POWER SYSTEMS LAB

___ YEAR ___ SEM

EEE

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Institute of Engineering & Technology

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CERTIFICATE

This is to certify that it is a record of practical work done in the Power Systems Lab in ___ sem of __ year during the year ________________________

Name:

Roll No:

Branch:EEE

Signature of staff member

INDEX

Date: **Experiment-1**

CHARACTERISTICS OF OVER CURRENT RELAY FOR PHASE FAULT

AIM: To study the characteristics of over current realy for phase fault

APPARATUS: Over current relay

Auxiliary supply kit (Step-down Transformer-230/24V, Bridge rectifier, filter)

Auto transformer (0-230v, 2A)

Ammeter (0-2A)

Rheostat (110Ω, 1.8A)

THEORY:

The function of a relay is to detect abnormal conditions in the system and to initiate through appropriate circuit breakers the disconnection of faulty circuits so that interference with the general supply is minimized. Relays are of many types. Some depend on the operation of an armature by some form of electromagnet. A very large number of relays operate on the induction principle. When a relay operates it closes contacts in the trip circuit .The passage of current in the coil of the trip circuit actuates the plunger, which causes operation of the circuit breaker, disconnecting the faulty system.

OVER CURRENT PROTECTION:

The protective relaying which responds to a rise in current flowing through the protected element over a pre-determined value is called 'over current protection' and the relays used for this purpose are known as over current relays. Earth fault protection can be provided with normal over current relays, if the minimum earth fault current is sufficient in magnitude. The design of a comprehensive protection scheme in a power system requires the detailed study of time-current characteristics of the various relays used in the scheme. Thus it is necessary to obtain the time current characteristics of these relays. The over current relay works on the induction principle. The moving system consists of an aluminum disc fixed on a vertical shaft and rotating on two jeweled bearings between the poles of an electromagnet and a damping magnet. The winding of the electromagnet is provided with seven taps (generally0, which are brought on the front panel, and the required tap is selected by a push-in -type plug. The pick-up current setting can thus be varied by the use of such plug multiplier setting. The operating time of all overcurrent relays tends to become asymptotic to a definite minimum value with increase in the value of current. This is an inherent property of the electromagnetic relays due to saturation of the magnetic circuit. By varying the point of saturation, different characteristics can be obtained and these are

1. Definite time
2. Inverse Definite Minimum Time (IDMT)
3. Very Inverse
4. Extremely Inverse

Principle:

Overcurrent protection is practical application of magnitude relays since it picks up when the magnitude of current exceeds some value (setting value). Overcurrent relays can be used to protect practically any power system elements, i.e. transmission lines, transformers, generators, or motors. As an example, a radial transmission line can be used. For a fault within the zone of protection, the fault current is smallest at the end of the line and greatest at the relay end. If the minimum fault current possible within the zone of protection is greater than the maximum possible load current, it would be possible to define the operating principle as follows:

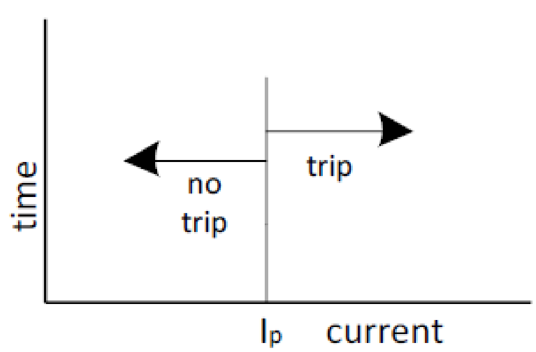
$$|I| \geq I_p \text{ fault zone, trip}$$

$$|I| < I_p \text{ no fault in zone, do not trip.}$$

Where I is the current in the relay and is Ip the pickup setting of the relay.

Instantaneous overcurrent relays :

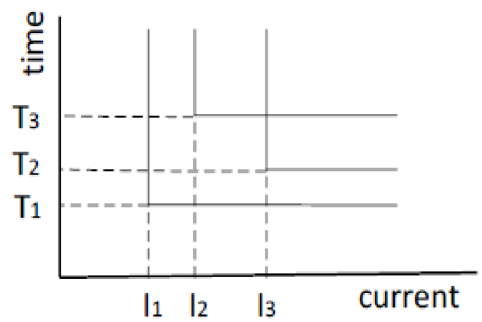
Its operation criterion is only current magnitude (without time delay). This type is applied to the outgoing feeders.



Characteristics of instantaneous over current Relay

Definite Time Overcurrent Relays :

In this type, two conditions must be satisfied for operation (tripping), current must exceed the setting value and the fault must be continuous at least a time equal to time setting of the relay. Modern relays may contain more than one stage of protection each stage includes each own current and time setting.



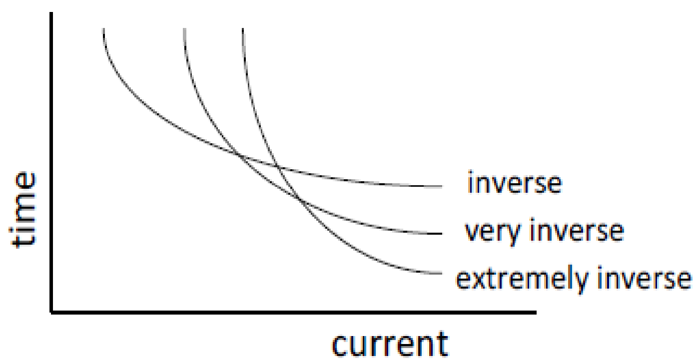
Characteristics of definite time over current Relay

Definite time overcurrent relay is the most applied type of over current. It is used as:

1. Back up protection of distance relay of transmission line with time delay.
2. Back up protection to differential relay of power transformer with time delay.
3. Main protection to outgoing feeders and bus couplers with adjustable time delay setting.

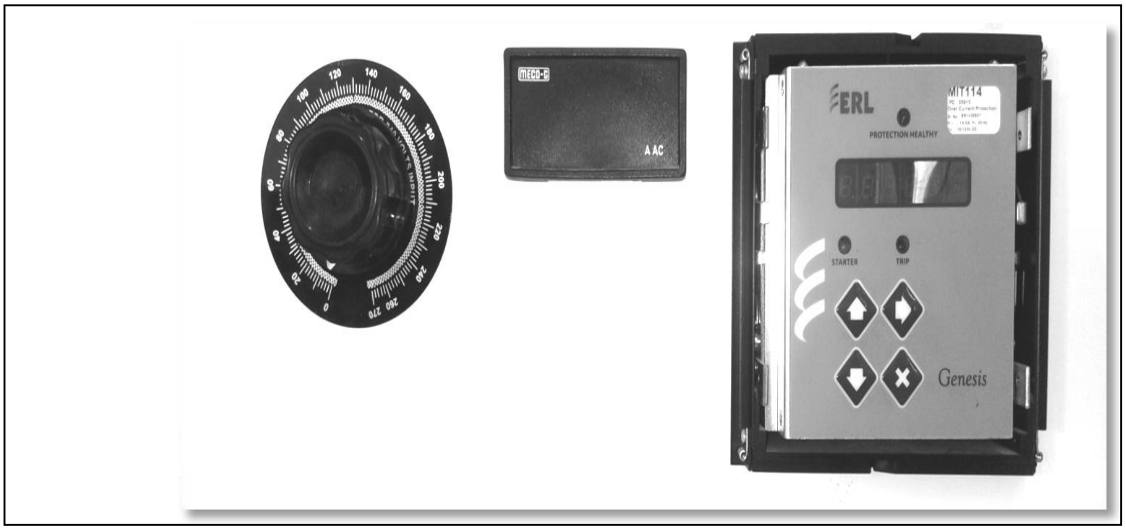
Inverse Time Overcurrent Relays

In this type of relays, operating time is inversely changed with current. So, high current will operate overcurrent relay faster than lower ones. There are standard inverse, very inverse and extremely inverse types



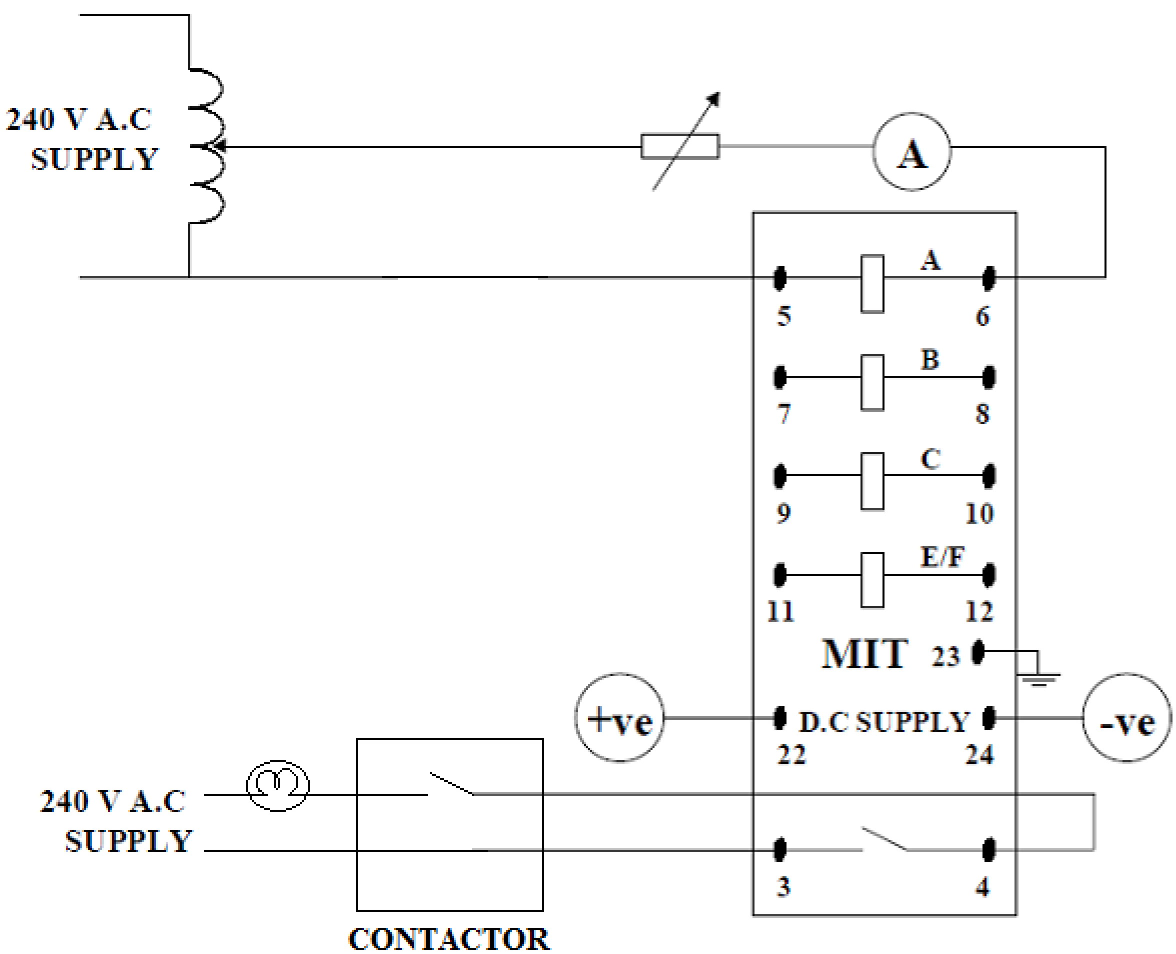
Characteristics of inverse time over current Relay

PANEL VIEW:



OVER CURRENT RELAY (PHASE FAULT)

CIRCUIT DIAGRAM:



Experimental procedure:

1. Study the construction of the relay and identify the various parts.
2. Set the pick-up value of the current marked 1 A(100 % f. l current)
3. Set the Time Multiplier Setting (TMS) initially at 1.0.
4. Adjust the load current to about 1.8 times the f.l current. Record the time taken for the overload condition.
5. Vary the value of the load current in steps and record the time taken for the operation of the relay in each case with the help of the timer.
6. Repeat steps 5 and 6 for TMS values of 0.2, 0.4,0.6 and 0.8.
7. Repeat the above experiment with different pick up current values using the plug setting bridge.

Tabular form-Range of Experimental values:
Pick-up current = 1 Amps

IP - Current setting: 10% = 0.1A

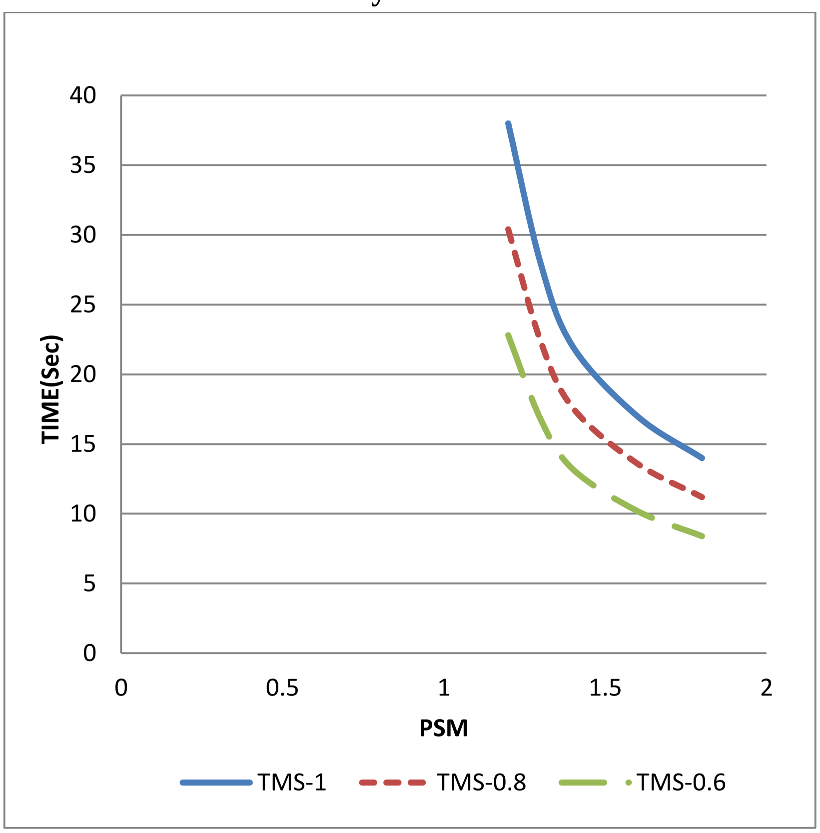
S.No	Current(A)	Current(A) times the plug setting multiplier	Tp- Operating time in sec. for TMS of				
			1.0	0.8	0.6	0.4	0.2
1	0.12	1.2	38	30.4	22.8	15.2	7.6
2	0.13	1.3	28	22.4	16.8	11.2	5.6
3	0.14	1.4	22	17.6	13.2	8.8	4.4
4	0.16	1.6	17	13.6	10.2	6.8	3.4
5	0.18	1.8	14	11.2	8.4	5.6	2.8

Tabular form-practical values:
Pick-up current = 1 Amps

IP - Current setting :10%

S.No	Current(A)	Current(A) times the plug setting multiplier	Tp- Operating time in sec. for TMS of				
			1.0	0.8	0.6	0.4	0.2
1							
2							
3							
4							
5							

Model graph-Characteristics of over current relay



Signature of the faculty

RESULT:

Signature of the faculty

Date: **Experiment-2**

CHARACTERISTICS OF OVER CURRENT RELAY FOR EARTH FAULT

Aim: To study the characteristics of over current relay for earth fault

Apparatus: Earth Fault relay

Auxiliary supply kit (Step-down Transformer-230/24V, Bridge rectifier, filter)

Auto transformer (0-230v, 2A)

Ammeter (0-2A)

Rheostat (110Ω, 1.8A)

Theory:

The function of a relay is to detect abnormal conditions in the system and to initiate through appropriate circuit breakers the disconnection of faulty circuits so that interference with the general supply is minimized. Relays are of many types. Some depend on the operation of an armature by some form of electromagnet. A very large number of relays operate on the induction principle. When a relay operates it closes contacts in the trip circuit .The passage of current in the coil of the trip circuit actuates the plunger, which causes operation of the circuit breaker, disconnecting the faulty system.

Overcurrent Protection –EARTH FAULT:

The protective relaying which responds to a rise in current flowing through the protected element over a pre-determined value is called 'overcurrent protection' and the relays used for this purpose are known as overcurrent relays. Earth fault protection can be provided with normal overcurrent relays, if the minimum earth fault current is sufficient in magnitude. The design of a comprehensive protection scheme in a power system requires the detailed study of time-current characteristics of the various relays used in the scheme. Thus it is necessary to obtain the time current characteristics of these relays. The overcurrent relay works on the induction principle. The moving system consists of an aluminum disc fixed on a vertical shaft and rotating on two jeweled bearings between the poles of an electromagnet and a damping magnet. The winding of the electromagnet is provided with seven taps (generally0, which are brought on the front panel, and the required tap is selected by a push-in -type plug. The pick-up current setting can thus be varied by the use of such plug multiplier setting. The operating time of all over current relays tends to become asymptotic to a definite minimum value with increase in the value of current. This is an inherent property of the electromagnetic relays due to saturation of the magnetic circuit. By varying the point of saturation, different characteristics can be obtained and these are

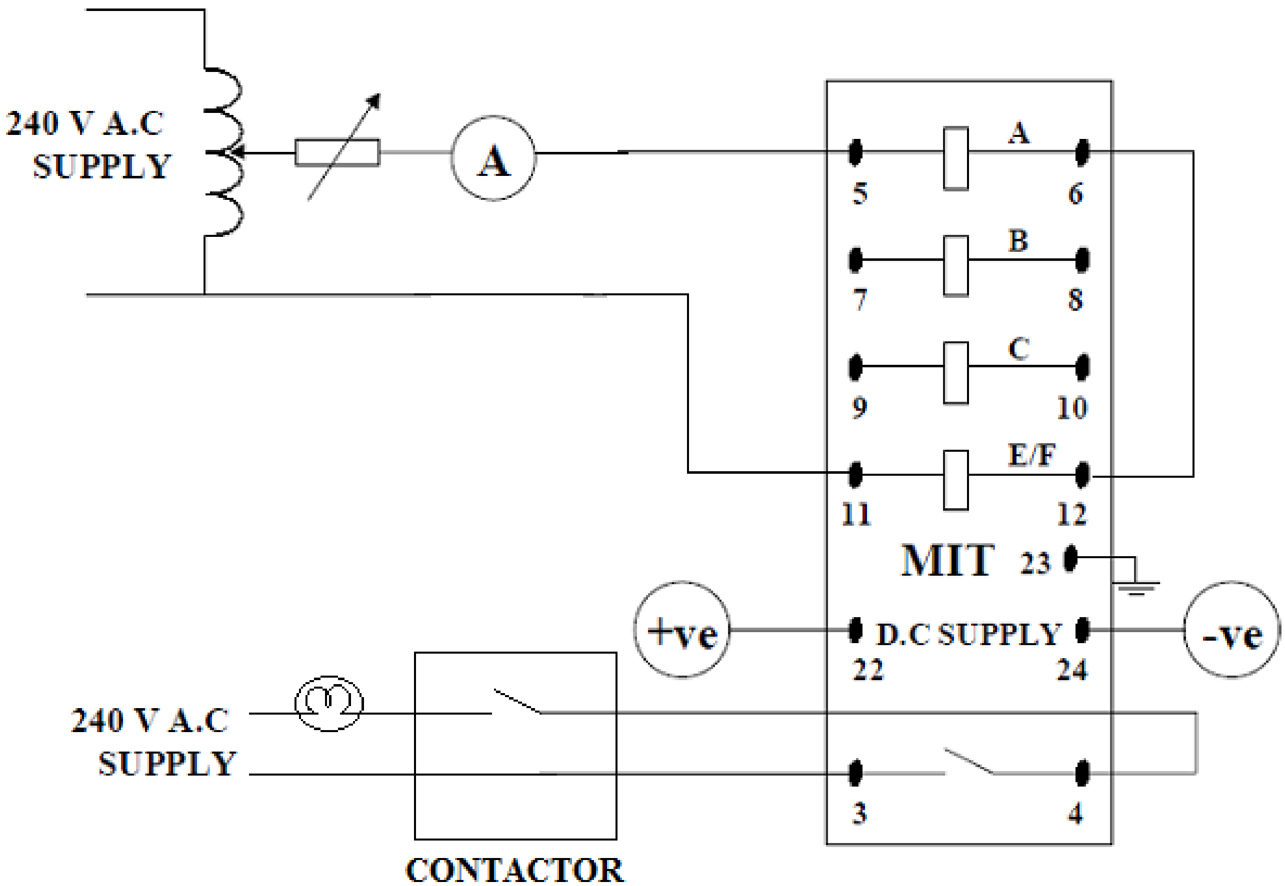
1. Definite time
2. Inverse Definite Minimum Time (IDMT)
3. Very Inverse
4. Extremely Inverse

Protection against earth faults can be obtained by using a relay that responds only to the residual current of the system, since a residual component exists only when fault current flows to earth. The earth-fault relay is therefore completely unaffected by load currents, whether balanced or not, and can be given a setting which is limited only by the design of the equipment and the presence of unbalanced leakage or capacitance currents to earth. This is an important consideration if settings of only a few percent of system rating are considered, since leakage currents may produce a residual quantity of this order.

PANEL VIEW:

OVER CURRENT RELAY (EARTH FAULT)

Circuit Diagram:



Experimental procedure:

1. Study the construction of the relay and identify the various parts.
2. Set the pick-up value of the current marked 1 A(100 % f. l current)
3. Set the Time Multiplier Setting (TMS) initially at 1.0.
4. Adjust the load current to about 1.8 times the f.l current. Record the time taken for the overload condition.
5. Vary the value of the load current in steps and record the time taken for the operation of the relay in each case with the help of the timer.
6. Repeat steps 5 and 6 for TMS values of 0.2, 0.4,0.6 and 0.8.
7. Repeat the above experiment with different pick up current values using the plug setting bridge.

Tabular form-Range of Experimental values:

Pick-up current = 1 Amps

IE - Current setting: 10% = 0.1A

S.No	Current(A)	Current(A) times the plug setting multiplier	Tp- Operating time in sec. for TMS of			
			1.0	0.8	0.6	0.4
1	0.12	1.2	35	26	20	12
2	0.13	1.3	20	16	10	7
3	0.14	1.4	14	11	8	5
4	0.16	1.6	12	9	7	4
5	0.18	1.8	10	8	6	3

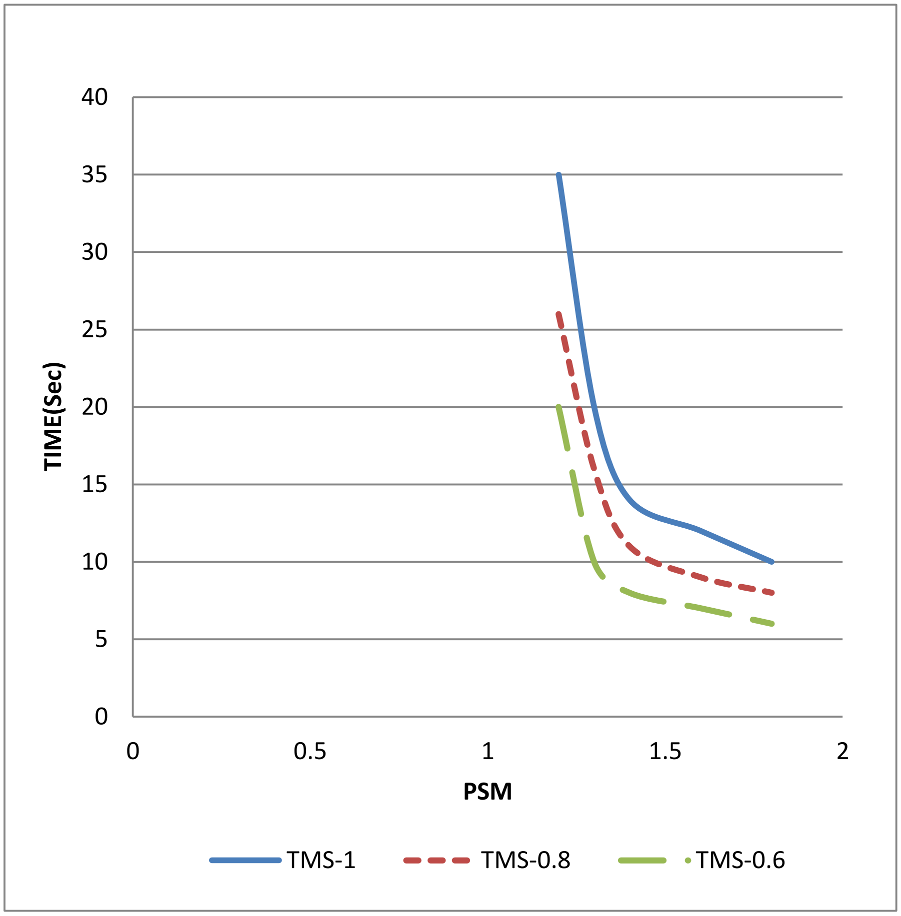
Tabular form-practical values:

Pick-up current = 1 Amps

IE - Current setting :

S.No	Current(A)	Current(A) times the plug setting multiplier	Tp- Operating time in sec. for TMS of			
			1.0	0.8	0.6	0.4
1						
2						
3						
4						
5						

Model graph-Characteristics of Earth fault relay



Signature of the faculty

RESULT:

Signature of the faculty

Date: **Experiment-3**

CHARACTERISTICS OF INDUCTION DISC TYPE RELAY

Aim: To study the characteristics of induction disc type relay

Apparatus: Induction disc type relay

Auxiliary supply kit (Step-down Transformer-230/24V, Bridge rectifier, filter)

Auto transformer (0-230v, 20A)

Ammeter (0-20A)

Rheostat (110Ω, 1.8A)

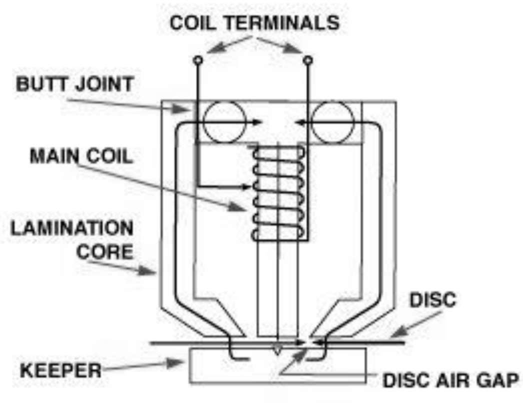
Theory:

The function of a relay is to detect abnormal conditions in the system and to initiate through appropriate circuit breakers the disconnection of faulty circuits so that interference with the general supply is minimized. Relays are of many types. Some depend on the operation of an armature by some form of electromagnet. A very large number of relays operate on the induction principle. When a relay operates it closes contacts in the trip circuit .The passage of current in the coil of the trip circuit actuates the plunger, which causes operation of the circuit breaker, disconnecting the faulty system.

Induction disc type relay:

The electromagnetic induction disc relay is frequently used where the time of relay operation should depend upon the amount of an overcurrent. The relay is essentially a small induction motor. This is probably the most widely used protective relay in the industry. It starts to turn when the current exceeds a (previously selected) threshold current, and rotates faster as the current increases. This relay has one set of stationary contacts and one set which moves as the disc turns. The distance which the disc must travel to close the contacts is adjusted by setting the position of the time dial control. The magnitude of current which initiates disc movement is set by the choice of the tap on the current coil. The results is that relay contact operation is dependent upon the tap and the time dial settings. The relay timing can be varied from a few cycles to as long as 30 seconds.

An induction relay works only with alternating current. It consists of an electromagnetic system which operates on a moving conductor, generally in the form of a disc or cup, and functions through the interaction of electromagnetic fluxes with the parasitic Fault currents which are induced in the rotor by these fluxes. These two fluxes, which are mutually displaced both in angle and in position, produce a torque.



Induction disc type Relay

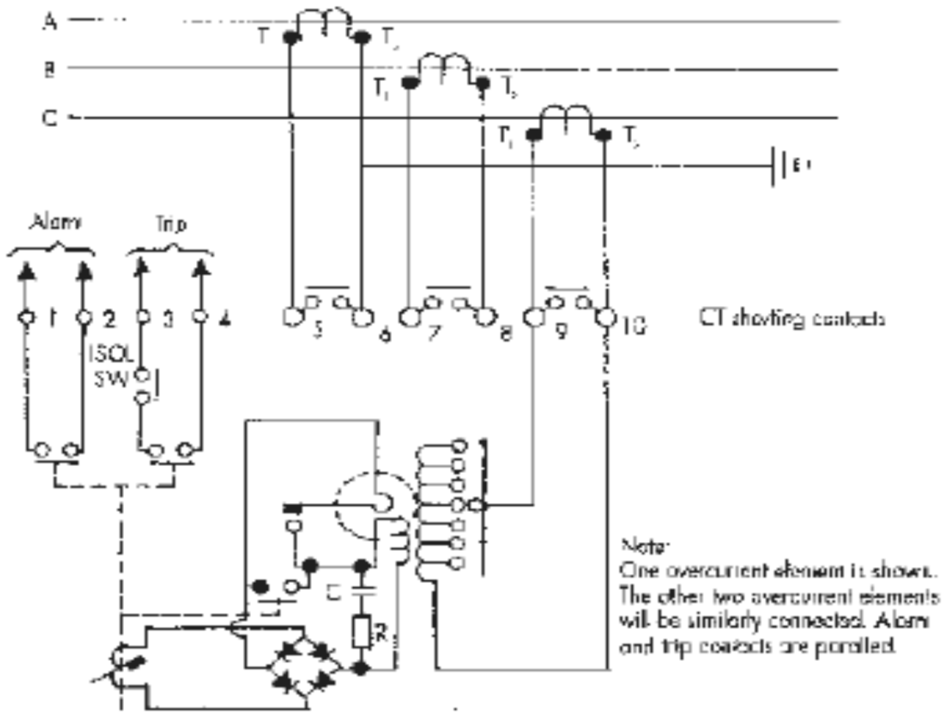
Basic torque/current equation

$$T = K1.\Phi1.\Phi2 .\sin \theta$$

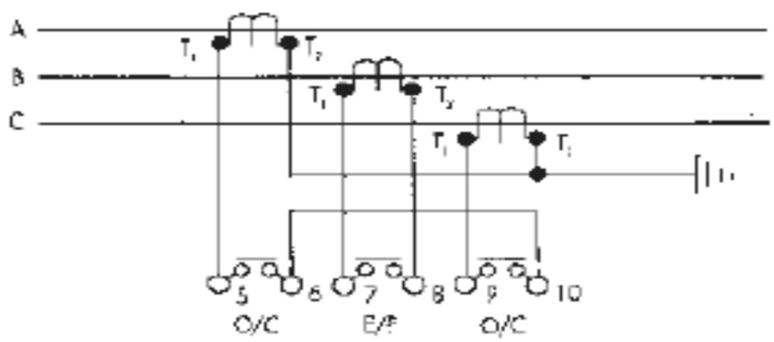
Where Φ1 and Φ2 are the interacting fluxes and θ is the phase angle between Φ1 and Φ2. It should be noted that the torque is a maximum when the fluxes are out of phase by 90º, and zero when they are in phase.

The relay's primary winding is supplied from the power systems current transformer via a plug bridge, which is called the plug setting multiplier (psm). Usually seven equally spaced tappings or operating bands determine the relays sensitivity. The primary winding is located on the upper electromagnet. The secondary winding has connections on the upper electromagnet that are energised from the primary winding and connected to the lower electromagnet. Once the upper and lower electromagnets are energised they produce eddy currents that are induced onto the metal disc and flow through the flux paths. This relationship of eddy currents and fluxes creates torque proportional to the input current of the primary winding, due to the two flux paths been out of phase by 90°.A restraining spring forces the disk to rotate in the direction that opens the trip contacts while current creates operating torque to close the contacts. The net positive torque closes the contacts. The IPU relay setting fixes the value of the pickup current. When the current applied to the relay equals the pickup current, the contact closing torque just equals the restraining torque and the disk will not move regardless of its position. If the applied current increases above the pickup current, the disk will begin to rotate so that the trip contacts come closer together

Wiring Diagram:



Three phase overcurrent protection in size 3D double ended vertical case



Experimental procedure:

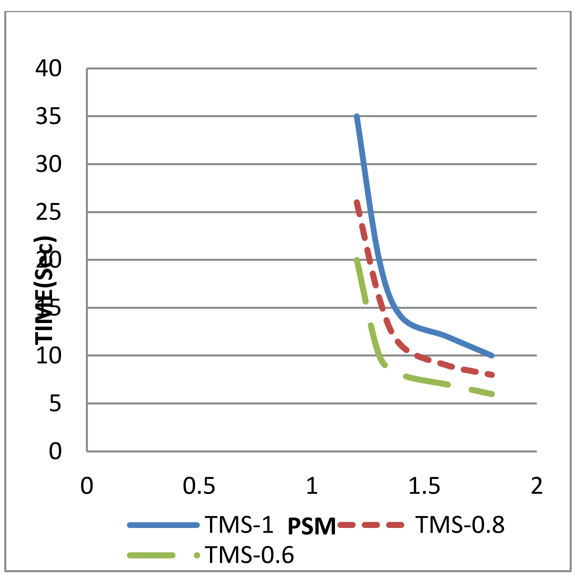
1. Study the construction of the relay and identify the various parts.
2. Set the pick-up value of the current as 2.5A
3. Adjust the load current to about 1.3 times the full load current. Record the time taken for the overload condition.
4. Vary the value of the load current in steps and record the time taken for the operation of the relay in each case with the help of the timer.
5. Repeat the above experiment with different pick up current values.

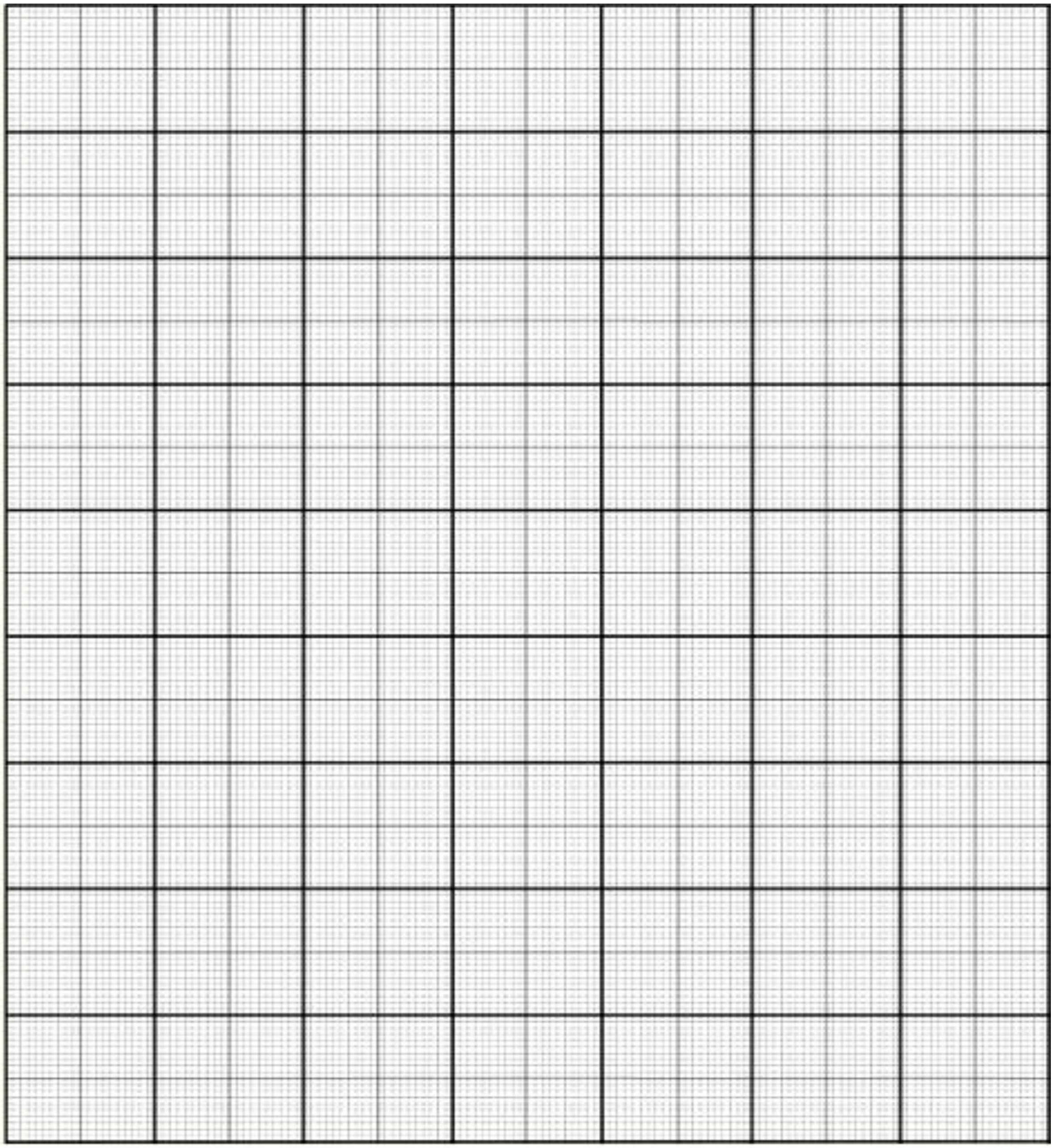
Tabular form-Range of Experimental values:

Pick-up current = 2.5 Amps

S.No	Current(A)	Current(A) times the plug setting multiplier	Operating Time in seconds
1			
2			
3			
4			
5			

Model graph :Characteristics of induction disc type relay





RESULT:

Signature of the faculty

Date: **Experiment-4**

TESTING OF DIFFERENTIAL RELAY

Aim: To study the operation of Differential Relay

Apparatus: Differential Relay

Auxiliary supply kit (Step-down Transformer-230/24V, Bridge rectifier, filter)

Auto transformer (0-230v, 2A)-2 No.s

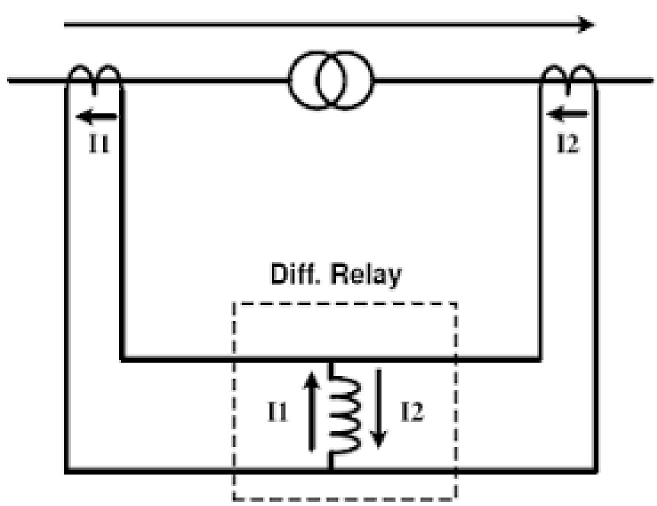
Ammeter (0-2A)-2 No.s

Rheostat (110Ω, 1.8A) -2 No.s

Theory:

The relay which is used to checks the difference between the output and input currents for power system current in known as differential relay. The difference amongst the currents may also be in phase angle or in magnitude or in each the angle and magnitude variations must be zero. In case there's a difference which difference go beyond some value, the relay can work and interconnected electrical fuse can disconnect.

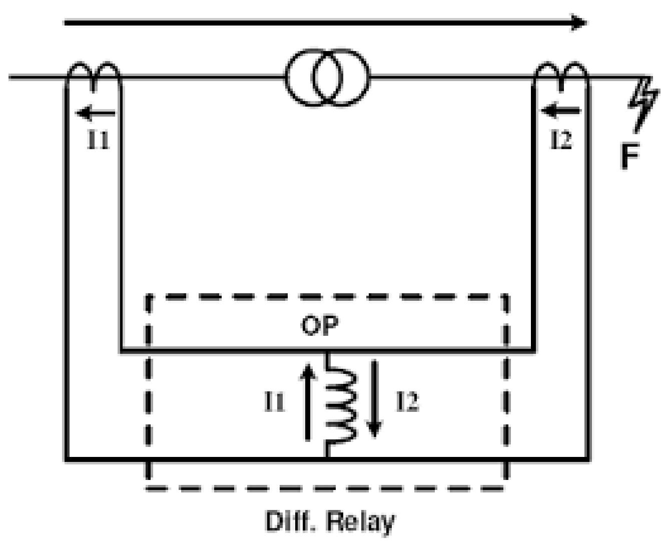
<u>Principle Operation of differential relay</u>:



Differential Relay at Normal Condition

Consider a power transformer with transformation magnitude (ratio) relation 1:1 and (Y/Y) connection and therefore the CT_1 and CT_2 ensure a similar transformation magnitude relation as shown. The current flows within the primary side and secondary side of power transformer are equal, presumptuous ideal power transformer. The secondary current I_1 and I_2 are same in magnitude and reverse in direction. Therefore, the net current within the differential coil is nil at load situation (without any fault), and therefore the relay won't operate.

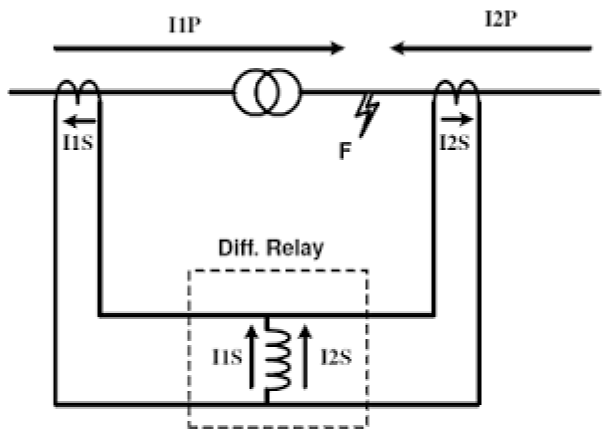
External Fault Condition in Differential Relay:



Differential Relay External Fault condition

Assigning the previous one the power transformer with an external fault F is shown in figure. During this case the 2 currents I_1, and I_2 can increase to terribly high magnitudes values however there's no modification in phase angle. Hence, net current within the differential coil continues to be zero and therefore the relay won't operate.

Internal Fault Condition in Differential Relay:



Differetial Relay With Internal Fault Condition

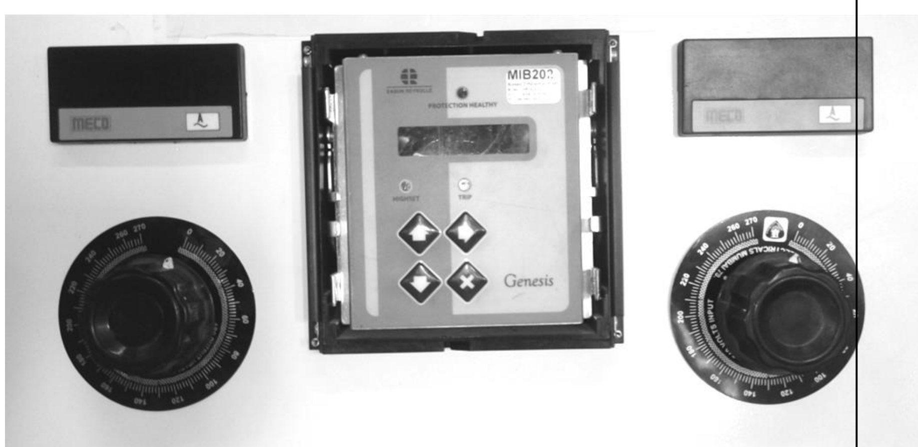
An internal fault F is shown in this figure. Now, there are 2 anticipated conditions:

There's other supply to feed the fault thus I_{2P} includes a nonzero value $I_{diff} = I_{1S} + I_{2S}$ which can be terribly high and sufficient to function the differential relay.

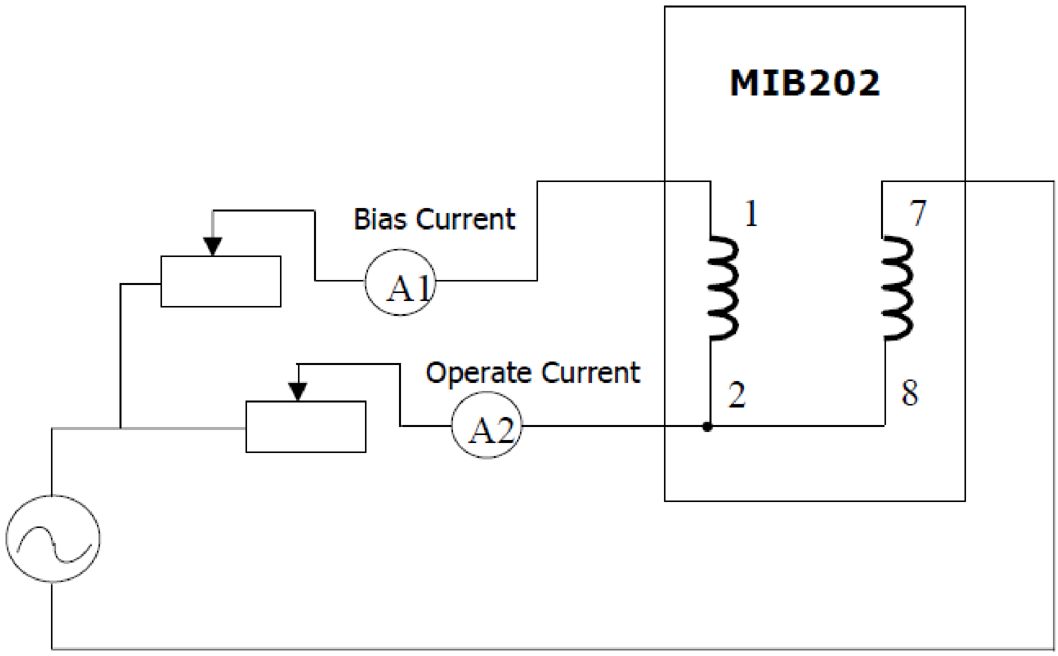
Radial system, $I_{2P} = 0$. So, $I_{diff} = I_{1S}$ and additionally the relay can work and disconnect the breaker.

PANEL VIEW:

DIFFERNTIAL RELAY



Circuit Diagram



Procedure:

1. Study the construction of the relay and identify the various parts.
2. Set the Bias current and current setting.
3. With zero bias current (ammeter A2=0), inject operate current in to phase A. When the relay operates, shown bythe LED "Trip" illuminating, record the value of the current indicated on ammeter A1.
4. Repeat the test with increasing bias currents up to 2times the relay rating.
5. Record the results in Table.

Model Tabular Form:

Initial settings	Bias settings	Bias current Ammeter A2 multiples of rated current in				
		0	1	1.5	2	2.5
		Operate current, ammeter A1 Amps				
10%	10%	0.1	0.11	0.16	0.21	2.26
20%	20%	0.2	0.21	0.33	0.44	0.56
30%	30%	0.3	0.35	0.53	0.71	0.88
40%	40%	0.4	0.5	0.75	1	1.25
50%	50%	0.5	0.67	1	1.33	1.67
-	70%	0.5	0.86	1.29	1.71	2.14
-	80%	0.5	1.08	1.62	2.15	2.69

Tabular form :practical readings

Intial settings	Ammeter A2 multiples of rated current in				
	Operate current, ammeter A1 Amps				
10%					
20%					
30%					
40%					
50%					
-					

RESULT:

Signature of the faculty

Date: **Experiment-5**

CHARACTERISTICS OF OVER VOLTAGE RELAY

AIM: To study the characteristics of over voltage relay

APPARATUS: Over voltage relay

Auxiliary supply kit (Step-down Transformer-230/24V, Bridge rectifier, filter)

Auto transformer (0-230v, 2A)

Voltmeter (0-200v)

Rheostat (110Ω, 1.8A)

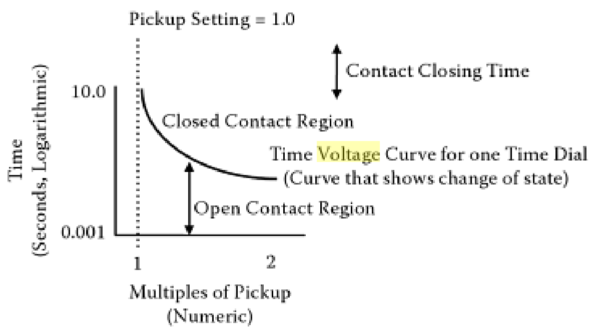
THEORY:

OVERVOLTAGE PROTECTION

The function of a relay is to detect abnormal conditions in the system and to initiate through appropriate circuit breakers the disconnection of faulty circuits so that interference with the general supply is minimized. There are always a chance of suffering an electrical power system from abnormal over voltages. These abnormal over voltages may be caused due to various reason such as, sudden interruption of heavy load, lightening impulses, switching impulses etc. These over voltage stresses may damage insulation of various equipments and insulators of the power system. Although, all the over voltage stresses are not strong enough to damage insulation of system, but still these over voltages also to be avoided to ensure the smooth operation of electrical power system. These all types of destructive and non destructive abnormal over voltages are eliminated from the system by means of **overvoltage protection**. For generator protection an overvoltage relay is used to detect failure in voltage regulation. For transformers and transmission lines, overvoltage protection is sometimes used to detect excessive voltages

Principle:

An overvoltage relay is one that operates when input voltage exceeds a predetermined(pick up) value.over voltage relays must be instantaneous or time-delayed devices.In order to set a time overvoltage relay,pickup voltage and time dial need to be specified and VT ration needs to be documented.Time overvoltage relays start to time out every time input voltage exceeds the setpoint.overvoltage relays complete their function and close the output contact when the duration of the overvoltage exceeds the time delay described by the time voltage curve.



Inverse time characteristics of overvoltage relay

The inverse characteristic for overvoltage V>, is defined by the following equation:

$$t = \left[\frac{TMS}{\left| \frac{V}{Vs} - 1 \right|} \right]$$

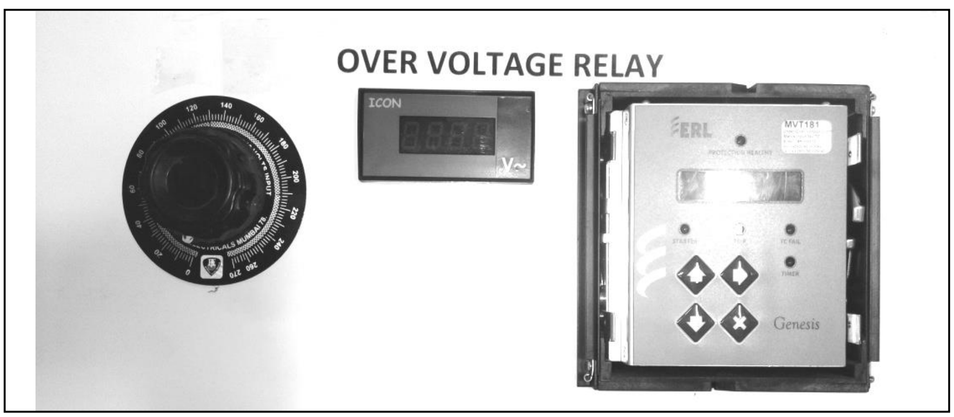
where:

t = operating time in seconds, TMS = time multiplier setting

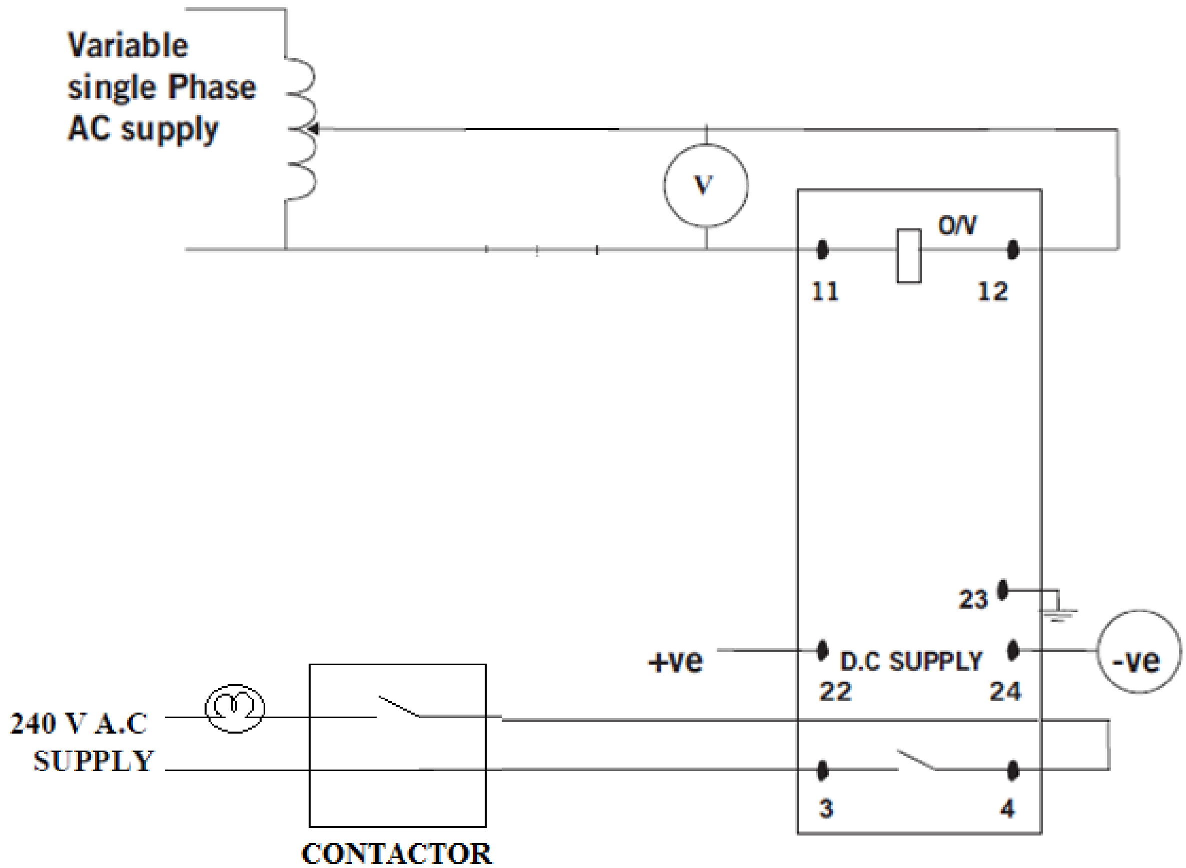
V = applied input voltage, Vs = relay setting voltage

NOTE: this equation is valid for V> Vs

PANEL VIEW:



Circuit Diagram:



Experimental procedure:

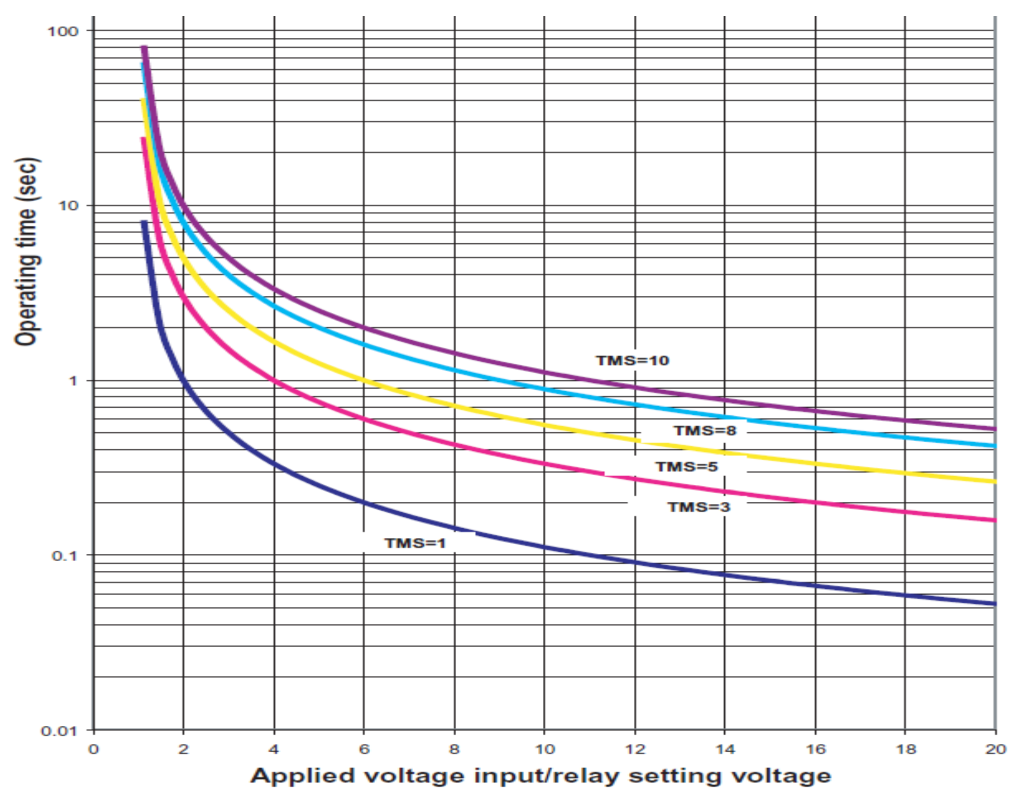
1. Study the construction of the relay and identify the various parts.
2. Set the pick-up value of the voltage .
3. Set the Time Multiplier Setting (TMS) initially at 1.0.
4. Adjust the voltage from 1.2 to 1.8 times the pick up voltage step wise. Record the time taken for the overvoltage condition.
5. Vary the value of the over voltage in steps and record the time taken for the operation of the relay in each case with the help of the timer.
6. Repeat steps 4 and 5 for TMS values of 0.8,0.6,0.5,0.2
7. Repeat the above experiment with different pick up voltage values using the plug setting bridge.

Tabular form

Pick-up voltage = ------ volts

S.No	Voltage(v)	Voltage(v) times the plug setting multiplier	Tp- Operating time in sec. for TMS of				
			1.0	0.8	0.6	0.5	0.2
1		1.2					
2		1.3					
3		1.4					
4		1.6					
5		1.8					

Model graph-Characteristics of over voltage relay :



RESULT:

Signature of the faculty

Date: **Experiment-6**

CHARACTERISTICS OF UNDER VOLTAGE RELAY

AIM: To study the characteristics of under voltage relay

APPARATUS: Under voltage relay

Auxiliary supply kit (Step-down Transformer-230/24V, Bridge rectifier, filter)

Auto transformer (0-230v, 2A)

Voltmeter (0-200v)

Rheostat (110Ω, 1.8A)

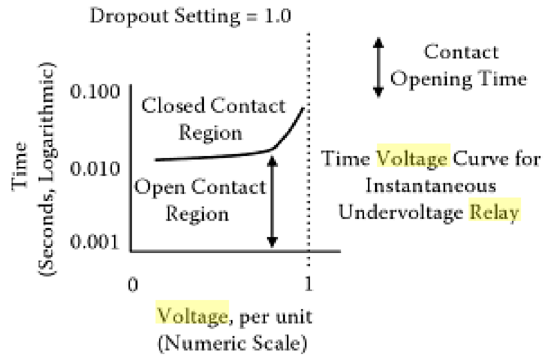
THEORY:

UNDER VOLTAGE PROTECTION

The function of a relay is to detect abnormal conditions in the system and to initiate through appropriate circuit breakers the disconnection of faulty circuits so that interference with the general supply is minimized. There are always a chance of suffering an electrical power system from abnormal under voltages. An undervoltage protection is used to disconnect motors at low system voltage to prevent problems with inrush at system voltage recovery. Single-phase versions connected phase-phase are used for asynchronous motors, whereas measuring of positive sequence voltage is used for synchronous motors.

Principle:

An undervoltage relay is one that operates when input voltage drops below a predetermined value(dropout value).Undervoltage relays are usually instantaneous devices.If time delays are needed,timers,initiated on undervoltage relay,are utilized.Undervoltage relays should complete their function every time input voltage drops below the setpoint.The dropout voltage needs to be specified and VT ratio needs to be documented.A typical time voltage curve for undervoltage relay is shown below.



Characteristics of under voltage relay

The inverse characteristic for undervoltage V<, is defined by the following equation:

$$t = \left[\frac{TMS}{\left| 1 - \frac{V}{Vs} \right|} \right]$$

where:

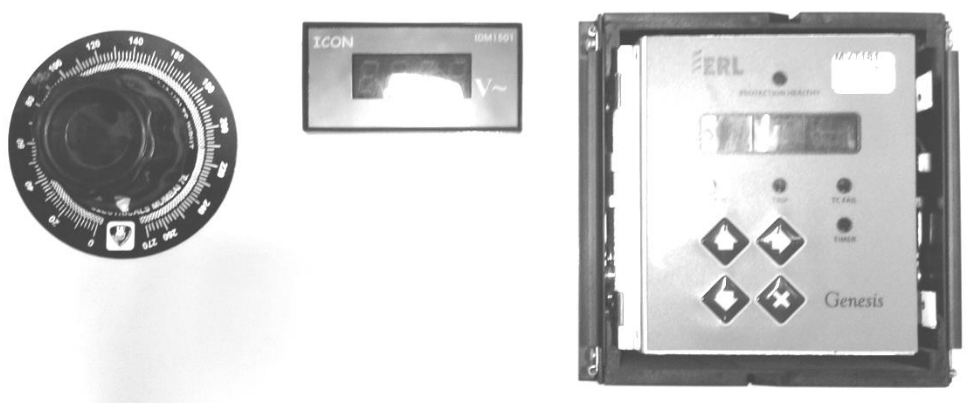
t = operating time in seconds, TMS = time multiplier setting

V = applied input voltage, Vs = relay setting voltage

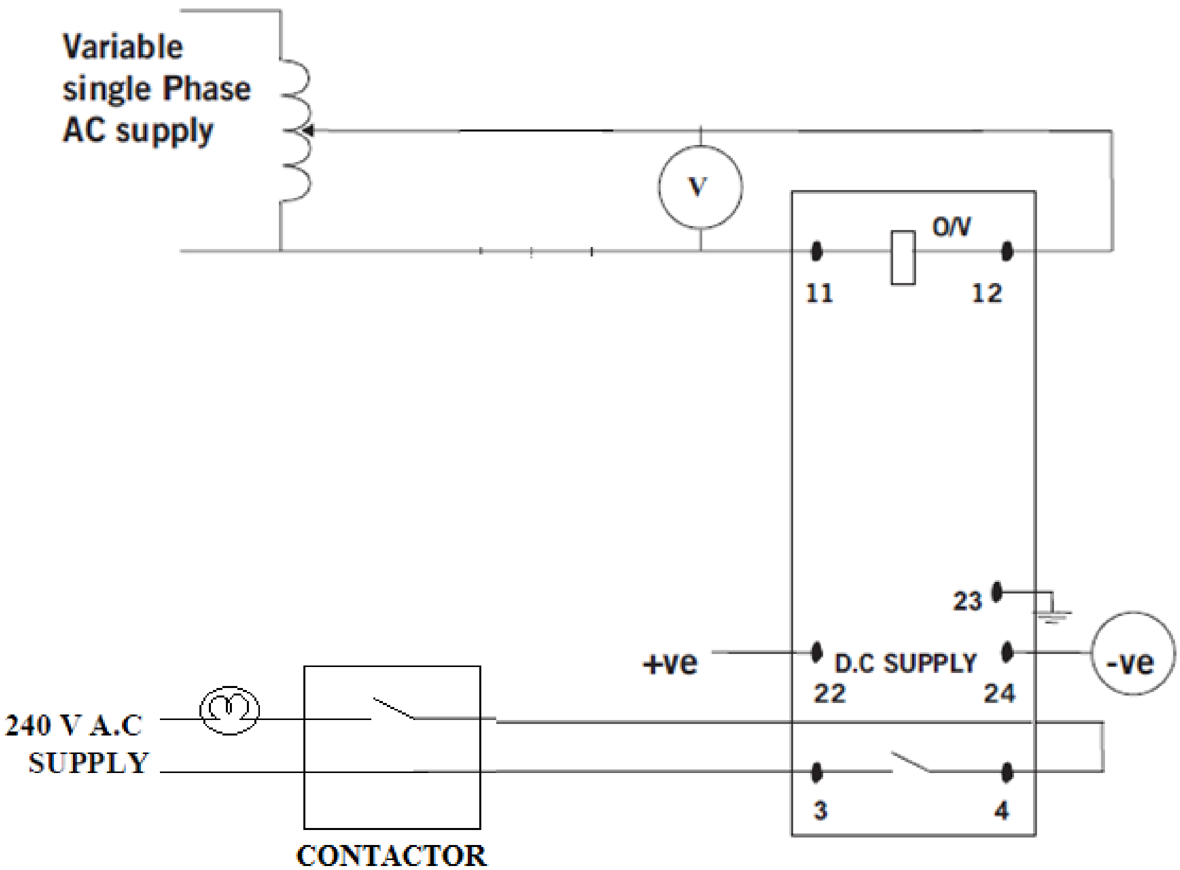
NOTE: this equation is valid for $Vs > V$

PANEL VIEW:

UNDER VOLTAGE RELAY



Circuit Diagram:



Experimental procedure:

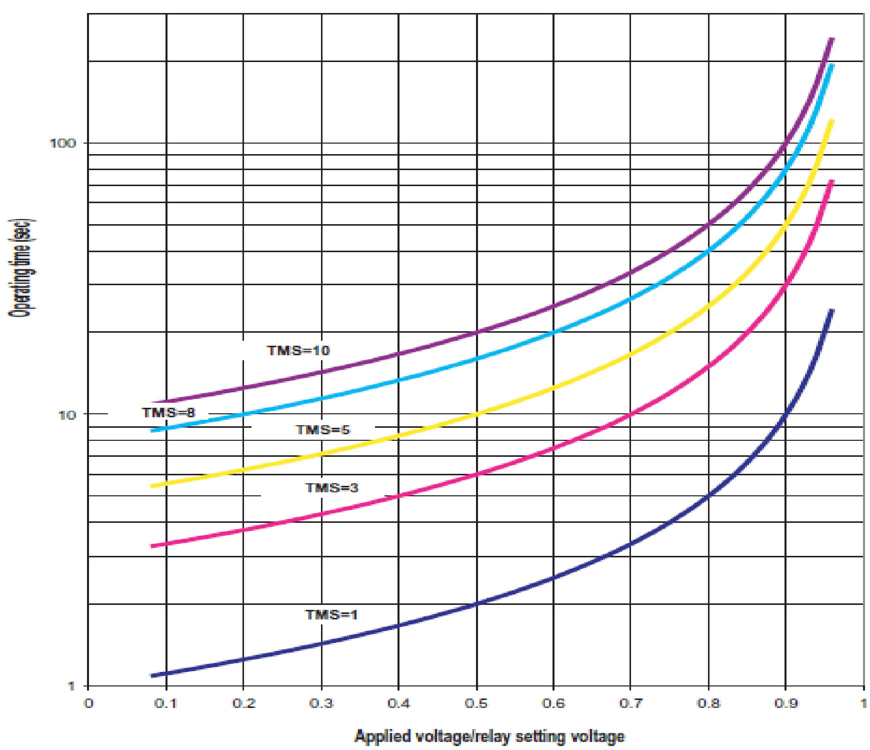
1. Study the construction of the relay and identify the various parts.
2. Set the drop out value of the voltage .
3. Set the Time Multiplier Setting (TMS) initially at 1.0.
4. Adjust the voltage from 0.5 to 0.9 times the dropout voltage step wise. Record the time taken for the under voltage condition.
5. Vary the value of the under voltage in steps and record the time taken for the operation of the relay in each case with the help of the timer.
6. Repeat steps 4 and 5 for TMS values of 0.8,0.6,0.5,0.2
7. Repeat the above experiment with different dropout voltage values using the plug setting bridge.

Tabular form

Drop-out voltage = ----- volts

S.No	Voltage(v)	Voltage(v) times the plug setting multiplier	Tp- Operating time in sec. for TMS of				
			1.0	0.8	0.6	0.5	0.2
1		0.9					
2		0.8					
3		0.7					
4		0.6					
5		0.5					

Model graph- Characteristics of under voltage relay :



Signature of the faculty

RESULT:

Signature of the faculty

Date: **Experiment-7**

TESTING OF NEGATIVE SEQUENCE RELAY

Aim: To study the operation of Negative sequence relay.

Apparatus: Negative sequence relay

Auxiliary supply kit (Step-down Transformer-230/24V, Bridge rectifier, filter)

Auto transformer (0-230v, 2A)

Ammeter (0-2A)

Rheostat (110Ω, 1.8A)

Theory:

Need for Negative Sequence Protection

Primary cause of motor failure is excessive heating, which if sustained over long time periods will result in motor burn out. Overheating also reduces the life of motor. If a motor is continuously over heated by just 10 degrees, its life can get reduced by almost 50%.

Overheating normally occurs due to over current, which in turn may be due to over loads or locked rotor condition or low voltage or phase failure or repeat starts or phase unbalance.

Bimetallic relays are most economical solution for heating due to over loads. However they suffer from inherent deficiencies like poor accuracy, rigid inverse time characteristics, poor repeatability etc. They are totally insensitive to current unbalance, which is one of the major contributors to overheating in motors.

Though the three-phase motor is supposed to be a balanced load, current unbalance occurs frequently in motor feeders due to following:

- voltage unbalance in the feeder supply

- phase reversal

- single phasing

Current unbalance in a motor is best represented by the presence of excessive negative sequence component in the motor current. Consequently it is necessary to protect motors against negative sequence.
When the power supply to the motor is unbalanced, the unbalanced voltage and the resulting unbalanced currents in the three phases can be resolved into three balanced components as follows :

Positive Sequence component: This component is in the same phase sequence as that of the motor current. All its three phases are perfectly balanced - they are equal in magnitude and are displaced by 120 degrees. The positive sequence component represents the amount of balance in the power supply and consequently is instrumental in delivering useful power.

Negative Sequence component: This component has a phase sequence opposite to that of the motor current hence the name negative sequence. It represents the amount of unbalance in the feeder. All its three phases are perfectly balanced - they are equal in magnitude and are displaced by 120 degrees. This component does not produce useful power - however by being present it contributes to the losses and causes temperature rise.

- **Zero Sequence component**: This, if present, represents extent of earth fault in the feeder. All its three phases are in the same direction.

Negative sequence relay:

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

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

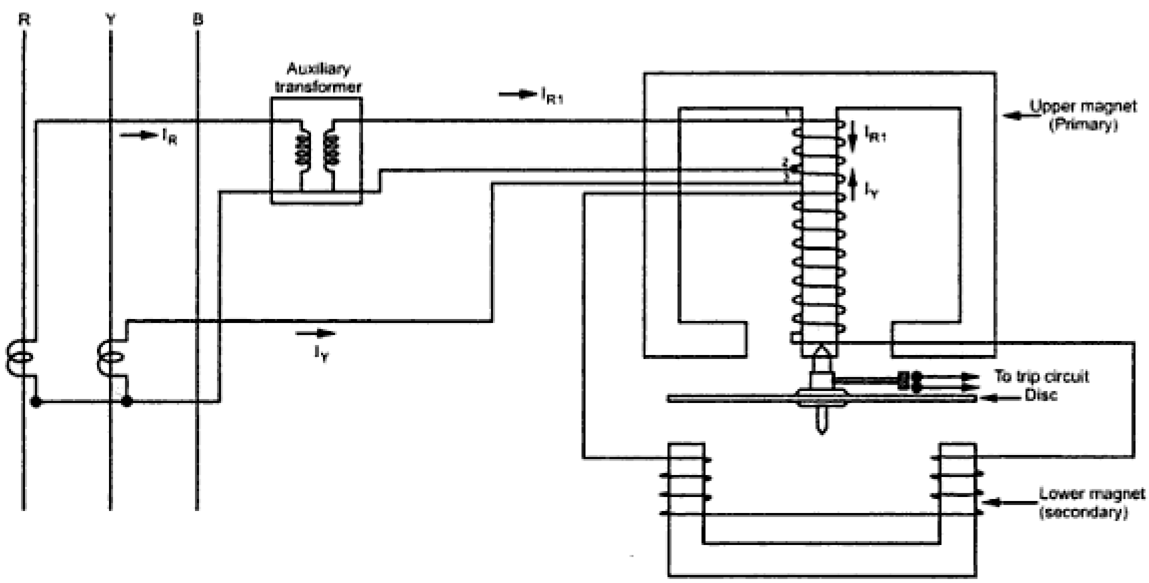
A negative sequence relay provides protection against phase to phase faults which are responsible to produce negative sequence components.

<u>Induction Type Negative Sequence Relay</u>:

It is commonly used negative sequence relay, The schematic diagram of this type of relay is shown in the Fig

The central limb of upper magnet carries the primary which has a Centre tap. Due to this, the primary winding has three terminal 1, 2 and 3. The section 1-2 is energized from the secondary of an auxiliary transformer to R-phase. The section 2-3 is directly energized from the Y-phase current.

The auxiliary transformer is a special device having an air gap in its magnetic circuit. With the help of this, the phase angle between its primary and secondary can be easily adjusted.



Induction type Negative sequence relay

In practice it is adjusted such that output current lags by 120°rather than usual 180°from the input.

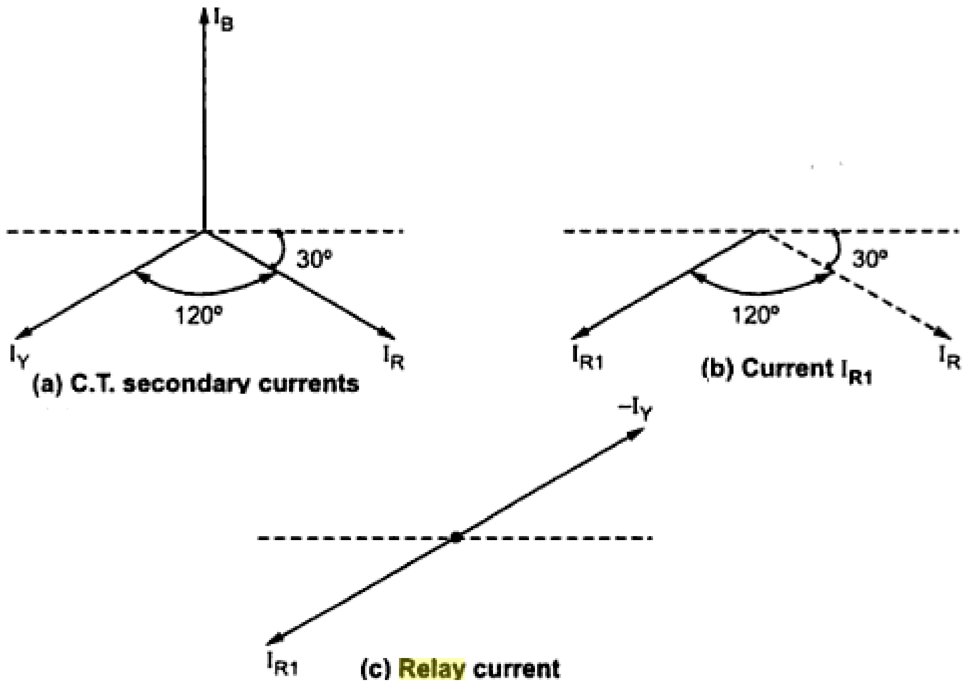
So, I_R = Input current of auxiliary transformer

I_{R1} = Output current of auxiliary transformer

and I_{R1} lags I_R by 120°

Hence the relay primary carries the current which is phase difference of I_{R1} and I_R .

Positive Sequence Currents: The C.T secondary currents are shown in the Fig.(a). The Fig.(b) shows the position of vector I_{R1} lagging I_R by120°. The Fig..(c) shows the vector sum of I_{R1} and - I_Y. The phase difference of I_{R1} and I_Y is the vector sum of I_{R1} and $-I_Y$. It can seen from the Fig..(c) that the resultant is zero. Thus the relay primary current is zero and relay is inoperative for positive sequence currents.

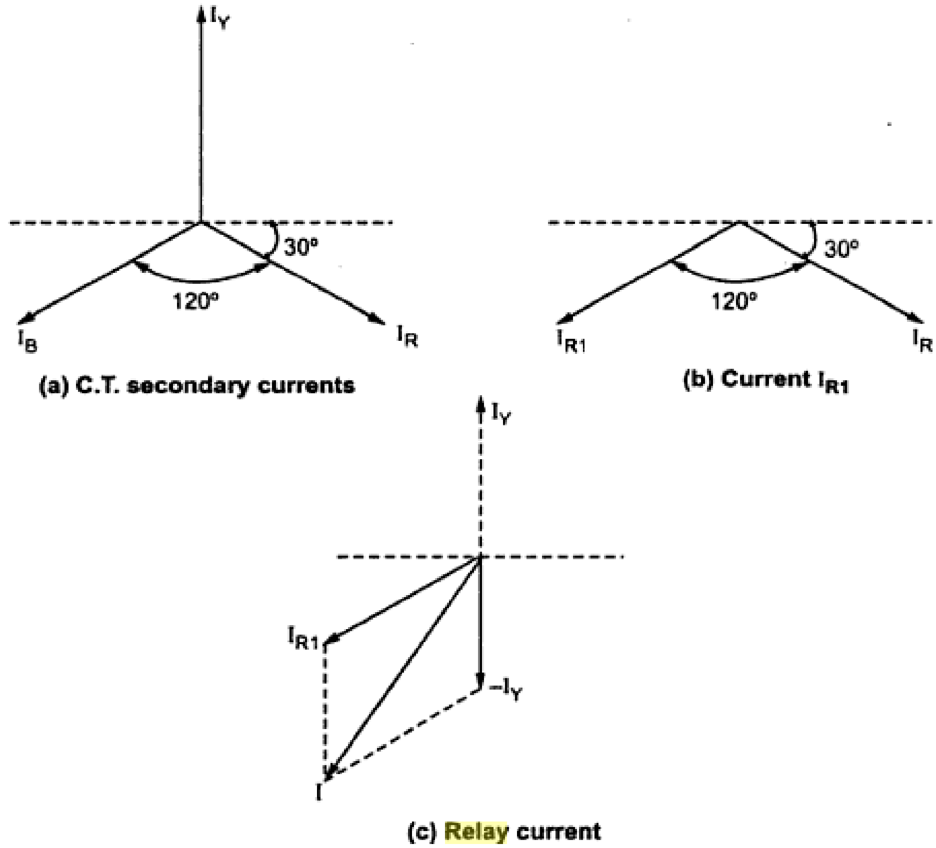


Positive sequence currents

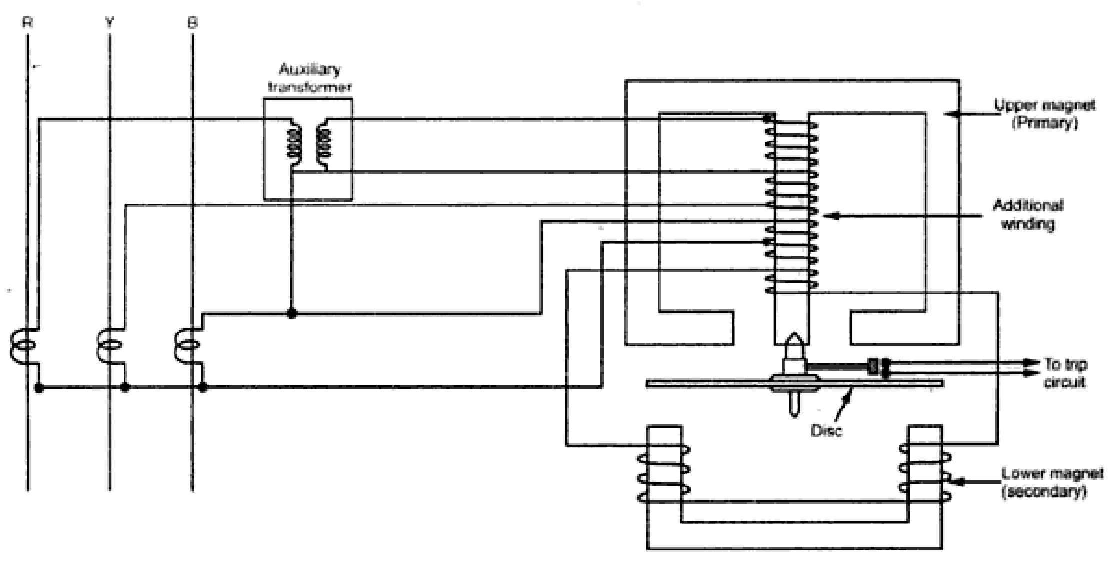
Negative Sequence Currents: The C.T. secondary currents are shown in the Fig..(a). The Fig..(b) Shows the position of I_{R1} lagging I_R by 120°. The Fig..(c) Shows the vector difference of I_{R1} and I_Y which is the relay current.

Under negative sequence currents, the vector difference of I_{R1} and I_Y results into a current I as shown in the Fig. This current flows through the primary coil of the relay. Under the influence of current I, the relay operates. The disc rotates to close the trip contacts and opens the circuit breaker.

This relay is inoperative for zero sequence currents. But the relay can be made operative for the flow of zero sequence currents also by providing an additional winding on the central limb of the upper magnet of the relay. This winding is connected in the residual circuit of three line C.T. This relay is called induction type negative and zero sequence relay. The schematic arrangement of induction type negative and zero sequence relay is shown in the Fig.

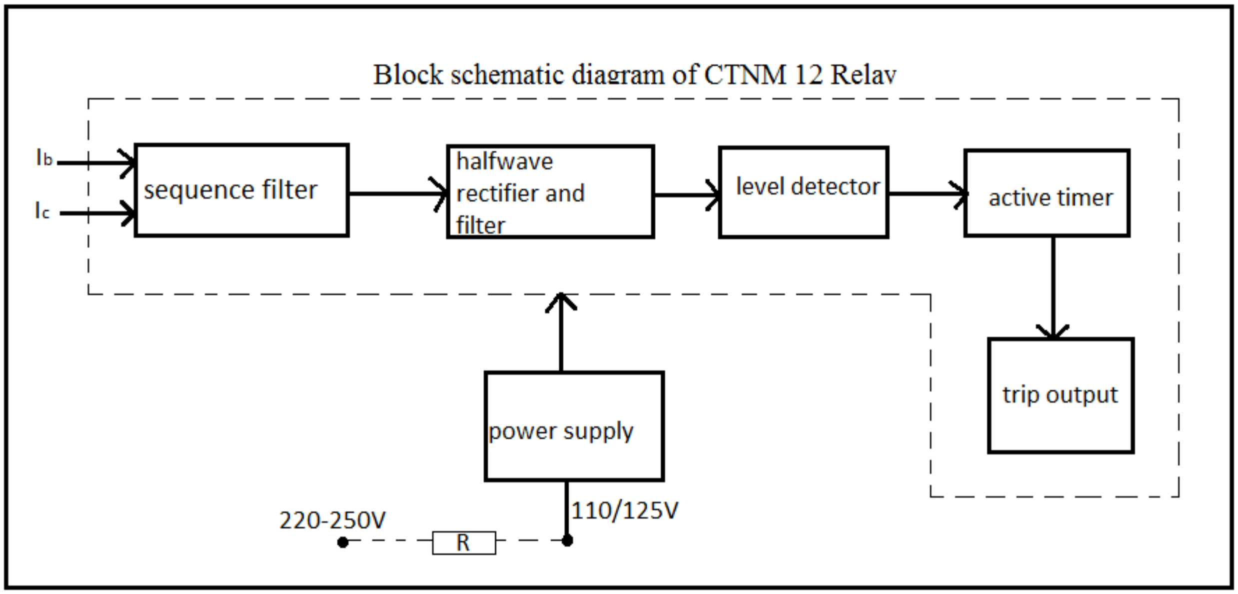


Negative sequence currents

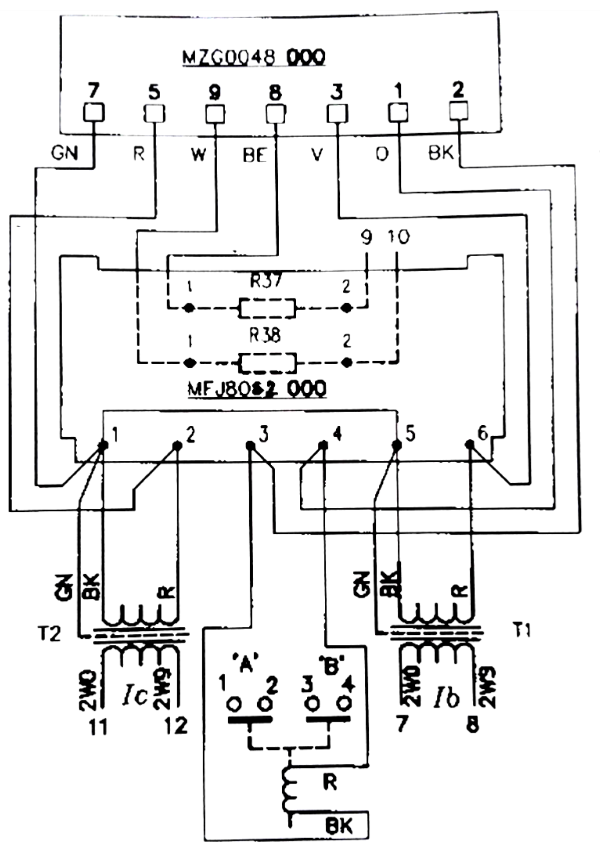


Induction type negative and zero sequence relay

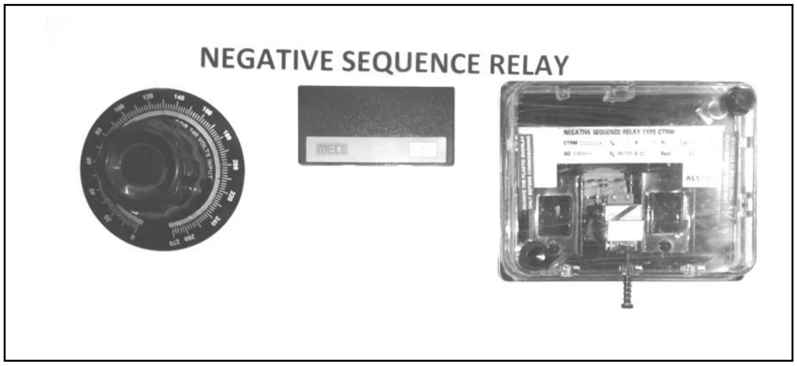
Block Diagram:



CTNM 12 wiring diagram



PANEL VIEW:



Experimental procedure:

1. Study the construction of the relay and identify the various parts.
2. Connect the circuit for phase B for unbalanced condition.
3. Increase the current and note the value of current & time at instant of tripping.
4. Repeat the above procedure by connecting circuit for phase C and tabulate the readings.

Tabular form:

S. No	Current (A)	Tripping Time (sec)
Phase B		
Phase C		

RESULT:

Signature of the faculty

Date: **Experiment-8**

To determine Efficiency and Regulation of 3 Phase Transmission model

AIM: To understand modeling and performance of Short, Medium and Long transmission lines.

Apparatus :

- Type of conductor: Twin Moose
- Voltage level: 400 KV
- Line length in km: 200
- Number of pi sections: 4 (Each Pi = 50km)

Transmission line parameters:

- Resistance R in ohm per km: 0.0328
- Inductive reactance X in ohm per km: 0.332
- Half of capacitive susceptance B/2 in μ℧ per km: 1.734375

THEORY:

The important considerations in the design and operation of a transmission line are the determination of voltage drop, line losses and efficiency of transmission. These values are greatly influenced by the line constants R, L and C of the transmission line. For instance, the voltage drop in the line depends upon the values of above three line constants. Similarly, the resistance of transmission line conductors is the most important cause of power loss in the line and determines the transmission efficiency.

A transmission line has three constants R, L and C distributed uniformly along the whole length of the line. The resistance and inductance form the series impedance. The capacitance existing between conductors for 1-phase line or from a conductor to neutral for a 3-phase line forms a shunt path throughout the length of the line.

Short Transmission Line:

When the length of an overhead transmission line is upto about 50km and the line voltage is comparatively low (< 20 kV), it is usually considered as a short transmission line.

Medium Transmission Lines:

When the length of an overhead transmission line is about 50-150 km and the line voltage is moderatly high (>20 kV < 100 kV), it is considered as a medium transmission line.

Long Transmission Lines:

When the length of an overhead transmission line is more than 150km and line voltage is very high (> 100 kV), it is considered as a long transmission line.

Voltage Regulation:

The difference in voltage at the receiving end of a transmission line between conditions of no load and full load is called voltage regulation and is expressed as a percentage of the receiving end voltage.

Performance of Single Phase Short Transmission Lines

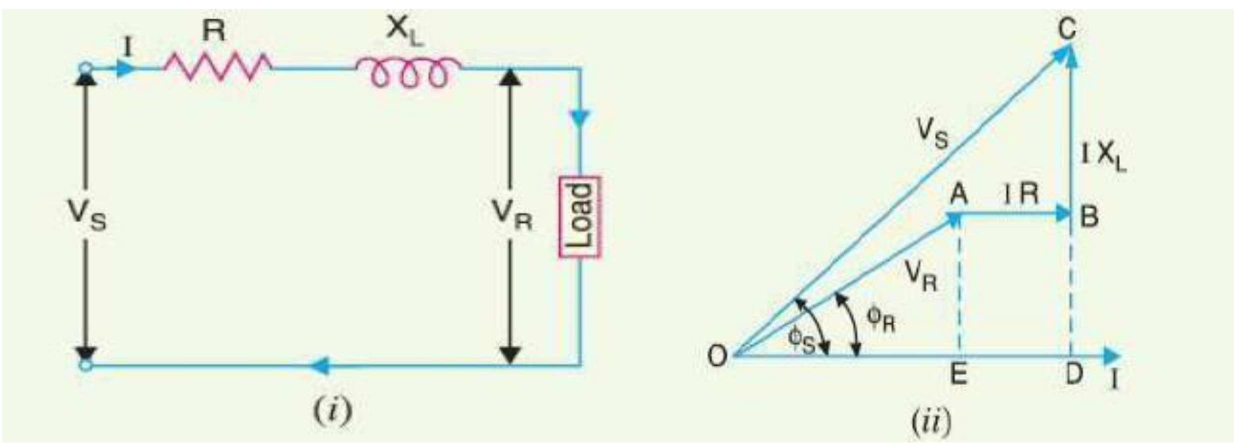
As stated earlier, the effects of line capacitance are neglected for a short transmission line. Therefore, while studying the performance of such a line, only resistance and inductance of the line are taken into account. The equivalent circuit of a single phase short transmission line is shown in Fig. (*i*).Here, the total line resistance and inductance are shown as concentrated or lumped instead of being distributed. The circuit is a simple a.c. series circuit.

Let I = load current

R = loop resistance i.e., resistance of both conductors XL = loop reactance

VR = receiving end voltage
cosϕR = receiving end power factor (lagging) VS = sending end voltage

cosϕS = sending end power factor



The phasor diagram of the line for lagging load power factor is shown in Fig. (ii). From the right angled triangle *ODC*, we get, $(OC)^2 = (OD)^2 + (DC)^2$

$VS^2 = (OE + ED)^2 + (DB + BC)^2$

$= (VR \cos\phi R + IR)^2 + (VR \sin\phi R + IXL)^2$

$$\therefore \quad V_S = \sqrt{(V_R \cos \phi_R + IR)^2 + (V_R \sin \phi_R + IX_L)^2}$$

(i) %age Voltage regulation $= \dfrac{V_S - V_R}{V_R} \times 100$

(ii) Sending end *p.f.*, $\cos \phi_S = \dfrac{OD}{OC} = \dfrac{V_R \cos \phi_R + IR}{V_S}$

(iii) Power delivered $= V_R I_R \cos \phi_R$

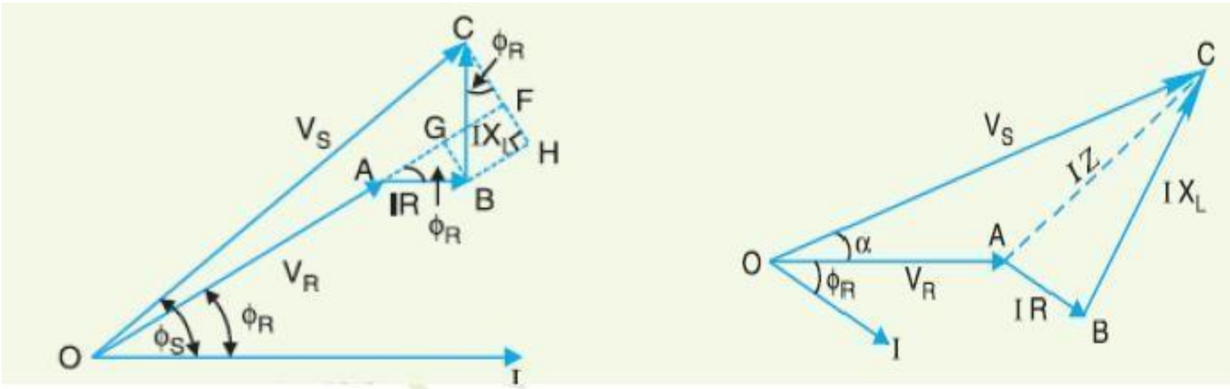
Line losses $= I^2 R$

Power sent out $= V_R I_R \cos \phi_R + I^2 R$

%age Transmission efficiency $= \dfrac{\text{Power delivered}}{\text{Power sent out}} \times 100$

$$= \frac{V_R I_R \cos \phi_R}{V_R I_R \cos \phi_R + I^2 R} \times 100$$

An approximate expression for the sending end voltage VS can be obtained as follows. Draw perpendicular from B and C on OA produced as shown in Fig. 2. Then OC is nearly equal to OF i.e.,

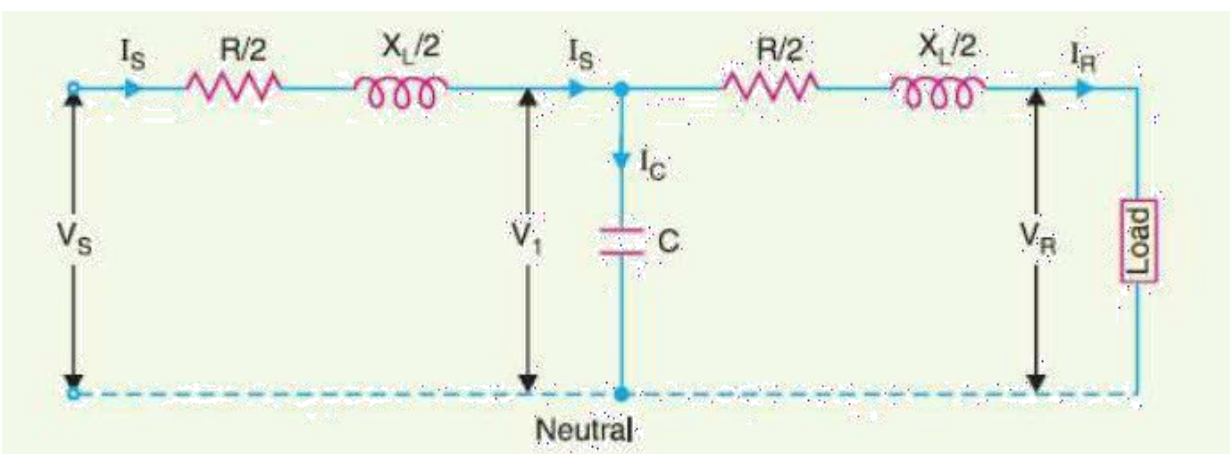


OC = OF = OA + AF = OA + AG +
GF = OA + AG + BH

$VS = VR + I R \cos\phi R + I XL \sin \phi R$

Medium Transmission Line
Nominal T Method

In this method, the whole line capacitance is assumed to be concentrated at the middle point of the line and half the line resistance and reactance are lumped on its either side as shown in Fig.1, Therefore in this arrangement, full charging current flows over half the line. In Fig.1, one phase of 3-phase transmission line is shown as it is advantageous to work in phase instead of line-to-line values.



Let IR = load current per phase
R = resistance per phase

XL = inductive reactance per phase

C = capacitance per phase

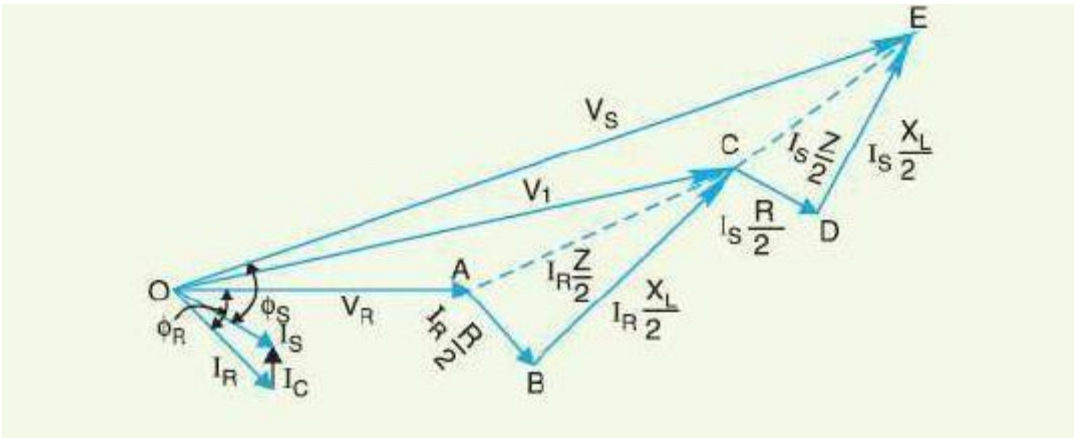
cosϕR = receiving end power factor (lagging)

VS = sending end voltage/phase

V1 = voltage across capacitor C

The phasor diagram for the circuit is shown in Fig.2. Taking the receiving end voltage VR as the reference phasor, we have,

Receiving end voltage, VR = VR + j 0
Load current, IR = IR (cosϕR - j sin ϕR)



Voltage across C, $\vec{V_1} = \vec{V_R} + \vec{I_R}\,\vec{Z}/2$

$$= V_R + I_R(\cos\phi_R - j\sin\phi_R)\left(\frac{R}{2} + j\frac{X_L}{2}\right)$$

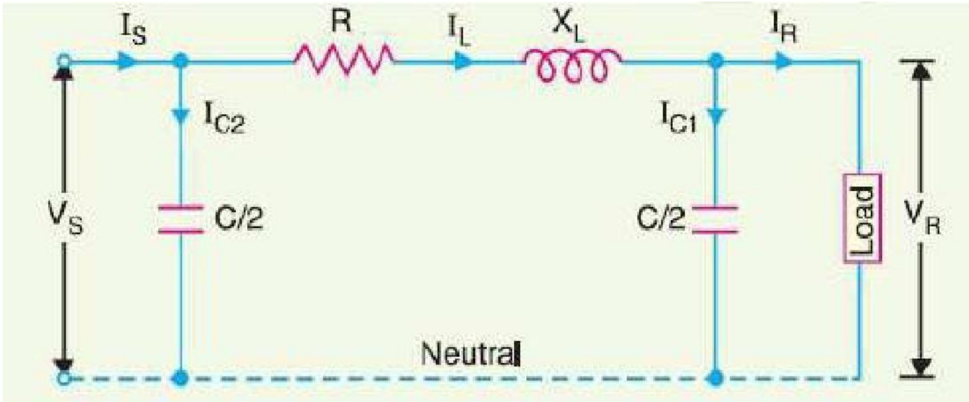
Capacitive current, $\vec{I_C} = j\,\omega\,C\,\vec{V_1} = j\,2\pi f C\,\vec{V_1}$

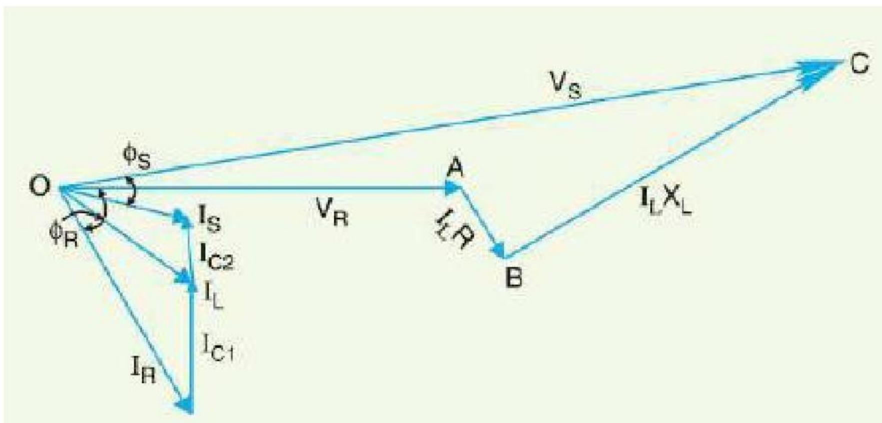
Sending end current, $\vec{I_S} = \vec{I_R} + \vec{I_C}$

Sending end voltage, $\vec{V_S} = \vec{V_1} + \vec{I_S}\,\frac{\vec{Z}}{2} = \vec{V_1} + \vec{I_S}\left(\frac{R}{2} + j\frac{X_L}{2}\right)$

Nominal π Method

In this method, capacitance of each conductor (*i.e.*, line to neutral) is divided into two halves; one half being lumped at the sending end and the other half at the receiving end as shown in Fig.3. It is obvious that capacitance at the sending end has no effect on the line drop. However, it's charging current must be added to line current in order to obtain the total sending end current.





IR = load current per phase

R = resistance per phase

XL = inductive reactance per
phase C = capacitance per phase

cos R = receiving end power factor (lagging) VS = sending end voltage per phase

The phasor diagram for the circuit is shown in Fig.4. Taking the receiving end voltage as the reference phasor, we have,

VR = VR + j 0

Load current, IR = IR (cos R - j sin R)

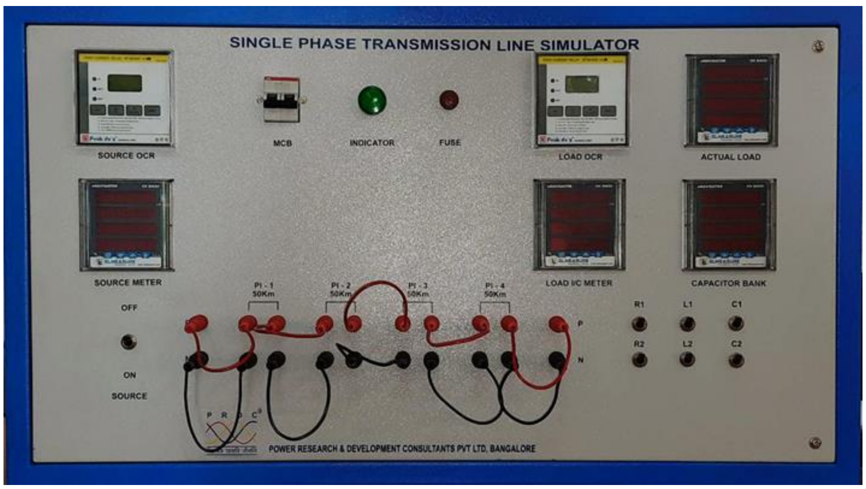
Line current, $\overrightarrow{I_L} = \overrightarrow{I_R} + \overrightarrow{I_{C1}}$

Sending end voltage, $\overrightarrow{V_S} = \overrightarrow{V_R} + \overrightarrow{I_L}\,\overrightarrow{Z} = \overrightarrow{V_R} + \overrightarrow{I_L}\,(R + jX_L)$

Charging current at the sending end is

$$\overrightarrow{I_{C2}} = j\,\omega\,(C/2)\,\overrightarrow{V_S} = j\,\pi\,f\,C\,\overrightarrow{V_S}$$

$\therefore$ Sending end current, $\overrightarrow{I_S} = \overrightarrow{I_L} + \overrightarrow{I_{C2}}$



EXERCISE:

1. A 220- KV, 3φ transmission line is 40 km long. The resistance per phase is 0.15 Ω per km and the inductance per phase is 1.3623 mH per km. The shunt capacitance is negligible. Use the short line model to find the voltage and power at the sending end and the voltage regulation and efficiency when the line supplying a three phase load of a) 381 MVA at 0.8 power factor lagging at 220 KV. b) 381 MVA at 0.8 power factor leading at 220 KV.

OUTPUT:

RESULT: Thus modeling of transmission line was executed and the output was verified with theoretical calculation. The value of the voltage and power at the sending end, voltage regulation and efficiency obtained

VS =

Vr=

Voltage regulation REG=

Efficiency EFF =

Signature of the faculty

Date: **Experiment-9**

Determination of ABCD parameters for short, medium and long lines

Aim : To determine ABCD parameters of short, medium and long lines

Apparatus :

- Type of conductor: Twin Moose
- Voltage level: 400 KV
- Line length in km: 200
- Number of pi sections: 4 (Each Pi = 50km)

Transmission line parameters:

- Resistance R in ohm per km: 0.0328
- Inductive reactance X in ohm per km: 0.332
- Half of capacitive susceptance B/2 in µ℧ per km: 1.734375

Transmission line model:

Transmission line of 400kms, 220kv is modelled with four models. Cascaded each representing 100kms having following parameters.R=4.7Ω,C=0.47µf,L=110mH [2]. With current capacity 1 Ampere

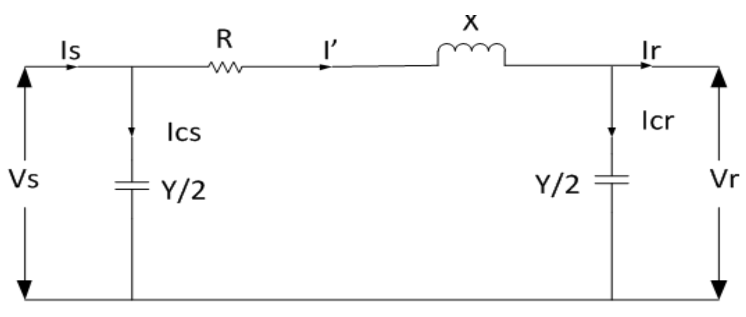


Fig.1:Medium transmission line

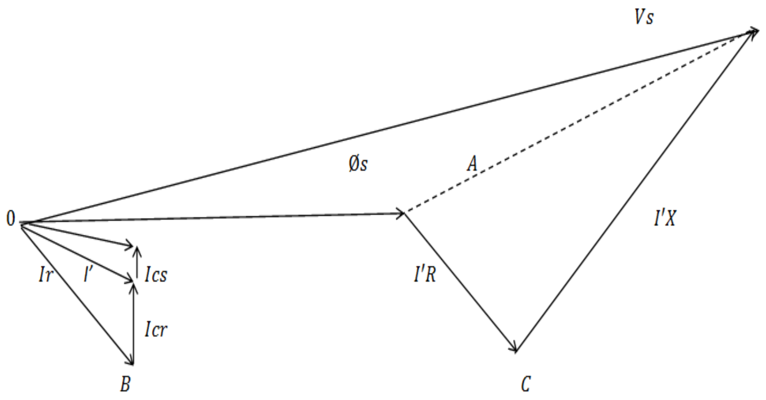
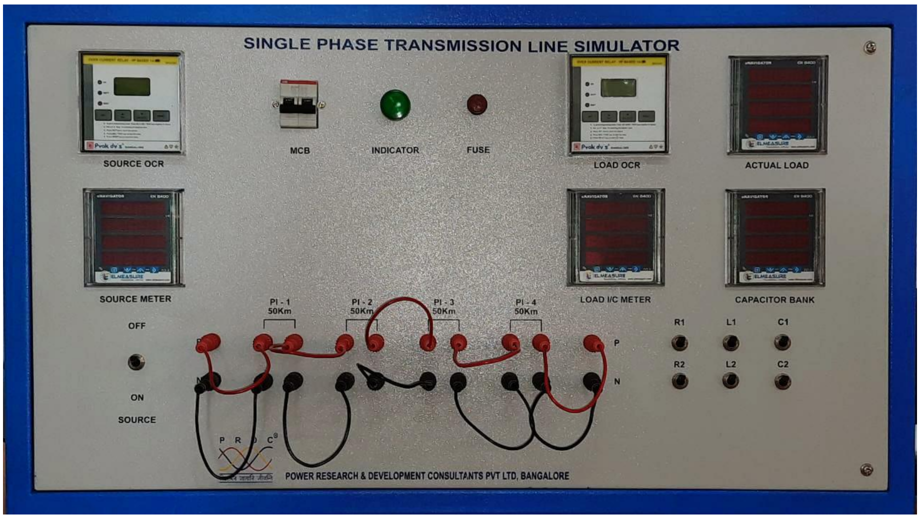


Fig.2:Phasor diagram for nominal π circuit

We have prepared a single phase prototype model to show performance of short, medium and long transmission line. We can select any type of transmission line for analysis just by adding or removing the sections. Each section consists of lumped parameters for 100km line. The performance of a transmission line such as Ferranti effect and ABCD parameters will be different for different transmission lines.

The performance of a transmission line is mainly depend upon its active and reactive parts of power being transmitted through it. This can done by knowing the ABCD parameters. A single phase prototype model can be taken as a two port network.



Observation:

Line condition	Vs (volts)	Is (amp)	Vr (volts)	Ir (amp)
Open circuit				
Short circuit				

Sl No.	Type of line	Vs (volts)	Is (amp)	Vr(volts)	Ir (amp)
1	Short Transmission line				
2	Medium Transmission Line				
3	Long Transmission Line				

OUTPUT:

RESULT:

Signature of the faculty

Date: **Experiment-10**

Ferranti effect of Transmission line

Aim: To demonstrate the concepts of Ferranti effect for a transmission line

Apparatus :

- Type of conductor: Twin Moose
- Voltage level: 400 KV
- Line length in km: 200
- Number of pi sections: 4 (Each Pi = 50km)

Transmission line parameters:

- Resistance R in ohm per km: 0.0328
- Inductive reactance X in ohm per km: 0.332
- Half of capacitive susceptance B/2 in μ℧ per km: 1.734375

Theory

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

Figures 1 and 2 show the equivalent pi modeling of transmission line used to demonstrate Ferranti effect and the phasor diagram showing relation between sending - end and receiving end voltage.

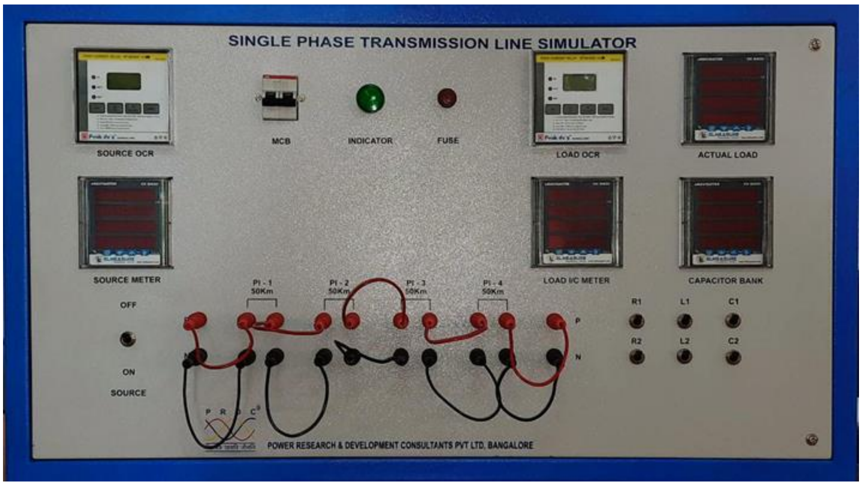


Figure 1: Pi-model of transmission line at no load

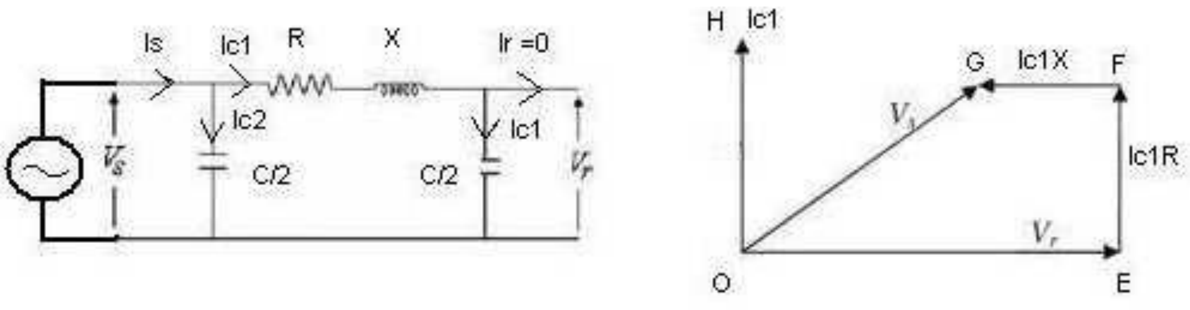


Figure 2: Phasor diagram

PROCEDURE

1. Determine the simulator pi section R, L and C values, as explained.
2. Ensure that the load is off.
3. Switch on the main supply.
4. Switch on the line input supply.
5. Note the sending end voltage to measure around 63.5V LN
6. Note down the sending end current.
7. Note down the receiving terminal voltage. LN Results:

Results are tabulated as per table 1

OBSERVATION:

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

Sl No.	Length of Transmission Line (in KM)	Sending end voltage (Vs) (volts)	Receiving end voltage (Vr) (volts)	Vs-Vr(volts)
1				
2				
3				

OUTPUT:

RESULT:

Signature of the faculty

Date: **Experiment-11**

Zones Protection using Distance Relay

Aim: To demonstrate the performance of three zones distance relay Characteristics

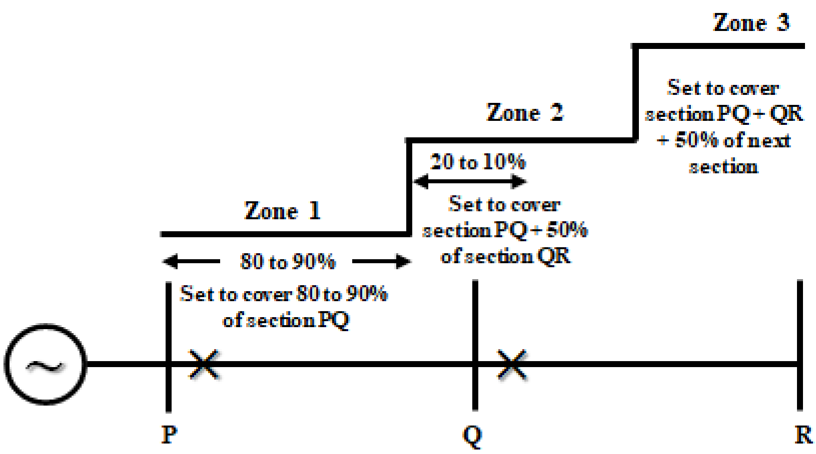
Apparatus:

- Distance Relay
- Ammeter
- Voltmeter

Theory:

Distance Protection is a Non-unit System of Protection, which measures the Impedance between the Relay Location and the point where the fault is incident and compares it with the Set Value. If the measured Impedance is less than the Set Value, the Relay operates and Isolates the Faulty Section. Since, the Line Impedance is directly Proportional to Line Length, we get the exact Location of the Fault in Kms. Since it protects a certain Length of Transmission Line, it is called a Distance Relay. If, the Measured Impedance < Setting Impedance, the Relay Operates.

So, the Input Quantities to the Distance Relay is Voltage and Current and the Output it gives is V/I which is Impedance (Z). Since it uses two Input Quantities, its Reliablity is more than that of Overcurrent Relay, which uses only one Input Quantity (i.e. current).



Three Zone Protection and Time Distance Characteristics

To provide Reliability, Distance Protection is divided into number of zones, which are given in the Tab Module below.

Zone 1:

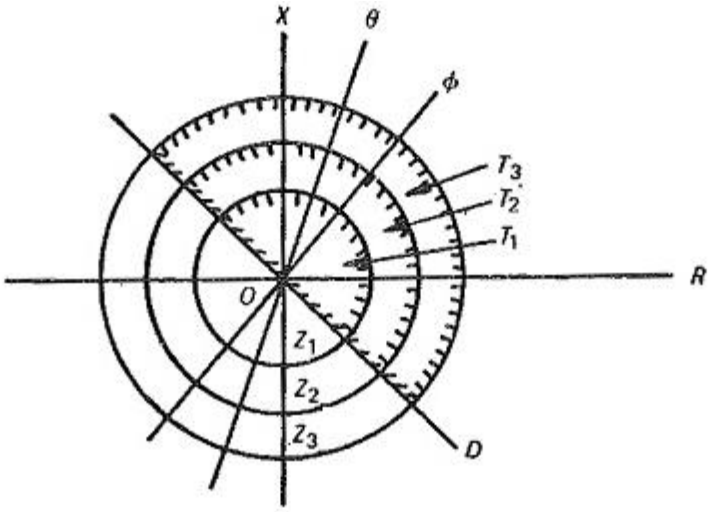
1. Mainly intended to cover the entire length of the Protected Line Length and set to operate instantaneously i.e with no intentional Time Delay.
2. To avoid the Loss of Discrimination with the Zone 1 Protection of the following Line Section, Zone I Distance is set at 80 to 90 % of the Line and not 100%. Hence, it is called as an Under-reaching Element.
3. This Safety Margin of 10 to 20 % is kept for Relay/CT/PT Errors, Infeed/Outfeed Effects and inaccuracies in line Impedance parameters. Suppose the Line is set at 100% of the Protected Line and the Fault Occurs on the Adjacent Line, but due to CT/PT Errors, it may appear to the Relay that the Fault is on the Protected Line, therby Tripping the Protected Line, which is a Wrong Operation.

Zone 2:

1. Mainly intended to cover the remaining 10 % to 20 % of the Protected Line and provide Backup for the Adjoining Lines (50% of the Adjoning Length).
2. It set to cover Remote End Busbar and Hence it is called as an Overreaching Element.
3. It is set at 150% of the Protected Line lenghth or 100% of the Protected Line Length plus the 50% of the shortest Adjoning Line Length, whichever is the Less. It is set in such a way, so that the Zone 2 of he Adjacent lines do not overlap, so as avoid loss of Discrimination.
4. The Operating Time of Zone 2 is Delayed by 15-45 cycle time, so as to be selective with Zone 1 of the Adjacent Line i.e the Zone 1 Relays that are supposed to Trip get a chance to do their job first. For a 220KV Feeder, the operating Time of the Zone 2 it is about 400ms.
5. Zone II should not overlap
6. In case of Long Line, followed by Short Line, the above mentioned Formula may not give us margin against possible underreaching. In such cases, Zone II can be set to Cover 120% of the Protected Line Length.

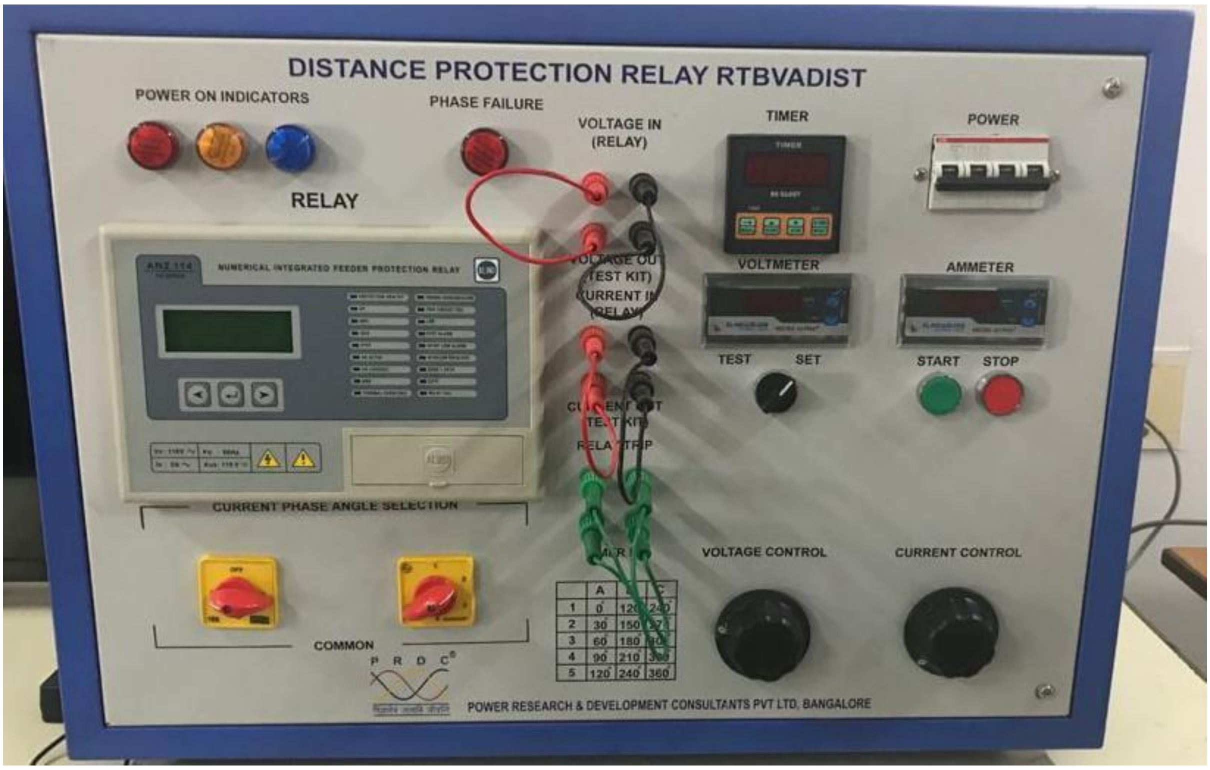
Zone 3:

1. It is intended to give Full Backup to the Adjoning Line Section.
2. Zone III is primarily intended to provide Backup against External Uncleared Faults and Hence set to cover the Longest Adjoining Line.
3. It covers Full Protected Line Length and Full Adjacent line plus the Safty Margin of 20 %.
4. Zone III covers, 100% of the Line Length Plus the 100% of the Longest Adjacent Line Length Plus a 10 Km of additional Length is considered, to clear the Bus Fault at the Remote End.
5. The Operating Time of Zone III should be slightly more than the Zone II Operating Time. For a 220 KV Line, it is about 700 ms.
6. In case of Long Heavily Loaded Line, the Zone III Settings should be checked for possible Load Encroachment



Impedance Characteristics for 3 Zone Protection

Experimental Kit:



Procedure:

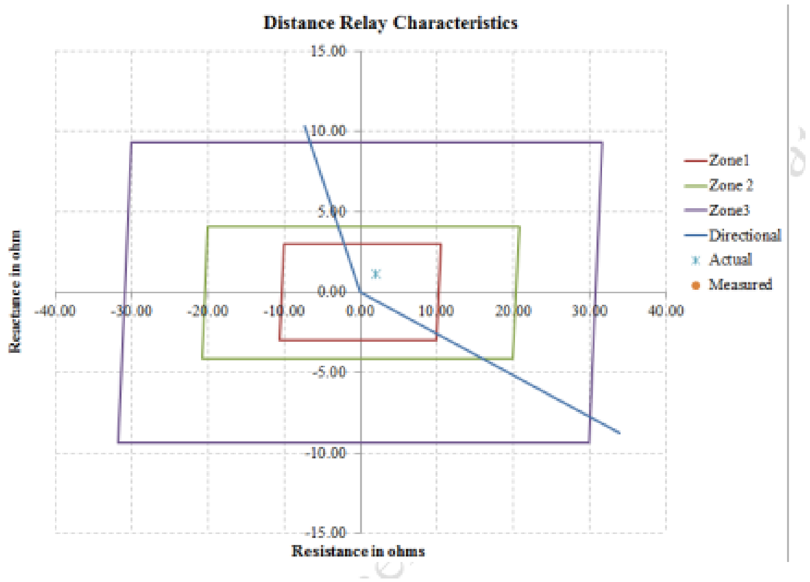
- Select the value of R and X such that it lies within the desired Zone of operation.
- The values of R and X selected must be such that tan-1 (X/R) is in between 0° to 360° and in multiples of 30°.
- For example consider, R = 2 ohms, and angle to be 30°.
- Then the value of X will be 1.154 ohm. 3. Fix the voltage to be applied. As the voltage during fault is less than the rated voltage, select the voltage less than 110 V. Consider 20 V.
- Then the current to be injected will be,

$$I = \frac{20\angle 0}{2.0 + j1.154} = 8.66 \angle -30\ A$$

- Similarly obtain other points for distance relay operation in Zone 1 and tabulate the results.

Sl. No.	Set Impedance (R+jX) (ohm)	Voltage Applied (V)	Current Injected (A)	Phase Angle (Degree)	Calculated Impedance by relay (R+jX) (ohm)	Zone of Operation	Time of Operation (s)
1	2+j1.154	20	8.66	-30		Zone 1	0

- Plot the graph of relay characteristic and the impedance points, as shown in Figure and verify the relay performance.



Impedance Characteristics

OUTPUT:

RESULT:

Signature of the faculty

Date: **Experiment-12**

Reactive Power Compensation of a Transmission line

AIM : To demonstrate the concepts of reactive power compensation as a solution for maintain the voltage within the limits due to unloaded line.

APPARATUS :

- Type of conductor: Twin Moose
- Voltage level: 400 KV
- Line length in km: 200
- Number of pi sections: 4 (Each Pi = 50km)

Transmission line parameters:

- Resistance R in ohm per km: 0.0328
- Inductive reactance X in ohm per km: 0.332
- Half of capacitive susceptance B/2 in μ℧ per km: 1.734375

THEORY:

The compensation of reactive power of the circuit is quite important as it is associated with the value of the power factor. The reactive power compensation corresponds to the controlling of reactive power to increase the performance characteristics of the AC system. There are some methods by which the power factor of the system can be improved and hence these are regarded as methods of reactive power compensation.

On a practical basis, it is said that the value of the load power factor should be nearly unity as this value is economically viable.

Reactive power is defined as the amount of power that remains unused and gets generated within an AC circuit or system by the reactive components. This is sometimes called imaginary power. A reactive circuit supplies the amount of power back to the supply which it has consumed thus, the average consumed power of the circuit will be zero. The reactive power is regarded as a fundamental part of the total power of the circuit.

The reactive power is regarded as a fundamental part of the total power of the circuit. It is expressed in a unit called volt-ampere reactive (VAr) with the symbol ‘Q’ and is the product of volt and ampere that are out of phase with respect to each other.

With reactive power compensation, transmission efficiency is increased. Along with this, the steady-state and temporary over-voltages can be regulated that resultantly avoids blackouts.

The demand for this reactive power is mainly originated from the inductive load connected to the system. These inductive loads are generally electromagnetic circuits of electric motors, electrical transformers, the inductance of transmission and distribution networks, induction furnaces, fluorescent lightings, etc. This reactive power should be properly compensated otherwise, the ratio of actual power consumed by the load, to the total power i.e. vector sum of active and reactive power, of the system becomes quite less.

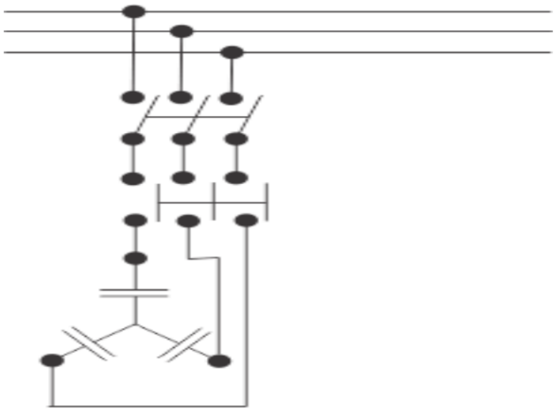
This ratio is alternatively known as the electrical power factor, and a lower ratio indicates a poor power factor of the system. If the power factor of the system is poor, the ampere burden of the transmission, distribution network, transformers, alternators and other types of equipment connected to the system, becomes high for required active power. And hence reactive power compensation becomes so important. This is commonly done by a capacitor bank. A low value of power factor requires large reactive power and this affects the voltage level.

Hence in order to compensate for the reactive power, the power factor of the system must be improved.

Thus, the methods for reactive power compensation are nothing but the methods by which poor power factors can be improved. The methods are as follows:

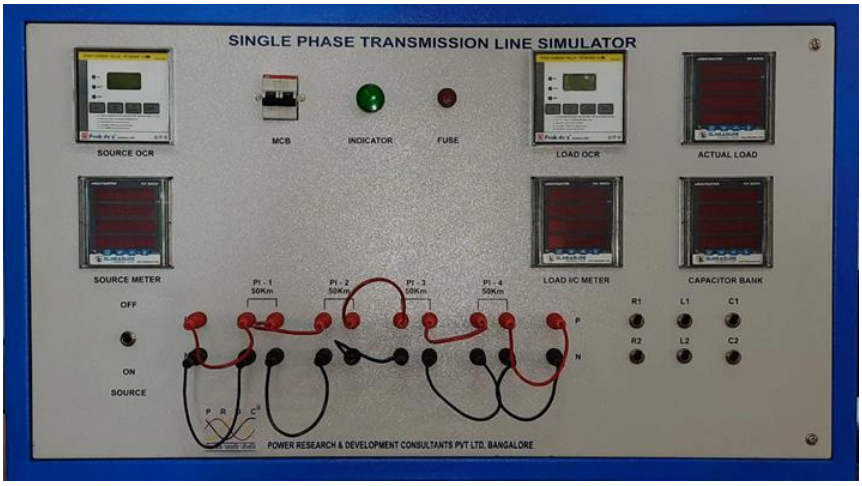
- Using capacitor banks
- Using synchronous condensers
- Using static VAr compensators

In this experiment, a bank of capacitors forms a connection across the load. As we know that the capacitor takes the leading reactive power, thus this causes the decrease in power taken from the source. This resultantly improves the value of the power factor of the system



There are some specific advantages of using shunt capacitors such as,

- It reduces the line current of the system.
- It improves the voltage level of the load.
- It also reduces system Losses.
- It improves the power factor of the source current.
- It reduces the load of the alternator.
- It reduces capital investment per megawatt of the Load.



Transmission Line Simulator(TLS)

PROCEDURE:

- Compute the TLS parameters and simulate unloaded line as described.
- Switch ON only inductive load to maximum
- Note the VAR at Receiving End
- Now Switch On the Capacitive Load
- Increase the stage of capacitive load till the receiving end voltage is almost equal to
- sending voltage.
- Note down the sending end and receiving end current and power factor.

OUTPUT:

S.No	Description	TLS Results
1	Sending end Voltage(V)	
2	Sending end current (A)	
3	Sending end Power factor	
4	Receiving end Voltage (V)	
5	Receiving end VAR Compensation (Inductive VAR)	
6	Receiving end VAR Compensation (After Switching On Capacitor)	

RESULT:

Signature of the faculty