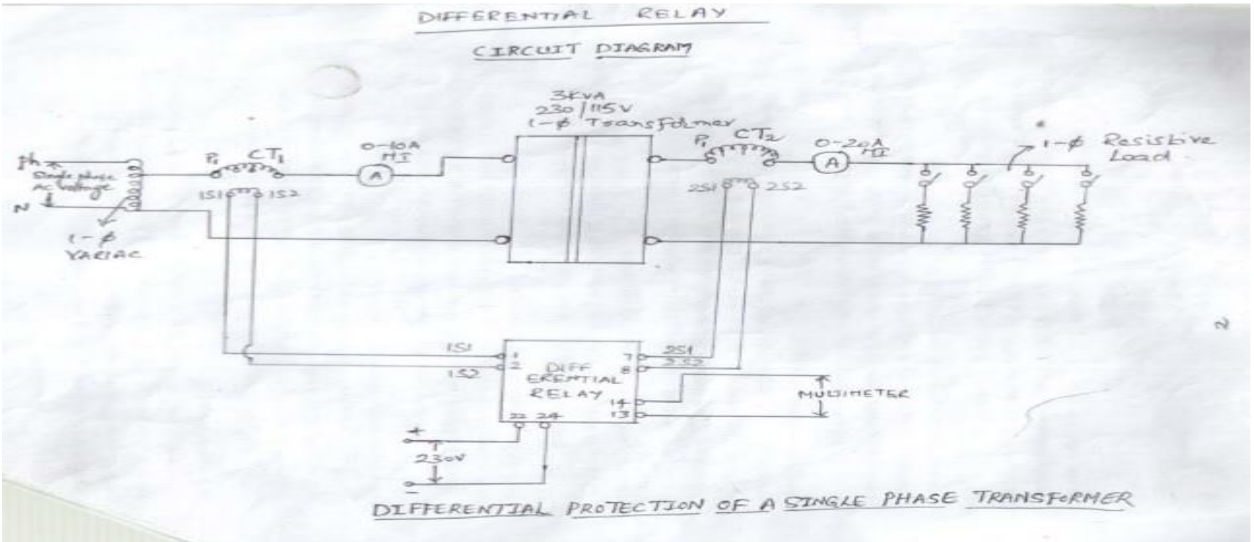
Transformers are normally protected against short – circuits and overheating. For short – circuits normally percentage differential protection is recommended for transformers rated for more than one mega volts amps, for low rating over current relaying is used.

The primary and secondary currents of a transformer are normally different from each other are and related by their turn's ratio. These currents are displaced by in phase from each other by 30 if the winding are connected in as star – delta connection. The current transformers on the star side of the power transformer are connected in delta, and as delta side. They are connected in star as the current of the star – delta power transformer will be displaced in phase by 30 it is required that this phase displacement must be nullified by connecting the current transformer in that fashion.

In this experiment, the MIB202 is micro-controller based Numerical Biased Differential Protection Relay within build Current Amplitude and Vector Group Compensation features and also with Instantaneous Differential High set Element for two winding Power Transformer and Auto Transformers.

MIB202 relay, which can be used to operate for internal faults, like phase to phase, phase to earth and inter turn faults in the Transformers. The same relay, we can use for 1A or 5A CT input on both LV & HV side. The relay has supervisory components and self – monitoring features give high confidence of serviceability.

Circuit Diagram:



Procedure:

1) Connect the circuit as per the circuit diagram.

2) Apply the rated voltage of 230 V using variac to primary transformer.

3) Note down the readings & then switch 'ON ' the load at various steps until the relay "Trips" & then note down the readings of Transformer Currents & CT Currents.

4) Repeat the same procedure for same biasing & change the CT terminals.

Tabular Column:

V=220 V Biasing 10%

CT—15 CT—10

I_1	I_2	CT_1	CT_2

Result: The Transformer is protected by Differential protection.

VIVA QUESTIONS:

1. Can you explain the basic principle behind the operation of a micro-controller based biased single phase differential relay?
2. What are the key components required in designing a micro-controller based biased single phase differential relay?
3. How does the micro-controller handle the biasing mechanism in the relay?

4. What are the advantages of using a micro-controller in differential relays compared to traditional methods?
5. How does the relay differentiate between normal operating conditions and fault conditions?
6. What measures are taken to ensure the reliability and accuracy of the micro-controller based relay?
7. Can you describe the algorithm used by the micro-controller to detect differential current?
8. How does the micro-controller communicate the detected fault to the protection system?
9. What types of faults can be detected and protected against by this relay?
10. How is the sensitivity of the differential relay adjusted and maintained?
11. What challenges may arise in the implementation of a micro-controller based biased single phase differential relay?
12. How does the relay ensure selectivity in tripping only the faulty section of the system?
13. Can you discuss the testing and calibration procedures for this type of relay?
14. What are the potential applications of micro-controller based biased single phase differential relays?
15. How does the relay respond to transient conditions or inrush currents?

EXPERIMENT NO: 10 & 11

Objective: To determine the operating characteristics of micro-controller un biased and biased three phase differential relay.

Theory: The MicomP634 relay is designed for the protection of transformer. For the application of the device as transformer differential protection, amplitude matching of current is required. This is achieved simply by setting of the reference power, generally the nominal power of the transformer and of the primary nominal voltages for all windings of the transformer. Vector group matching is achieved by the straightforward input of the relevant vector group identification number in the device.

Calculation of Reference Values:

Based on the reference power and nominal voltage settings of the windings, reference currents for the corresponding windings are calculated.

$$I_{ref,a} = \frac{S_{ref}}{\sqrt{3}V_{nom,a}}$$

$$I_{ref,b} = \frac{S_{ref}}{\sqrt{3}V_{nom,b}}$$

with

Sref: reference power

Iref,a/ b: reference current of winding a / b

Vnom,a/b: nominal voltage of winding a/b

(1) Amplitude Matching Factor Calculation: The transformers have a certain transformation ratio, so the measured rmscurrents of different windings are not directly comparable. Moreover, there may be mismatches in the CT ratios of different windings. To make the currents comparable, amplitude of measured current across the windings should be matched. The amplitude matching factors in the relay are calculated considering the reference current obtained in step (1) and the set nominal current of the corresponding windings:

$$K_{am,a} = \frac{I_{nom,a}}{I_{ref,a}} k_{am,b} = \frac{I_{nom,b}}{I_{ref,b}}$$

with

kam,a/b: amplitude matching factor of end a/ b

Inom,a/b: primary nominal currents of the system transformers

After calculating the amplitude matching factors for the windings the device checks a condition 0.5 <kam,a/b< 16. If the condition is satisfied then it becomes functional.

(2) Amplitude Matching:

Once the device becomes functional the CT and VT secondary are connected to the relay and the nominal current and voltage ratings, input to the device are set. The device calculates the current phasors of all phases and calculates the amplitude matched currents (Iam,x,y) of the windings by multiplying the current phasors with the amplitude matching factors of the corresponding windings.

$$I_{am,x,z} = k_{am,z}.I_{x,z}$$

With

Iam,x,z= Amplitude matched current phasor of x phase of z winding kam,z= Amplitude matching for of z winding

Consequently, all threshold values and measured values always refer back to the relevant reference currents rather than the transformer nominal currents or the nominal currents of the device

(3) *Zero-sequence Current Filtering:* The zero-sequence current is eliminated from the phase currents of windings. The calculations for zero-sequence current are calculated as Follows:

$$I_{am,0,z} = \frac{1}{3}\left[I_{am,A,z} + I_{am,B,z} + I_{am,C,z}\right]$$

$$I_{s,y,z} = I_{am,A,z} - I_{am,0,z}$$

Where

z: end a, b

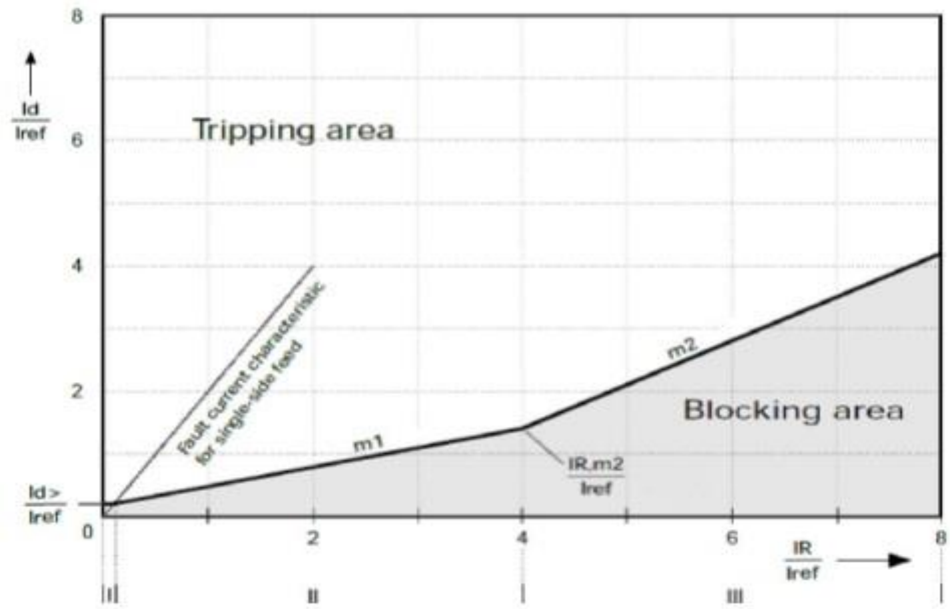
x: phase A, B, C

y: Measuring system 1, 2, 3

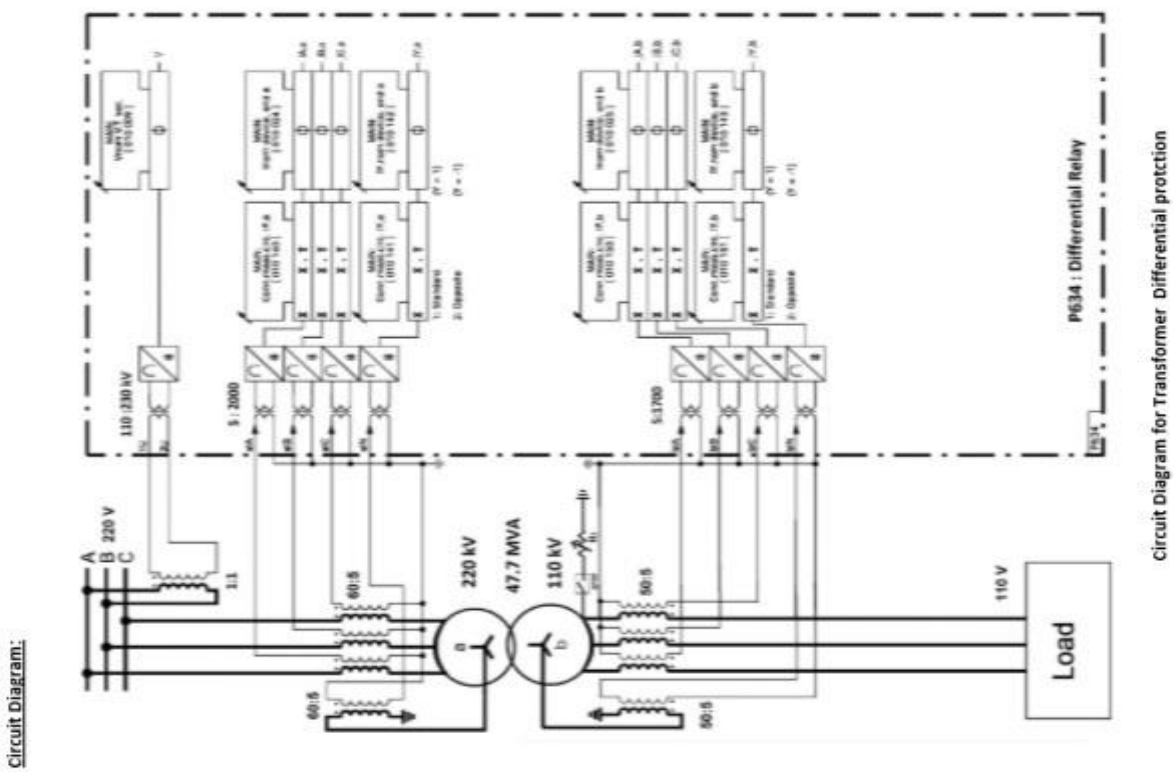
Iam: amplitude-matched current phasor

Measuring system is the internal convention of MicomP634 relay to measure phase currents. In default settings 1 corresponds to phase A, 2 corresponds to phase B and 3 corresponds to phase C.

Tripping characteristics of relay:



Circuit Diagram:



Results-

VIVA QUESTIONS:

1. What is the fundamental principle behind the operation of a three-phase differential relay?
2. How does biasing affect the operation of a three-phase differential relay?
3. Can you explain the concept of an unbiased three-phase differential relay?
4. What are the advantages of using a biased three-phase differential relay over an unbiased one?
5. Describe the construction and components of a microcontroller-based three-phase differential relay.
6. How does the microcontroller facilitate the operation of the three-phase differential relay?
7. What are the key parameters that need to be configured in a microcontroller-based differential relay?
8. How does the microcontroller analyze the phase currents to detect faults in the system?
9. Explain the role of filtering techniques in the operation of a microcontroller-based differential relay.
10. What are the common types of faults detected by a three-phase differential relay?
11. How does the relay differentiate between internal and external faults in the system?
12. Discuss the importance of coordination between the differential relay and other protective devices in a power system.
13. Can you explain the concept of sensitivity in the context of a three-phase differential relay?
14. How do you calibrate a microcontroller-based three-phase differential relay?
15. What are the challenges associated with implementing a microcontroller-based three-phase differential relay in real-world power systems?

EXPERIMENT NO 12

OBJECT: Study gas actuated Buchholz relay.

THEORY:-Buchholz relay is a gas-actuated relay installed in oil immersed transformers for protection against all kinds of faults. Named after its inventor, Buchholz, it is used to produce an alarm in case of incipient (i.e. slow-developing) faults in the transformer and to disconnect the transformer from the supply in the event of severe internal faults. It is usually installed in the pipe connecting the conservator to the main tank. It is a universal practice to use Buchholz relays on all such oil immersed transformers having ratings in excess of 750 kVA.

The Buchholz relay is a protective rely for equipment immersed in oil for insulating and cooling purpose. It is intended mainly for transformers or choke coils having a conservator vessel.

The relay responds to the accumulation of gas or air inside the apparatus when the oil level is too low or the flow of oil unusually strong. The relay then either gives a warning signal or disconnects the endangered equipment. The Buchholz relay operates even on very slight faults which are just in process of developing, so that greater damage may be prevented.

PROTECTION RANGE :

There is practically no operational fault in transformers or other oil immersed apparatus to which the Buchholz relay does not respond. Its protective value applies, among others, to the following cases:

1- Flashover between live conductors

2- Flashover between conductor and iron core

3- Earth leakage

4- Insulation breakdown between turns

5- Interruption of a phase or lead connection

6- Excessive heating of the iron core

7- Leakage in the oil container or oil pipes

CONSTRUCTION:

The Buchholz relay takes the form of a domed vessel placed in the connecting pipe between the main tank and the conservator. The device has two elements.

1- The upper element

The upper element consists of a mercury type switch attached to a float. The upper element of the relay closes the alarm circuit during incipient faults.

2- The lower element

The lower element contains a mercury switch mounted on a hinged type flap located in the direct path of the flow of oil from the transformer to the conservator. The lower element is arranged to trip the circuit breaker in case of severe internal faults.

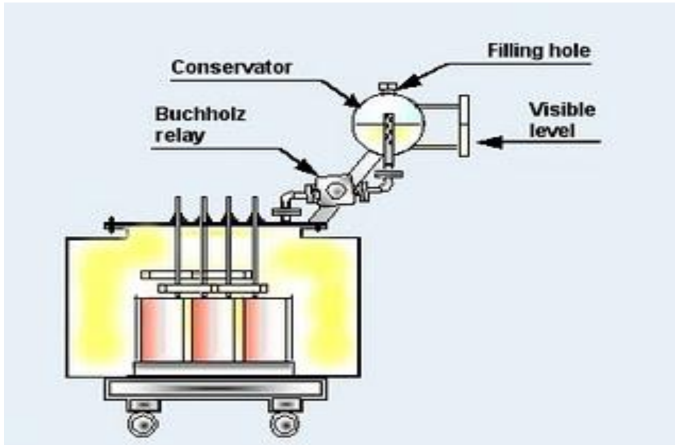


FIGURE: Buchholz relay location in transformer

OTHER COMPONENTS:

The cast-iron cover plate carries below it the whole assembly of the relay elements. It mounts on the top, the oil-tight terminal box with the cable entry, the ceramic insulated connection terminals and the test cock. Through, the cock, the gas collected in the relay can be released. In addition, air can be pumped through the test cock to see if the top float and the mercury switch are operating properly.

GAS TESTER:

By examining the decomposition gases collected in the relay, the gas tester can be provided by the manufacturer, providing the information as about the cause and type of the fault. It prevents the wastage of time for unnecessary dismantling, thus greatly facilitating fault detection.The gas tester contains two silver nitrate solutions which, on the passage of decomposition gases, form two easily distinguishable precipitates. For instance, the precipitates formed by passing gasified oil through the solutions differs considerably from the one formed by gasified insulating materials, such as paper, cotton, etc. If the tested gas does not form a precipitate, this means that air has collected in the relay.

MODE OF OPERATION :

All operational faults occurring in an apparatus using oil as insulating medium, with the exception of those due to air lock and oil leakage, are the consequence of local overheating or arcing. This causes oil or other insulating medium adjacent to the fault to form gases. The rate of gas development is dependent upon the nature of the fault and the effect produced on the relay varies accordingly.In the case of slight faults, the slowly developing gas bubbles accumulate in the upper part of the relay housing, which is constructed as a gas chamber.

The Buchholz relay is built into the connecting pipe between the oil tank and the conservator vessel, so that rising gas and air bubbles are trapped by the relay.Under the normal conditions, the relay is completely filled with oil, but with the accumulation of oil gases, this gas tends to replace the oil, the oil level falls and causes the relay float to tilt a mercury switch, which then either makes or breaks the contact.In the case of a serious fault with violent gas formation, pressure waves are set up in the oil, forcing it to flow towards the conservator vessel. Should the speed of the oil exceed the adjusted sensitivity of the operating vane, which is coupled to a mercury switch, this switch is already tilted by the pressure wave and disconnects the transformer even before the gases reach the Buchholz relay itself.

The float and mercury switch-tube are connected to each other in such a way that the switch tube tilts with the float into tripping position. The setting range of the operating vane is from 50 to 150 cm/sec oil flow speed. It is usually set at 100 cm/sec response speed when delivered from the factory.In the single float Buchholz relay, the operating vane is soldered to the float itself. The mercury switches connected to the floats can either operate an alarm or switch off the endangered apparatus altogether; the choice depends upon the particular installation. That is why, small transformers in unattended substations are best provided with the single-float relays, and the transformers simply disconnected when a fault occurs. A warning signal is only useful when a station is manned; then single float relay can also be used or alarm purpose.The double float relay can be supplied for any type of transformer and with this pattern it is usually found advisable to use the upper float for an alarm. This float responds only when gas or air accumulates or when the oil level sinks. The lower mercury switch tube, on the other hand, is frequently used to disconnect the apparatus or transformer, since it responds to oil loss via the float and to pressure waves via the opening vane. It is however possible, by means of a locking device, to cancel the response of the lower float when the oil level sinks so that disconnection will not take place on account of this particular fault.

Finally, summing up the discussion to a very brief and precise ending, the operation of the Buchholz relay is given as under:

1- In case of incipient faults within the transformer, the heat due to fault causes the decomposition of some transformer oil in the main tank. The products of the decomposition contain more than 70% hydrogen gas. The hydrogen gas being light tries to go into the conservator and in the process gets entrapped in the upper part of the relay chamber. When a predetermined amount of gas gets accumulated, it exerts sufficient pressure on the float to cause it to tilt and closes the contacts of mercury switch attached to it. This completes the alarm circuit to sound an alarm. But it does not call for an immediate removal of the faulty transformer. The reason is that sometimes, the air bubbles in the oil circulation system of a healthy transformer may operate the float. For this reason, float is arranged to sound an alarm; not to trip the transformer. Therefore, on alarm, steps can be taken to verify the gas and its composition.

2- If a serious fault occurs in the transformer, an erroneous amount of gas is generated in the main tank. The oil in the main tank rushes towards the conservator via the Buchholz relay and in doing so tilts the flap to close the contacts of mercury switch. This completes the trip circuit to open the circuit breaker controlling the transformer.

ADVANTAGES:

1. It is the simplest form of transformer protection.
2. It detects the incipient faults at a stage much earlier than is possible with other forms of protection.

DISADVANTAGES:

1. It can only be used with oil immersed transformers equipped with conservator tanks.
2. The device can detect only faults below oil level in the transformer. Therefore, separate protection is needed for connecting cables.

RESULT:-Thus we have Study gas actuated Buchholz relay.

VIVA QUESTIONS:

1. What is the basic principle behind the operation of a gas actuated Buchholz relay?
2. Can you describe the construction and components of a gas actuated Buchholz relay?
3. What role does the Buchholz relay play in the protection of a transformer?
4. How does the gas actuation mechanism function within the Buchholz relay?
5. What are the typical gases used in gas actuated Buchholz relays, and why are they chosen?
6. How does the presence of gas bubbles indicate different types of faults in the transformer?
7. What are the differences between a gas actuated Buchholz relay and a traditional mechanical Buchholz relay?
8. What are the advantages of using a gas actuated Buchholz relay over other types of protection mechanisms?
9. Can you explain the process of installing and maintaining a gas actuated Buchholz relay in a transformer system?
10. How do you calibrate a gas actuated Buchholz relay to ensure accurate operation?
11. What are the common failure modes associated with gas actuated Buchholz relays, and how can they be detected and rectified?
12. How does the sensitivity of a gas actuated Buchholz relay impact its performance in detecting faults?
13. Can you discuss any safety precautions that need to be taken when working with gas actuated Buchholz relays?
14. What are some practical applications where gas actuated Buchholz relays are commonly employed?
15. In what scenarios would you recommend the use of a gas actuated Buchholz relay as opposed to other types of protective devices?

EXPERIMENT NO 13

AIM: To study the protection of bus-bars by differential protection

INTRODUCTION

In early days only conventional over current relays were used for busbar protection. But it is desired that fault in any feeder or transformer connected to the busbar should not disturb busbar system. In viewing of this time setting of busbar protection relays are made lengthy. So when faults occurs on busbar itself, it takes much time to isolate the bus from source which may came much damage in the bus system.In recent days, the second zone distance protection relays on incoming feeder, with operating time of 0.3 to 0.5 seconds have been applied for busbar protection. But this scheme has also a main disadvantage. This scheme of protection can not discriminate the faulty section of the busbar. Now days, electrical power system deals with huge amount of power. Hence any interruption in total bus system causes big loss to the company. So it becomes essential to isolate only faulty section of busbar during bus fault.

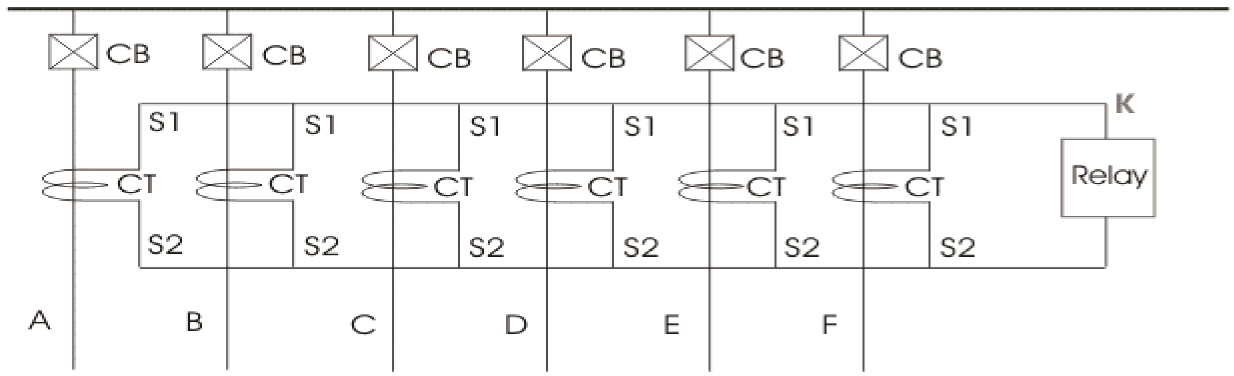
Another drawback of second zone distance protection scheme is that, sometime the clearing time is not short enough to ensure the system stability. To overcome the above mentioned difficulties, differential busbar protection scheme with an operating time less than 0.1 sec., is commonly applied to many SHT bus systems.

DIFFERENTIAL BUSBAR PROTECTION

CURRENT DIFFERENTIAL PROTECTION

The scheme of busbar protection, involves, Kirchoff's current law, which states that, total current entering an electrical node is exactly equal to total current leaving the node. Hence, total current entering into a bus section is equal to total current leaving the bus section.

The principle of differential bus-bar protection is very simple. Here, secondaries of CTs are connected parallel. That means, S_1 terminals of all CTs connected together and forms a bus wire. Similarly S_2 terminals of all CTs connected together to form another bus wire. A tripping relay is connected across these two bus wires.



Here, in the figure above we assume that at normal condition feed, A, B, C, D, E and F carries current I_A, I_B, I_C, I_D, I_E and I_F. Now, according to Kirchoff's current law,

$$I_A + I_B + I_C + I_D + I_E + I_F = 0$$

Essentially all the CTs used for differential busbar protection are of same current ratio. Hence, the summation of all secondary currents must also be equal to zero. Now, say current through the relay connected in parallel with all CT secondaries, is i_R, and i_A, i_B, i_C, i_D, i_E and i_F are secondary currents. Now, let us apply KCL at node X. As per KCL at node X,

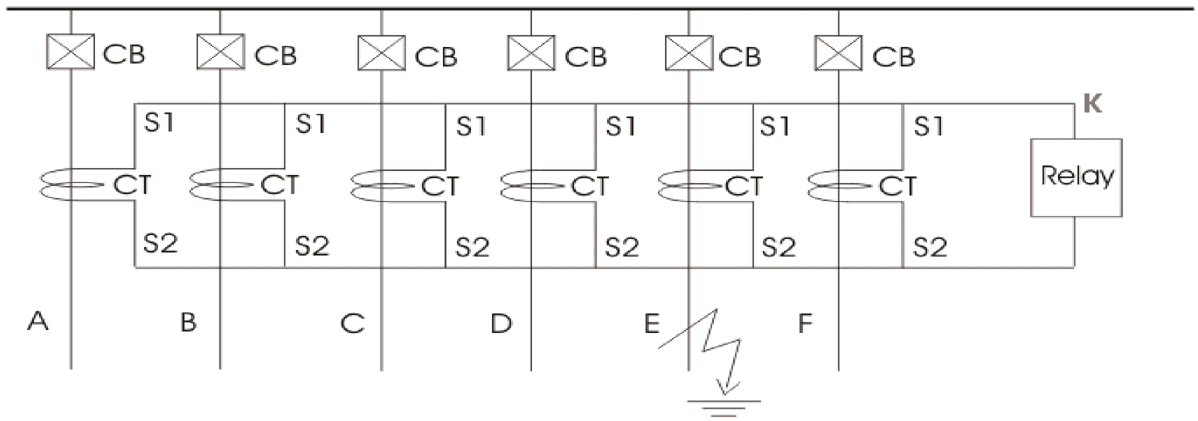
$$i_R + i_A + i_B + i_C + i_D + i_E + i_F = 0$$

$$\Rightarrow i_R + (i_A + i_B + i_C + i_D + i_E + i_F) = 0$$

$$\Rightarrow i_R + (\textit{Sum of all secondary currents}) = 0$$

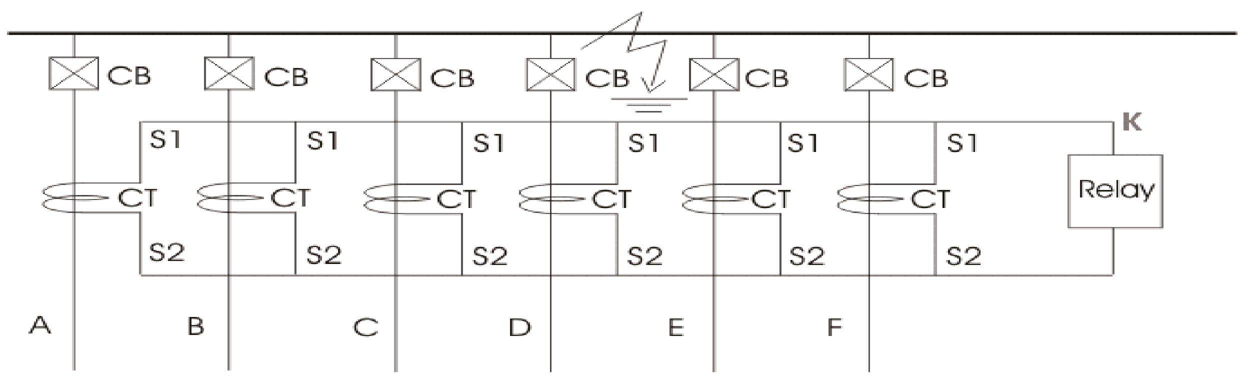
$$\Rightarrow i_R + 0 = 0 \, [\textit{As sum of all secondary currents is zero}]$$

So, it is clear that under normal condition there is no current flows through the busbar protection tripping relay. This relay is generally referred as Relay 87. Now, say fault is occurred at any of the feeders, outside the protected zone. In that case, the faulty current will pass through primary of the CT of that feeder. This fault current is contributed by all other feeders connected to the bus. So, contributed part of fault current flows through the corresponding CT of respective feeder. Hence at that faulty condition, if we apply KCL at node K, we will still get, $i_R = 0$.



That means, at external faulty condition, there is no current flows through relay 87. Now consider a situation when fault is occurred on the bus itself.

At this condition, also the faulty current is contributed by all feeders connected to the bus. Hence, at this condition, sum of all contributed fault current is equal to total faulty current. Now, at faulty path there is no CT. (in external fault, both fault current and contributed current to the fault by different feeder get CT in their path of flowing).



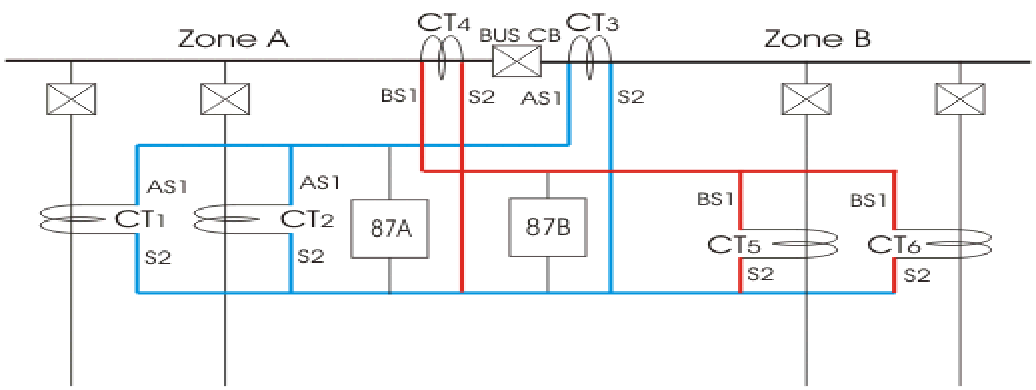
The sum of all secondary currents is no longer zero. It is equal to secondary equivalent of faulty current. Now, if we apply KCL at the nodes, we will get a non zero value of i_R.

So at this condition current starts flowing through 87 relay and it makes trip the circuit breaker corresponding to all the feeders connected to this section of the busbar. As all the incoming and outgoing feeders, connected to this section of bus are tripped, the bus becomes dead. This differential busbar protection scheme is also referred as current differential protection of busbar.

DIFFERENTIAL PROTECTION OF SECTIONALIZED BUS

During explaining working principle of current differential protection of busbar, we have shown a simple non sectionalized busbar. But in moderate high voltage system electrical bus sectionalized in than one sections to increase stability of the system. It is done because, fault in one section of bus should not disturb other section of the system. Hence during bus fault, total bus would be interrupted.

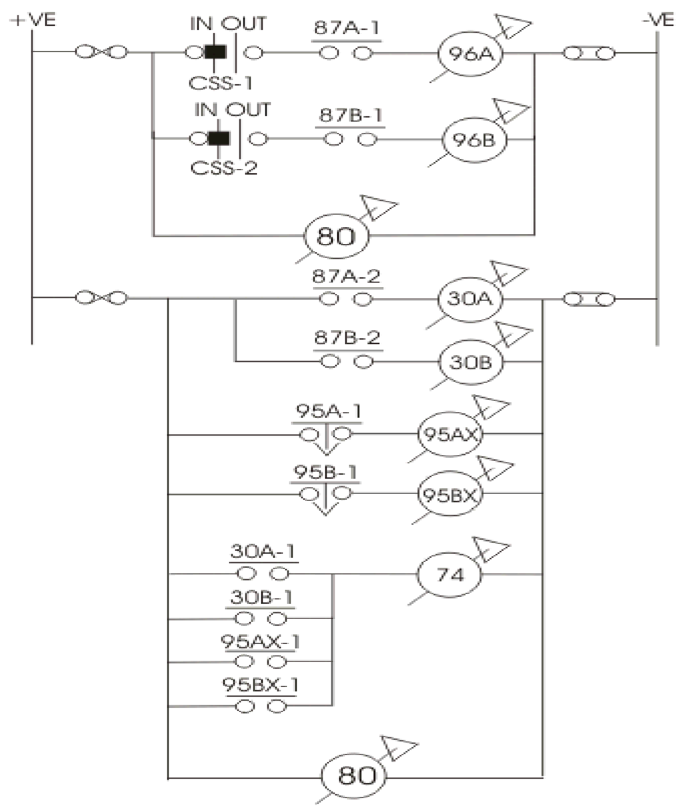
Let us draw and discuss about protection of busbar with two sections.



Here, bus section A or zone A is bounded by CT_1, CT_2 and CT_3 where CT_1 and CT_2 are feeder CTs and CT_3 is bus CT. Similarly bus section B or zone B is bounded by CT_4, CT_5 and CT_6 where CT_4 is bus CT, CT_5 and CT_6 are feeder CT. Therefore, zone A and B are overlapped to ensure that, there is no zone left behind this busbar protection scheme. ASI terminals of CT_1, 2 and 3 are connected together to form secondary bus ASI BSI terminals of CT_4, 5 and 6 are connected together to form secondary bus BSI. S_2 terminals of all CTs are connected together to form a common bus S_2. Now, busbar protection relay 87A for zone A is connected across bus ASI and S_2. Relay 87B for zone B is connected across bus BSI and S_2. This section busbar differential protection scheme operates in some manner simple current differential protection of busbar. That is, any fault in zone A, with trip only CB_1, CB_2 and bus C_B. Any fault in zone B, will trip only CB_5, CB_6 and bus CB. Hence, fault in any section of bus will isolate only that portion from live system. In current differential protection of busbar, if CT secondary circuits, or bus wires is open the relay may be operated to isolate the bus from live system. But this is not desirable.

DC CIRCUIT OF DIFFERENTIAL BUSBAR PROTECTION

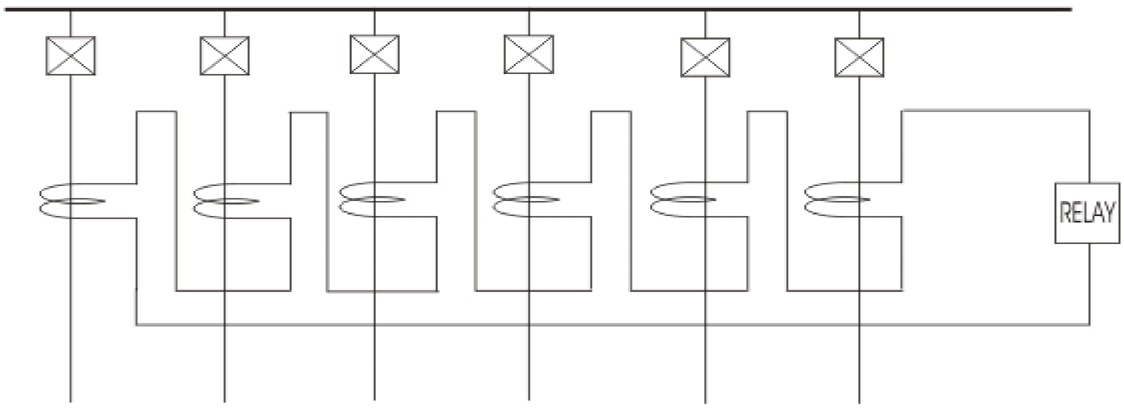
A typical DC circuit for busbar differential protection scheme is given below.



Here, CSSA and CSSB are two selector switch which are used to put into service, the busbar protection system for zone A and zone B respectively. If CSSA is in “IN” position, protection scheme for zone A is in service. If CSSB is in “IN” position, protection for zone B is in service. Generally both of the switches are in “IN’ position in normal operating condition. Here, relay coil of 96A and 96B are in series with differential busbar protection relay contact 87A-1 and 87B-1 respectively. 96A relay is multi contacts relay. Each circuit breaker in zone A is connected with individual contact of 96A. Similarly, 96B is multi contacts relay and each circuit breaker in zone-B is connected with individual contacts of 96B. Although here we use only one tripping relay per protected zone, but this is better to use one individual tripping relay per feeder. In this scheme one protective relay is provided per feeder circuit breaker, whereas two tripping relays one for zone A and other for zone B are provided to bus section or bus coupler circuit breaker. On an interval fault in zone A or bus section A, the respective bus protection relay 87A, be energized whereas during internal fault in zone B, the respective relay 87B will be energized. As soon as relay coil of 87A or 87B is energized respective no. contact 87A-1 or 87B-1 is closed. Hence, the tripping relay 96 will trip the breakers connected to the faulty zone. To indicate whether zone A or B busbar protection operated, relay 30 is used. For example, if relay 87A is operated, corresponding “No” contact 87A-2 is closed which energized relay 30A. Then the No contact 30A-1 of relay 30A is closed to energized alarm relay 74. Supervision relay 95 of respective zone is also energized during internal fault, but it has a time delay of 3 second. So, it reset as soon as the fault is cleared and therefore does not pick up zone bus wire shorting relay 95x which in turn shorts out the bus wires. An alarm contact is also given to this auxiliary 95x relay to indicate which CT is open circuited. No volt relay 80 is provided in both trip and non-trip section of the D. C. circuit of differential busbar protection system to indicate any discontinuity of D. C. supply.

VOLTAGE DIFFERENTIAL PROTECTION OF BUSBAR

The current differential scheme is sensitive only when the CTs do not get saturated and maintain same current ratio, phase angle error under maximum faulty condition. This is usually not 80, particularly, in the case of an external fault on one of the feeders. The CT on the faulty feeder may be saturated by total current and consequently it will have very large errors. Due to this large error, the summation of secondary current of all CTs in a particular zone may not be zero. So there may be a high chance of tripping of all circuit breakers associated with this protection zone even in the case of an external large fault. To prevent this maloperation of current differential busbar protection, the 87 relays are provided with high pick up current and enough time delay. The greatest troublesome cause of current transformer saturation is the transient dc component of the short circuit current. This difficulties can be overcome by using air core CTs. This current transformer is also called linear coupler. As the core of the CT does not use iron the secondary characteristic of these CTs, is straight line. In voltage differential busbar protection the CTs of all incoming and outgoing feeders are connected in series instead of connecting them in parallel.



The secondaries of all CTs and differential relay form a closed loop. If polarity of all CTs are

properly matched, the sum of voltage across all CT secondaries is zero. Hence there would be no resultant voltage appears across the differential relay. When a buss fault occurs, sum of the all CT secondary voltage is no longer zero. Hence, there would be current circulate in the loop due to the resultant voltage. As this loop current also flows through the differential relay, the relay is operated to trip all the circuit beaker associated with protected bus zone. Except when ground fault current is severally limited by neutral impedance there is usually no selectivity problem. When such a problem exists, it is solved by use of an additional more sensitive relaying equipment including a supervising protective relay.

RESULT: Thus we have study differential protection for bus- bars.

VIVA QUESTIONS:

1. What is the primary purpose of using differential protection for bus-bars?
2. How does differential protection scheme operate to protect bus-bars?
3. What are the main components required for implementing a differential protection scheme for bus-bars?
4. Can you explain the principle of current balance in the context of bus-bar protection?
5. What factors contribute to the sensitivity of a differential protection relay for bus-bars?
6. How do you differentiate between internal faults and external faults using bus-bar differential protection?

7. What are the challenges associated with setting the operating characteristics of a bus-bar differential relay?
8. What measures can be taken to minimize the effects of CT saturation in bus-bar differential protection?
9. Can you discuss the coordination aspects of bus-bar differential protection with other protective relays in a power system?
10. What are the advantages and limitations of using communication-assisted bus-bar differential protection schemes?
11. How do you verify the correct operation of a bus-bar differential protection scheme during testing and commissioning?
12. What are the typical fault scenarios that bus-bar differential protection schemes are designed to detect and clear?
13. Can you explain the concept of zone-selective interlocking (ZSI) and its application in bus-bar protection?
14. What are the consequences of a false trip in a bus-bar differential protection scheme, and how can they be mitigated?
15. How do advancements in digital relaying technology impact the performance and reliability of bus-bar differential protection systems?