Jaipur Institute of Technology Group of Institutions

/ Jaipur - Near Mahindra SEZ Kalwara, Ajmer Road

LAB-MANUAL

VI SEM EE

DEPARTMENT OF ELECTRICAL ENGINEERING LAB

MANUAL -2020

LAB NAME: POWER SYSTEM PROTECTION LAB (6EE4-23)

PREPERED BY: Mr. K.D. KANSAL

EXPERIMENTS LIST 6EE4-23:

POWER SYSTEM PROTECTION LAB

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.

Experiment: -1

Aim: To determine the fault type, fault impedance and fault location during single line to ground fault.

Circuit Diagram:

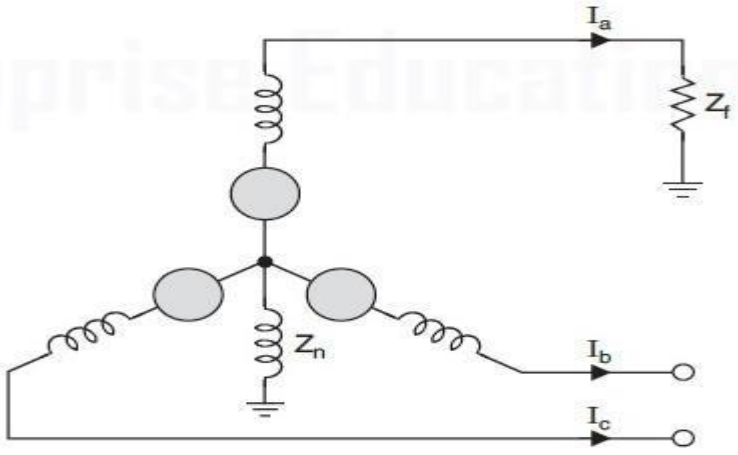

Fig: Single line to ground fault with fault impedance **Theory:**

Fault type, Fault impedance and Fault location can be described as:

1) **Fault Type: -**It is defined as violation of parameter of power system.

It is classified into two types: -

a) **Shunt fault: -** In this type of fault either power conductors or power conductors to ground.
b) **Series fault: -** In this type of fault the power conductor will be break or open.

Shunt fault again classified into two types: -

1. Symmetrical fault
2. Unsymmetrical fault

The unsymmetrical fault is of three types i.e. L-G, L-L, L-L-G.

In symmetrical fault there is only L-L-L fault.

In this fault, parameter of any phase vibrates from normal condition, so it is single line to ground fault.

2) **Fault Impedance: -** The fault impedance of the line is Z_f since only phase 'a' is connected to ground at the fault. And phase 'b' & 'c' has no fault i.e. $I_a=I_c=0$.

3) **Fault location: -** The fault location is used in power system for accurate pointing at fault location.

Advantage of fault location: -

1). Fast repair to restore power system.

2). Save tone and express of crew searching in led whether and tough it.

3). Improve system ability and performance as well as reduce operating cost.

The sequence network of single line to ground fault with fault impedance Z_f as Shown here.

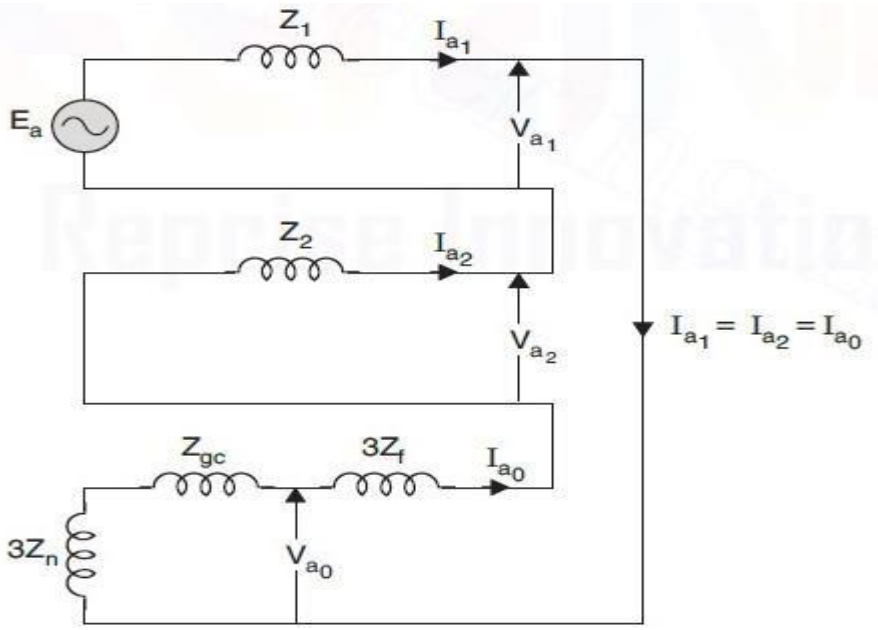

Fig: Sequence network of single line to ground fault with fault impedance

Result: We have studied the fault type, fault impedance and fault location during single line to ground fault.

Experiment: -2

Aim: To determine the fault type, fault impedance and fault location during line to line fault.

Circuit Diagram:

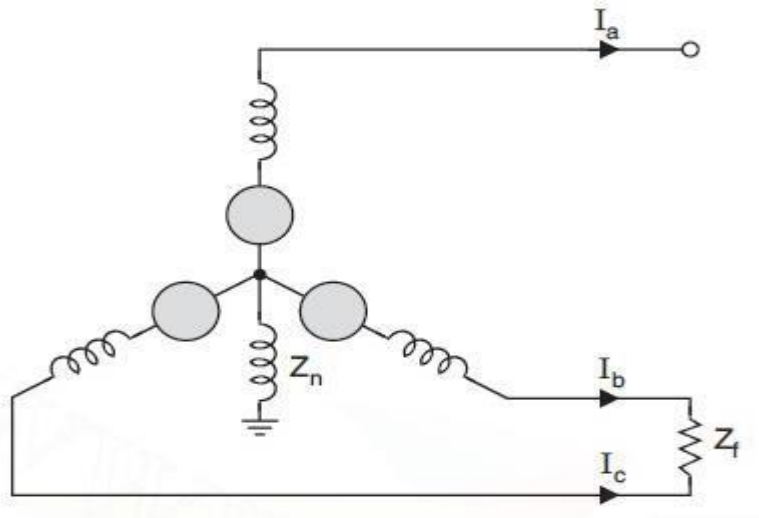

Fig: Line to Line fault with fault impedance **Theory:**

Fault type, Fault impedance and Fault location can be described as:

1) **Fault Type: -**It is defined as violation of parameter of power system.

It is classified into two types: -

a) **Shunt fault: -** In this type of fault either power conductors or power conductors to ground.

b) **Series fault: -** In this type of fault the power conductor will be break or open.

Shunt fault again classified into two types: -

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In symmetrical fault there is only L-L-L fault.

In this fault, parameter of any phase vibrates from normal condition, so it is single line to ground fault.

2) **Fault Impedance: -** The fault impedance of the line is Z_f since only phase 'a' is connected to ground at the fault. And phase 'b' & 'c' has no fault i.e. $I_a=I_c=0$.

3) **Fault location: -** The fault location is used in power system for accurate pointing at fault location.

Advantage of fault location: -

1). Fast repair to restore power system.

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3). Improve system ability and performance as well as reduce operating cost.

The sequence network of single line to ground fault with fault impedance Z_f as Shown here.

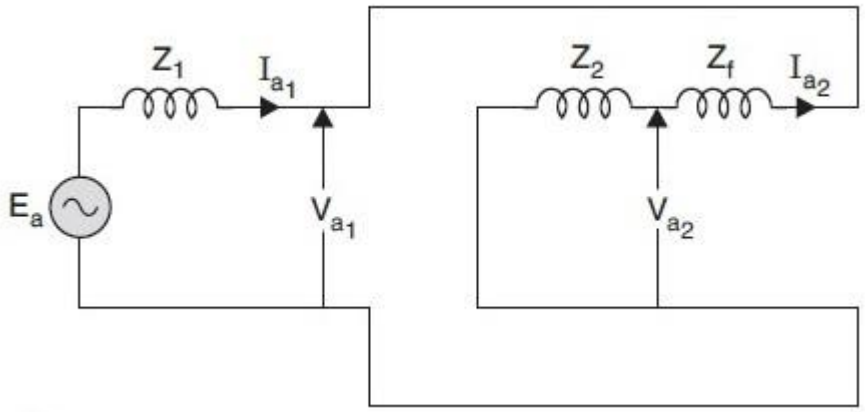

Fig: Sequence network of line to line fault with fault impedance

Result: We have studied the fault type, fault impedance and fault location during line to line fault.

Experiment: -3

Aim: To determine the fault type, fault impedance and fault location during double line to ground fault.

Circuit Diagram:

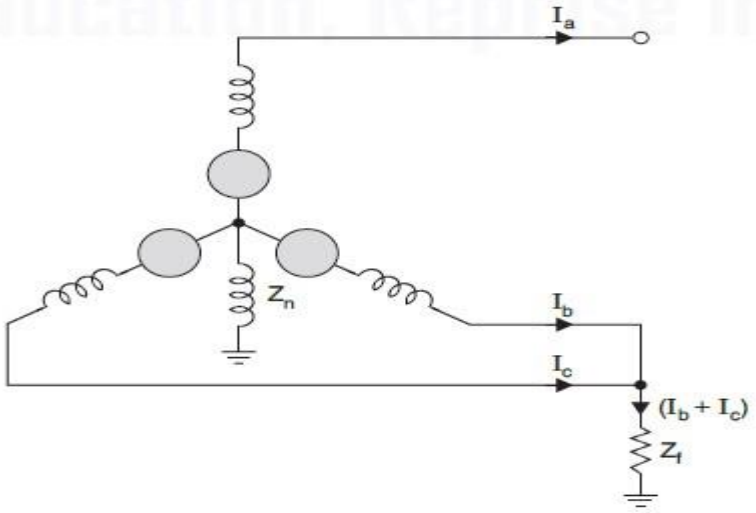

Fig: Double Line to Ground fault with Fault Impedance **Theory:**

Fault type, Fault impedance and Fault location can be described as:

1) **Fault Type: -**It is defined as violation of parameter of power system.

It is classified into two types: -

a) **Shunt fault: -** In this type of fault either power conductors or power conductors to ground.

b) **Series fault: -** In this type of fault the power conductor will be break or open.

Shunt fault again classified into two types: -

1. Symmetrical fault

2. Unsymmetrical fault

The unsymmetrical fault is of three types i.e. L-G, L-L, L-L-G.

In symmetrical fault there is only L-L-L fault.

In this fault, parameter of any phase vibrates from normal condition, so it is single line to ground fault.

2) **Fault Impedance: -** The fault impedance of the line is Z_f since only phase 'a' is connected to ground at the fault. And phase 'b' & 'c' has no fault i.e. $I_a=I_c=0$.

3) **Fault location: -** The fault location is used in power system for accurate pointing at fault location.

Advantage of fault location: -

1). Fast repair to restore power system.

2). Save tone and express of crew searching in led whether and tough it.

3). Improve system ability and performance as well as reduce operating cost.

The sequence network of single line to ground fault with fault impedance Z_f as Shown here.

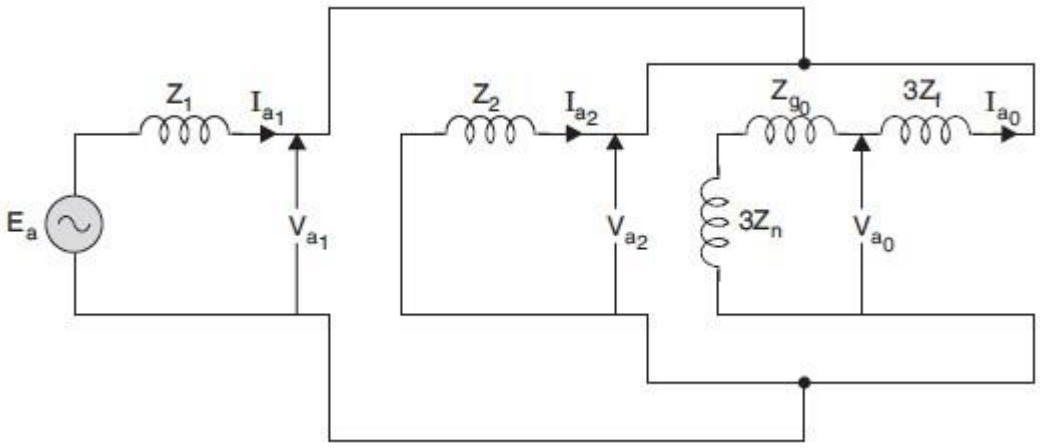

Fig: Sequence network of double line to ground fault with fault impedance **Result**:

We have studied the fault type, fault impedance and fault location during double line to ground fault.

Experiment No. 4

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

Circuit Diagram:

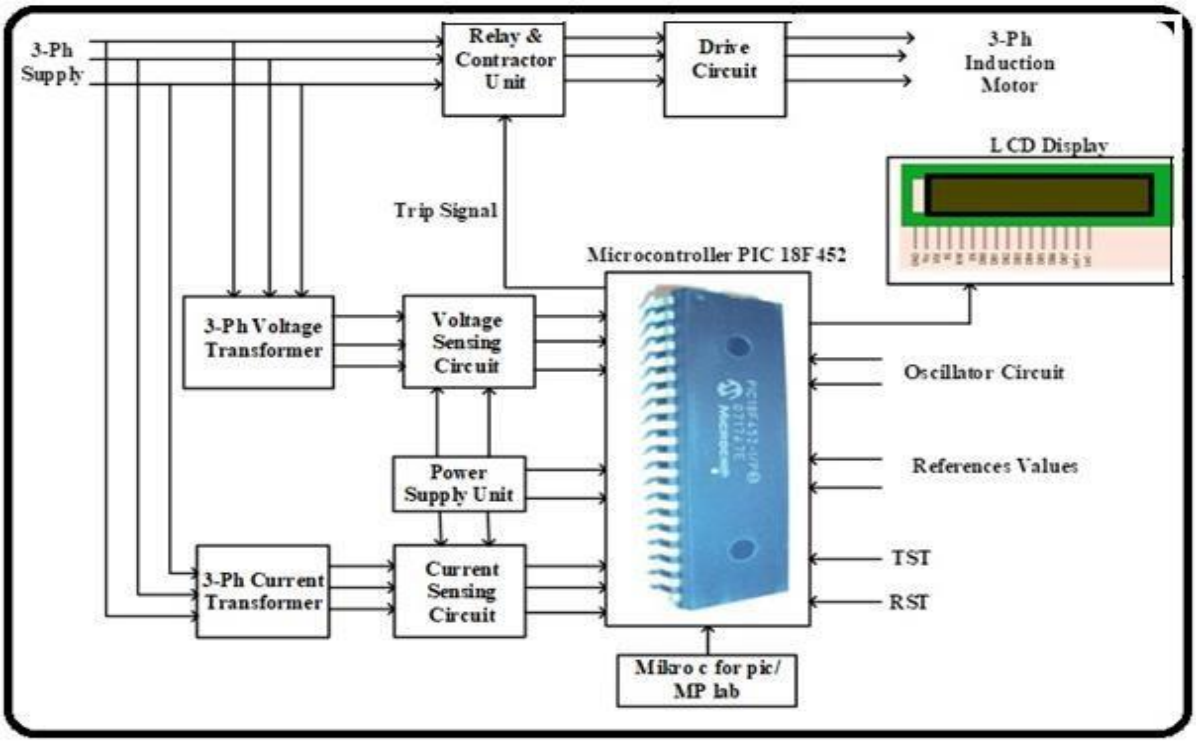

Fig.: Micro-Controller based over current relay in DMT type and IDMT type **Theory:**

MICROCONTROLLER: A microcontroller is a compact integrated circuit designed to govern a specific operation in an embedded system. A typical microcontroller includes a processor, memory and input/output (I/O) peripherals on a single chip.

Sometimes referred to as an embedded controller or microcontroller unit (MCU), microcontrollers are found in vehicles, robots, office machines, medical devices, mobile radio transceivers, vending

machines and home appliances, among other devices. They are essentially simple miniature personal computers (PCs) designed to control small features of a larger component, without a complex frontend operating system (OS).

The core elements of a microcontroller are:

- The processor (CPU)
- Memory
- I/O peripherals

Other supporting elements of a microcontroller include:

- Analog to Digital Converter (ADC)
- Digital to Analog Converter (DAC)
- System bus
- Serial port

Overview Of Over Current Protection

An Over Current Relay is a type of protective relay which operates when the load current exceeds a preset value. In a typical application the over current relay is used for over current protection, connected to a current transformer and calibrated to operate at or above a specific current level. This manual is used for over current protection relay using microcontroller in DMT type and IDMT type.

The micro controller will cause the circuit breaker to trip when the current from load current reaches the setting value in the microcontroller. In order to design it, first the load current need to measure in order to monitor it using current sensor including testing the fault (Over Current) and when such condition arise, it will isolate in the shortest time possible without harming the any other electrical devices. In this manual, microcontroller will be used to control and operate the tripping coil in circuit breaker.

Definite Time Over Current Relay

This relay is created by applying intentional time delay after crossing pick up the value of the current. A **definite time over current relay** can be adjusted to issue a trip output at an exact amount of time after it picks up. Thus, it has a time setting adjustment and pickup adjustment.

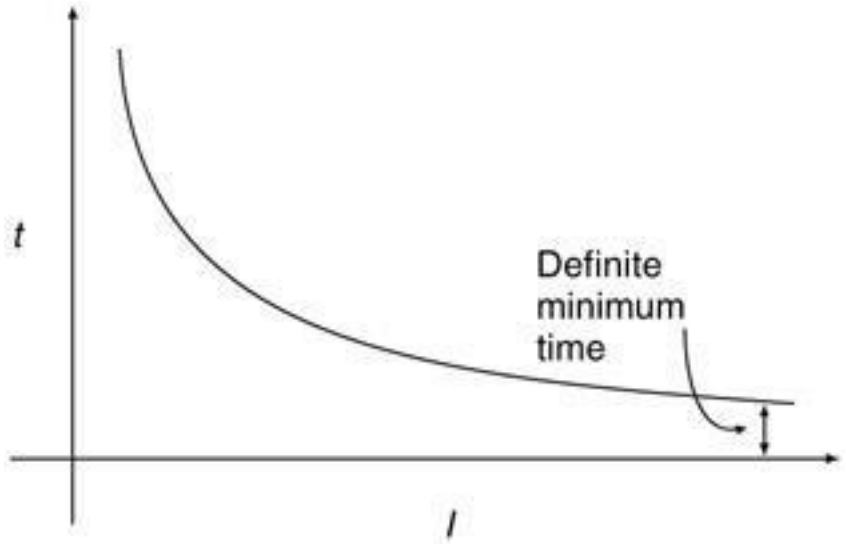

Fig.: Definite Minimum Type Over current Relay

Inverse Definite Minimum Time Over Current Relay

Ideal inverse time characteristics cannot be achieved, in an over current relay. As the current in the system increases, the secondary current of the current transformer is increased proportionally. The secondary current enters the relay current coil. But when the CT becomes saturated, there would not be a further proportional increase of CT secondary current with increased system current. From this phenomenon, it is clear that from trick value to certain range of faulty level, an inverse time relay shows specific inverse characteristic. But after this level of fault, the CT becomes saturated and relay current does not increase further with increasing faulty level of the system. As the relay current does not increase further, there would not be any further reduction in time of operation in the relay. We define this time as the minimum time of operation. Hence, the characteristic is inverse in the initial part, which tends to a definite minimum operating time as the current becomes very high. That is why the relay is referred as **inverse definite minimum time over current relay** or simply **IDMT relay**. **Result:** We have studied the operation of micro-controller based over current relay in DMT type and IDMT type.

Experiment No. 5

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

Circuit Diagram:

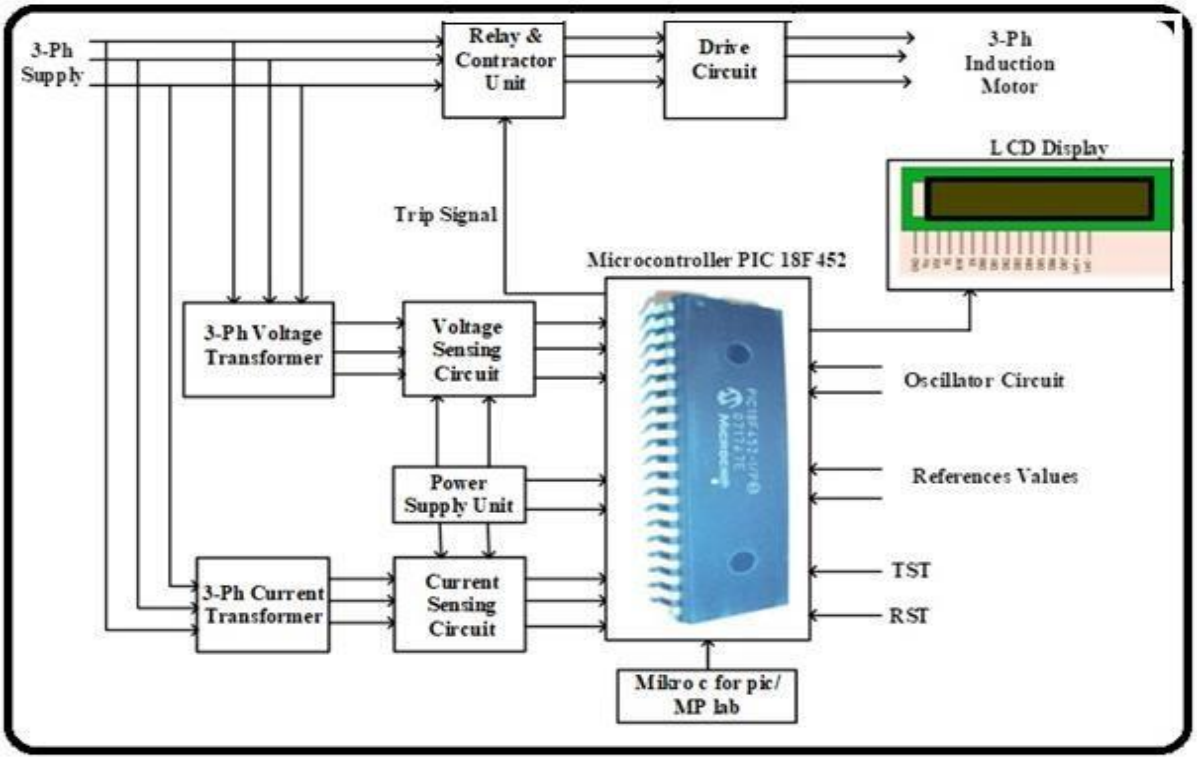

Fig.: Micro-Controller based over current relay in DMT type and IDMT type **Theory:**

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The core elements of a microcontroller are:

- The processor (CPU)
- Memory
- I/O peripherals

Other supporting elements of a microcontroller include:

- Analog to Digital Converter (ADC)
- Digital to Analog Converter (DAC)
- System bus
- Serial port

Overview Of directional Over Current Protection

Directional over current relays are normally used on incoming line circuit breakers on buses which have two or more sources. They are connected to trip an incoming line breaker for fault current flow back into the source, so that a fault on one source is not fed by the other sources. This manual is used for over current protection relay using microcontroller in DMT type and IDMT type.

The micro controller will cause the circuit breaker to trip when the current from load current reaches the setting value in the microcontroller. In order to design it, first the load current need to measure in order to monitor it using current sensor including testing the fault (Over Current) and when such condition arise, it will isolate in the shortest time possible without harming the any other electrical devices. In this manual, microcontroller will be used to control and operate the tripping coil in circuit breaker.

Definite Time Over Current Relay

This relay is created by applying intentional time delay after crossing pick up the value of the current. A **definite time over current relay** can be adjusted to issue a trip output at an exact amount of time after it picks up. Thus, it has a time setting adjustment and pickup adjustment.

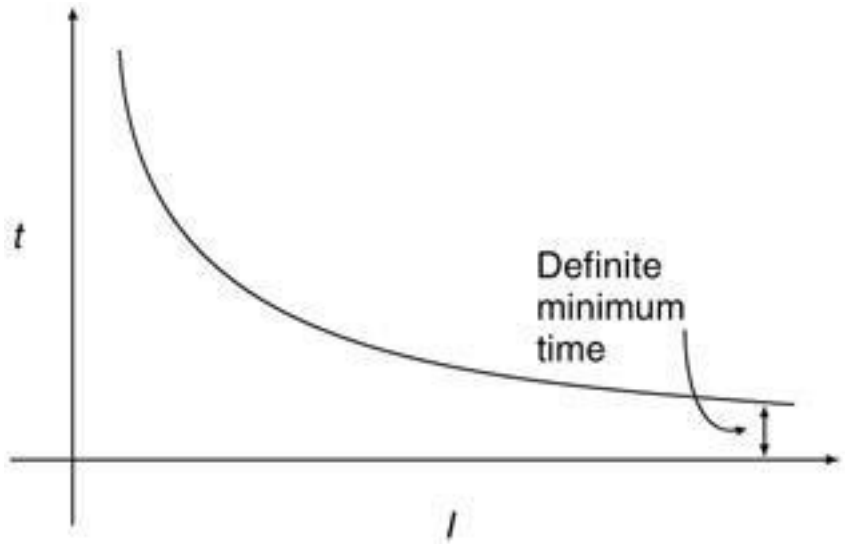

Fig.: Definite Minimum Type Over current Relay

Inverse Definite Minimum Time over Current Relay

Ideal inverse time characteristics cannot be achieved, in an over current relay. As the current in the system increases, the secondary current of the current transformer is increased proportionally. The secondary current enters the relay current coil. But when the CT becomes saturated, there would not be a further proportional increase of CT secondary current with increased system current. From this phenomenon, it is clear that from trick value to certain range of faulty level, an inverse time relay shows specific inverse characteristic. But after this level of fault, the CT becomes saturated and relay current does not increase further with increasing faulty level of the system. As the relay current does not increase further, there would not be any further reduction in time of operation in the relay. We define this time as the minimum time of operation. Hence, the characteristic is inverse in the initial part, which tends to a definite minimum operating time as the current becomes very high. That is why the relay is referred as **inverse definite minimum time over current relay** or simply **IDMT relay**.

Result: We have studied the operation of micro-controller based over current relay in DMT type and IDMT type.

Experiment No. 6

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

Circuit Diagram:

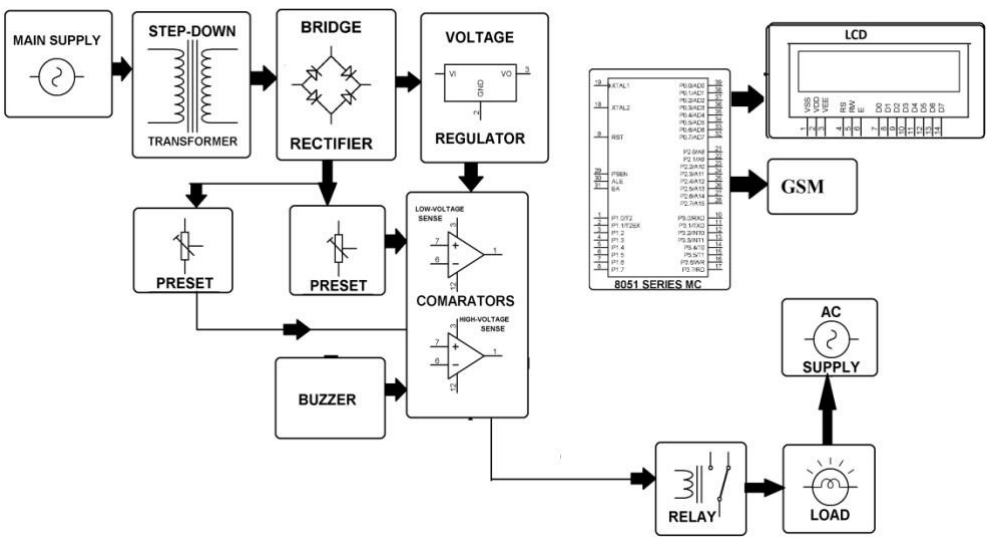

Fig: Micro-controller based under voltage relay

Theory:

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The core elements of a microcontroller are:

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- Memory
- I/O peripherals

Other supporting elements of a microcontroller include:

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- Digital to Analog Converter (DAC)
- System bus
- Serial port

UNDER VOLTAGE RELAY: Under voltage fault protection is used to protect the alternator/generator/transformer winding from low voltage operation. Under voltage protection sense the phase to phase voltage of the generator/transformer using instrument transformer (Potential transformer). When the voltage drops below the rated voltage typically 85% (stage 2)-90% (stage 1) the under voltage protection will be activated.

Principle of under voltage protection: Three number of potential transformer normally installed in the generator LAVT panel (lighting arrester voltage transformer). They detect the voltage across the generator in real time. When the voltage across the generator winding drops the simultaneous voltage drop occurs in the PT output also. The reduced or dropped voltage activates the power system alarm or trip circuit.

Reason Under voltage protection: The output from the generator's LAVT (Lightening Arrestor & *Voltage Transformer*) potential transformer will be given to the under voltage coil typically 110 Volts relay coil. In principle of U/V coil, which do not trip the circuit breaker when the voltage across the PT is high? When the voltage drops the preset the value, the voltage coil operates the circuit breaker.

The generator under voltage protection consists of two stage tripping. Stage 1 trip command is given to grid circuit breaker and stage 2 trip commands are given to generator circuit breaker. Most of the time in synchronous generator, the under voltage fault occurs from the grid due to earth fault and line short circuit. That's why; the first stage will be given to grid circuit breaker.

At that same time, the under voltage fault occurs due to failed excitation, diode failure, under frequency or turbine low speed, failed PT fuse etc.

Under voltage relay setting:

Stage1: 90% of the rated voltage trip command to grid circuit breaker.

Stage2: 85% of the rated voltage, trip command to Generator circuit breaker.

Result :- We have studied the micro-controller based under voltage relay.

Experiment No 7

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

Circuit Diagram:

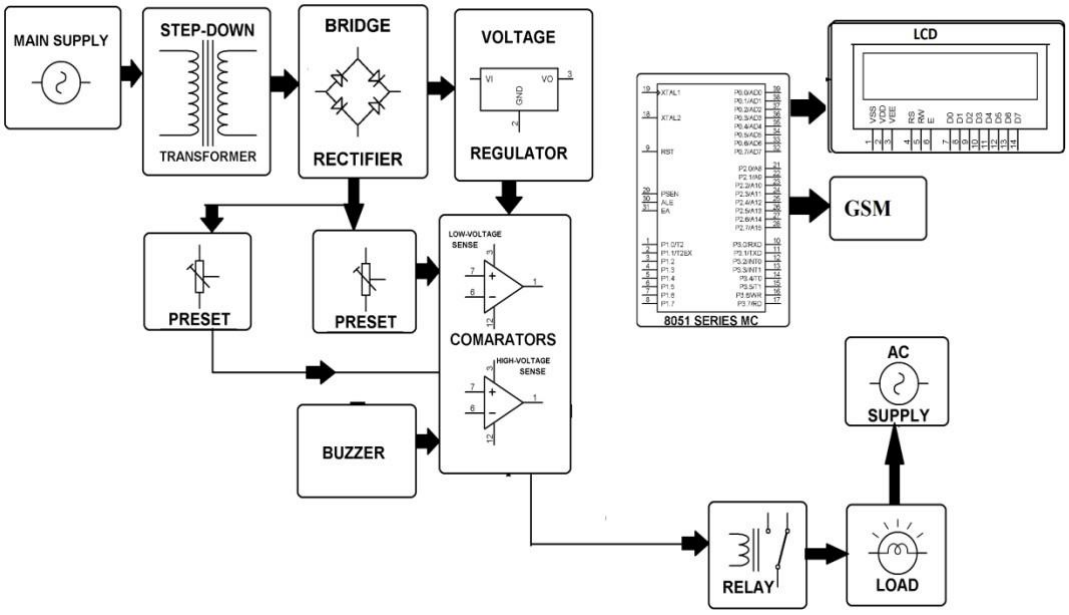

Fig: Microcontroller based over voltage relay **Theory:**

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Other supporting elements of a microcontroller include:

- Analog to Digital Converter (ADC)
- Digital to Analog Converter (DAC)
- System bus

- Serial port

OVER VOLATGE RELAY: Over voltage protection is used to protect the synchronous Generator/transformer/alternator form high voltage. Generally, overvoltage occurs due to sudden load through off, elevated grid synchronized voltage, AVR malfunctioning, power transformer taps changer failure, lightning strike on the transmission line, turbine over speed etc. the power system must be isolated when the system voltage high. Severe overvoltage causes the winding or electrical insulation failure, over fluxing (u/f), transformer's core saturation etc. The over voltage protection can be considered as a backup to the Volts-per-Hertz protection (Over fluxing).

The overvoltage protection consists of two stage operation. Stage 1 trip command will be given to the 110kV grid circuit breaker and stage 2 trip commands will be given to synchronous generator's circuit breaker.

Raise the generator voltage slowly with manual mode in AVR and keep generator voltage within the limits of normal voltage. If it is unable to control the generator voltage, trip the field breaker and inform to the maintenance staff for rectification of the AVR.

Result: We have studied the micro-controller based over voltage relay.

Experiment No. 8

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

Circuit Diagram:

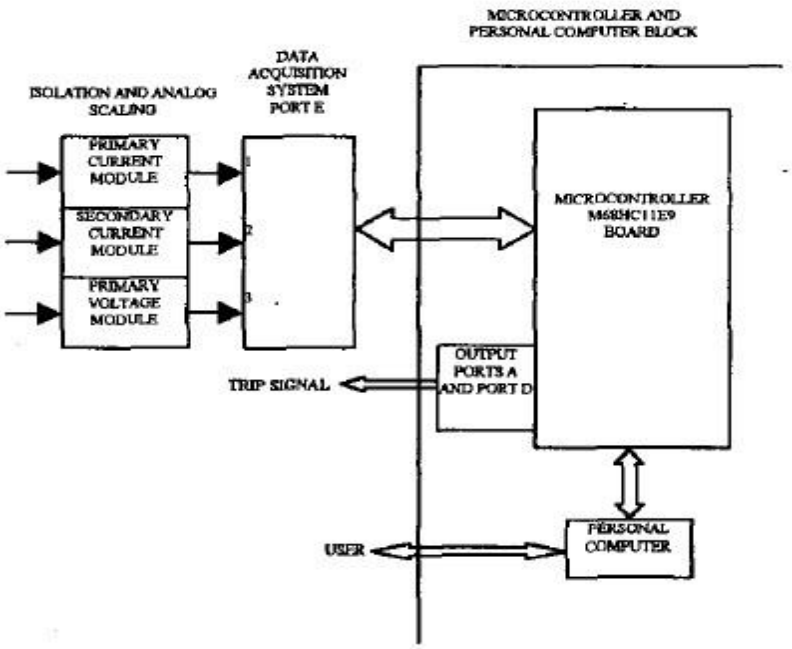

Fig: Microcontroller based un-biased single-phase differential relay **Theory:**

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Other supporting elements of a microcontroller include:

- Analog to Digital Converter (ADC)
- Digital to Analog Converter (DAC)
- System bus

- Serial port

Differential Relay:

Definition: The relay whose operation depends on the phase difference of two or more electrical quantities is known as the differential protection relay. It works on the principle of comparison between the phase angle and the magnitude of the same electrical quantities.

The differential protection relay is used for the protection of the generator, transformer, feeder, large motor, bus-bars etc. The following are the classification of the differential protection relay.

- Current Differential Relay
- Voltage Differential Relay
- Biased or Percentage Differential Relay
- Voltage Balance Differential Relay

A relay, which senses and operates the phase difference between the current entering into the electrical system and the current leaving the electrical system is called a current differential relay. An arrangement of over current relay connected to operate as a differential relay is shown in the figure below.

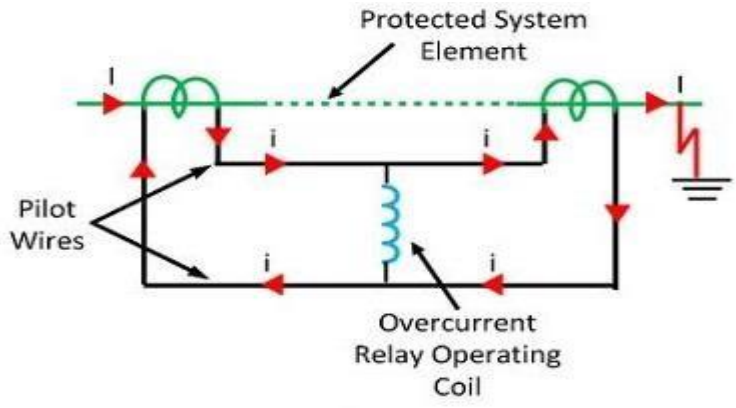

Fig: un-biased single-phase differential relay for external fault

The arrangement of the over current relay is shown in the figure below. The dotted line shows the section which is used to be protected. The current transformer is placed at both the ends of the protection zone. The secondary of the transformers is connected in series with the help of the pilot wire. Thereby, the current induces in the CTs flows in the same direction. The operating coil of the relay is connected on the secondary of the CTs.

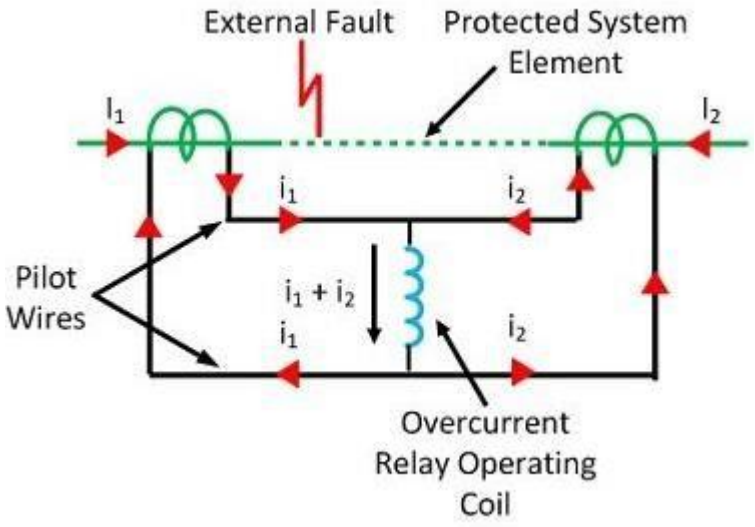

Fig:un-biased single-phase differential relay for internal fault

Result : We have studied the operation of micro-controller based un-biased single-phase differential relay.

Experiment No. 9

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

Circuit Diagram:

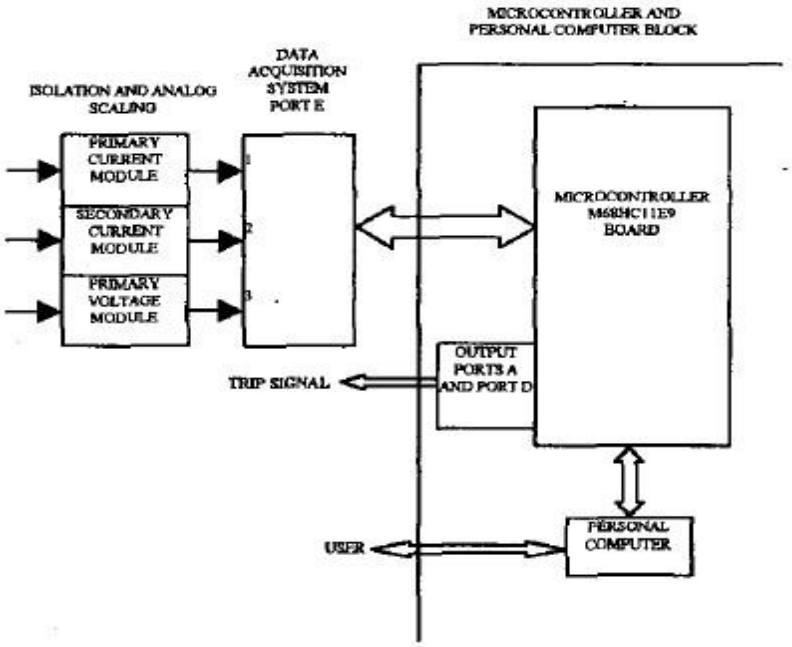

Fig: Microcontroller based biased single-phase differential relay **Theory:**

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- Memory
- I/O peripherals

Other supporting elements of a microcontroller include:

- Analog to Digital Converter (ADC)
- Digital to Analog Converter (DAC)
- System bus

- Serial port

Biased Differential Relay:

Definition: The percentage differential relay is defined as the relay that operates on the phase difference of two or more similar electrical quantities. It is the advanced form of differential protection relay. The only difference between them is the restraining coil. The percentage differential relay consists restraining coil for overcoming the trouble arising out of differences in the current ratio for the high value of an external short circuit current.

The percentage differential system consists of a restraining coil connected in the pilot wire as shown in the figure below and the current induced in both the CTs flows through it. The operating coil places between the midpoint of the restraining coil.

The restraining coil controls the sensitive characteristic of the relay. It restricts the unwanted tripping of the transformer due to the imbalance current. The restraining coil also restrains the harmonics in the inrush current.

Working of Percentage Differential Relay

The torque due to the restraining coil prevents the closing of the trip circuit while the torque due to the operating coil tends to close the trip circuit contacts. Under normal operating conditions and through load condition the torque developed by the restraining coil is greater than the operating coil torque. Thus the relay remains inoperative.

When an internal fault occurs, the operating torque exceeds the restraining torque then the trip circuit contacts are closed to open the circuit breaker. The restraining torque may adjust by varying the number of turns of the restraining coil.

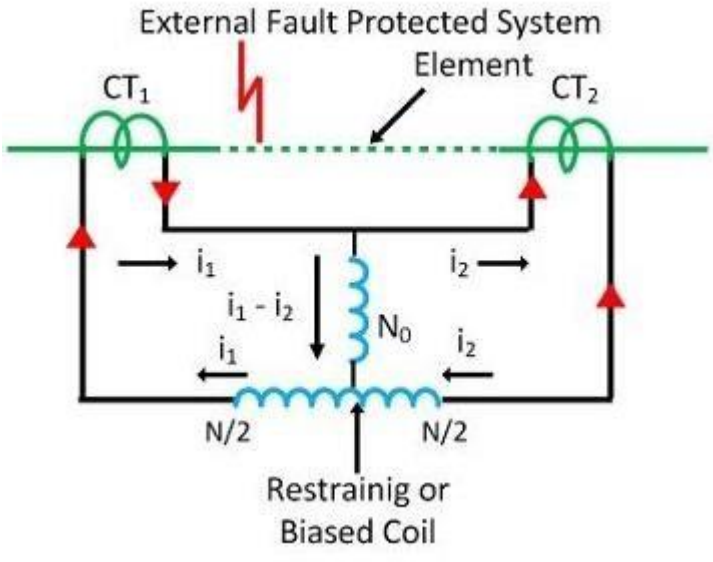

Fig: biased single-phase differential relay

The differential current required to utilize this relay is a variable quantity, due to the effect of the restraining coil. The differential current in the operating coil is proportional to (I_1-I_2), and the restraining coil is proportional to (I_1-I_2)/2 as the operating current is connected to the midpoint of the restraining coil. For external faults both I_1 and I_2 increase and thereby the restraining torque increase, which prevents the maloperation.

Result : We have studied the operation of micro-controller based biased single-phase differential relay.

Experiment No. 10

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

Circuit Diagram:

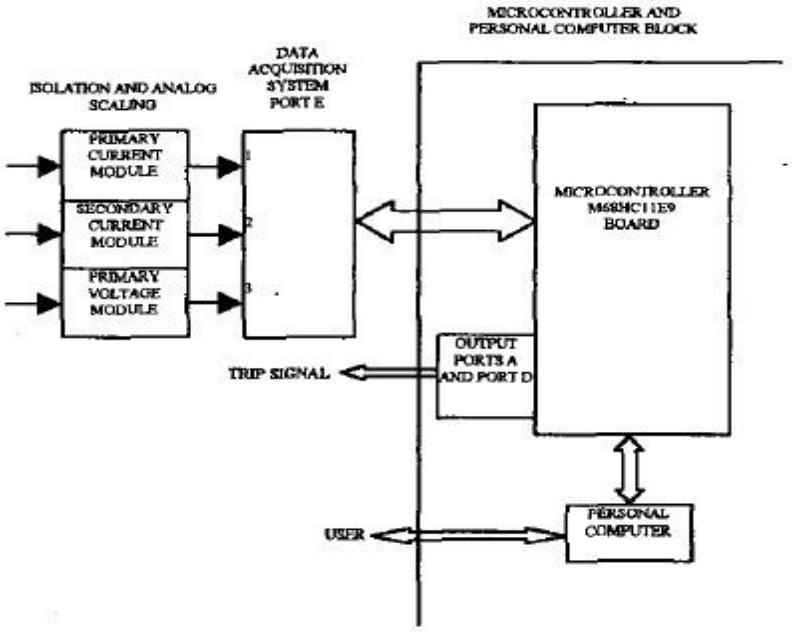

Fig: Microcontroller based un-biased three phase differential relay **Theory:**

MICROCONTROLLER: A microcontroller is a compact integrated circuit designed to govern a specific operation in an embedded system. A typical microcontroller includes a processor, memory and input/output (I/O) peripherals on a single chip.

Sometimes referred to as an embedded controller or microcontroller unit (MCU), microcontrollers are found in vehicles, robots, office machines, medical devices, mobile radio transceivers, vending machines and home appliances, among other devices. They are essentially simple miniature personal computers (PCs) designed to control small features of a larger component, without a complex frontend operating system (OS).

The core elements of a microcontroller are:

- The processor (CPU)
- Memory
- I/O peripherals

Other supporting elements of a microcontroller include:

- Analog to Digital Converter (ADC)
- Digital to Analog Converter (DAC)
- System bus

- Serial port

UN-BIASED THREE PHASE DIFFERENTIAL RELAY:

Differential Relay:

Definition: The relay whose operation depends on the phase difference of two or more electrical quantities is known as the differential protection relay. It works on the principle of comparison between the phase angle and the magnitude of the same electrical quantities.

The differential protection relay is used for the protection of the generator, transformer, feeder, large motor, bus-bars etc. The following are the classification of the differential protection relay.

- Current Differential Relay
- Voltage Differential Relay
- Biased or Percentage Differential Relay
- Voltage Balance Differential Relay

A relay, which senses and operates the phase difference between the current entering into the electrical system and the current leaving the electrical system is called a current differential relay. An arrangement of over current relay connected to operate as a differential relay is shown in the figure below.

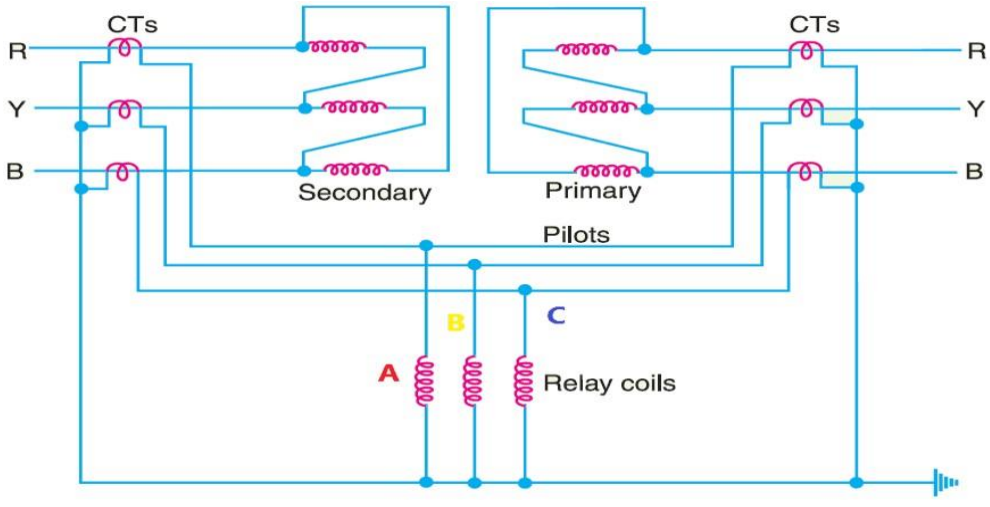

Fig: un-biased single-phase differential relay for external fault

The arrangement of the over current relay is shown in the figure below. The dotted line shows the section which is used to be protected. The current transformer is placed at both the ends of the protection zone. The secondary of the transformers is connected in series with the help of the pilot wire.

Thereby, the current induces in the CTs flows in the same direction. The operating coil of the relay is connected on the secondary of the CTs.

Result: We have studied the operation of micro-controller based un-biased three phase differential relay.

Experiment No. 11

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

Circuit Diagram:

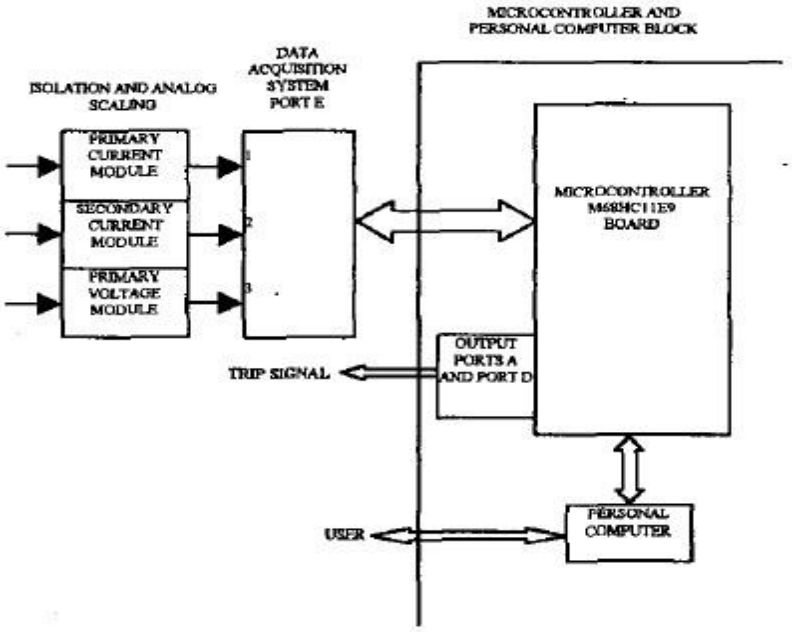

Fig: Micro-controller based biased three phase differential relay **Theory:**

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The core elements of a microcontroller are:

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Other supporting elements of a microcontroller include:

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- Serial port

BIASED THREE PHASE DIFFERENTIAL RELAY:

Biased Differential Relay:

Definition: The percentage differential relay is defined as the relay that operates on the phase difference of two or more similar electrical quantities. It is the advanced form of differential protection relay. The only difference between them is the restraining coil. The percentage differential relay consists restraining coil for overcoming the trouble arising out of differences in the current ratio for the high value of an external short circuit current.

The percentage differential system consists of a restraining coil connected in the pilot wire as shown in the figure below and the current induced in both the CTs flows through it. The operating coil places between the mid point of the restraining coil.

The restraining coil controls the sensitive characteristic of the relay. It restricts the unwanted tripping of the transformer due to the imbalance current. The restraining coil also restrains the harmonics in the inrush current.

The torque due to the restraining coil prevents the closing of the trip circuit while the torque due to the operating coil tends to close the trip circuit contacts. Under normal operating conditions and through load condition the torque developed by the restraining coil is greater than the operating coil torque. Thus the relay remains inoperative.

When an internal fault occurs, the operating torque exceeds the restraining torque then the trip circuit contacts are closed to open the circuit breaker. The restraining torque may adjust by varying the number of turns of the restraining coil.

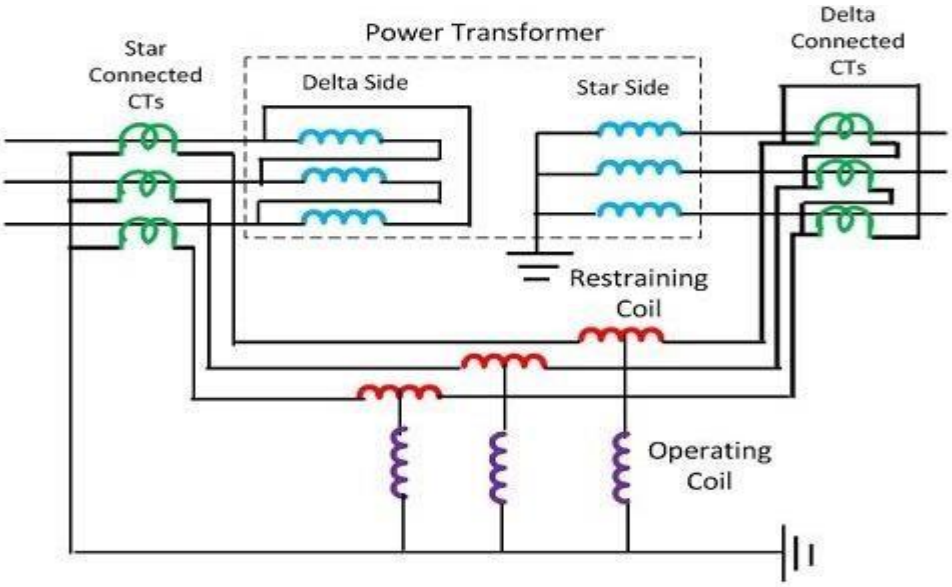

Fig: Biased Single-Phase Differential Relay

The differential current required to utilize this relay is a variable quantity, due to the effect of the restraining coil. The differential current in the operating coil is proportional to (I_1-I_2), and the restraining coil is proportional to $(I_1-I_2)/2$ as the operating current is connected to the midpoint of the restraining coil. For external faults both I_1 and I_2 increase and thereby the restraining torque increase, which prevents the maloperation.

Result: We have studied the operation of micro-controller based biased three phase differential relay.