EE 8602 - PROTECTION & SWITCHGEAR

EDWINLAWRANCE.M

AP/EEE,NPRCET

UNIT 2 - RELAY


RS


SIEMENS


10A
10A

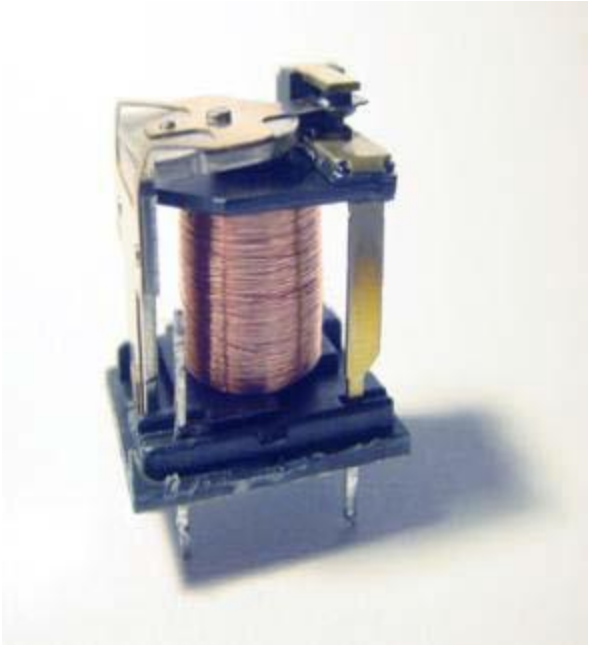
UNIT 2 SYLLABUS

- Electromagnetic relays
- over current relay
- directional relay
- non-directional relay
- distance relay
- negative sequence relay
- differential relay
- under frequency relay
- Introduction to static relays

Relay Overview

What are Relays?

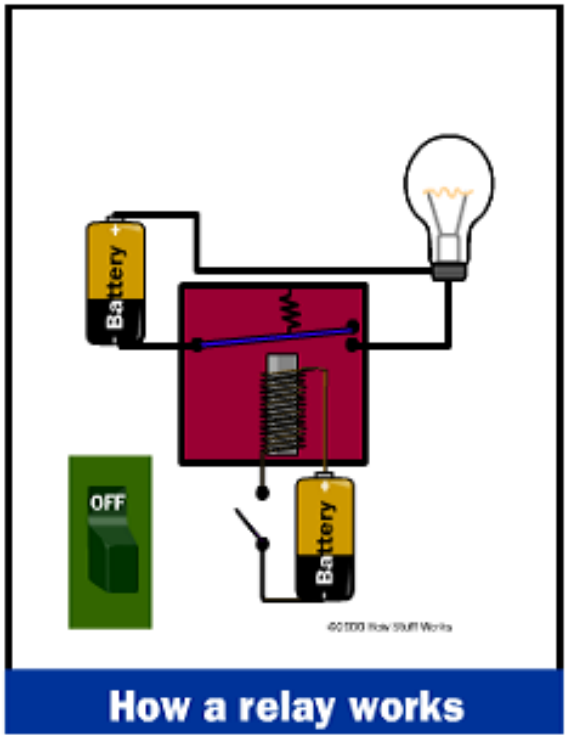
- Relays are electrical switches that open or close another circuit under certain conditions.

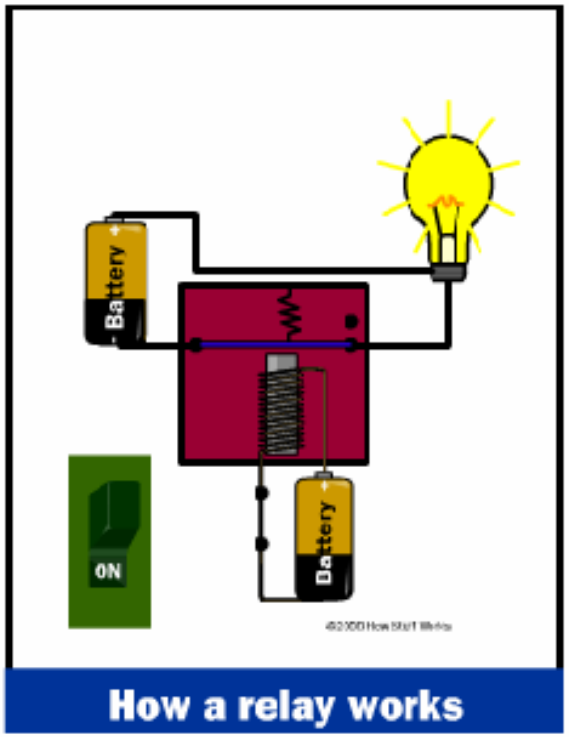


Relay Purpose

- Isolate controlling circuit from controlled circuit.
- Control high voltage system with low voltage.
- Control high current system with low current.
- Logic Functions.

How a Relay Works?





Electromagnetic Relay

They work on the following two main operating principles :

(i) Electromagnetic attraction

(ii) Electromagnetic induction

Electromagnetic Attraction Relays

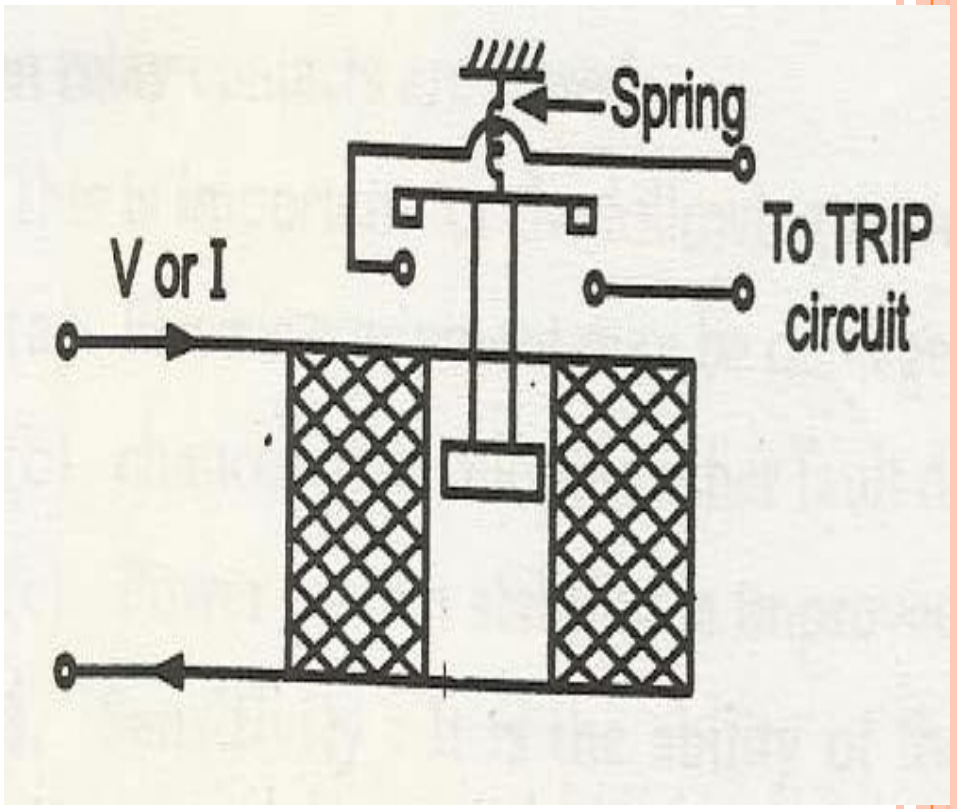
- (i)Attracted armature type relay
- (ii)Solenoid type relay
- (iii)Balanced beam type relay

Induction Relays / Electromagnetic induction

- (i)Induction type overcurrent Relay(**Non Directional Relay**)
- (ii)Induction Cup Relay (**Directional Relay**)

1. Attracted Armature Type Relays

- These have a coil or electromagnet energized by a coil .The coil is energized by operating quantity like V or I.
- Under normal conditions the coil cannot attract the plunger due to spring force. Under fault condition the fault current increases so armature or plunger gets attracted to close the contacts .



1. Attracted Armature Type Relays

Operating Principle : The electromagnetic force developed on moving element is proportional to square of the flux in air gap. If saturation is neglected force will be proportional to I^2.

$$F = K_1 I^2 - K_2$$

F = Net force

K_1 = Constant

K_2 = Restraing force including friction

I = Current in the relay coil

When relay is on the verge of operation.

$$K_1 I^2 = K_2$$

$$\therefore \quad I = \sqrt{\frac{K_2}{K_1}} \text{ ..... constant}$$

Advantages :

1. Relay responses to both A.C. and D.C. ($\because$ Torque $\propto I^2$).
2. Light moving parts, small length of travel of armature or plunger in air gap. Therefore, relays are fast in operation.
3. These relays are instantaneous but operating time varies with current (see characteristics). The **operating time and resetting time can be adjusted by adjusting the air gap so relays can be made slow operating relay.**

1. Attracted Armature Type Relays

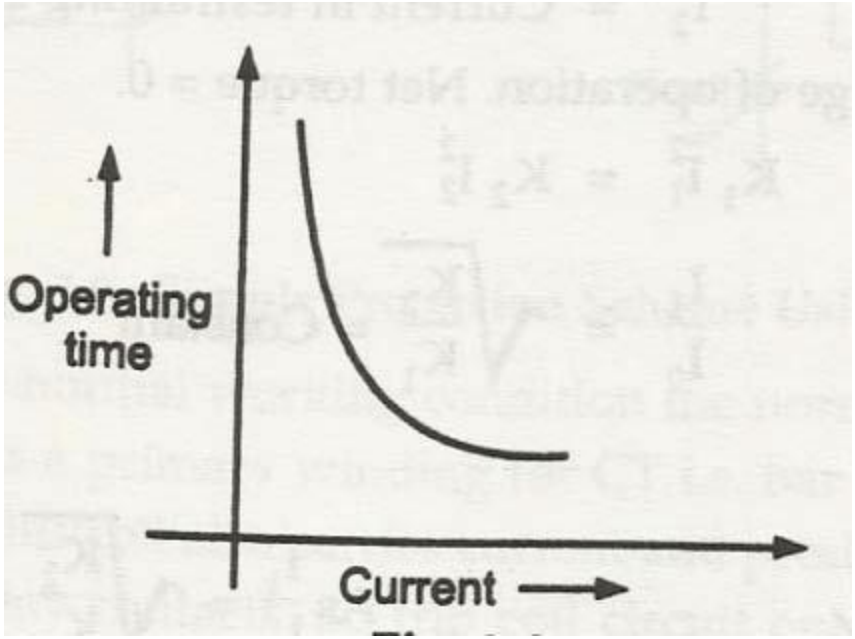
Applications

1.For over current protection

2.Differential Protection

3.Auxiliary Relays

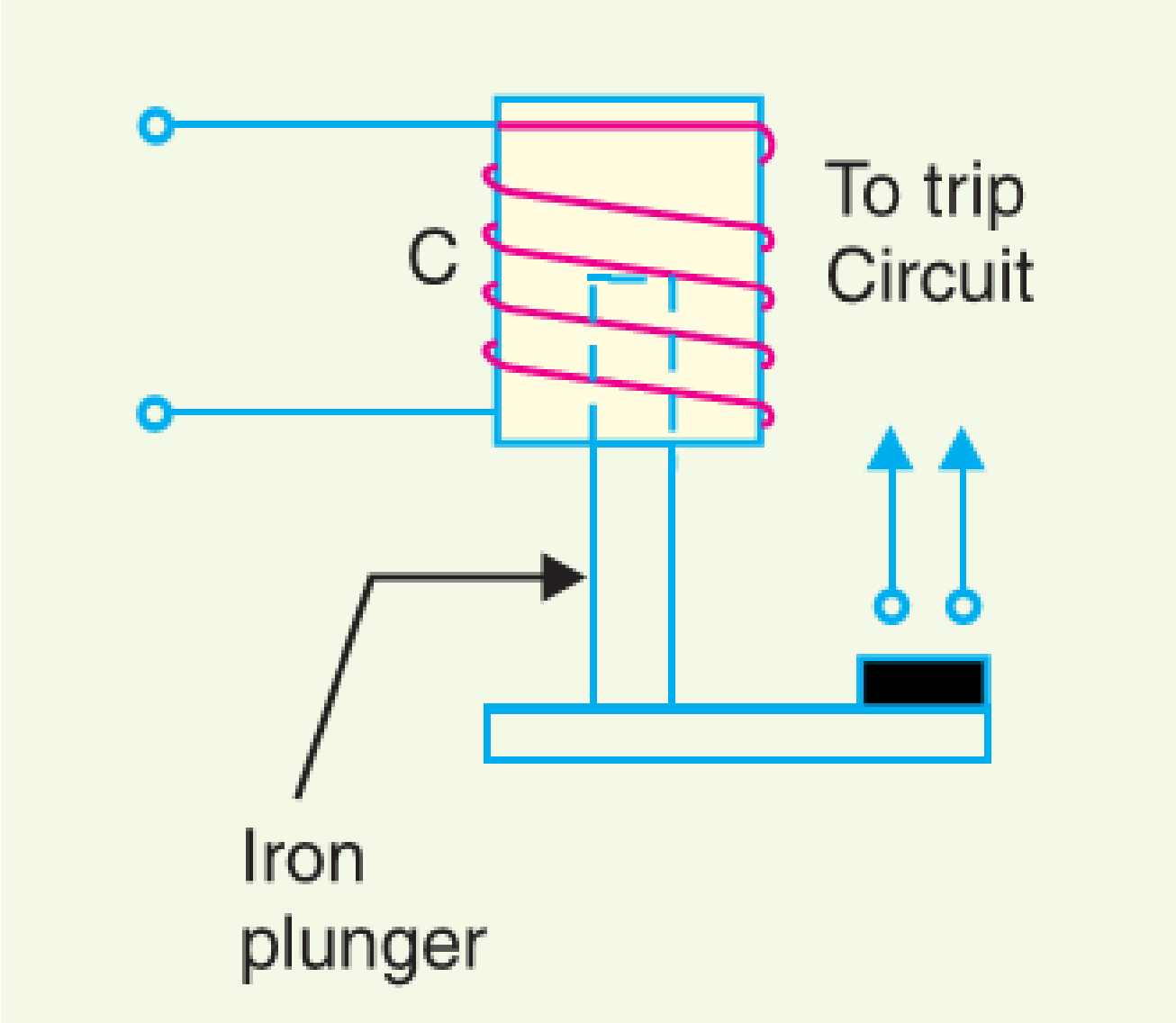
4.Definite time lag over current and earth fault protection



2. Solenoid type relay

- It consists of a solenoid and movable iron plunger arranged as shown.
- Under normal operating conditions, the current through the relay coil C is such that it holds the plunger by gravity or spring in the position shown.
- However, on the occurrence of a fault, the current through the relay coil becomes more than the pickup value, causing the plunger to be attracted to the solenoid. The upward movement of the plunger closes the trip circuit, thus opening the circuit breaker and disconnecting the faulty circuit.

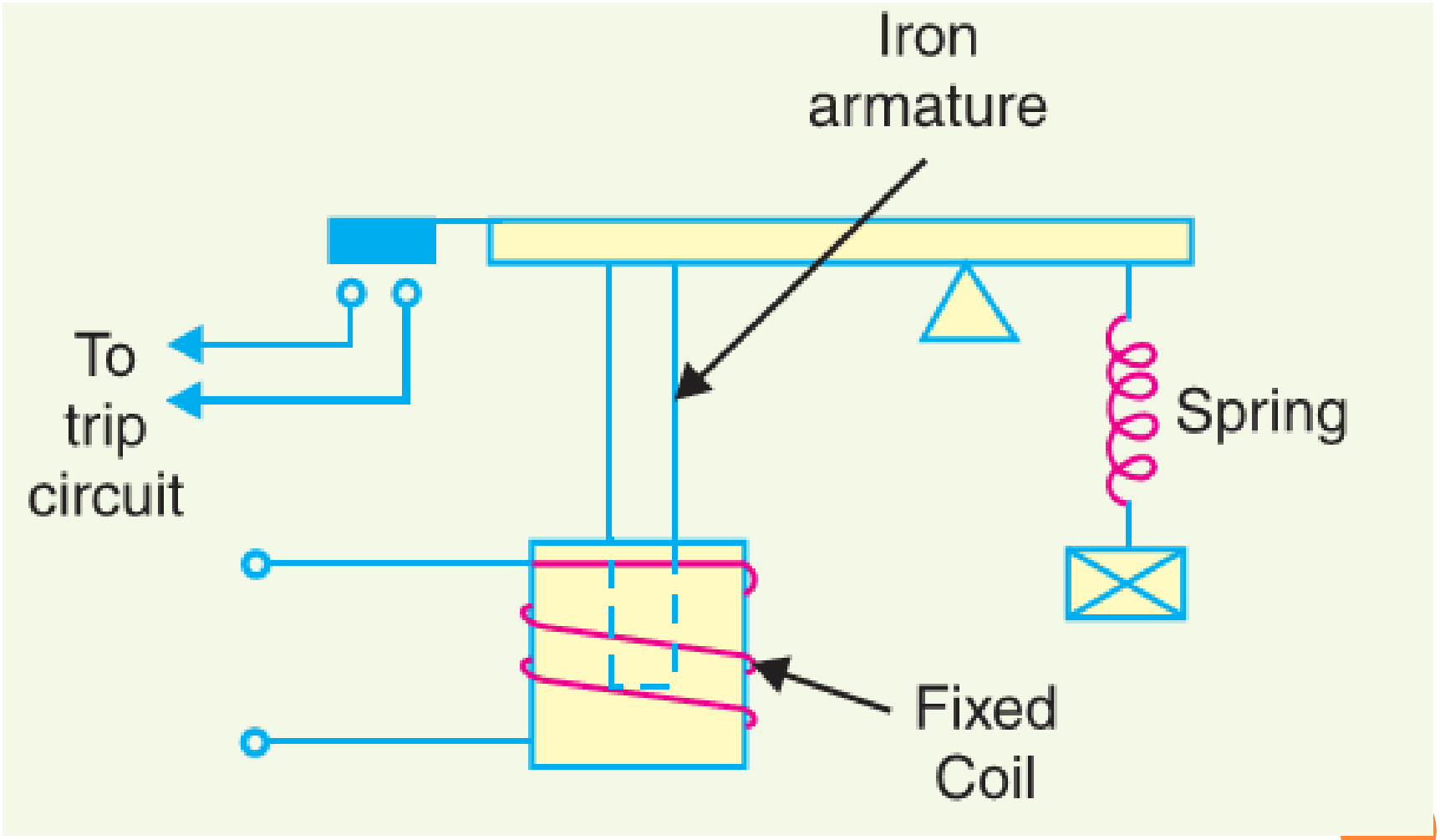
2. Solenoid type relay



3. Balanced beam type relay

- It consists of an iron armature fastened to a balance beam. Under normal operating conditions, the current through the relay coil is such that the beam is held in the horizontal position by the spring.
- When a fault occurs, the current through the relay coil becomes greater than the pickup value and the beam is attracted to close the trip circuit. This causes the opening of the circuit breaker to isolate the faulty circuit.

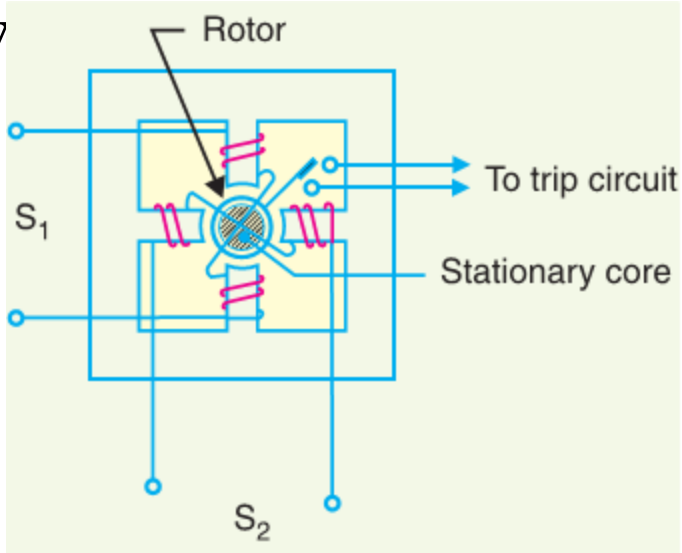
3. Balanced beam type relay



Induction cup structure

Induction cup structure

- It most closely resembles an induction motor, except that the rotor iron is stationary, only the rotor conductor portion being free to rotate.
- The moving element is a hollow cylindrical rotor which turns on its axis. The rotating field is produced by two pairs of coils wound on four poles as shown.
- The rotating field induces currents in the cup to provide the necessary driv



INDUCTION CUP STRUCTURE

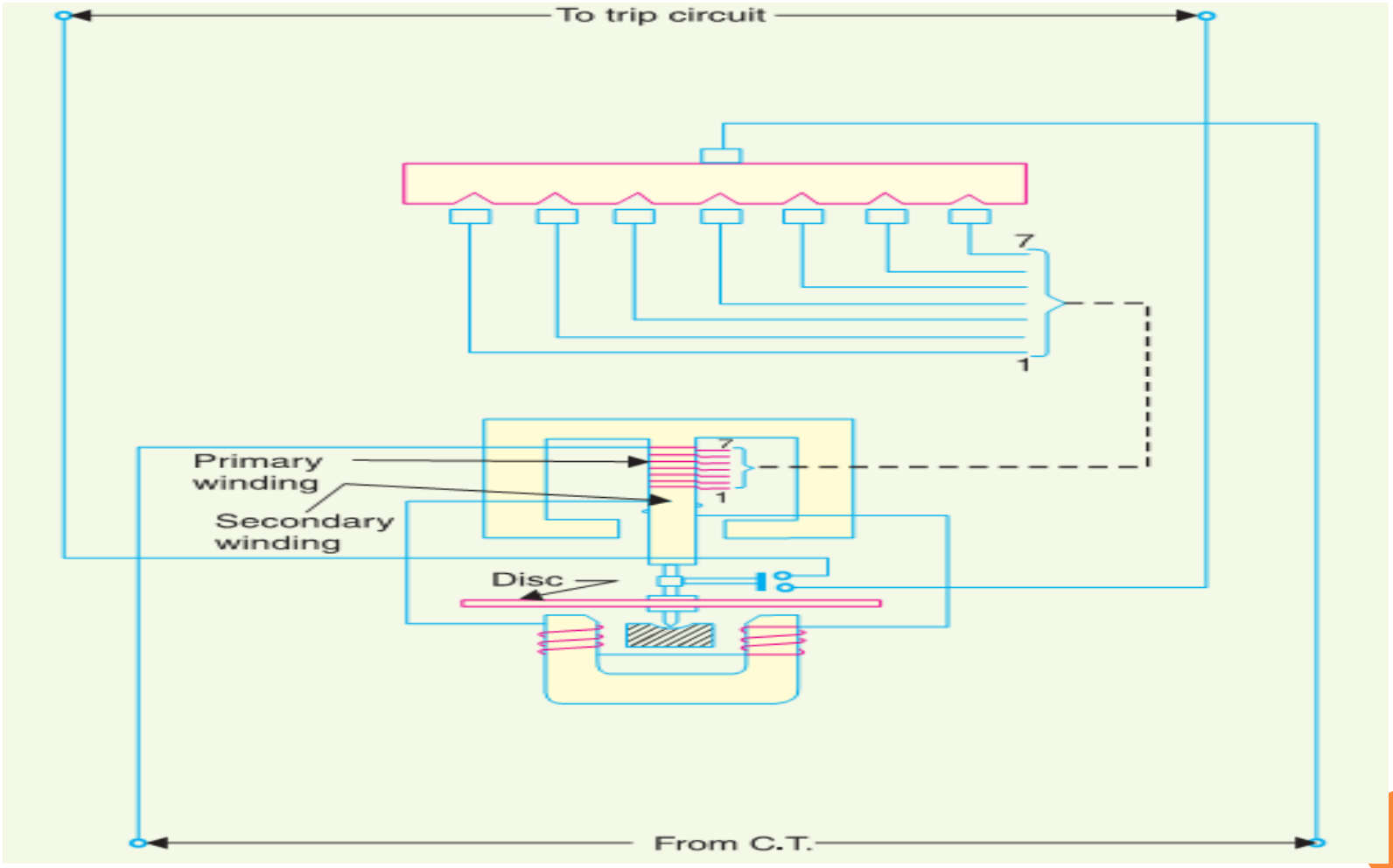
- If **φ1** and **φ2** represent the fluxes produced by the respective pairs of poles, then torque produced is proportional to **φ1 Φ2 sinα**.
- Where α is the phase difference between the two fluxes. A control spring and the back stop for closing of the contacts carried on an arm are attached to the spindle of the cup to prevent the continuous rotation.
- Induction cup structures are more efficient torque producers than either the shaded-pole or the watthour meter structures. Therefore, this type of relay has very high speed and may have an operating time less then 0.1 second.

Induction type overcurrent Relay (Non Directional Relay)

Induction type overcurrent Relay (Non Directional Relay)

- This type of relay works on the induction principle and initiates corrective measures when current in the circuit exceeds the predetermined value.
- The actuating source is a current in the circuit supplied to the relay from a current transformer. These relays are used on a.c. circuits only and can operate for fault current flow in either direction.

Induction type overcurrent Relay (Non Directional Relay)



CONSTRUCTIONAL DETAILS

- It consists of a metallic (aluminium) disc which is free to rotate in between the poles of two electro magnets. The upper electro magnet has a primary and a secondary winding. The primary is connected to the secondary of a C.T. in the line to be protected and is tapped at intervals. The tappings are connected to a plug-setting bridge by which the number of active turns on the relay operating coil can be varied, there by giving the desired current setting.
- The secondary winding is energized by induction from primary and is connected in series with the winding on the lower magnet. The controlling torque is provided by a spiral spring.
- The spindle of the disc carries a moving contact which bridges two fixed contacts (connected to trip circuit) when the disc rotates through a pre-set angle. This angle can be adjusted to any value between 0° and 360°. By adjusting this angle, the travel of the moving contact can be adjusted

Operation

- The driving torque on the aluminium disc is set up due to the induction principle. This torque is opposed by the restraining torque provided by the spring.
- Under normal operating conditions, restraining torque is greater than the driving torque produced by the relay coil current. Therefore, the aluminium disc remains stationary.
- If the current in the protected circuit exceeds the pre-set value, the driving torque becomes greater than the restraining torque. Consequently, the disc rotates and the moving contact bridges the fixed contacts when the disc has rotated through a pre-set angle. The trip circuit operates the circuit breaker which isolates the faulty section.

DIRECTIONAL RELAY

INDUCTION RELAYS

induction relays are two types

non directional relays

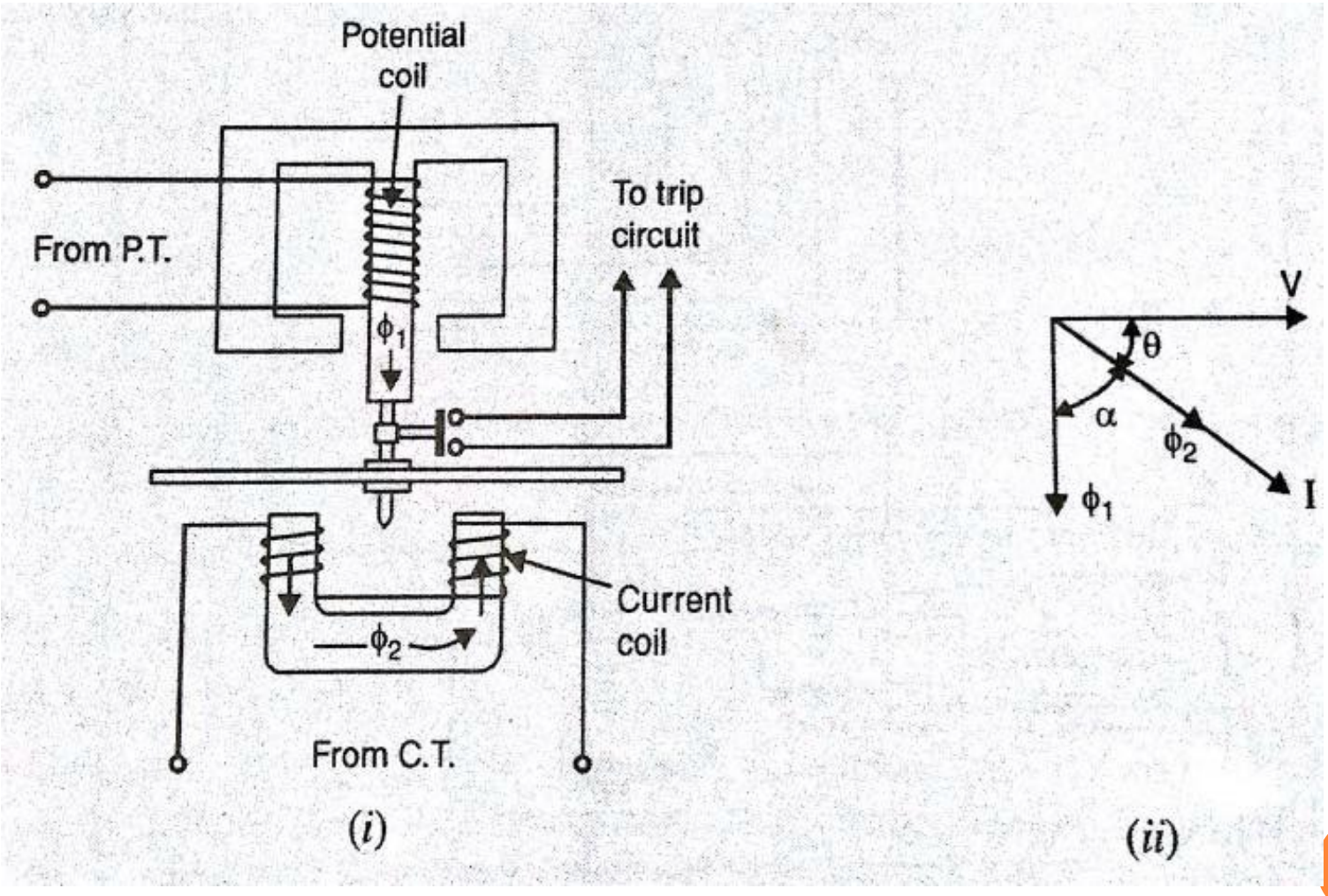
directional relays

Difference between the two:……?

- non directional relays are activated by only **current flowing in the circuit to be protected**.
- directional relays are activated by **power flowing in the specific direction. Hence it requires both current and voltage of the circuit to be protected.**

  * it requires specific direction of current flow*

DIRECTIONAL POWER RELAY



DIRECTIONAL POWER RELAY

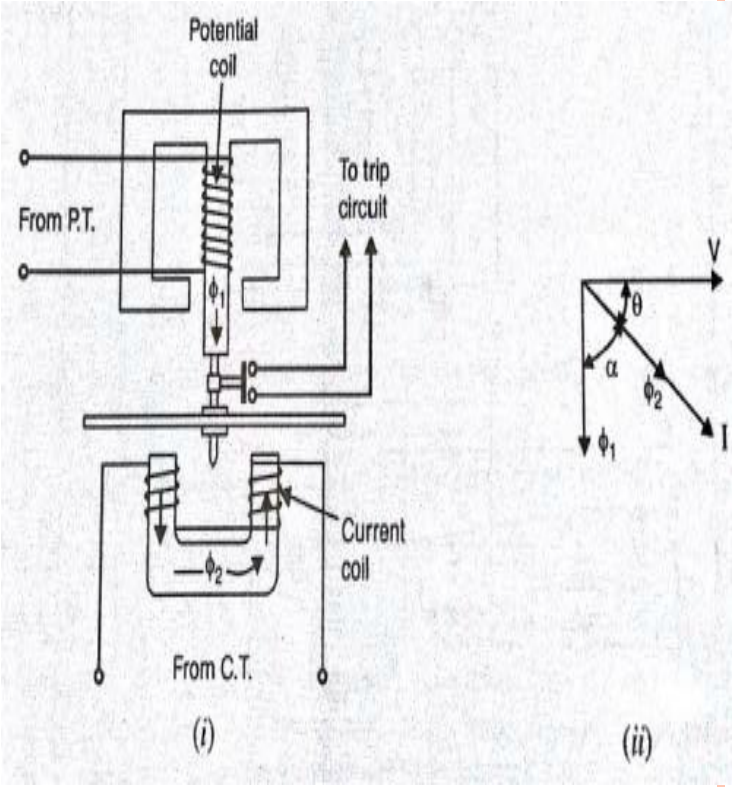
Constructional details:

- It consists of two electro magnets
  1) upper magnet which is E-shaped
  2) lower magnet which is U-shaped.

- The upper magnet consists of primary winding on the central limb which is energized by voltage from secondary of P.T

- lower magnet houses secondary winding which is energized by current of the circuit from secondary of C.T.

Further lower magnet is connected to PSM as previous case (not shown)



DIRECTIONAL POWER RELAY

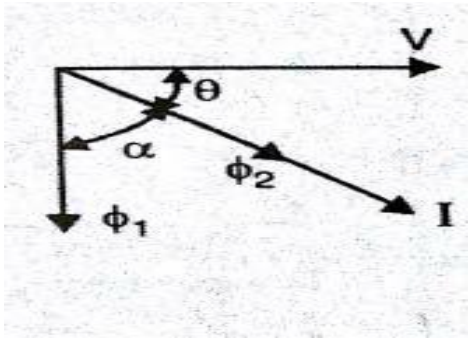
- In between this two electro magnets we have aluminum disc pivoted as shown
- This aluminum disc carries a moving contact which can bridge fixed contact by rotating though a pre set angle.
- The time of operation depends upon the pre set angle
- Restraining torque is provide by spring which twists in reverse direction.

Operation:

- from the diagram we can conclude that we have two flux quantaties: φ1 & φ2 .

always φ1 laggs V by 90 0

φ2 inphase with current I



DIRECTIONAL POWER RELAY

- Due to phase difference between two flux quantities i.e., $\alpha = 90-\theta$

$$\Phi 1 \propto V \;\&\; \varphi 2 \propto I$$

Hence $T = \varphi 1\, \varphi 2 \sin \alpha$

$= \varphi 1\, \varphi 2 \sin(90-\theta)$

$= VI \cos\theta$

= POWER

- Hence the relay activated only when there is a specific direction of power flow.
- when power flows in normal direction both driving torque and restraining torque twists in same direction and relay does not operates.
- when the power flow is in reverse direction, driving torque and restraining torque acts in opposite direction and relay operates. therefore CB operates and disconnects faulty section.

DIRECTIONAL OVER CURRENT RELAY

- From the previous discussion

$$T = V I \cos\theta$$

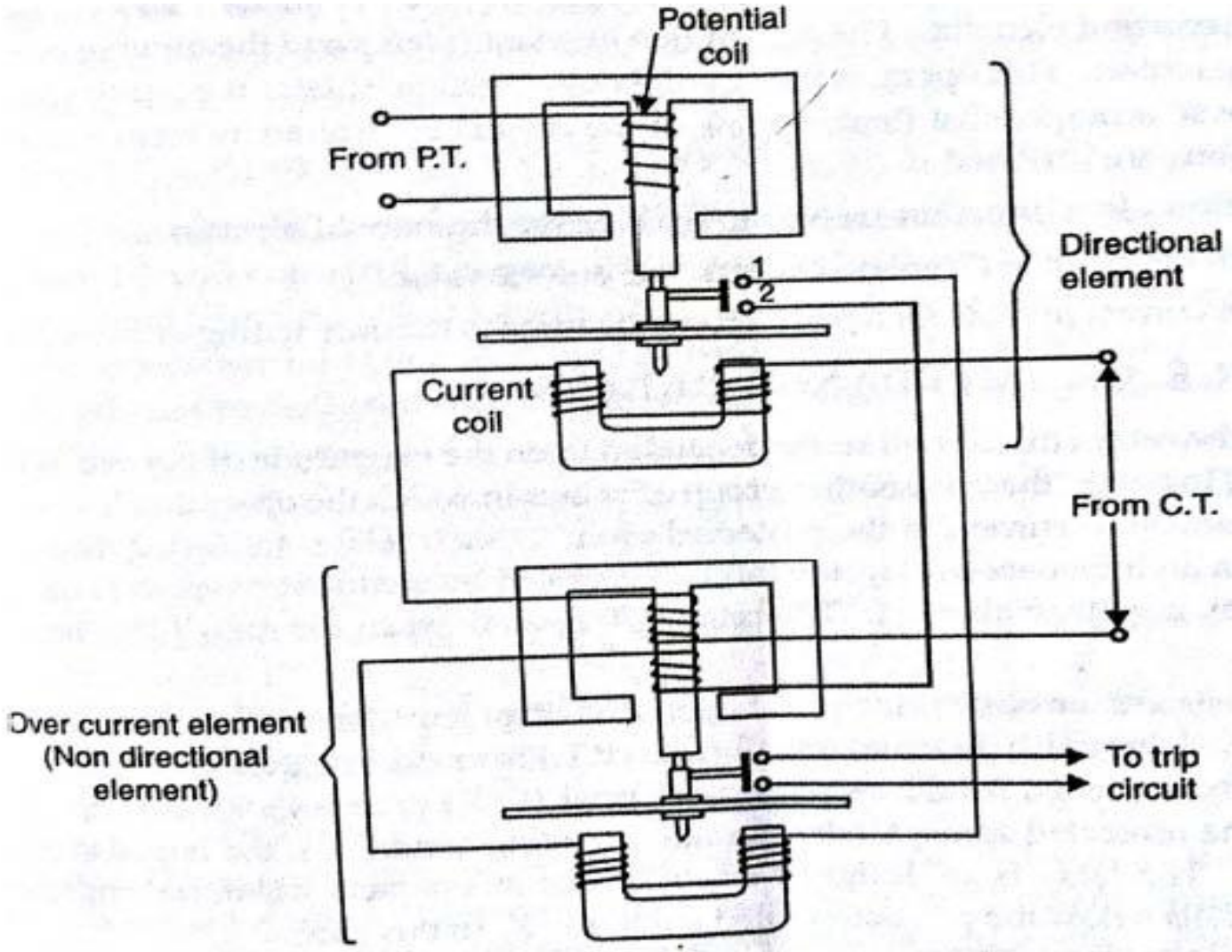
Under abnormal condition

under abnormal conditions voltage in the circuit is too low. Therefore the driving torque becomes abnormally too small. Hence the relay does not operate.

ie., the directional power relay is not suitable for short circuit conditions.

This problem can be overcome by directional over current relay.

DIRECTIONAL OVERCURRENT RELAY



DIRECTIONAL OVERCURRENT RELAY

- Directional overcurrent relay makes use of two relays

  1) directional power relay (directional element)

  2) Non directional current relay (non-directional element)

Construction:

1)<u>Directional element :</u>

  - It is similar in construction to directional power relay.
- It consists of upper magnet which is E-shaped and carries primary winding which is excited by voltage of the circuit to be protected through secondary of PT.
- The lower magnet is U-shaped carries secondary winding which is excited by current of the circuit to be protected through secondary of CT.
- The secondary winding is extended to lower magnet primary winding as shown.
- The trip contacts 1 & 2 are connected in series with secondary winding of lower magnet.

therefore for the relay to operate, at first directional element should be activated first.

DIRECTIONAL OVERCURRENT RELAY

2) Non directional element:

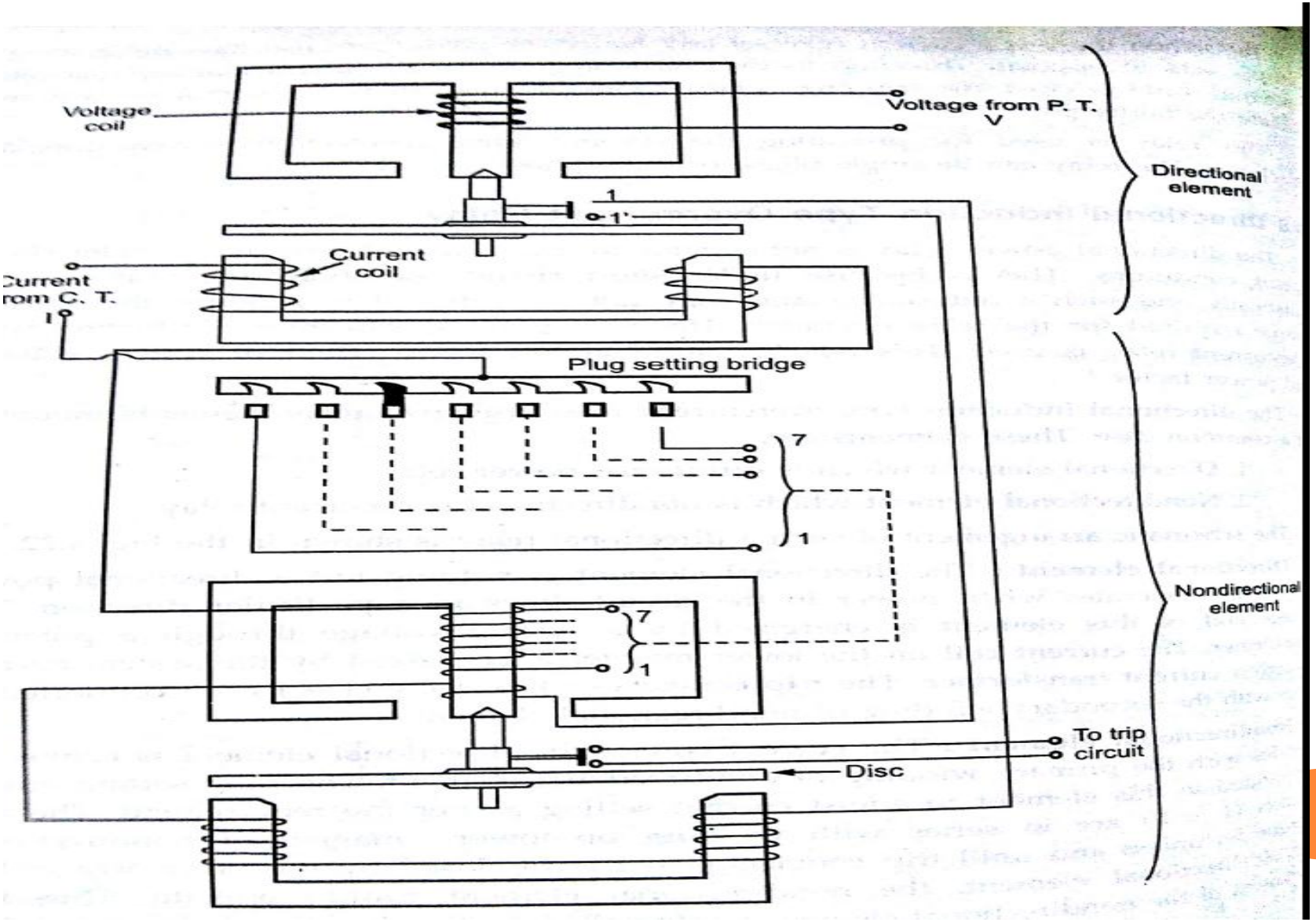
*** It is activated only by current flowing in the circuit***

- it is similar in construction to non-directional over current relay. For this element to operate ,at first directional element should be activated first.
- the secondary winding is further connected to PSM(not shown), for current setting.

Operation :

- When short circuit occurs current tend to be reversed. Hence directional element starts operating and closes the trip contact.
- with closing of trip contact, the secondary winding of non directional element is complete and disc starts rotating. When moving contact bridges fixed contact the circuit breaker operates and separates the faulty section.

DIRECTIONAL OVERCURRENT RELAY



Distance Relay(mho relay)

1. IMPEDANCE RELAY

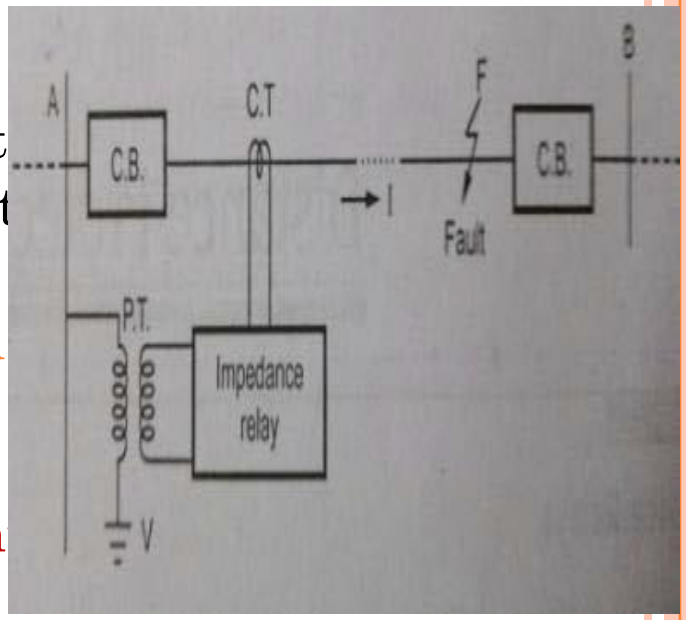
Distance relay :

1.IMPEDANCE RELAY

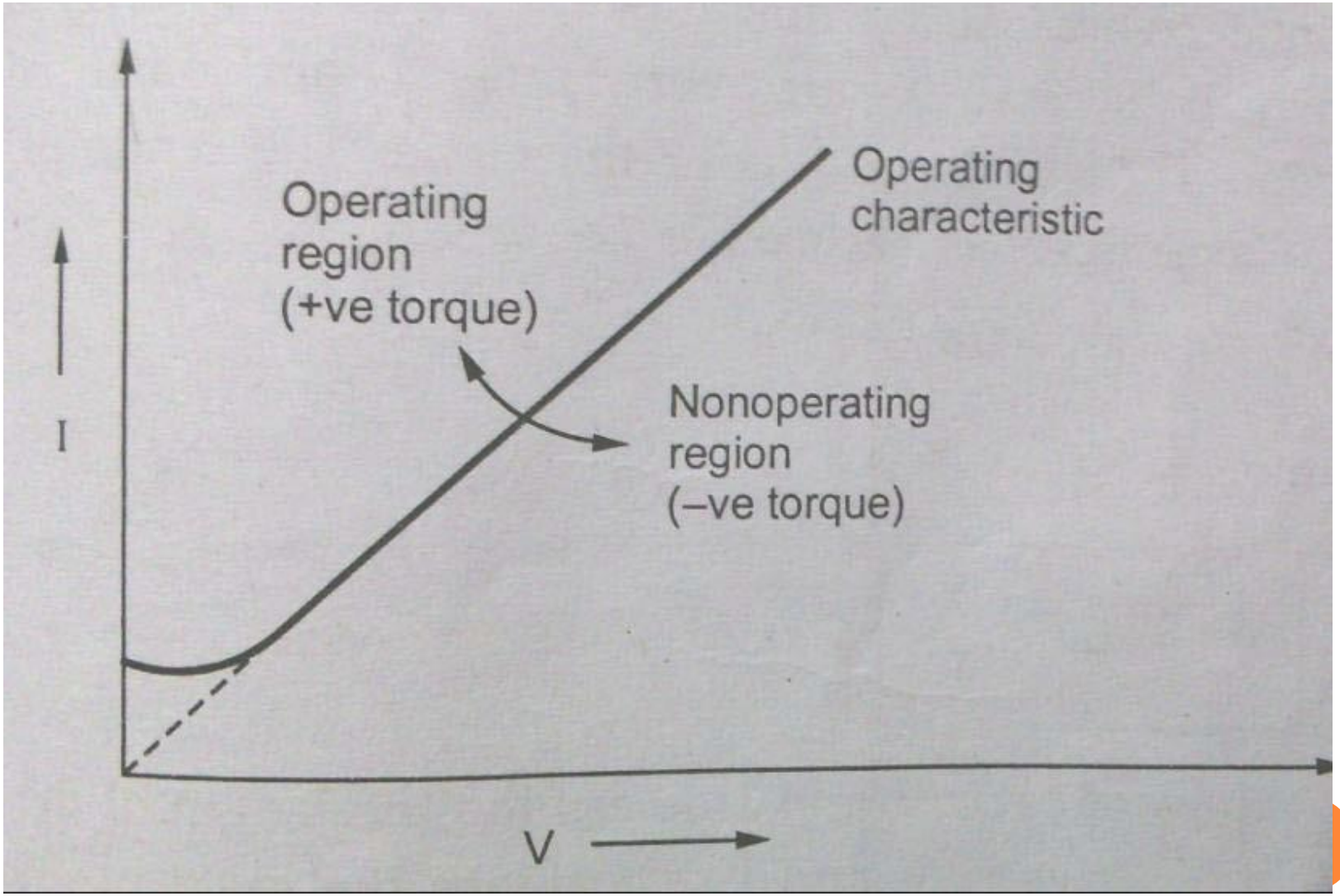
- +ve (operative)Torque by current element
- -ve(restraining)Torque by voltage element
- At normal condition

  operative torque = restraining torqu
- At fault

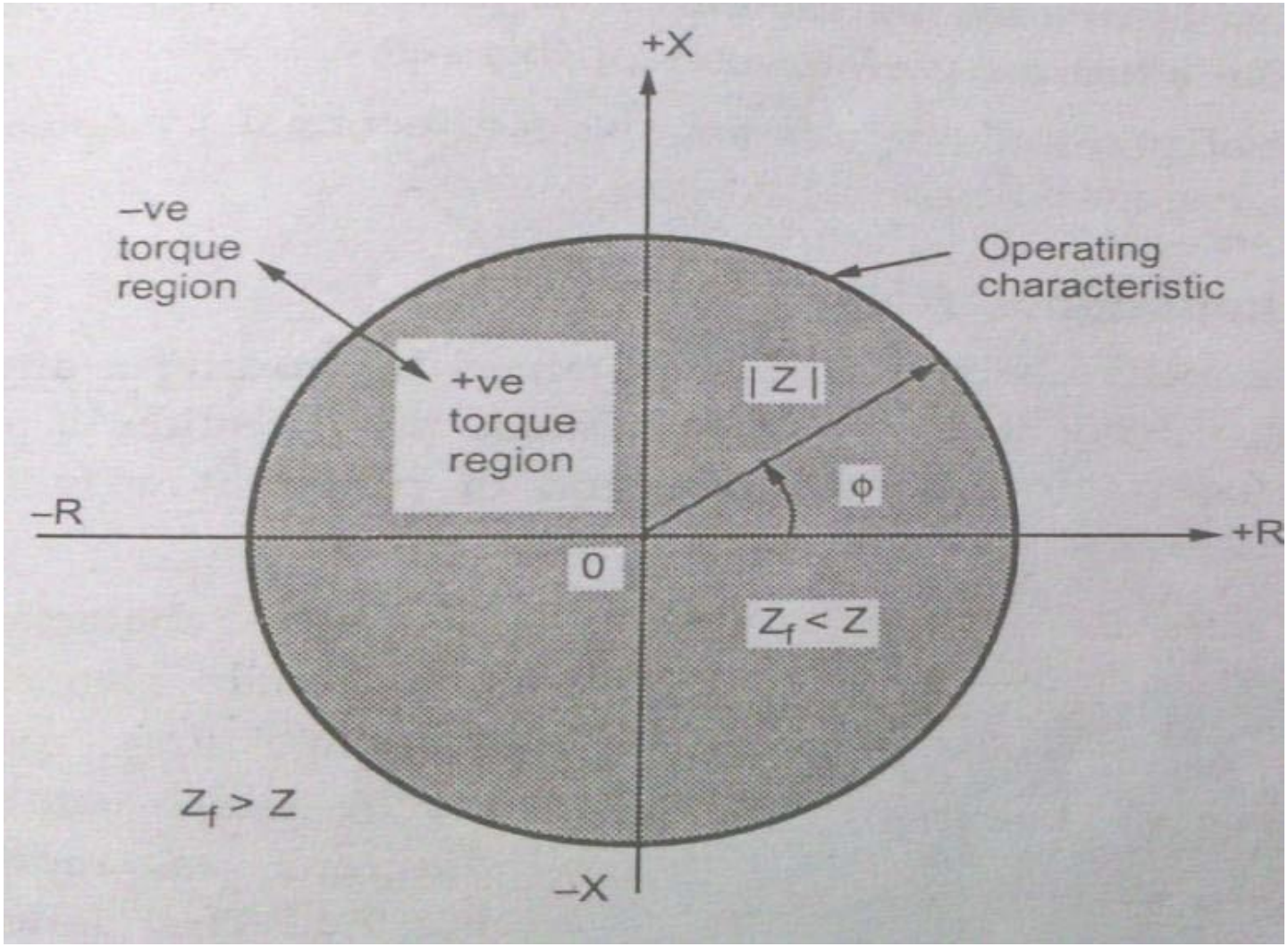
  operative torque > restraining torque
- Also called voltage restrained over curren



1. IMPEDANCE RELAY



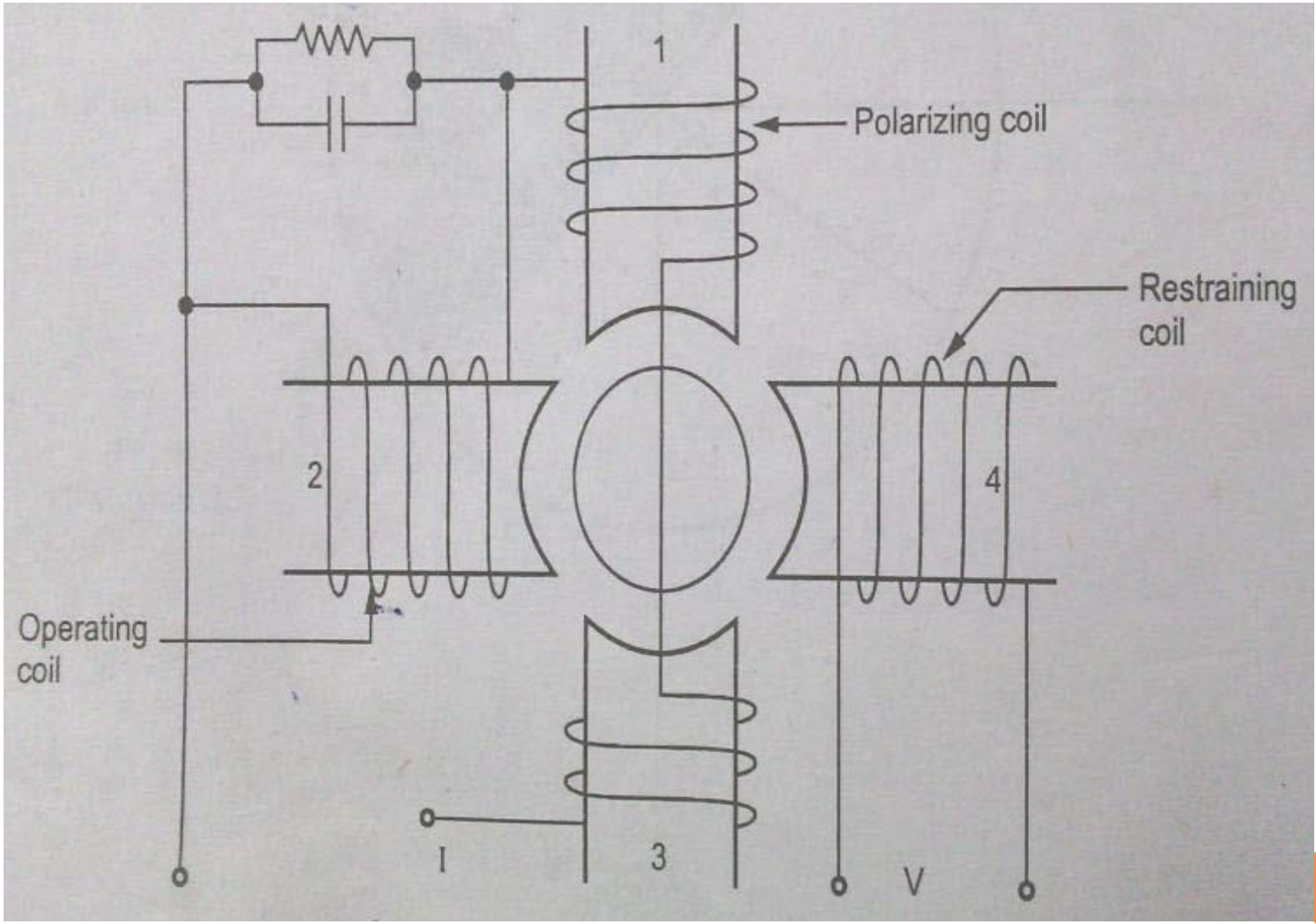
1. IMPEDANCE RELAY



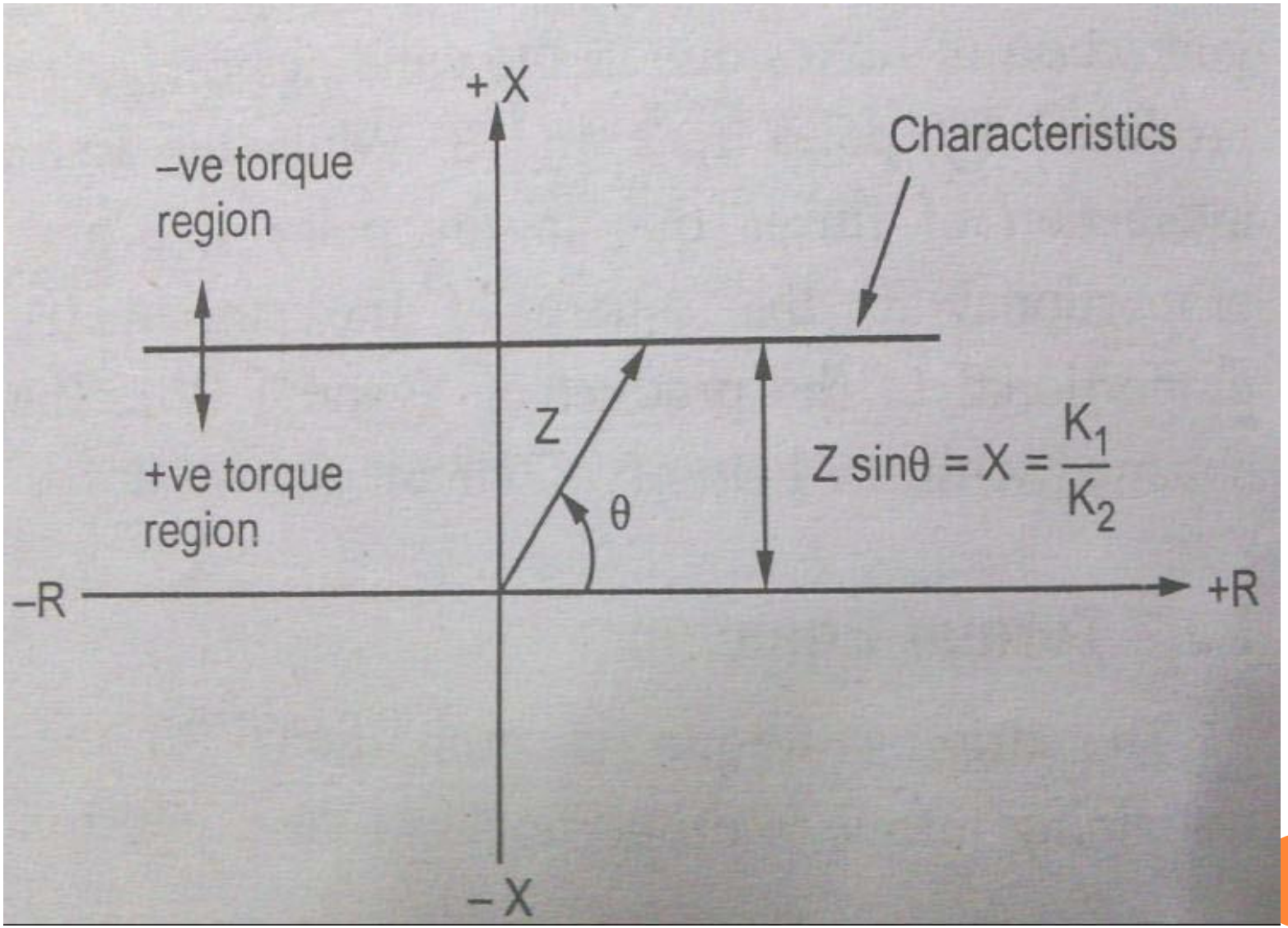
2. Reactance relay

- Operative Torque by current
- Restraining Torque by Current-Voltage Directional relay
- +ve torque by over current element
- -ve torque by directional unit
- Directional element designed for maxi. Torque angle = 90 degree

2. Reactance relay



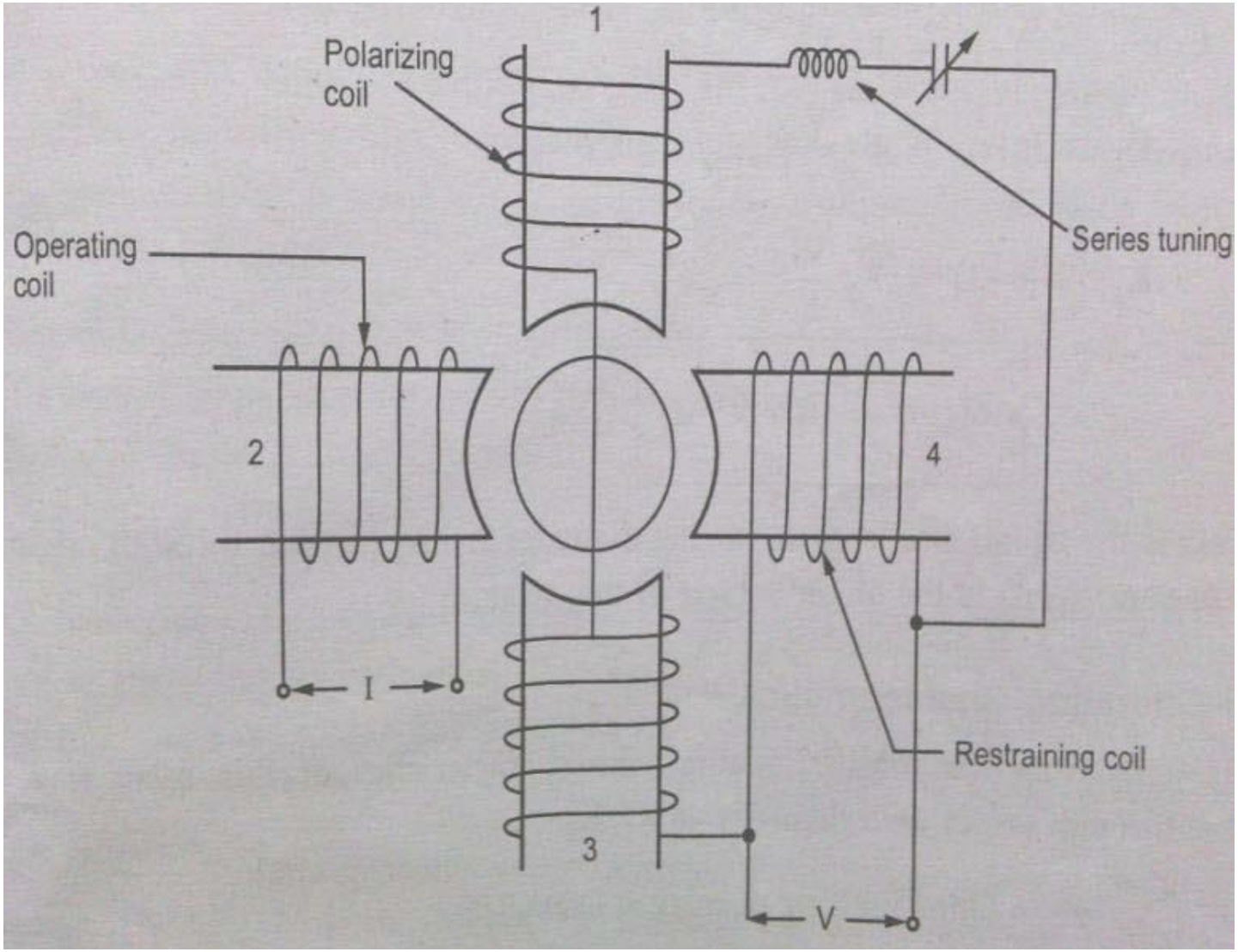
2. REACTANCE RELAY



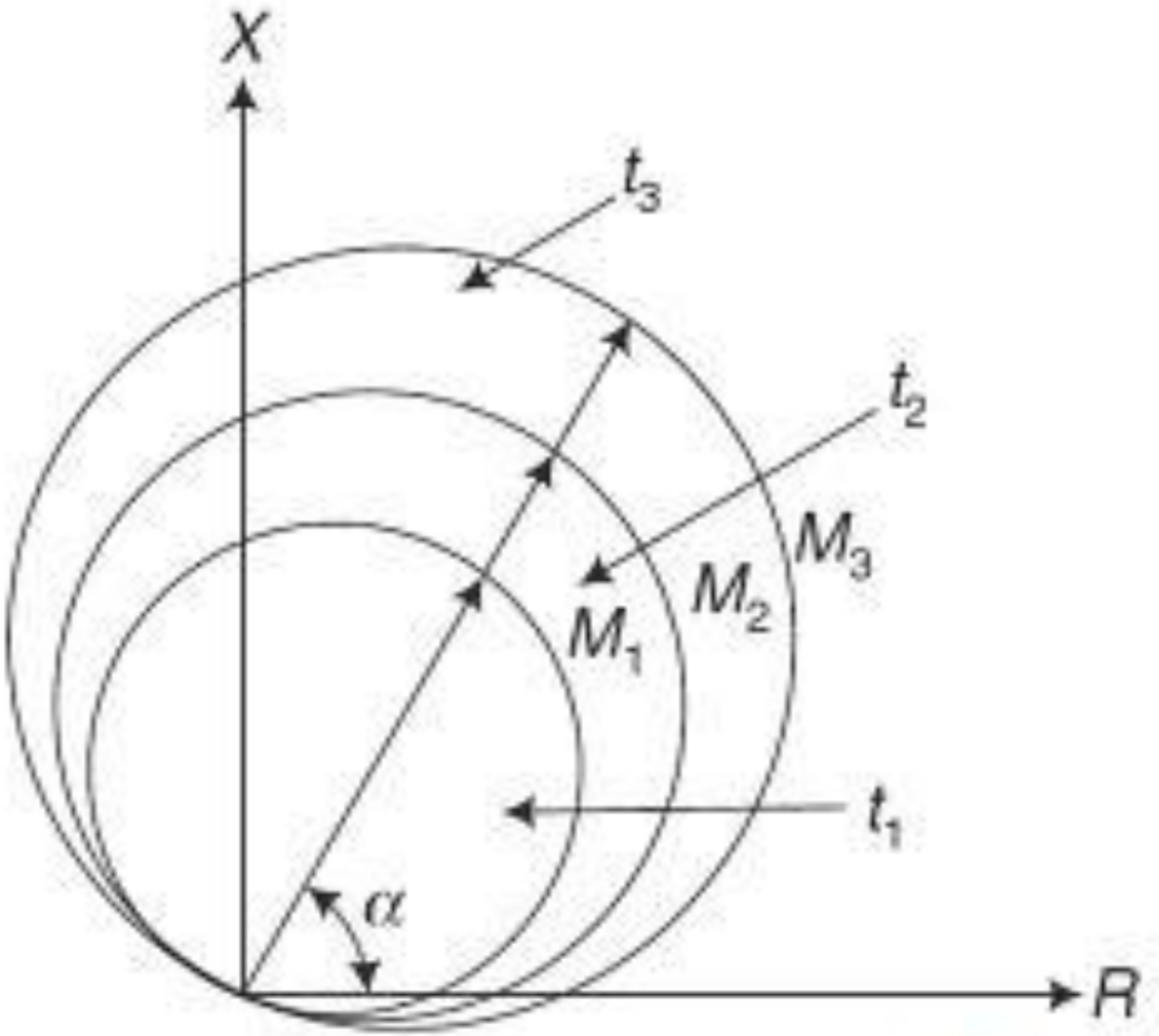
3. Mho relay

- Induction cup type structure.
- Operative Torque produced by V & I element.
- Restraining Torque by Voltage element.
- Also called ***Admittance relay.***

3. Mho relay


1
Polarizing coil
Operating coil
Series tuning
2
4
I
3
Restraining coil
V

3. Mho relay

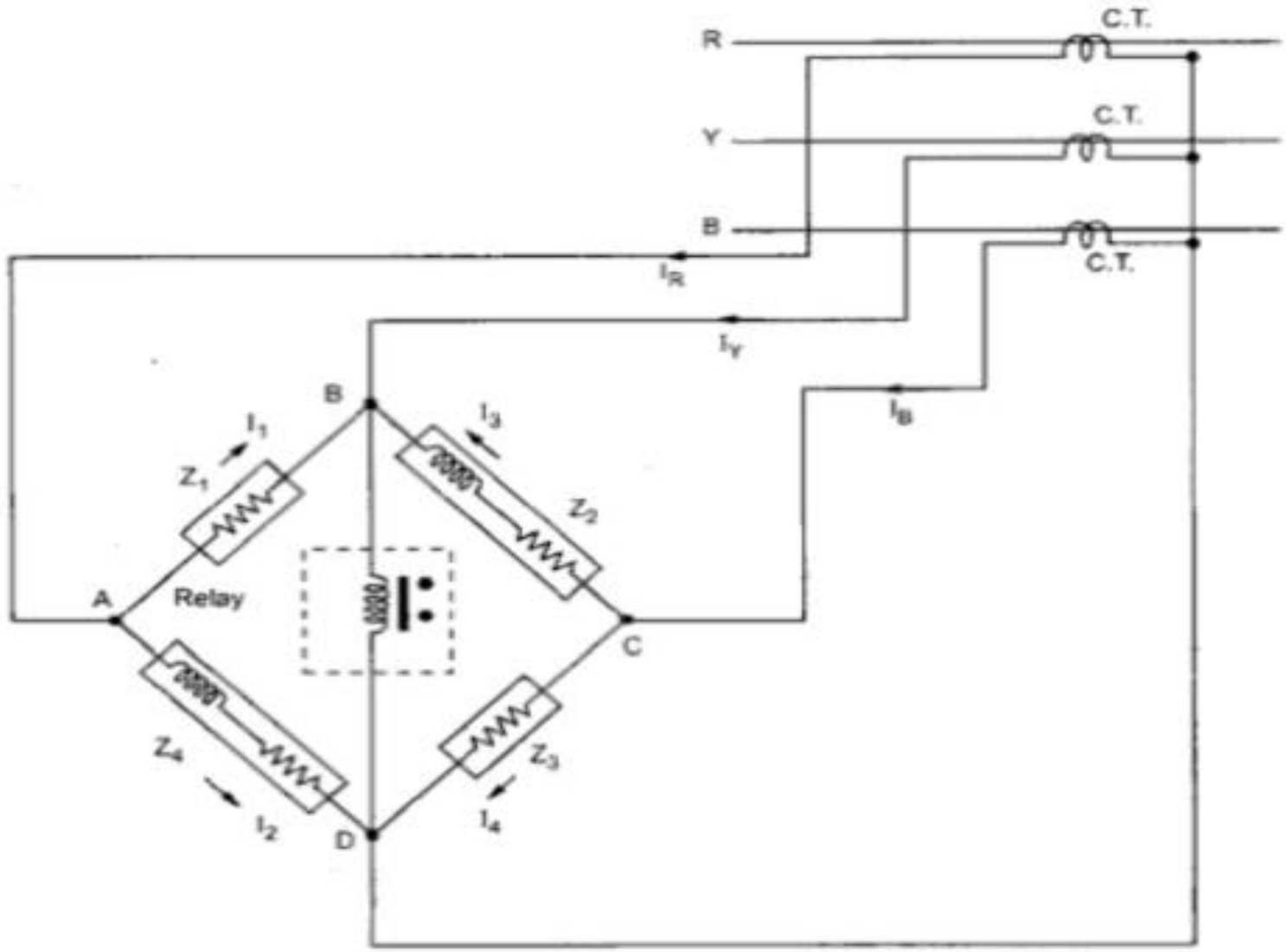


NEGATIVE SEQUENCE RELAYS

NEGATIVE SEQUENCE RELAYS

- 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 over heating. Negative sequence relays are generally used to give protection to generators and motors against unbalanced currents.

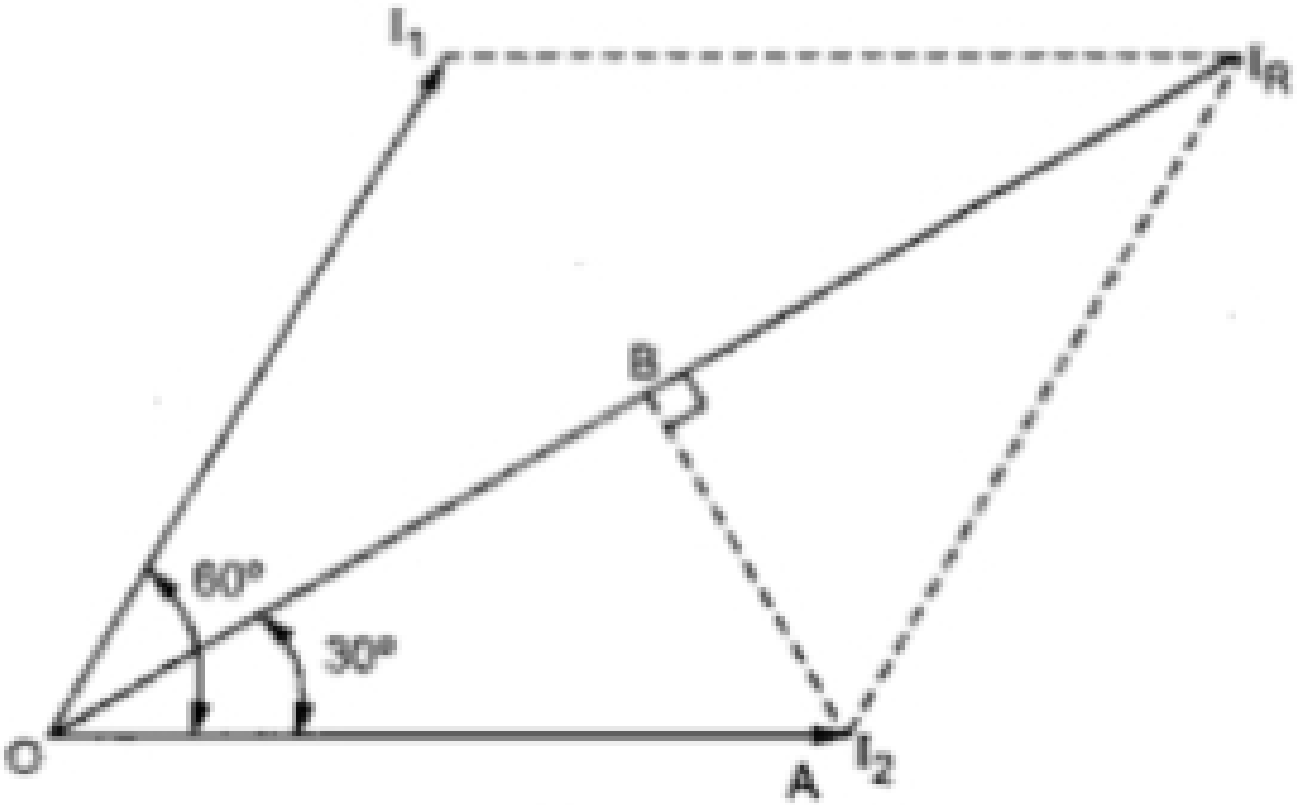
NEGATIVE SEQUENCE RELAYS DIAGRAM



CONSTRUCTION

- It consists of a resistance bridge network.
- The magnitudes of the impedances of all the branches of the network are equal.
- The impedances Z1 and Z3 are purely resistive while the impedances Z2 and Z4 are the combinations of resistance and reactance.
- The currents in the branches Z2 and Z4 lag by 60 degree from the currents in the branches Z1 and Z3.
- The vertical branch B-D consists of inverse time characteristics relay. The relay has negligible impedance.

PHASOR DIAGRAM



NEGATIVE SEQUENCE RELAYS

The current IRgets divided into two equal parts I1and I2. And I2lags I1by 60o.

$\bar{I}1 + \bar{I}2 = \bar{I}rs$

Let $I1 = I2 = I$

The perpendicular is drawn from point A on the diagonal meeting it at point B. This bisects the diagonal.

HENCE, $OB = IR/2$

Now in triangle OAB,

$\cos 30 = OB/OA$

HENCE, $\sqrt{3}/2 = (IR/2)/I$

HENCE, $I = IR/\sqrt{3} = I1 = I2$ .....(1)

NEGATIVE SEQUENCE RELAYS

- Now I1 leads IR by 30 degree while I2 lags IR by 30 degree.
- Similarly the current IB gets divided into two equal parts I3 and I4. The current I3 lags I4 by 60 degree. From equation(1) we can write,

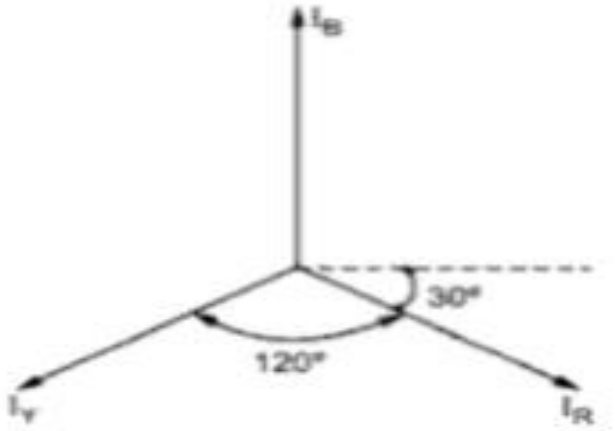
  IB/√3=I3=I4.....(2)
- The current I4 leads by IB while current I3 lags IB by 30 degree.
- The current entering the relay at the junction point B in the Fig.1 is the vector sum of, and.

Irelay =Ī1+Ī3+ĪY

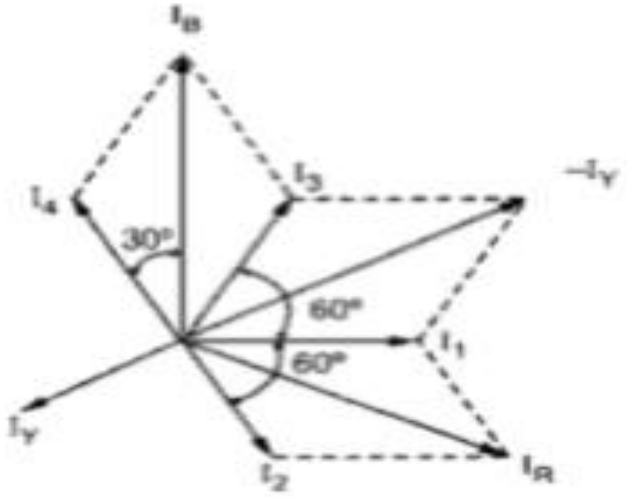
=IY+(IR/√3)(leadsIRby30degree)+IB/√3(lagsIBby30degree)

- **When the load is balanced and no negative sequence currents exist**

NEGATIVE SEQUENCE RELAYS



(a) C. T. secondary currents



(b) Vector sum

$\bar{I}1 + \bar{I}3 = -\bar{I}Y$

Hence, $\bar{I}1 + \bar{I}3 + \bar{I}Y = 0$

Thus the current entering the relay at point B is zero. Similarly the resultant current at junction D is also zero. Thus the relay is inoperative for a balanced system.

CONDITION

- Now consider that there is unbalanced load on generator or motor due to which negative sequence currents exist.
- The component I1and I3 are equal and opposite to each other at the junction point B. Hence I1and I3cancel each other. Now the relay coil carries the current IY and when this current is more than a predetermined value, the relay trips closing the contacts of trip circuit which opens the circuit breaker.

ZERO SEQUENCE CURRENT

- Under zero sequence currents the total current of twice the zero sequence current flows through the relay. Hence the relay operates to open the circuit breaker.
- To make the relay sensitive to only negative sequence currents by making it inoperative under the influence of zero sequence currents is possible by connecting the current transformers in delta .Under delta connection of current transformers, no zero sequence current can flow in the network.

DIFFERENTIAL RELAYS

DIFFERENTIAL RELAYS

Definition

- A two-winding relay that operates when the difference between the currents in the two windings reaches a predetermined value is called differential relays.
- A two-winding relay that operates when the difference between the currents in the two windings reaches a predetermined value.

DIFFERENTIAL RELAYS

- In case of electrical quantities exceed a predetermined value, a current differential relay is one that compares the current entering a section of the system with current leaving the section.
- Under normal operating conditions, the two currents are equal but as soon as fault occurs, this condition no longer applies. The difference between the incoming and outgoing currents is arranged to flow through relay operating coil. If this difference is equal to or greater than the pick up value the relay will operate and open the circuit breaker and isolate the faulty section.
- Any type of relay when connected in a particular way can be made to operate as a differential relay. It is not the relay construction but the way in which relay is connected in a circuit makes it a differential relay.

DIFFERENTIAL RELAYS

There are three fundamental systems of differential or balanced protection:

1. current differential relay
2. voltage differential relay
3. Biased beam relay or percentage differential relay

(i) Current balance protection

Fig 16 a shows an arrangement of an over current relay connected to operate as a differential relay. A pair of identical current transformers is fitted on either end of the section to be protected (alternator winding in this case). The secondary's of CT's are connected in series in such a way that they carry the induced currents in the same direction. The operating coil of over current relay i ential relay nator windir

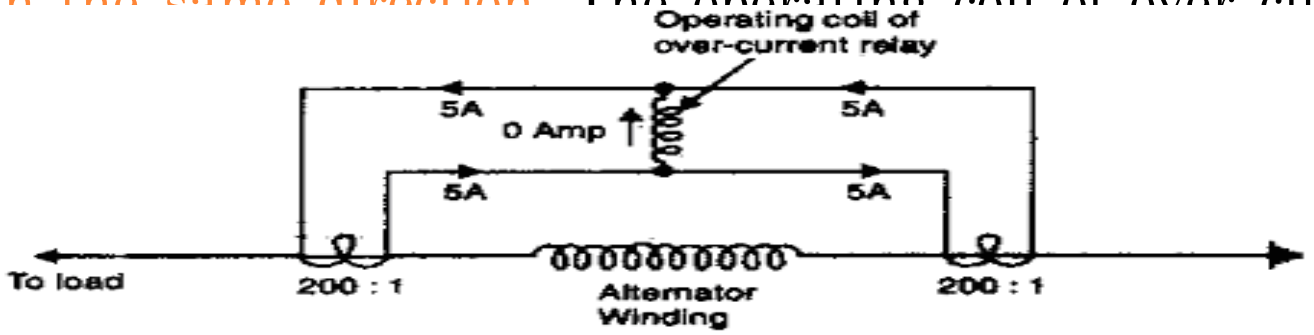


fig 16 a

1. Current differential relay

- Under normal operating conditions, suppose the alternator winding carries a normal current of 1000 A. Then the current in the two secondary's of CT's are equal as in figure. These currents will merely circulate between the two CT's and no current will flow through the differential relay as shown in the diagram fig 16 a. Therefore, the relay remains inoperative.
- If a ground fault occurs on the alternator winding as shown in fig 16 b. the two secondary currents will not be equal and the current flows through the operating coil of the relay, causing the relay to operate. The amount of current flow through the relay will depend upon the way the fault is being fed.

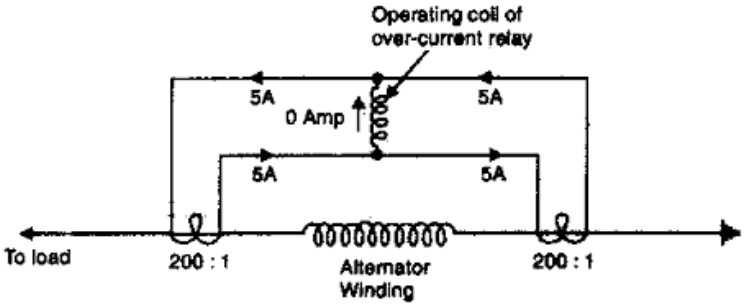


fig 16 a

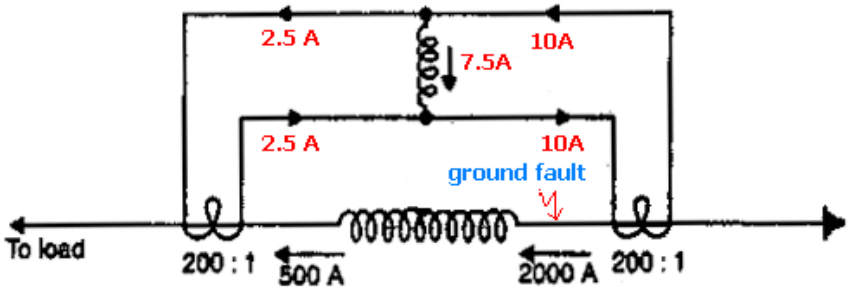


fig 16 b

DIS-ADVANTAGES

- The impedance of the pilot cables generally causes a slight difference between the currents at the two ends of the section to be protected, then the small differential current flowing through the relay may cause it to operate even under no fault conditions.
- Pilot cable capacitance causes incorrect operation of the relay when a large current flows.
- Accurate matching of current transformers can not be achieved due to pilot circuit impedance.

2. VOLTAGE DIFFERENTIAL RELAY

Fig. 18 shows the arrangement of voltage balance protection.

- In this scheme of protection, two similar current transformers are connected at either end of the element to be protected (e.g. an alternator winding) by means of pilot of wires.
- The secondary's of current transformers are connected in series with a relay in such a way that under normal conditions. their induced e.m.f's are ir

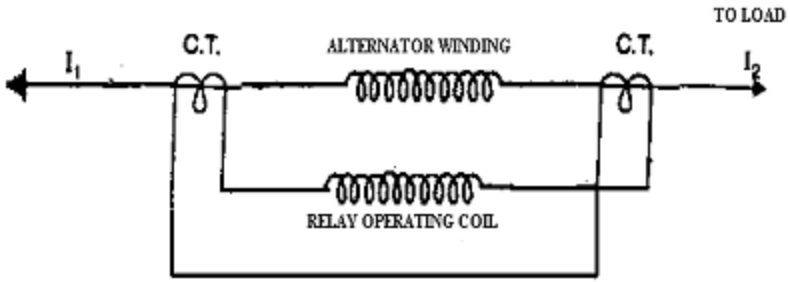


fig 18

2. VOLTAGE DIFFERENTIAL RELAY

- Under healthy conditions, equal currents will flow in both primary windings. Therefore, the secondary voltages of the two transformers are balanced against each other and no current will flow through the relay-operating coil.
- When a fault occurs in the protected zone, the currents in the two primaries will differ from one another and their secondary voltages will no longer be in balance.
- This voltage difference will cause a current to flow through the operating coil of the relay, which closes the trip circuit.

Dis-advantages

The voltage balance system suffers from the following drawbacks

- A multi-gap transformer construction is required to achieve the accurate balance between current transformer pairs.
- The system is suitable for protection of cables of relatively short, lengths due to the capacitance of pilot wires.

3. Biased beam relay or percentage differential relay

- The biased beam relay also called percentage differential relay is designed to respond to the differential current in terms of its fractional relation to the current flowing through the protected section.
- It's called percentage differential relay because the ratio of differential operating current to average restraining current is a fixed percentage.
- It's called bias relay because restraining known as biased coil produces the bias force. Fig 17 a, shows the schematic arrangements of biased beam relay. It is essentially an over curren ıining coil. T posite directi

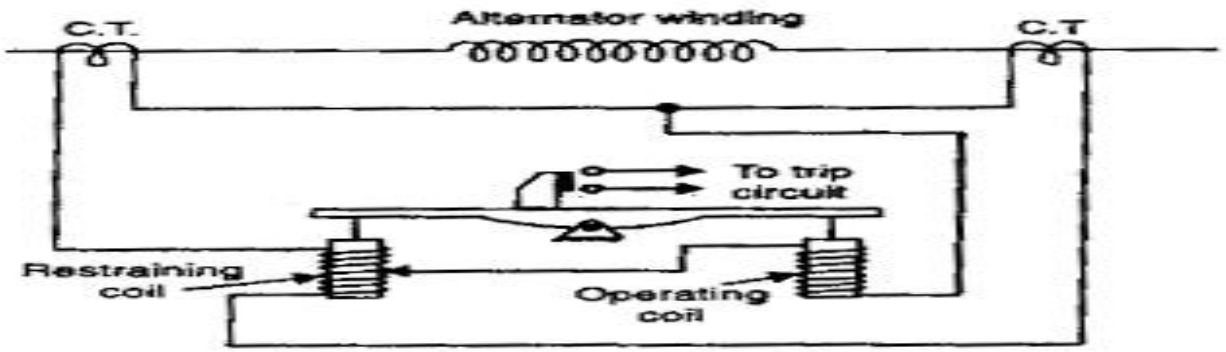


fig 17 a

3. Biased beam relay or percentage differential relay

- Under normal and through load conditions, the bias force due to restraining coil is greater than operating force. Therefore, the relay remains inoperative.

UNDER NORNAL OPERATION

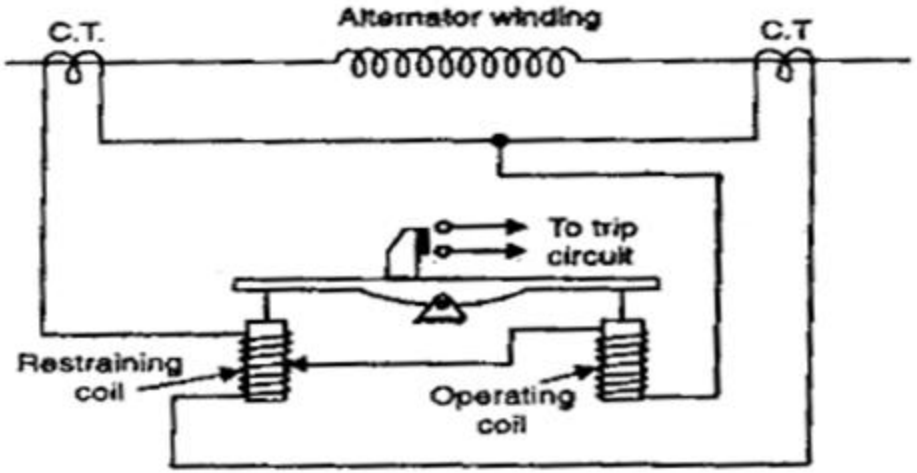


fig 17 a

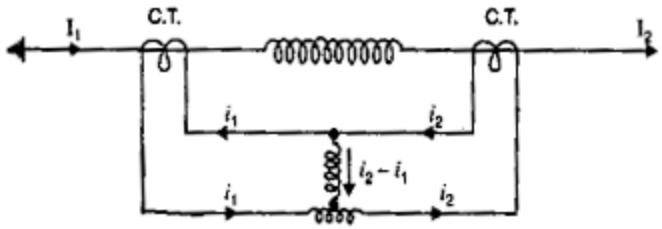
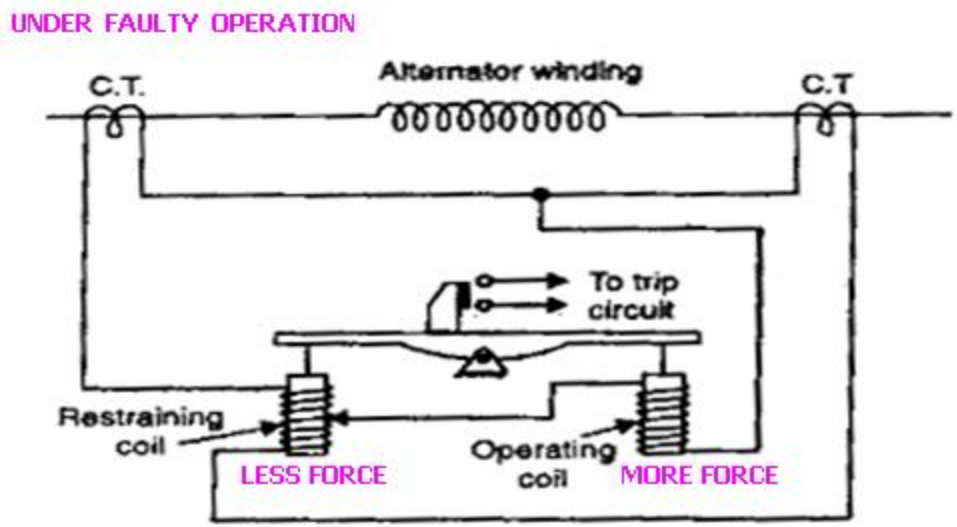


fig 17 b

3. Biased beam relay or percentage differential relay

- When an internal fault occurs, the operating force exceeds the bias force. Consequently the trip contacts are closed to open the circuit breaker.
- The bias force can be adjusted by varying the number of turns on the restraining coil.



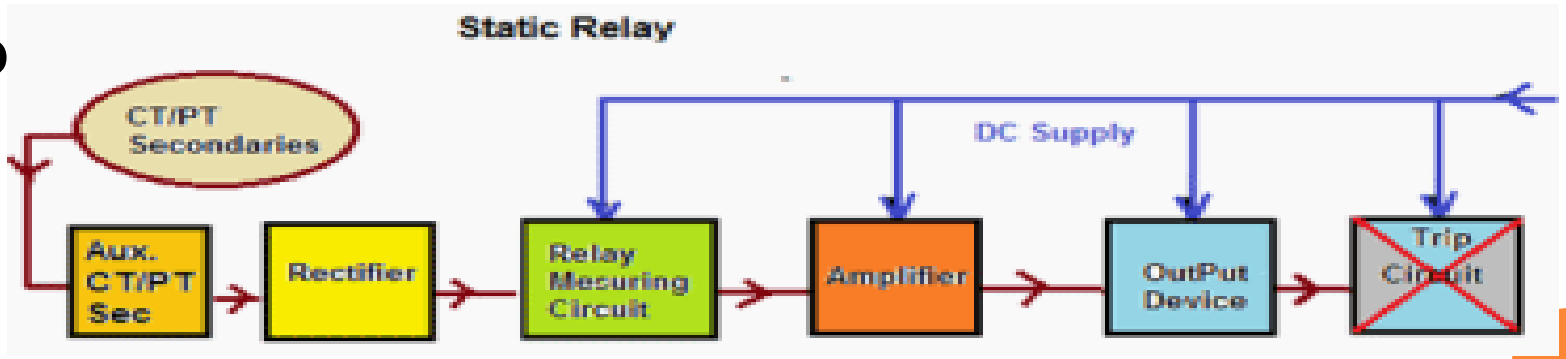
Introduction to Static Relay

STATIC RELAY

- The **static relay** is the next generation relay after electromechanical type.
- The Solid Static relays was first introduced in 1960's. The term '***static***' implies that the relay***has no moving mechanical parts*** in it.
- Compared to the Electromechanical Relay, the Solid Static relay has ***longer life-span***, ***decreased noise*** when operates and faster respond speed.
- The static relays have been designed to replace almost all the functions which were being achieved earlier by **electromechanical relays**.

Principle of operation

- The essential components of static relays are shown in figure below. The output of CT and PT are not suitable for static components so they are brought down to suitable level by auxiliary CT and PT. Then auxiliary CT output is given to rectifier.
- Rectifier rectifies the relaying quantity i.e., the o



Principle of operation

- The rectified output is supplied to a measuring unit comprising of comparators, level detectors, filters, logic circuits.
- The output is actuated when the dynamic input (*i.e., the relaying quantity*) attains the threshold value. This output of the measuring unit is amplified by amplifier and fed to the output unit device, which is usually an electromagnetic one.
- *The output unit energizes the trip coil only when relay operates.*

Advantages of Solid State Relay

- Low Weight
- Arc less switching
- Static Relay burden is less than electromagnetic type of relays. Hence error is less.
- Fast response.
- Long life
- Less power consumption
- More Accurate compared to electromechanical Relay

THANK YOU