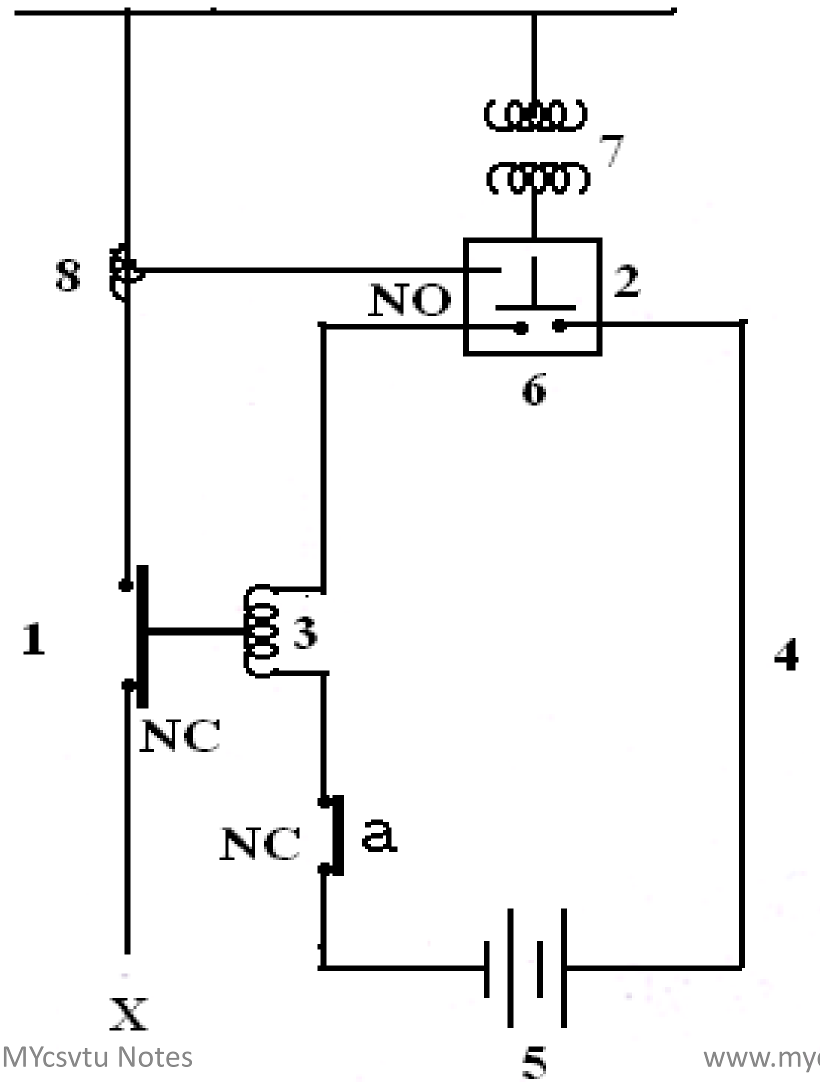
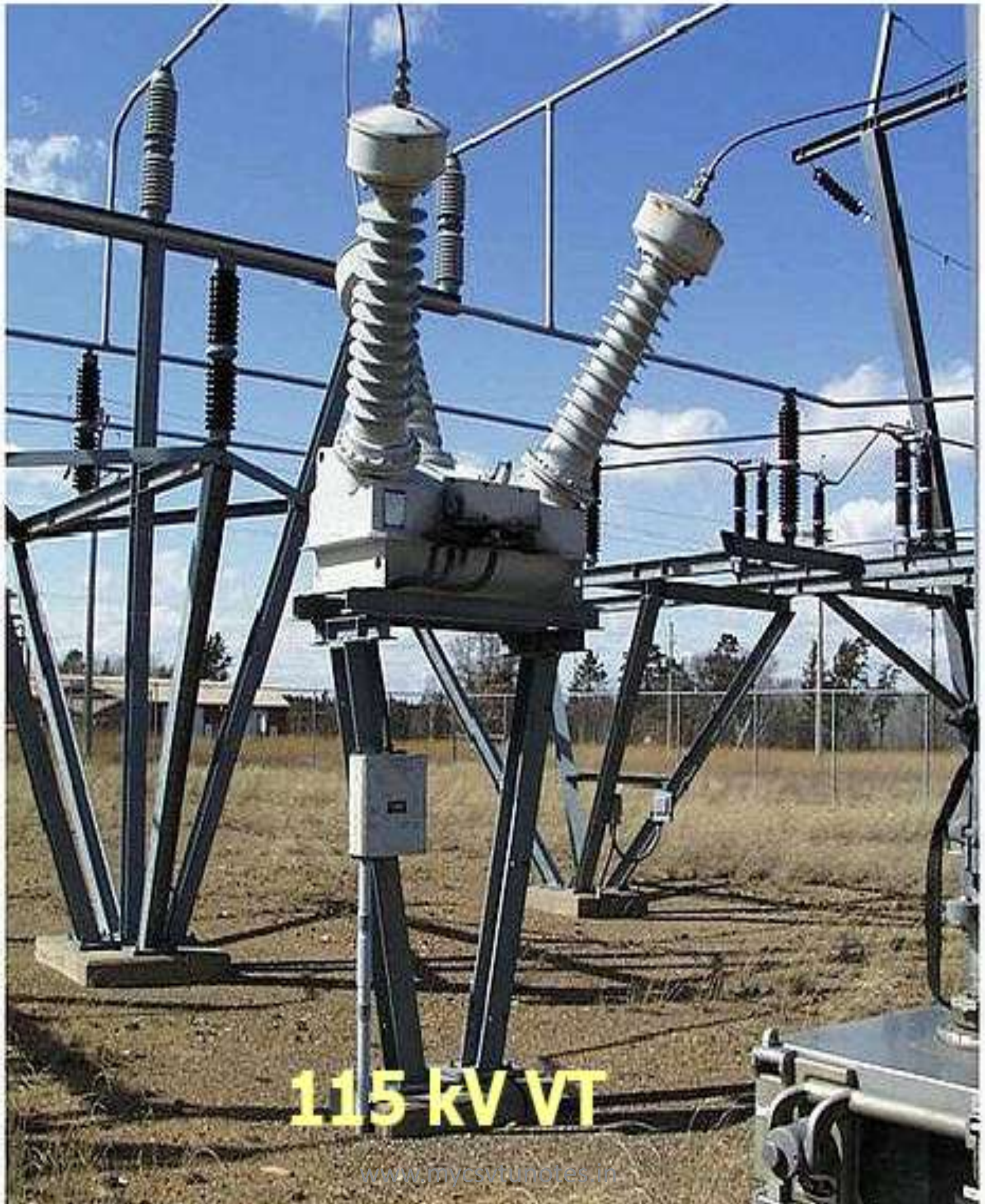
RELAY DIAGRAM



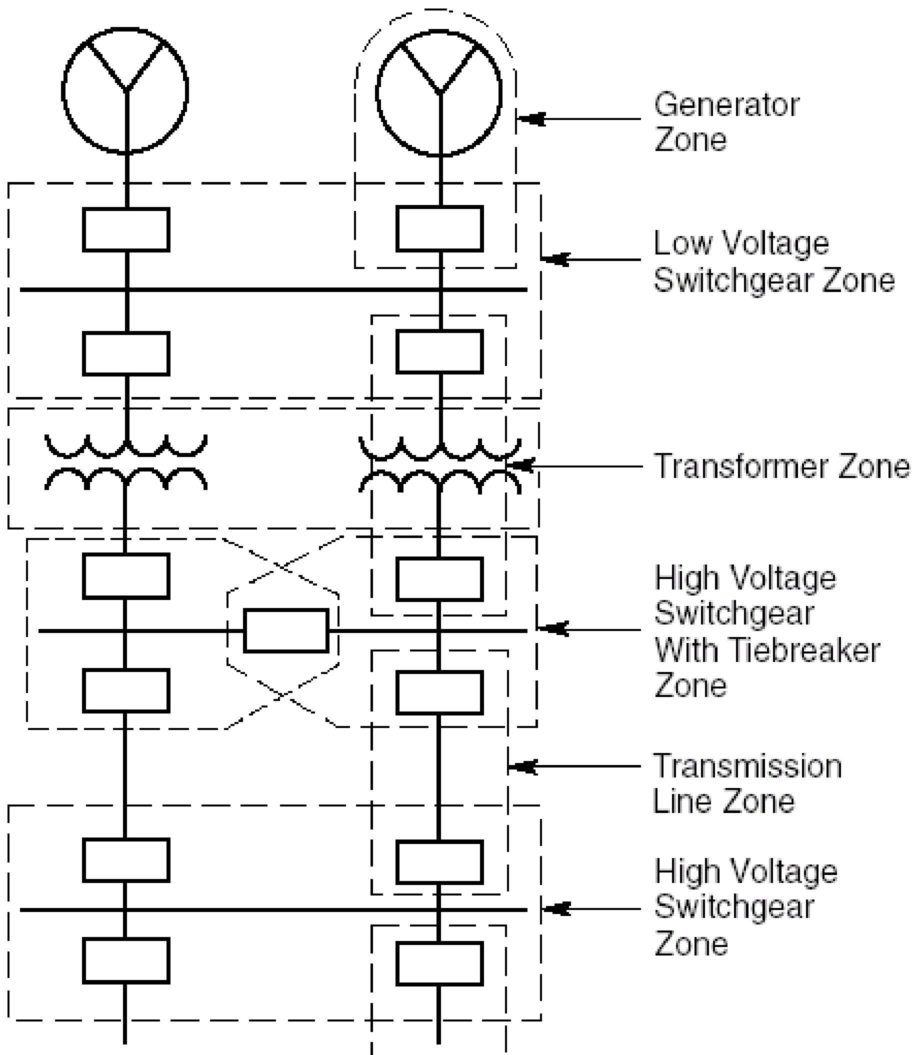
1. Circuit breaker
2. Relay
3. Trip coil of the C.B
4. Trip circuit
5. Battery
6. Relay contacts
7. Potential transformers
8. Current transformers

a-- auxiliary switch contacts
X -- protected element


69 kV Metering CT's
Strain Bus
Bushing CT's


115 kV VT

Protective Relays



Protective Relays

- Each element of the system has *zones of protection* surrounding the element.
- A fault within the given zone should cause the tripping of all circuit breakers within that zone and no tripping of breakers outside that zone.
- If faults occur in the overlap region, several breakers respond and isolate the sections from the power system.

TYPES OF PROTECTION

- A). PRIMARY PROTECTION :

  i). First line of defense.

  ii). Clear fault as soon as possible.

- It fails due to failure of :

  1). Protective relays (moving mechanism).

  2). Circuit breaker.

  3). DC tripping voltage supply.

  4). Current or voltage supply to the relays.

B). BACK-UP PROTECTION :

i). Second line of defense.

ii). It should not have any thing common with primary relays.

iii). Act as a primary protection in case primary relay is taken out for repair & maintenance.

- Working of back-up protection:

The backup relays operate if the primary relays fail and cover not only the local section but the next one also and have a time delay long enough for the primary relays to operate if they can. A fault at F would normally be seen first by the relay R1 and isolated by the C.B at C. In the event of failure of the relay R1 or associated equipment at C the fault would be isolated by the operation of the relay R2 and C.B at B. Hence R2 is the back up relay of R1 and its characteristic is thus shifted upwards as evident from the figure. Similarly R3 is the back up of R2.

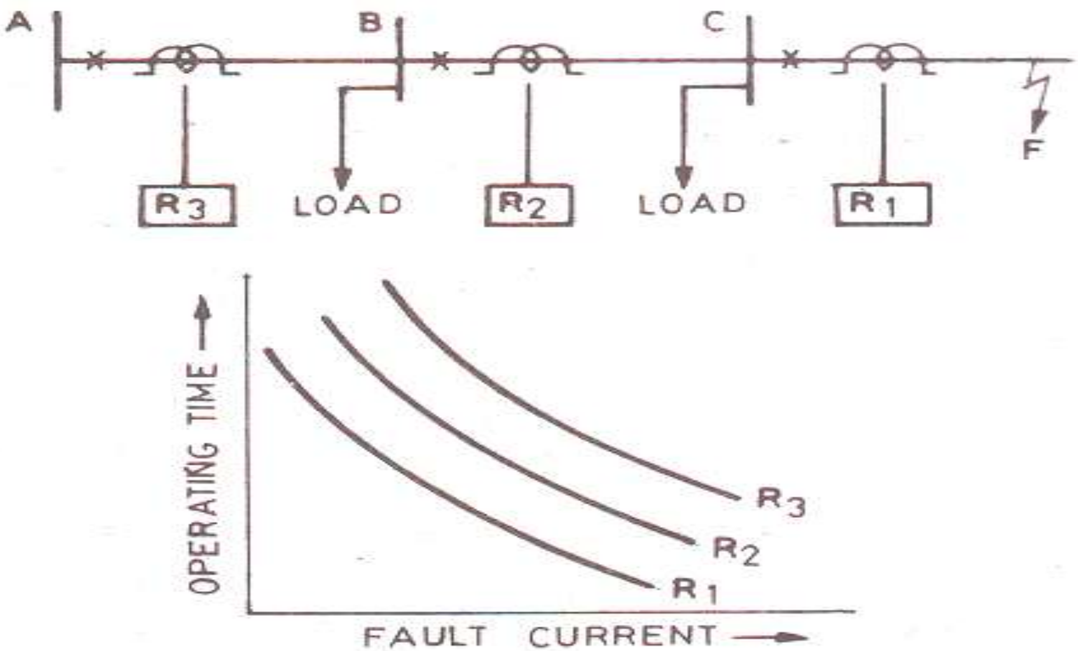


Fig. 8.3. Back-up protection by time over-current relays.

FUNCTIONAL (OPERATING) CHARACTERISTIC

- RELIABILITY
- SELECTIVITY
- SPEED
- SENSITIVITY

RELIABILITY

- It must operate when it is required.
- Requirement :

i) Each component should be perfect.

ii) Requisite amount of current & voltage from C.T & P.T.

iii) Proper and careful maintenance

iv) Simplicity and robustness in construction

v) High contact pressure

vi) Dust free enclosures

vii) Good contact material

viii) Good workmanship

SELECTIVITY

- Ability to select which part of the system is faulty and which is not and should isolate the faulty part of the system from the healthy one.
- Achieved in two ways:

i). Unit system of protection: Responds only to faults within its own zone and does not make note of the conditions elsewhere, e.g. the differential protection of transformers and generators.

ii). Non-unit system: The selectivity is obtained by grading the time or current settings of the relays at different locations, all of which may respond to a given fault.

SPEED

- Nor should be to slow or to fast, but should remove fault as soon as possible.
- High speed :

i) improves power system stability.

ii) decreases the amount of damage incurred.

iii) less outage time for power consumers.

iv) decreases the likelihood of development of one type of fault into other more severe type.

V). Quickly restore service to consumer.

- The shorter the time for which a fault is allowed to persist on the system, the more load can be transferred between given points on the power system without loss of synchronism.

Sensitivity

- Capability of the relaying to operate reliably under the actual conditions that produce the least operating tendency.
- It shall operate for low values of actuating quantity.
- More sensitive, more expensive.

Terms connected with Relays

1). Instantaneous relay :

The relay contacts are closed immediately after actuating quantity exceeds the minimum calibrated value without any intentional time delay.

2). **Inverse time relay** :

Operating time is approximately inversely proportional to the magnitude of the actuating quantity. The inverse time delay can be achieved by associating mechanical accessories (e.g.,drag magnet, oil dash pot or time limit fuse)

3). **Definite time lag relay** :

Definite time elapses between the instant of pick up and the closing of the relay contacts. It is independent of the amount of current flowing through the relay coil.

4). **Operating force or torque** :

It is the torque (or force) which tends to close the contacts of the relay.

5). **Restraining force or torque**:

It is the torque which opposes the operating torque and tends to prevent the closure the relay contacts.

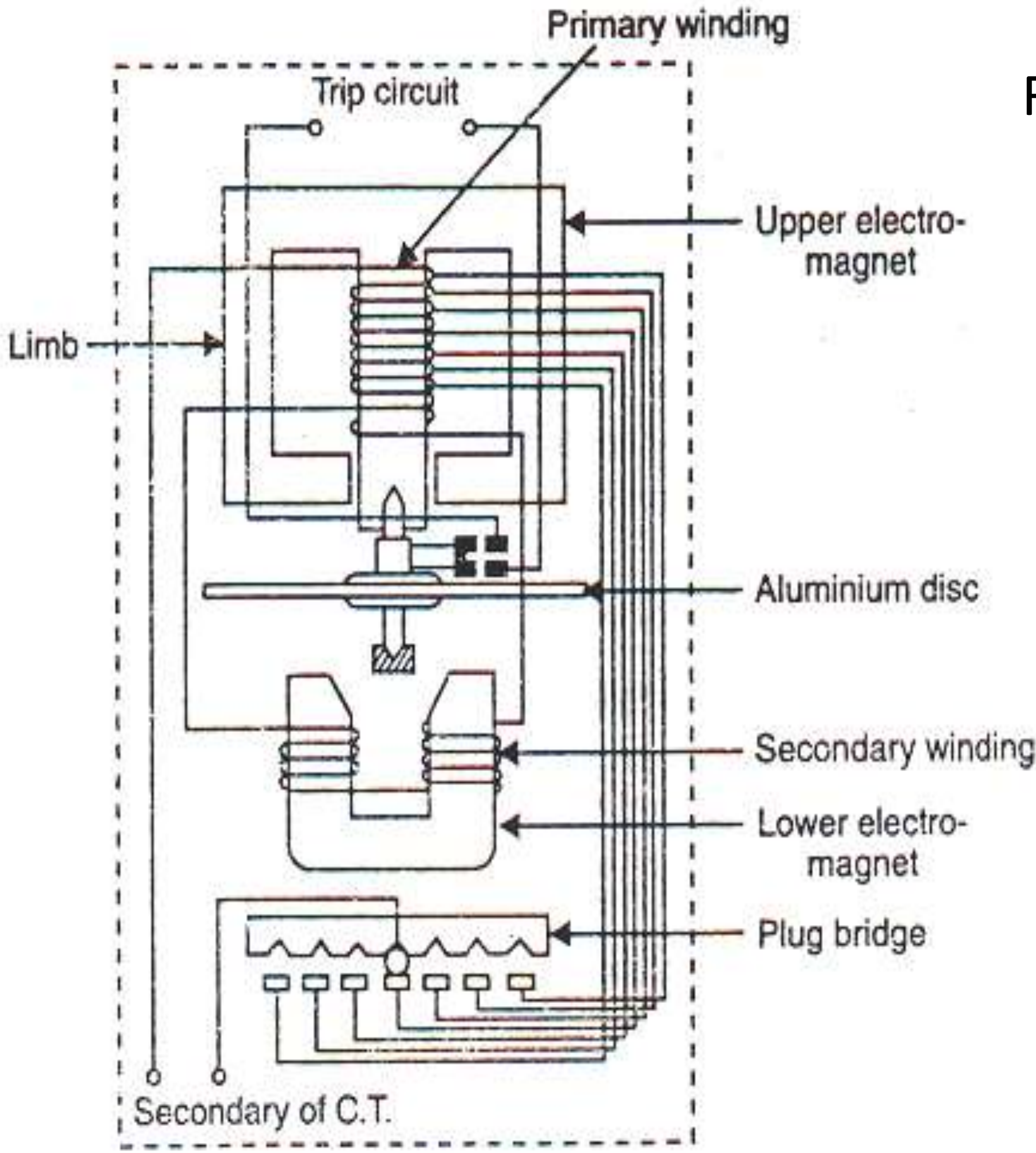
6). **Operating or pick up (level):**

It is defined as a threshold value of current, voltage etc. above which the relay will close its contacts.

7). **Drop out or reset level**:

It is defined as the value of current, voltage etc. below which the relay will open its contacts and return to normal position.

For pick-up value tripping time and reset time



8). **Holding ratio** : = Reset / pickup value

Since pick-up value is more than reset value, the holding ratio is always less than 1.

Pick-up value is high and reset value is low because once the relay has picked up the air gap is shortened and smaller magnitude of coil current can hold it in picked-up position.

9). **Flag or target**:

It is a device (usually spring or gravity operated) which indicates the operation of a relay.

10). **Operating time**:

The time which elapses between the instant when the actuating quantity exceeds the pick up value to the instant when the relay contacts close.

11). **Reset time**:

The time which elapses between the instants when the actuating quantity becomes less than the reset value to the instants when the relay contact returns to its normal position.

12). **Seal-in-coil:**

It is the coil which does not permit the relay contacts to open when the current is flowing through them.

13). **Maximum torque angle**:

It is defined as the designed angle of the relay that will yield maximum torque. It is also known as characteristic angle of relay.

14). **Reach** :

A distance relay operates whenever the impedance seen by the relay is less than a prespecified value. This impedance or the corresponding distance is known as the reach of the relay.

15). **Underreach** :

The tendency of the relay to operate at impedance lower than the set value is known as under-reach.

16). **Overreach** :

The tendency of the relay to operate at impedances larger than its setting is known as overreach.

(OR) A relay is said to overreach when it operates at a current which is lower than its setting.

17). **Pick up current**:

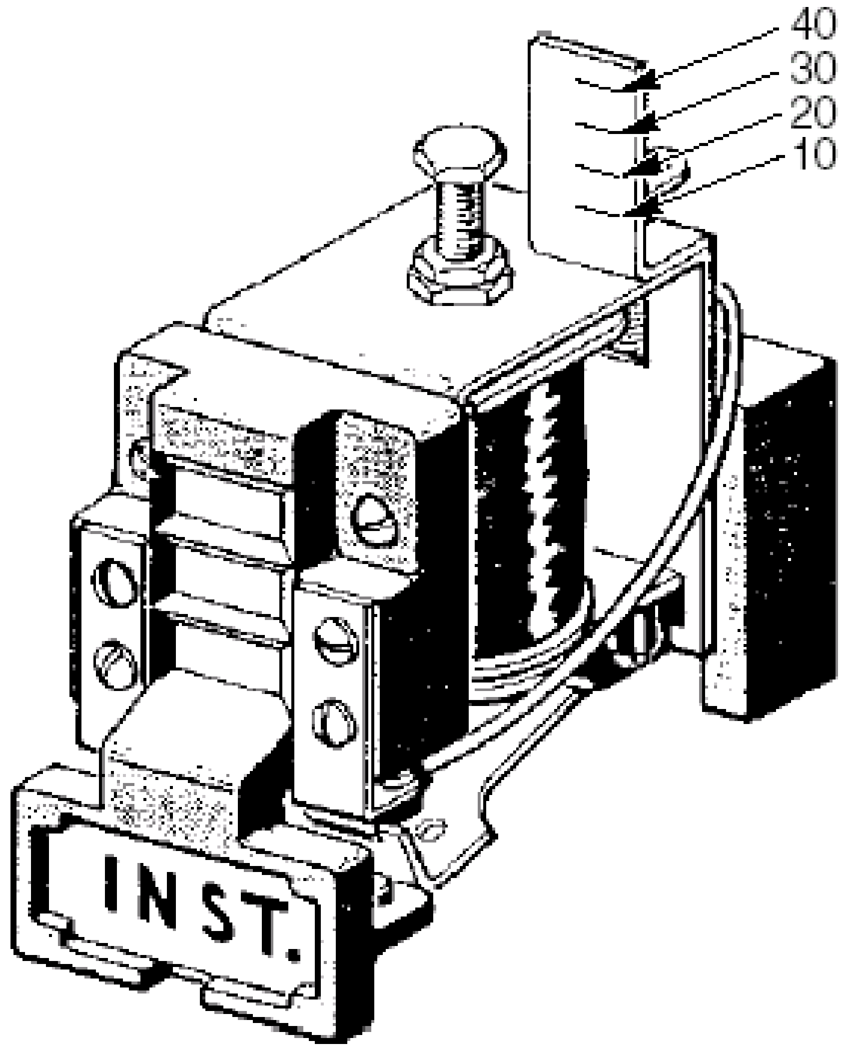
It is the minimum current in the relay coil at which the relay starts to operate.

18). **Current setting**:

Adjust the pick up current to any required value is known as current setting and is usually achieved by the use of tappings on the relay operating coil. The values assigned to each tap are expressed in terms of percentage full load rating of C.T with which the relay is associated and represents the value above at which the disc commences to rotate and finally closes the trip circuit.

$\therefore$ Pick up current = Rated secondary current of C.T X Current setting.

Current setting



19). **Plug setting multiplier (P.S.M)**:

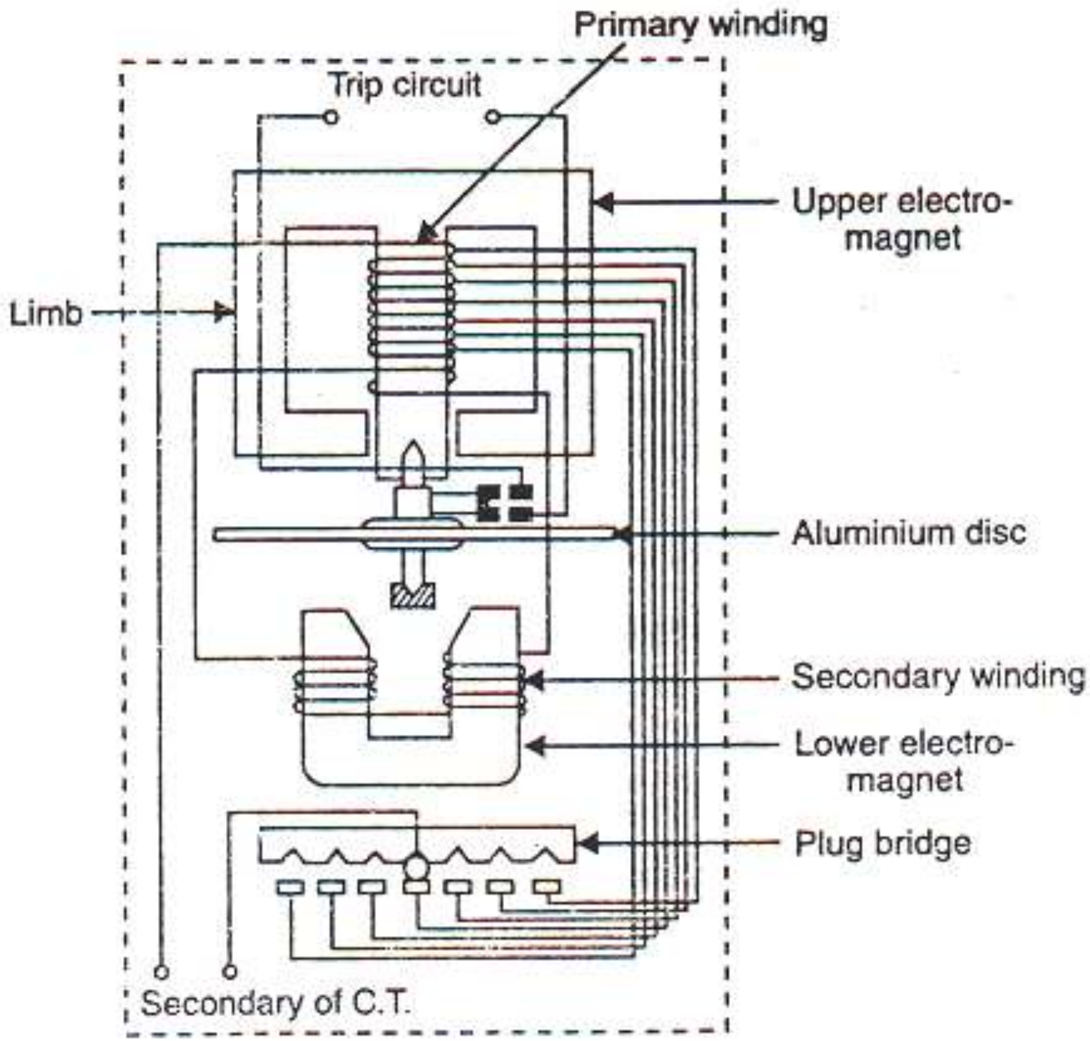
Plug setting refers to the reference value of operating quantity at which the relay starts to operate.

$$P.S.M = \frac{\text{Fault current in the relay coil}}{\text{Pickup current} \times \text{C.T ratio}} = \frac{\text{Fault current in the relay coil}}{\text{plug setting}}$$

$$= \frac{\text{Fault current in relay coil}}{\text{Rated secondary current of C.T} \times \text{current setting} \times \text{CT ratio}}$$

The plug setting bridge comprises connections tapped from the relay coil. By inserting the plug, in a particular gap in the bridge, a certain number of turns of the relay coil are brought into circuit. Actually the relay should start operating at current equal to plug setting. However, due to friction, dust etc. the operations may not take place at exact plug setting value. Suppose current injected in to relay coil is 10 A and plug setting is 2.5 A, then plug setting multiplier will be 10/2.5 = 4.

For plug setting and time setting multiplier



20). **Time setting multiplier**:

Controls the time of operation. It is in the form of an adjustable back-stop which decides the arc length through which the disc travels. By reducing the length of travel, the time is reduced. This adjustment is known as time-setting multiplier. The time setting dial is calibrated from 0 to 1, in steps of 0.05 sec. By reducing the time multiplier, the characteristic is shifted to lower side, indicating that operating time is reduced.

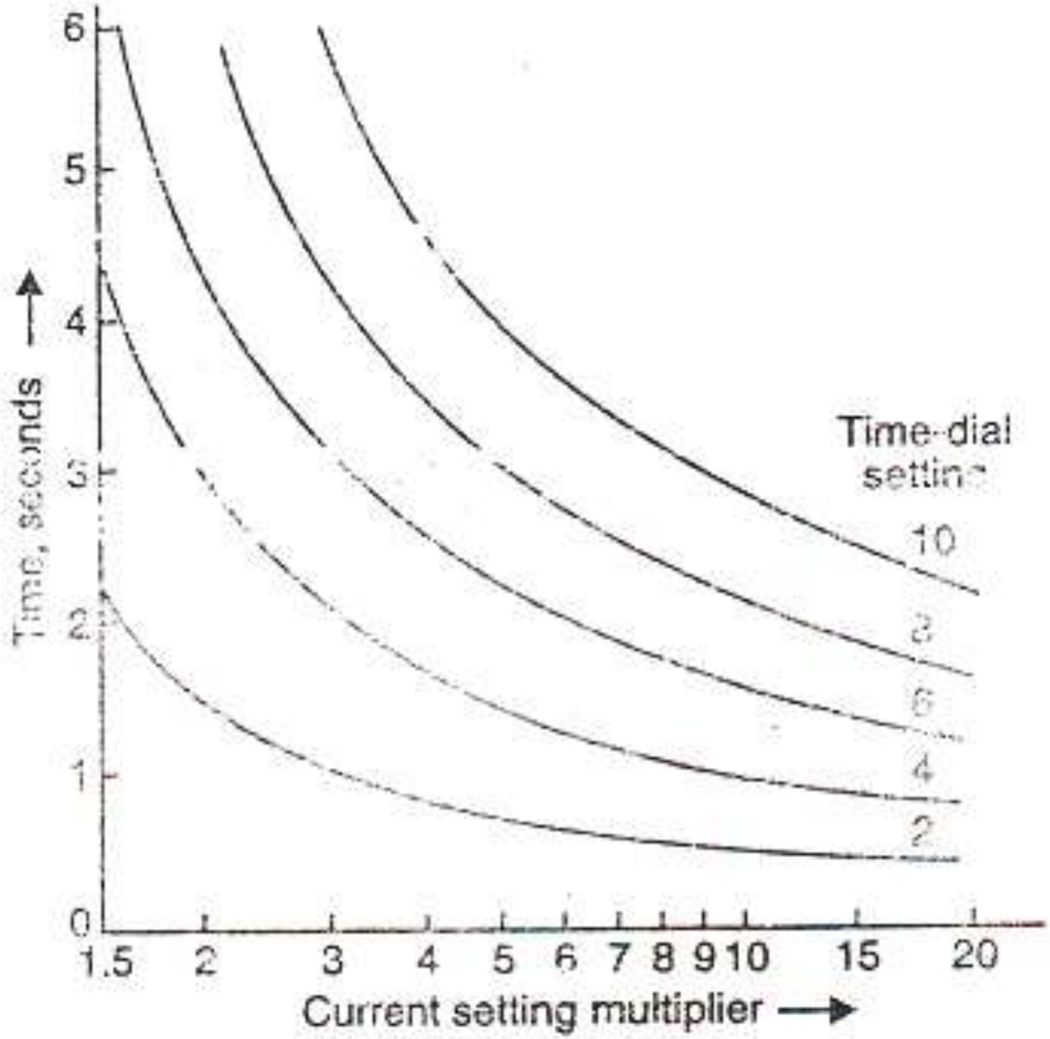


Fig. 23.16. Current-time characteristic of an induction relay.

21). **<u>Stability</u>**:

It is the quality of protective system by the virtue of which the protective system remains inoperative and stable under system disturbance, through faults, transients etc. Consider protection of transformer for faults beyond the protected zone, the protection of transformer should remain stable. To improve stability certain modification are necessary, for eg. Biased differential protection for protection of transformer is more stable than plain differential protection. Further to make the transformer protection insensitive to inrush of currents during switching-in, provision like Harmonic restraint relay are provided. In many cases time delay, mechanical and electrical bias, filter circuits etc. are provided to make the relays stable during certain disturbances.


11 KV FEEDER CONTROL PANEL
11 KV FEEDER CONTROL PANEL
11 KV FEEDER CONTROL PANEL

CLASSIFICATION OF RELAYS

1. According to their construction and principle of operation

(i) Electromagnetic attraction type relays:

a). 'attracted armature type' relays : operation depends on the movement of an armature under the influence of attractive force due to magnetic field set up by current flowing through the relay winding.

b). solenoid type relays: operation depends on the movement of an iron plunger core along the solenoid axis.

ii). Electromagnetic induction or simply induction relays: operation depends on the movement of a metallic disc or cylinder free to rotate by the interaction of induced eddy currents and the alternating magnetic field producing them.

iii). Electro-dynamic relays : In such a relay, moving member consists of a coil free to rotate in the air gap of a permanent magnet.

iv). Moving coil type relays: In such a relay moving member consists of a coil free to rotate in the air gap of a permanent magnet.

v). Thermal relays : In this type relay movement depends upon the action of heat produced by the current flowing through the element of the relay.

vi). Physio-Electric relays: Buchholz's relay is an example of this type of relay.

vii). Static relays: These relays employ thermionic valves, transistors or magnetic amplifiers to obtain the operating characteristics.

- **2. According to their applications:**

  i). Under voltage, under current, and under power relays: Operation occurs when the voltage, current or power falls below a specified value (mostly instantaneous or induction relays).

  ii). Over voltage, over current, and over power relays: Operation takes place when the voltage, current or power rises above a specified value.

  iii). Directional or reverse current relays: Operation occurs when the applied current assumes a specific phase displacement with respect to the applied voltage and the relay is compensated for fall in voltage (induction current relays).

  iv). Directional or reverse power relays: Operation takes place when the applied current and the voltage assume a specific phase displacement with respect to the applied voltage and the relay is compensated for fall in voltage (induction current relays).

  v). Differential relays: Operation occurs at some specific phase or magnitude difference between two or more electrical quantities.

  vi) Distance relays: Operation depends upon the ratio of voltage and current

3. According to their time of operation or timing characteristics

(i) Instantaneous relays... Operation occurs after a negligibly small interval of time from the incidence of the current or other quantity which causes operation.

(ii) Definite time-lag relays... Operation is quite independent of the magnitude of the current or other quantity which causes operation.

iii). Inverse time-lag: The time operation is approximately inversely proportional to the magnitude of the current or other quantity causing operation.

iv). Inverse definite minimum time lag (IDMT) relays: The time of operation is approximately inversely proportional to the smaller values of current and other quantities causing operation and tends to a definite minimum time as the value increases without limit.

OPERATING PRINCIPLE OF RELAY

(i) Electromagnetic attraction.

(ii) Electro-magnetic induction.

Electromagnetic Attraction

- The operation is obtained by virtue of an armature being attracted to the poles of an electromagnet or a plunger being drawn into a solenoid.
- These relays can be operated by both d.c. as well as a.c. quantities.

- With d.c. the torque developed is constant and if this force exceeds a predetermined value the relay operates.
- It is also termed as magnitude relay as they compare the magnitude of the quantity with the set value.
- In this electromagnetic force exerted on the moving element is proportional to the square of the flux in the air gap.

- In case of a.c. quantity the force is given by

$$F \propto I^2$$

$$F = K'I^2$$

Let $I = Im \sin wt$; then ($\sin^2 wt = 1 – \cos 2wt$)

$$F = K'Im^2 - K'Im^2 \cos 2wt$$

Also $F = K'I^2 - K$

where K' = a constant of current coil converting the current to force.

K = restraining force including friction

I = r.m.s value of operating current.

- This shows that the force consists of two components, one the constant, independent of time, whereas the other is a function of time and pulsates at double the supply frequency.
- The total deflecting force, therefore, pulsates at double the frequency.

- Since the restraining force is constant the net force is a pulsating one which means that the relay armature vibrates at double the power supply frequency. These vibrations will lead to sparking between the contacts and the relay will soon be damaged.

- To overcome this difficulty in a.c. electromagnet, the two fluxes producing the force are displaced in time phase so that the resultant deflecting force is always positive and constant.

- This phase displacement can be achieved either by providing two windings on the electromagnet having a phase shifting network or by putting shading ring on the poles of the magnet as shown in Fig. However, the shading ring or coil method is more simple and is widely used.

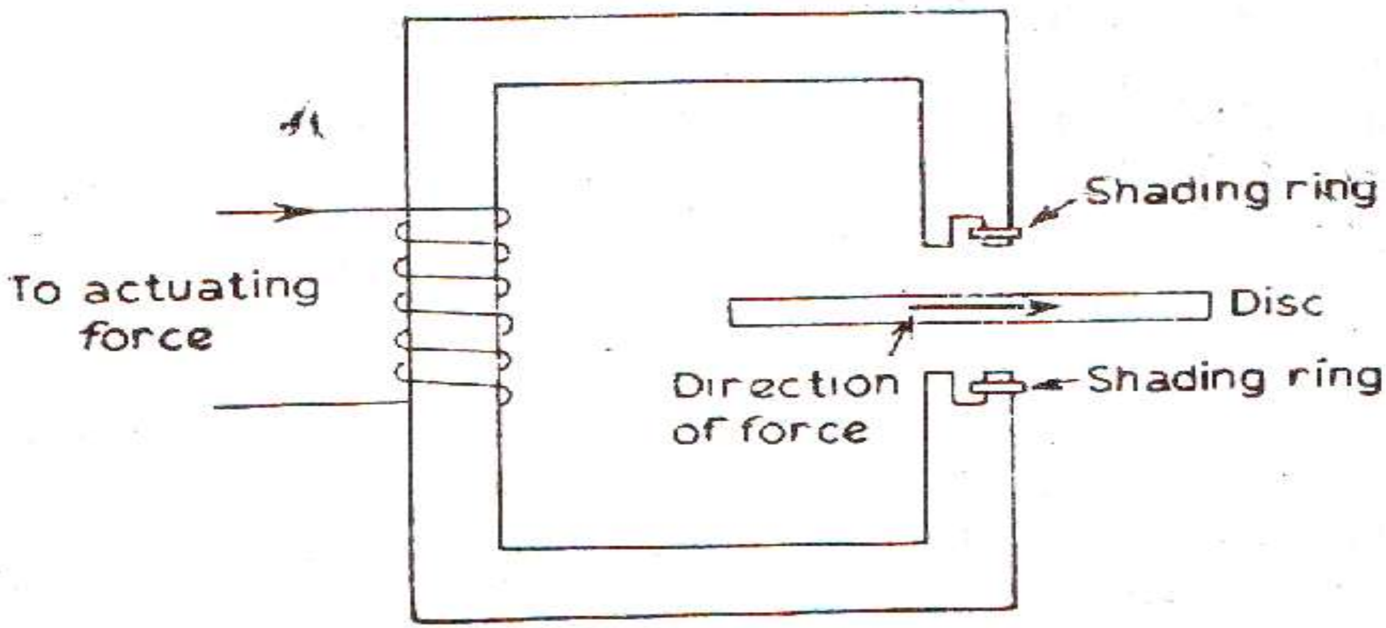


Fig. 14.2 Shaded pole structure

- Characteristics:

  i). These relays are non directional (i,e., it is bi-directional).

  ii). Simpler in construction.

  iii). Inherently very fast in operation (hence they are also called instantaneous relays).

- Applications :

  i). These relays are normally used for D.C operating quantities, but these can also be used for A.C operation by providing ‘shading rings’ on their poles to split the air flux into two out-of-phase components.

  ii). These are normally employed as undercurrent, short circuit, over-voltage, under-voltage relays in distribution circuits.

- Limitations:

  i). Not suitable for continuous operation on A.C in the picked up position because their would be excessive vibration and noise.

  ii). There is a large difference between their pick-up and reset values.

Types of electromagnetic attraction relays are:

- Attracted armature type relay.
- Solenoid type relay.
- Balanced beam type relay.

ATTRACTED ARMATURE TYPE RELAY

- **Construction**:

  i). Laminated electromagnet and a pivoted laminated armature.

  ii). Armature is usually balanced by a counter weight and carries a pair of spring contact fingers at its free end.

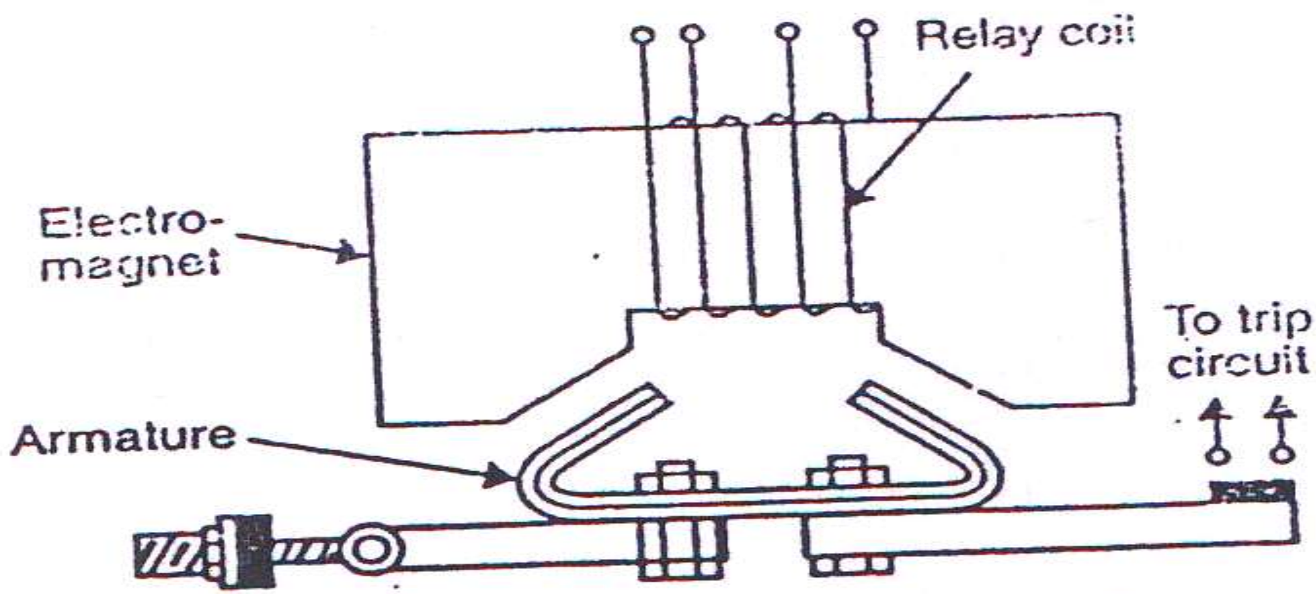


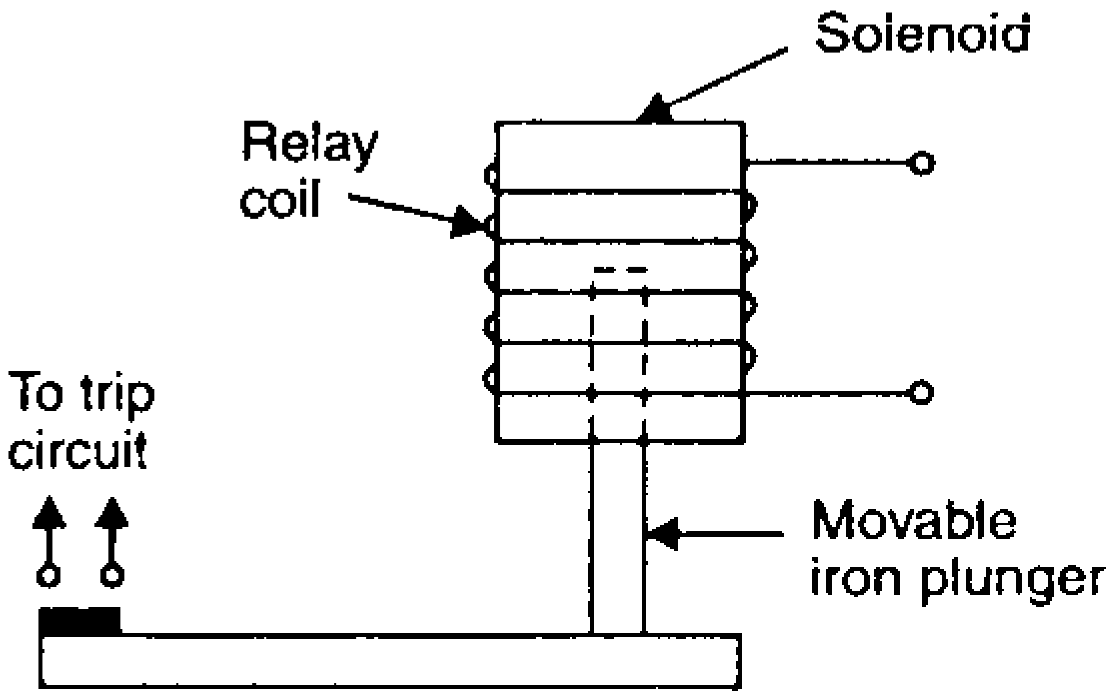
Fig. 23.5. Attracted armature type relay.

- Working : Under normal operating conditions, the current through the relay coil is such that the counterweight holds the armature in the balanced position as shown in the figure. However, when a fault takes place, the current through the relay coil increases considerably and the relay armature is attracted upwards. Subsequently, the stationary contacts attached to the relay frame are bridged and trip circuit is completed.

- Usually a numbers of tappings on the relay coil are provided so that the number of turns in use and the setting value at which the relay operates can be varied.

Solenoid type relay

- It consists of a solenoid & movable iron plunger.

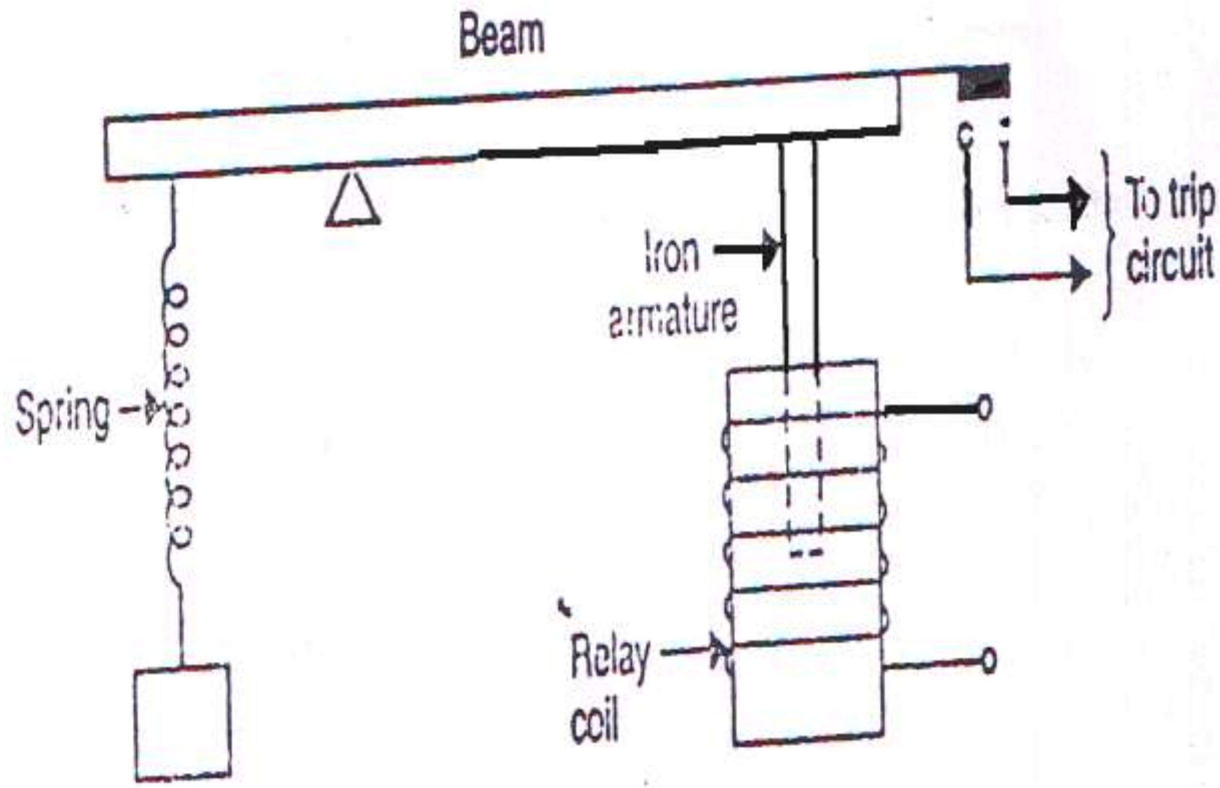


- Working :

  Under normal working conditions, the current through coil is such that it holds the plunger by gravity or spring in the position shown. However, when a fault occurs, the current through the relay coil exceeds the pick-up value, causing the plunger to be attracted to the solenoid. The upward movement of the plunger closes the trip circuit, consequently circuit breaker opens and the faulty circuit is disconnected.

Balanced Beam type relay

- It consists of an armature fastened to a balance beam.



- Working :

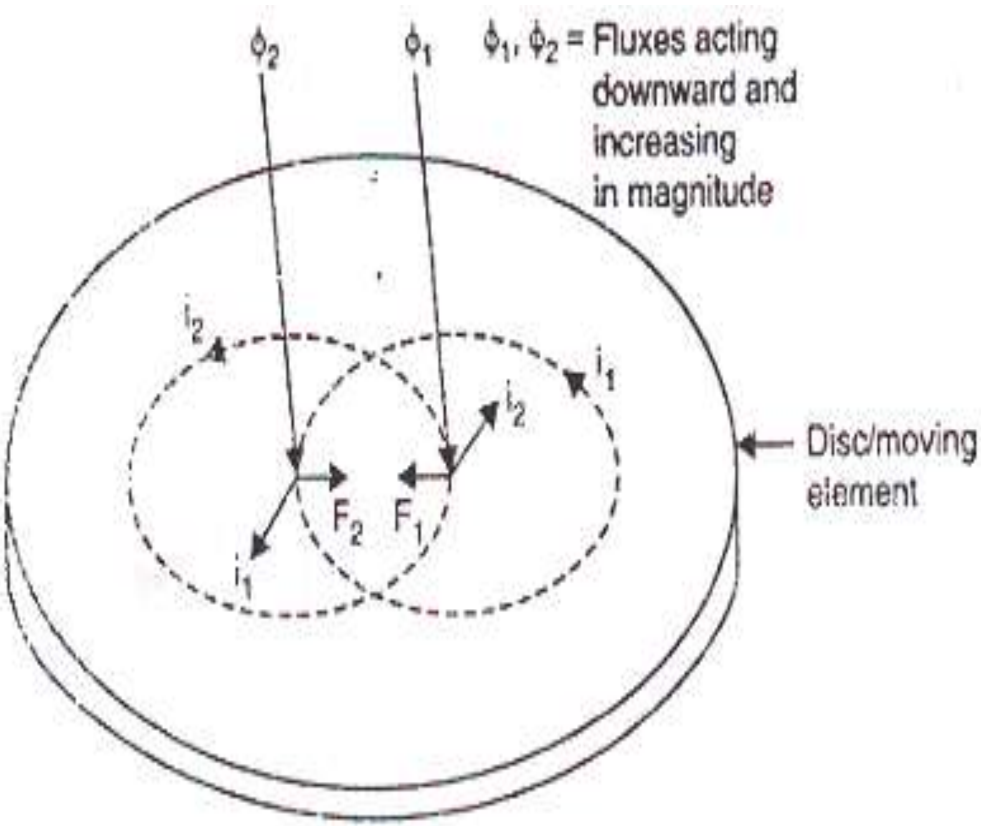
Under normal working conditions, the current through the coil is such that the beam is held in the horizontal position by the spring. However, when a fault takes place, the current through the relay coil becomes more than the pick-up value and the beam is attracted to close the circuit. Consequently the circuit breaker opens and the faulty circuit is isolated.

Torque production in Electromagnetic Induction Relay

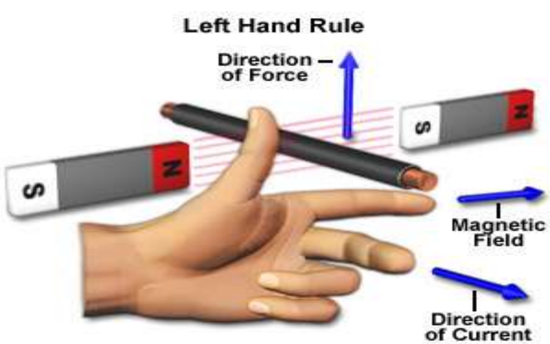
- For A.C quantities only.
- Principle : Acts on the principle of split phase induction motor. The actuating force is developed on a movable element, that may be a disc or other form of rotor of non-magnetic current-conducting material (such as aluminium) by the interaction of electromagnetic fluxes with eddy currents that are induced in the rotor by these fluxes.
- For producing torque, two fluxes displaced in space and time phase are required. Let these fluxes be

$$\phi_1 = \phi_m \sin \omega t \quad \text{(shaded pole)}$$

$$\phi_2 = \phi'_m \sin (\omega t + \theta) \quad \text{(unshaded pole)}$$



Flux $\phi 1$ is produced by the shaded pole and $\phi 2$ by the unshaded. The shaded pole flux lags that by the unshaded pole by angle θ. The two fluxes $\phi 1$ and $\phi 2$ will induce voltages e1 and e2 respectively in the disc due to induction. These voltages will circulate eddy currents in the disc of the relay. Assuming the disc to be non-inductive, these currents will be in phase with their respective voltages. Vector diagram shows the various phase relations between various vector quantities.



Direction of force can be determined by Fleming left hand rule

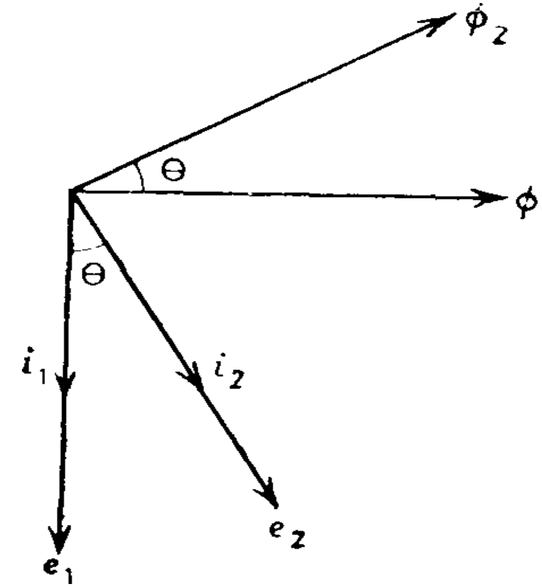
$$e_1 \propto \frac{d\phi_1}{dt}$$

$$\propto \phi_m \omega \cos \omega t$$

$$e_2 \propto \phi'_m \omega \cos (\omega t + \theta)$$

eddy current $i_1 \propto e_1$.

Assuming same resistance to flow of eddy current



$$i_2 \propto e_2$$

$$i_1 \propto \phi_m \omega \cos \omega t$$

$$i_2 \propto \phi'_m \omega \cos (\omega t + \theta)$$

- The flux $\phi 1$, will interact with eddy current i2, and $\phi 2$ will interact with i1,and since $\phi 2$ is leading $\phi 1$, the torque due to $\phi 2$ and i1, will be reckoned as positive whereas that due to $\phi 1$and i2, as negative.
- Resultant torque is

$$
\begin{aligned}
T &\propto \phi_2 i_1 - \phi_1 i_2 \\
&\propto \phi'_m \sin(\omega t + \theta) \cdot \phi_m \omega \cos \omega t - \phi_m \sin \omega t \cdot \phi'_m \omega \cos(\omega t + \theta) \\
&\propto \phi_m \phi'_m \sin(\omega t + \theta) \cos \omega t - \phi_m \phi'_m \sin \omega t \cos(\omega t + \theta) \\
&\propto \phi_m \phi'_m \sin \theta
\end{aligned}
$$

- Thus the torque is maximum when the two fluxes are displaced by 90° and since $\phi2$ leads $\phi1$, the rotation of the disc under the poles will be from unshaded pole towards the shaded pole. Also it is seen that the torque is of constant magnitude; therefore, there is no possibility of vibration.
- Control torque is provided with the help of a control spring which is attached to the spindle of the disc.
- Damping torque is provided by a permanent magnet of high retentivity steel.

Structures used in Induction relays

i). Shaded pole (disc type) structure.

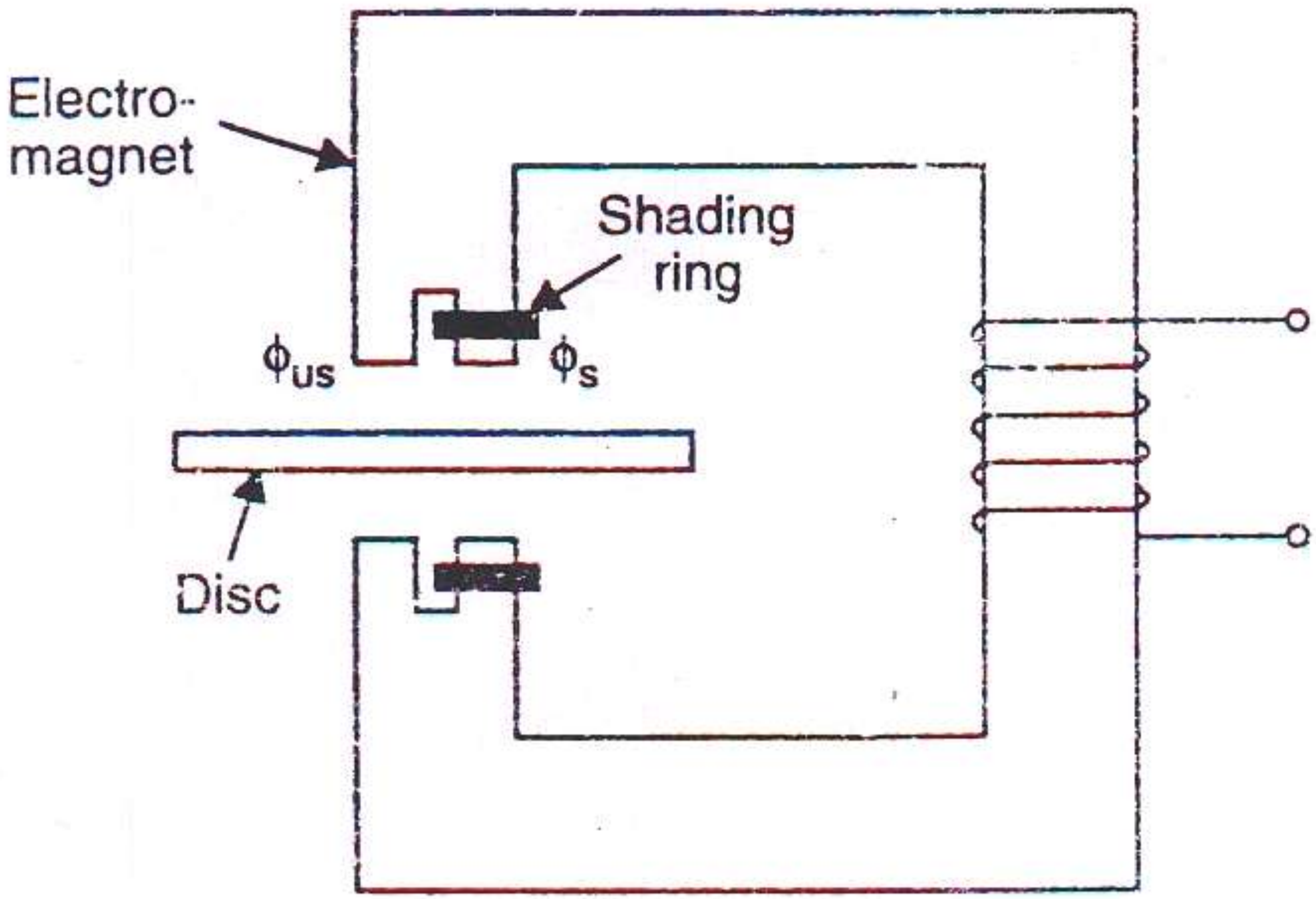
ii). Watt-hour meter or double winding structure (disc type) structure.

iii). Induction cup structure.

Shaded pole structure

- It consists of a pivoted aluminium disc free to rotate in the air-gap of an electromagnet. A portion of the pole face of each pole is surrounded by a copper band known as "shading ring". The alternator flux ϕs in the shaded portion of the poles will, owing to the reaction of the current induced in the ring, lags behind the flux ϕus in the unshaded portion by an angle $\propto$. These two A.C fluxes differing in phase will produce the necessary torque to rotate the disc. Rotation is from unshaded pole towards the shaded pole.

$$T \propto \phi_s \phi_{us} \sin \alpha$$



ϕ_s and ϕ_{us} to be each proportional to the current in the coil,

$$T \propto I^2 \sin \alpha$$

- Thus the torque is proportional to the square of the current, sin$\propto$ being constant depending upon the design.
- $T = kI^2$
- The control torque is provided with the help of a control spring which is attached to the spindle of the disc. As the disc moves towards closing of the contacts, the spring torque increases slightly with the winding of the spring. The relay disc is so shaped that as it turns towards the pick-up position (closing of contacts), there is an increase in the area of the disc between the poles of the actuating structure which causes increase in eddy currents and, therefore, increase in electrical torque that just balances the increase in the control spring torque. The shape of the disc usually is that of a spiral. The damping torque is provided by a permanent magnet of high retentivity steel.

Watt Hour Meter or Double winding structure (disc type) structure.

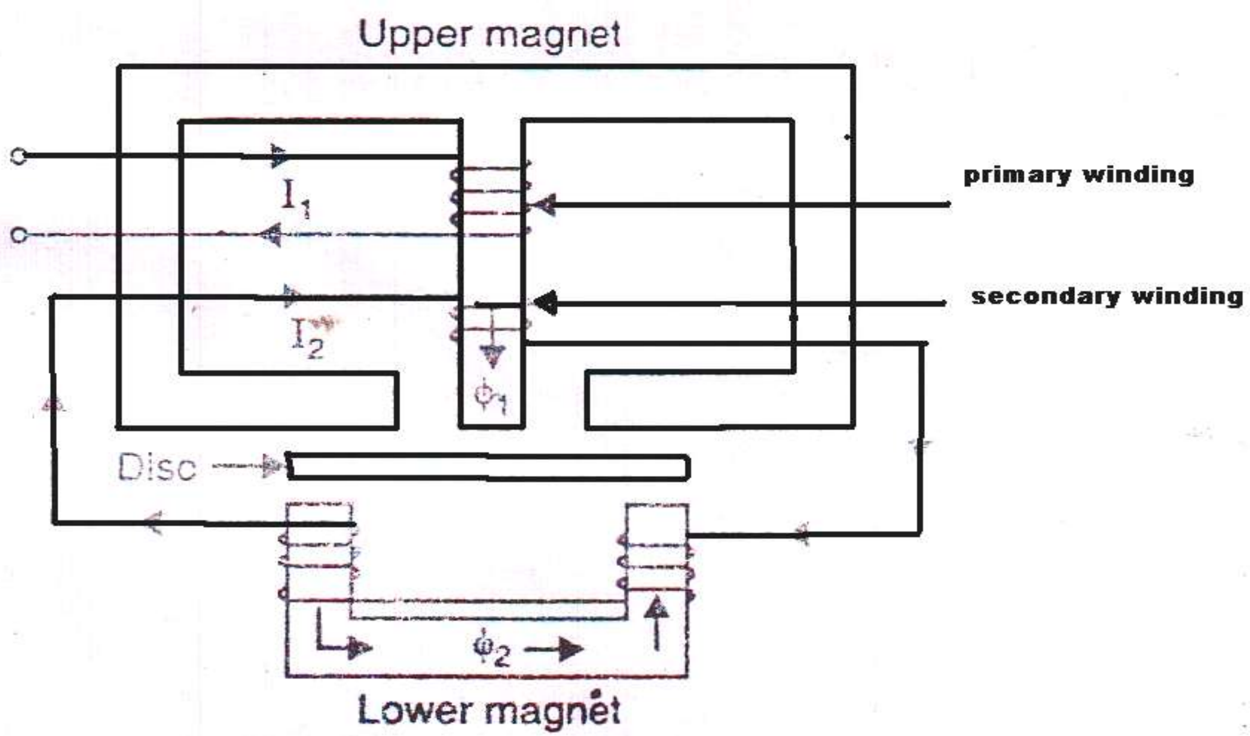
- Construction : Consists two electromagnets

  A). The upper magnet.

  B). The lower magnet.

- The upper magnet carries two windings; the primary and secondary. The primary winding carries the relay current I1, while the secondary winding is connected to the lower magnet.

- Working : . The primary current I1 induces the e.m.f in the secondary and so circulates a current I2 in it. The flux ϕ2 induced the lower magnet (by the current in the secondary winding of the upper magnet) will lag behind ϕ1 by an angle ∝



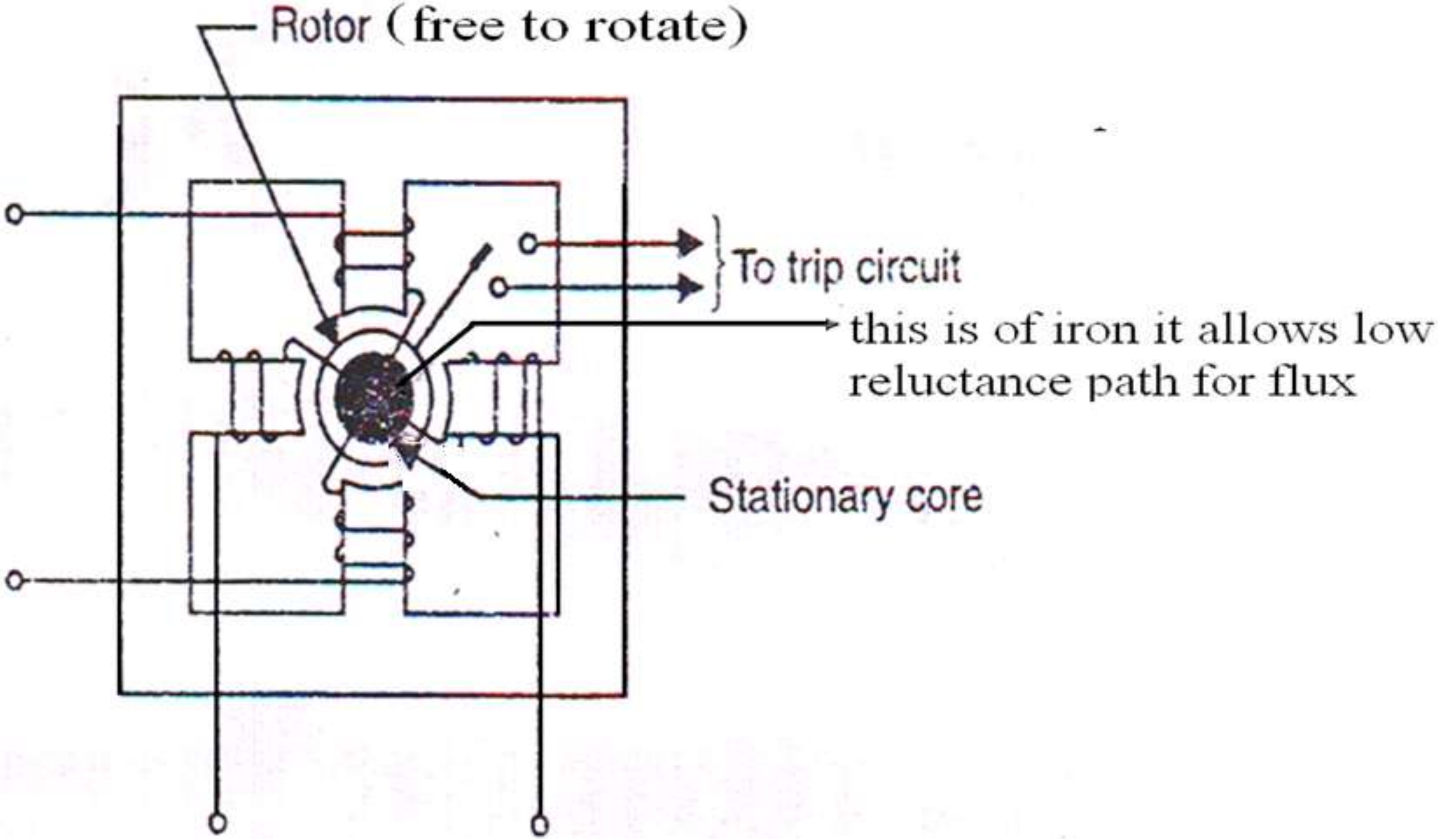
- Assuming that the whole of flux $\phi 1$ enters the disc from the lower magnet, the torque on the disc is given by:

$$T = \phi 1.\ \phi 2 \sin\propto$$

a). its operation can be controlled by opening or closing of the secondary winding circuit. If this circuit is opened, no torque will be produced & thus the relay can be made inoperative.

b). Majority of the induction type of relays are of double winding structure.

Induction Cup structure



- It closely resembles an induction motor, except that rotor iron is stationary, only the rotor conductor portion being free to rotate.
- The moving iron is a hollow metal cylinder or cup, which turns on its axis.
- The rotating field is produced by two pairs of coils wound on a four poles as shown in fig.

- The rotating field induces currents in the cup to provide the necessary driving torque. If $\phi 1$ and $\phi 2$ represent the fluxes produced by respective pair of poles and $\propto$ is the phase difference between the two fluxes then the torque produced is given as :

$$T = \phi 1 . \phi 2 \sin \propto$$

- It is more efficient torque producer.

- It has a very high speed and may have an operating time less than 0.1 sec.
- The ratio of reset to pick-up is inherently high in case of an induction relay as compared to attracted armature relays, as their operation doesn't involves any change in the air gap of the magnetic circuit as it is in the case of latter. The ratio lies between 95 – 100%. This is not perfectly 100% because of friction & imperfect compensation of the control spring torque.

OVER CURRENT RELAYS

- Depending upon the time of operation the relays are categorized as:

(i) Instantaneous over-current relay

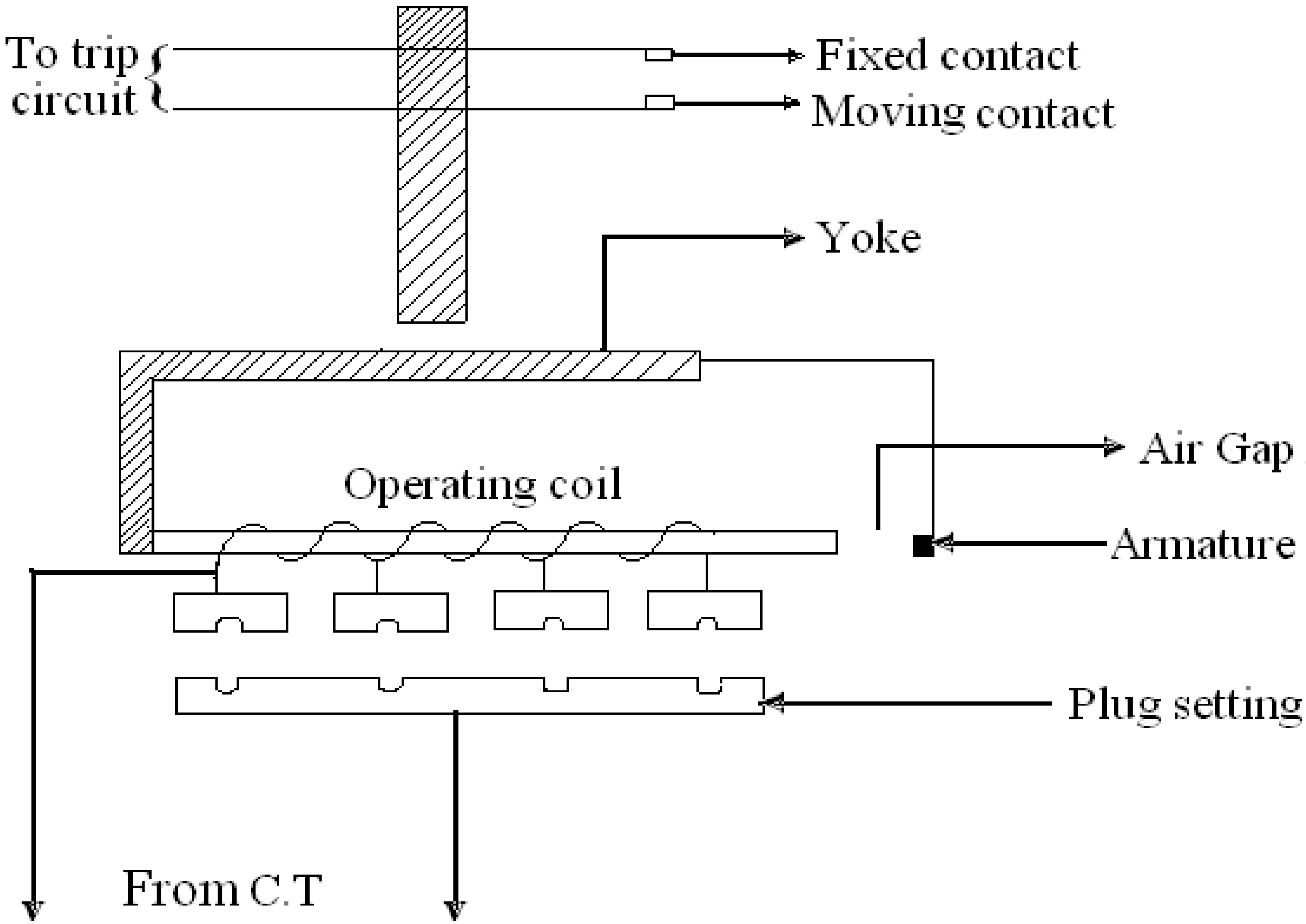
(ii) Inverse time-current relay

(iii) Inverse definite minimum time (IDMT) over-current relay

(iv) Very inverse relay

(v) Extremely inverse relay.

Instantaneous Over-current relay



- No intentional time delay is provided.
- Time of operation is approximately 0.1 sec
- This characteristic can be achieved with the help of hinged armature relays.
- The instantaneous relay is more effective where the impedance Zs between the source and the relay is small compared with the impedance Z, of the section to be protected.

- Operation : Two operating points of the relay are connected to the C.T when the current flows through the coil. An mmf will be developed in the O.C equal to the NI. The flux developed in air gap mmf/reluctance. Reluctance is constant, hence
- Ø α mmf

  Ø will develop flux density which has cross sectional area therefore
- B α Ø as cross sectional area is const.

- The force on the armature is $F \alpha B^2$

  and $B \alpha Ø$ therefore $Ø = NI$, therefore
- $F= (NI)^2$
- This force tries to move this armature towards the electromagnet only, when the force developed on the armature is greater than force developed on the steel spring. The force developed on the armature tries to move the steel spring upwards.

- A relay is said to operate when its contacts get closed. Thus the moving contacts moves upward & relay is said to operated.
- Armature will move towards the electromagnet when $F > k$

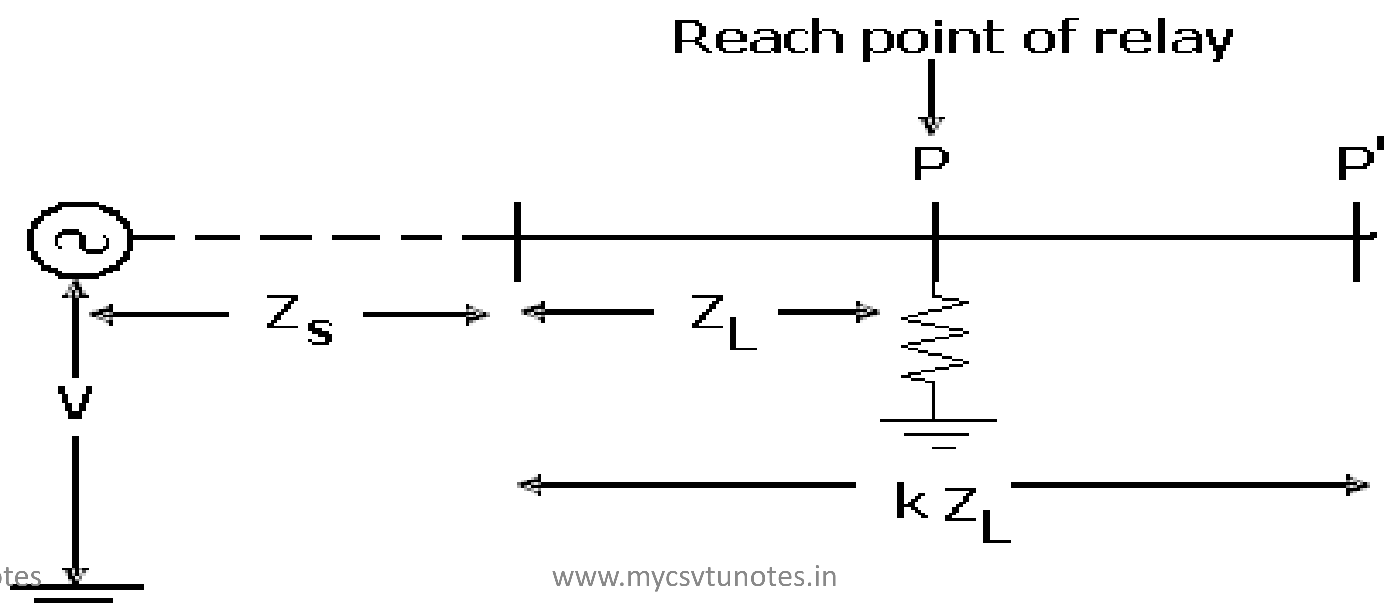
  k = depends on stiffness of steel strip
- Relay operates when $F > k$
- When relay picks up $F = k$
- Where $F \alpha (NI)^2$ at pick up condition.
- Therefore at pickup condition

  $(NI)^2 = k$

- In the pickup condition of the relay, the relay is on the verge of the operation.
- The current that flows through the relay in the pickup condition is known as I pickup
- $I_{pickup} = \sqrt{k/N}$

- Over current protection is used for short X-mission line. When this relay is used for over current protection of line, it suffers from drawback of overreach. There are two causes of overreach :
- 1). Short operating time of relay.
- 2). Initial offset nature of the fault current.

- Derivation : Prove that for 100% offset in fault current overreach factor of instantaneous over current relay is grater than 2.
- Solution : Let k be the over-reach factor of the instantaneous over current relay



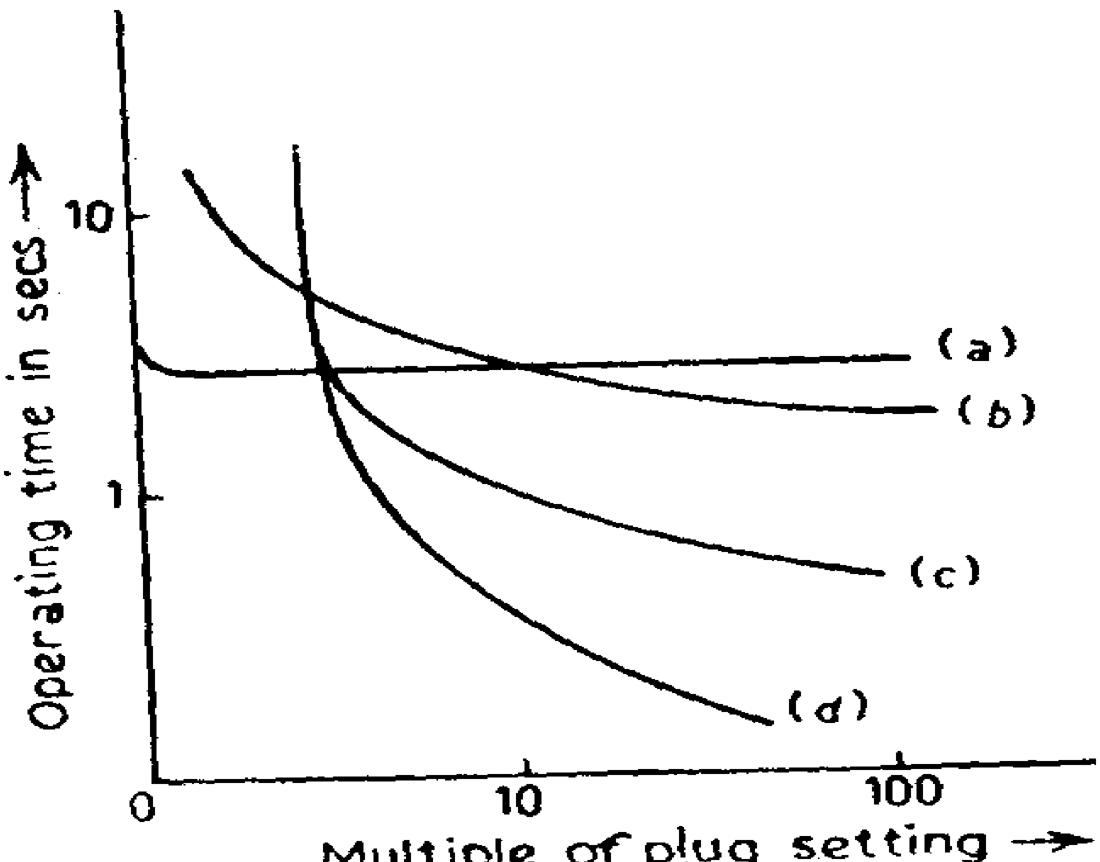
- For a fault occuring at P’ steady state value of fault current = V/ (Zs + kZL)
- For 100% offset, initial value of fault current = 2V/(Zs + kZL)
- This current will be just sufficient to operate the relay & it is equal to pickup value
- Ie. V/(Zs + ZL)

- Equating
- $V/(Z_s + Z_L) = 2V/(Z_s + kZ_L)$
- $Z_s + kZ_L = 2 Z_s + 2 Z_L$
- $Z_s = (k-2)Z_L$
- $k = (Z_s/Z_L) + 2$
- Hence proved

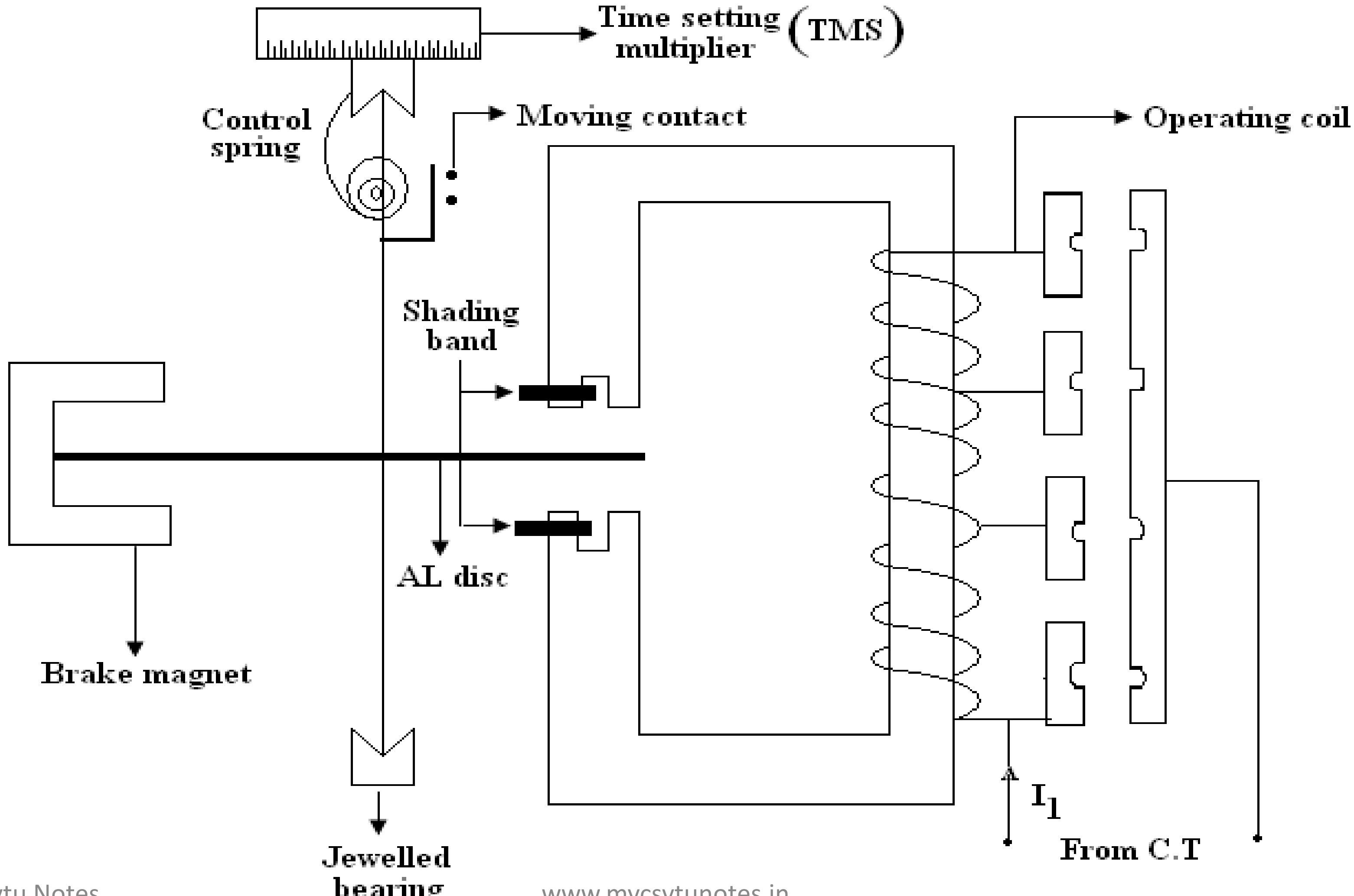
Inverse Time Current Relay

- Operating time reduces as the actuating quantity increases in magnitude.
- They are normally more inverse near the pick up value of the actuating quantity and become less inverse as it is increased.
- This characteristic can be obtained with induction type of relays by using a suitable core which does not saturate for a large value of fault current.
- If the saturation occurs at a very early stage, the time of operation remains same over the working range.

- The characteristic is shown by curve (a) in Fig. 14.6 and is known as definite time characteristic:



Inverse Definite Minimum Time Lag Relay



- This relay is also an over current relay.
- Operating time is approximately inversely proportional to the fault current near pick up value and becomes substantially constant slightly above the pick up value of the relay.
- This is achieved by using a core of the electromagnet which gets saturated for currents slightly greater than the pick up current.

- Here, electromagnet is split into 4 parts. On 2 of the 4 parts shading bands are placed. An Al disc can rotate on vertical axis which is rested on jewel bearing to reduce friction.
- Other end is fixed to brake magnet (permanent magnet). One end of axis is connected to control spring other end of spring is connected to jewelled bearing which is then connected to time settinng multiplier

- Operation : It also consists of flux setting arrangement. Alternating current develops an mmf and thus the flux Ø through electromagnet and will get divided into 2 parts Ø1 & Ø2, which will differ in time phase due to presence of shading bands and a torque will move the disc. As soon as the AL disc rotates rotates brake magnet develpos a magnetic flux which cuts the AL disc & as a result in this part of Aldisc an emf is induced which causes a current to flow through the AL disc. This is the induced current.

- Acc. To lenz's law, this induced current will oppose its cause (motion of the disc) w.r.t. the brake magnet. This induced current will develop a torque by acting with the magnetic flux crated by permanent magnet in direction opposite to the motion of AL disc hence will reduce the relative motion or speed of AL disc. Hence if the speed of AL disc reduces it will reduce the operating time of relay.

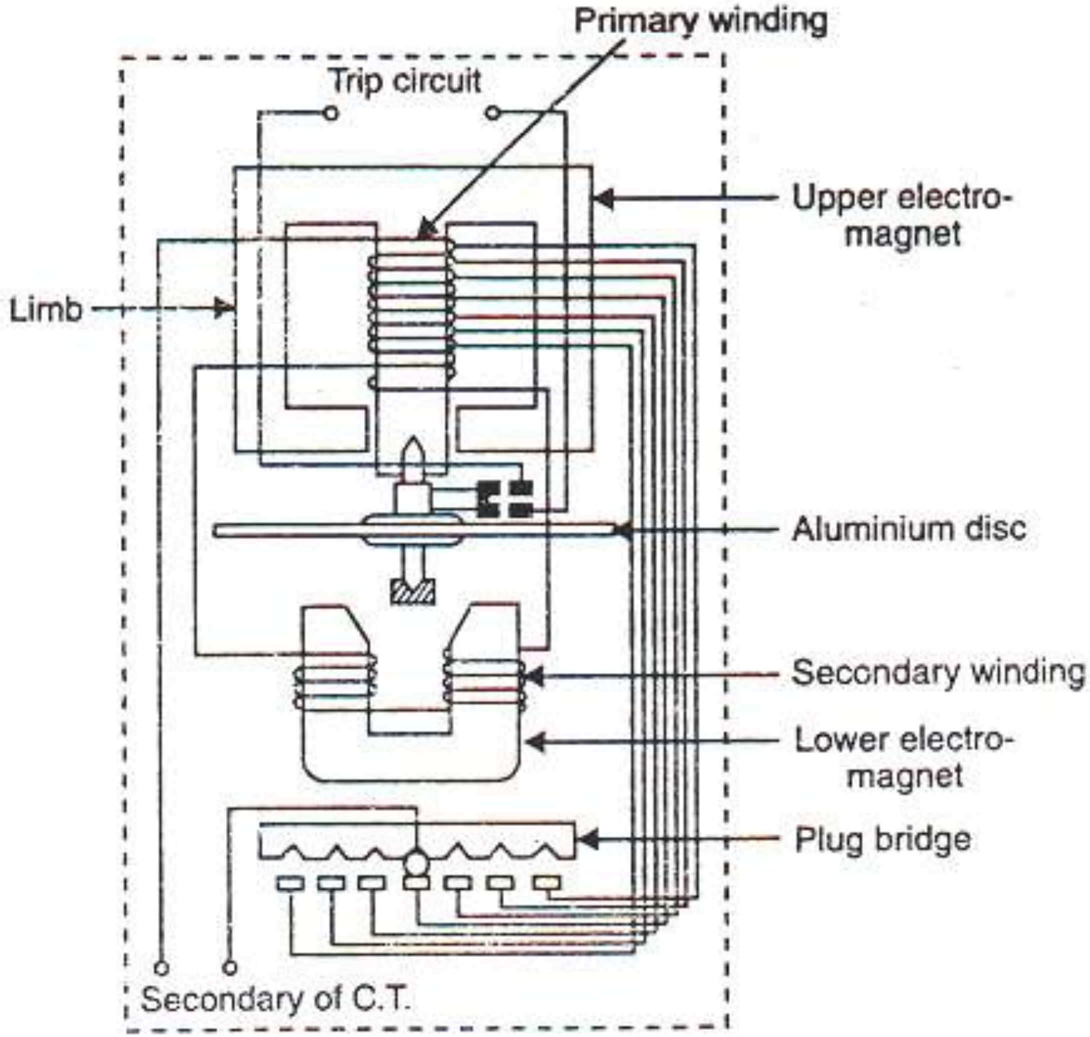
Very Inverse Relay

- Saturation of the core occurs at a later stage, the characteristic assumes the shape as shown in Fig. 14.6(c)
- The time-current characteristic is inverse over a greater range and after saturation tends to definite time.

Extremely Inverse Relay

- Saturation occurs at a still later stage than curve (c).
- The equation describing the curve (d) in the figure is approximately of the form $I^2t = K$, where 'I' is the operating current and 't' the operating time.
- Note: The inverse time current relays are non-directional relays and are used for the protection of feeders, transmission lines, transformers, machines, etc.

INDUCTION TYPE NON-DIRECTIONAL OVERCURRENT RELAY OR EARTH LEAKAGE RELAY



- Operates on induction principle.
- The actuating source is a current in the circuit supplied to the relay from a Current transformer (C.T).
- This relay gives inverse time operation with a definite minimum time characteristic.
- These relays are used on A.C circuits only and can operate for fault current flow in either direction.

- **Construction**: It consists of an aluminium disc which is free to rotate between two magnets. The upper electromagnet has three limbs whereas the lower electromagnet has two limbs. The upper magnet has a primary and secondary winding. The primary winding (wound on the central limb of the upper magnet) 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 plug setting bridge by which the number of active turns on the relay operating coil can be varied, thereby giving the desired current setting.

- The secondary winding is a closed one and wound on the central limb of the upper magnet and the lower magnet and this winding is energized by the primary winding. The controlling torque is provided by a spiral spring. The spindle of a disc carries a moving contact which bridges two fixed contacts (connected to trip circuit) when the disc rotates through a preset 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 and hence the relay can be given any desired time setting.

- **Operation** : The fluxes produced by the primary and secondary windings are separated in phase and space and a rotational torque is set-up on the aluminium disc. 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 and hence the aluminium disc remains stationary. However, when the current in the protected circuit exceeds the preset 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 preset angle. The trip circuit operates the circuit breaker and the faulty section is isolated.

- Characteristic curve:

  Since the time required to rotate the disc through the preset angle depends upon the torque which varies as the current in the primary circuit, therefore more the torque, lesser will be the time required. So the relay has inverse time characteristic of an induction relay.

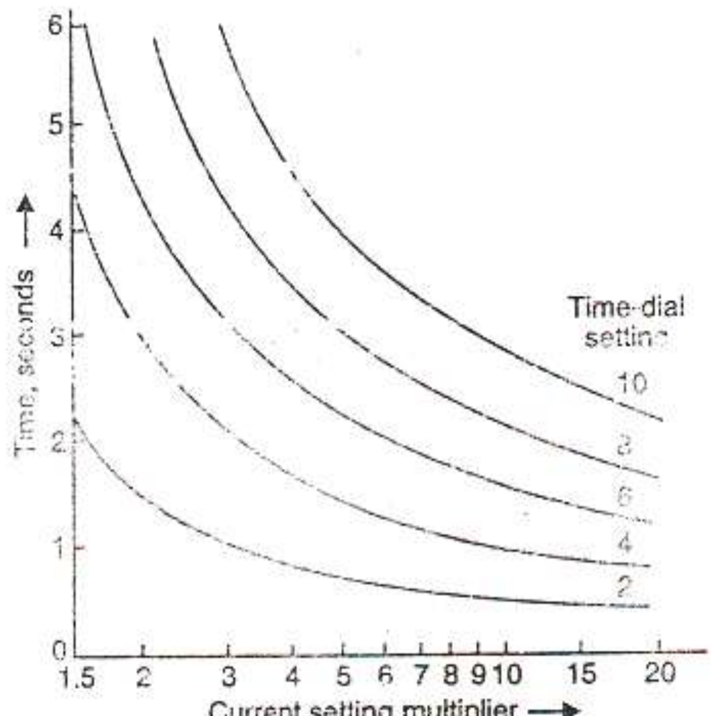


Fig. 23.16. Current-time characteristic of an induction relay.

DIRECTIONAL OVERCURRENT RELAY

- The relay consists of two units:

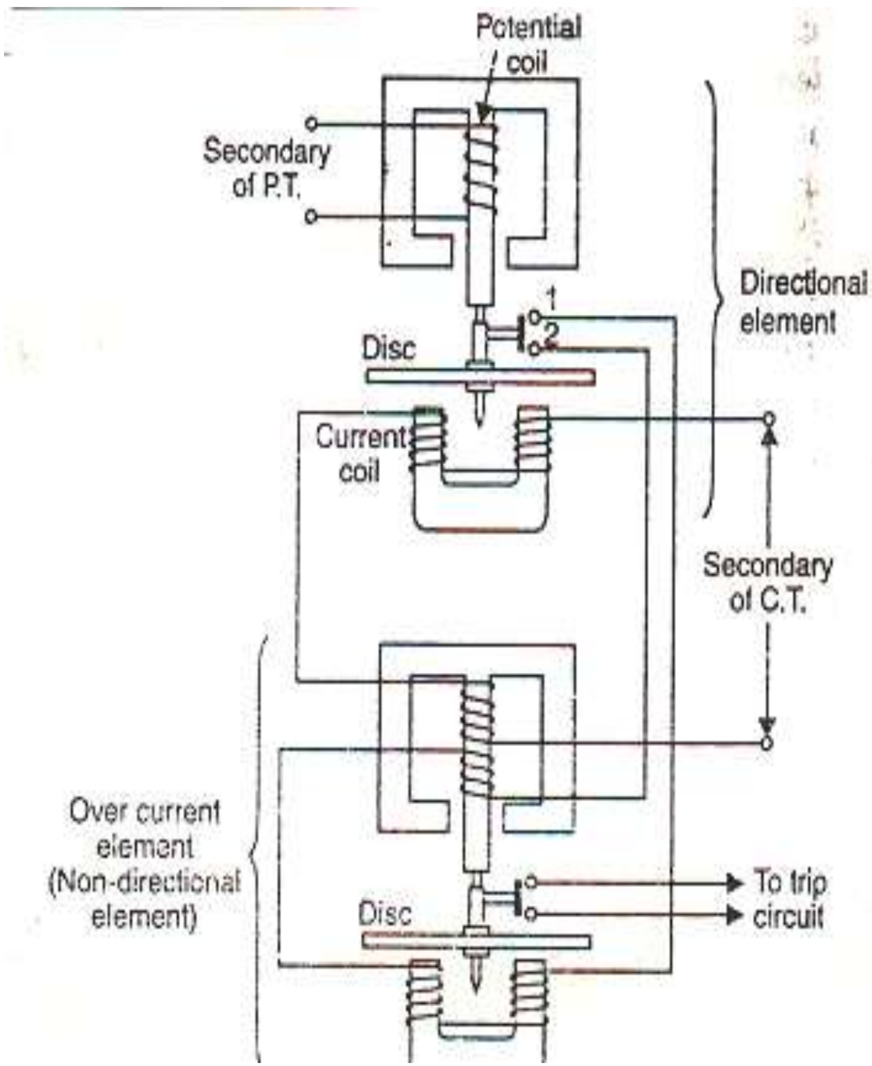
  i). Directional unit and,

  ii). Non-directional or inverse time current unit (over current unit)

- Directional Unit :

  i). Consists of four pole induction cup unit. Two fed with voltage, other two fed with current, therefore two flux produced which is essential for production of torque.

  ii). Directional unit means it will operate for only one designed direction and restrain for another direction.



$$T = K_1 VI - K$$

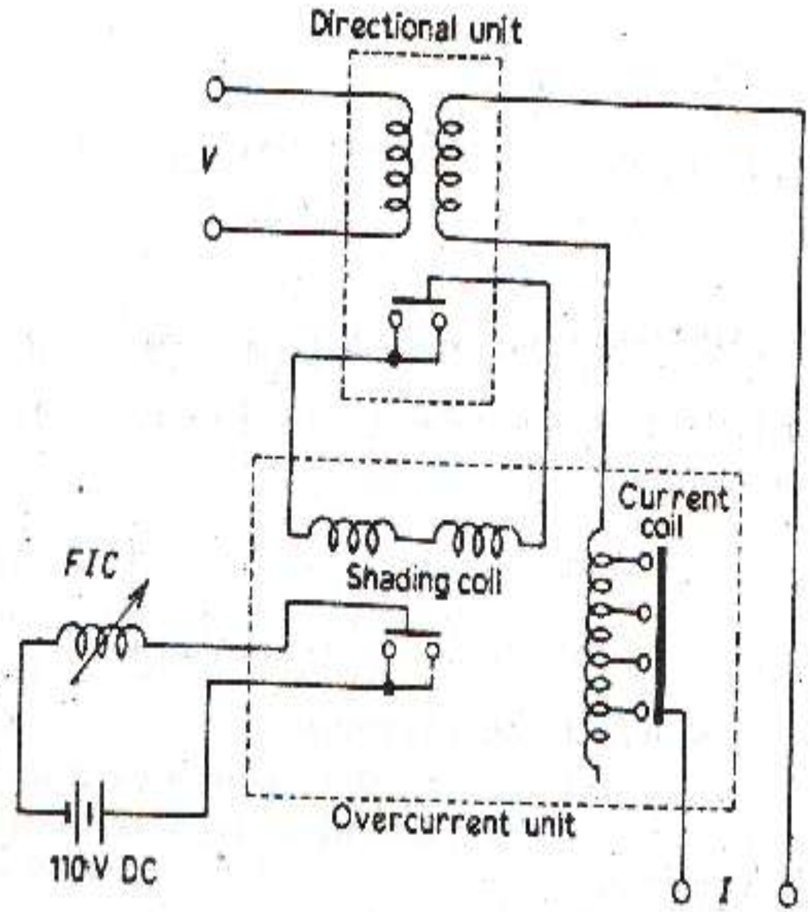


Fig. 14.8 Internal connection diagram of a directional over-current relay

- Over current unit will not energize unless directional unit contacts are closed.
- The torque developed by a directional unit is given by

$$T = VI \cos(\theta - \tau) - K$$

Where V = rms magnitude of the voltage feed to the voltage circuit.

I = rms magnitude of current in current coil

θ = the angle between I and V,

τ = the maximum torque angle

K = restraining torque including spring and friction

- Say for a particular installation $\cos(\theta - \tau)$ = constant K1, then the torque equation becomes

  $T = K1\ VI - K$

- Under threshold condition when the relay is about to start,

  $T = 0 = K1\ VI – K$

  $VI = K/K1 = K' = \text{constant}$

- Constant product characteristic & is of the form of rectangular hyperbola as shown in fig.

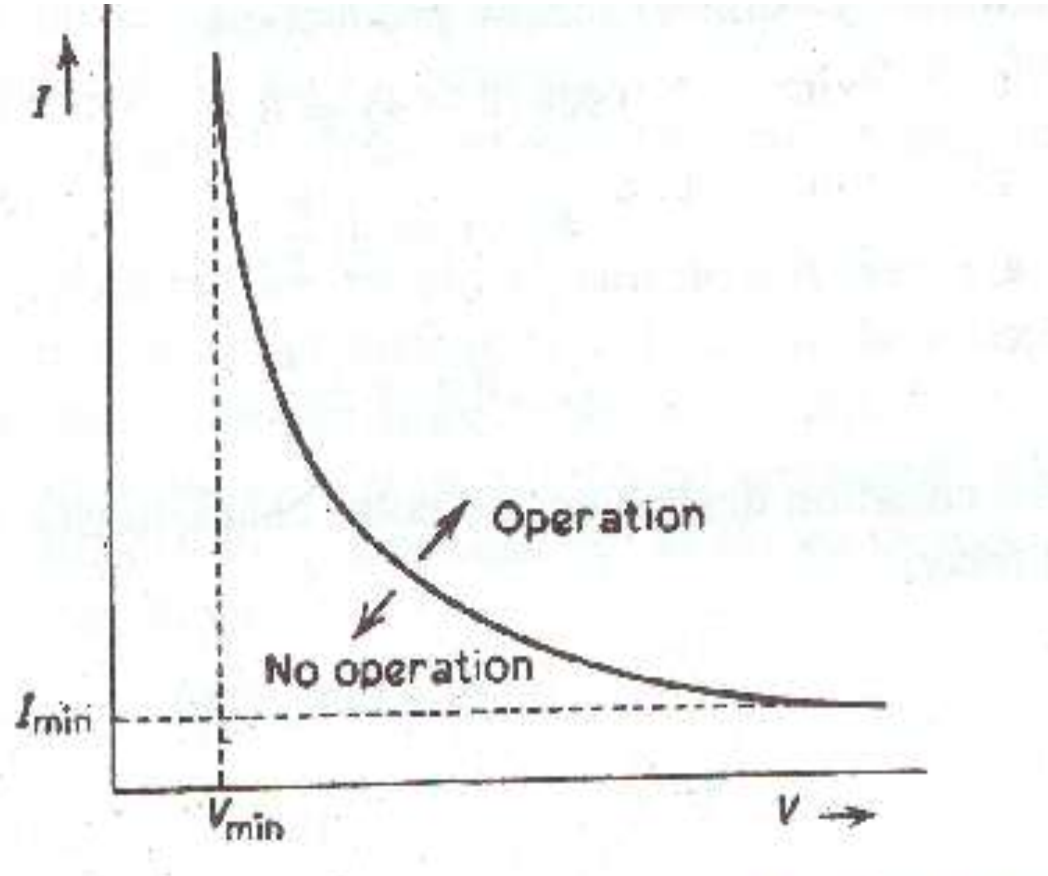


Fig. 14.9 Constant product characteristic of a directional relay

- For the operation of the relay the product of *V* and *I* should give a minimum torque which exceeds the friction and spring torque. From the characteristic it is clear that it is not enough to have the product greater than K' but there is a minimum value of voltage and a minimum value of current required for the torque to be developed. The product of any value of voltage and any value of current to exceed K' is not enough. *Say A* is the location of the directional relay (Fig. 14.10). In case the fault is close to the relay the voltage to be fed to the relay may be less than the minimum voltage required. The maximum distance up to which the voltage is less than the minimum voltage required is known as the dead zone of the directional relay, i.e. if the fault takes place within this zone the relay will not operate.

- Consider the torque equation again

$T = VI \cos(\theta - \tau) - K$

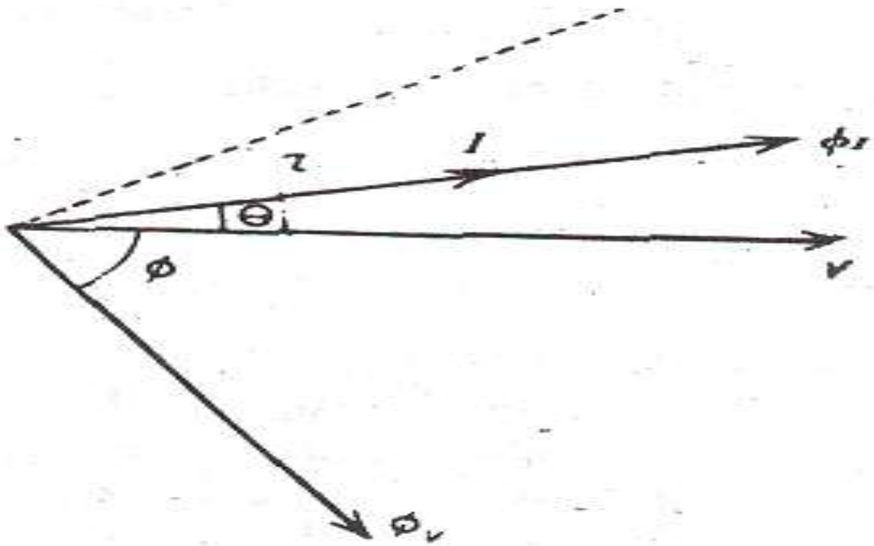


Fig. 14.11 Phasor diagram of a directional relay

where ϕv is the flux due to the voltage coil,

- Torque is produced by the interaction of ϕv and ϕi and is maximum when $\theta = 90°$
- Dotted line represents the desired position of ϕi for the maximum torque.

- Angle between dotted line and the polarizing quantity V is known as the maximum torque angle, denoted by τ.
- Referring again the torque equation, if V is fixed and under operating condition K is negligible, then

$$I \cos(\theta - \tau) = 0$$

Since I cannot be zero for torque production

$$\cos(\theta - \tau) = 0$$

$$\theta - \tau = \pm \frac{\pi}{2}$$

$$\therefore \quad \theta = \tau \pm \frac{\pi}{2}$$

This is the equation describing the polar characteristic of the directional relay

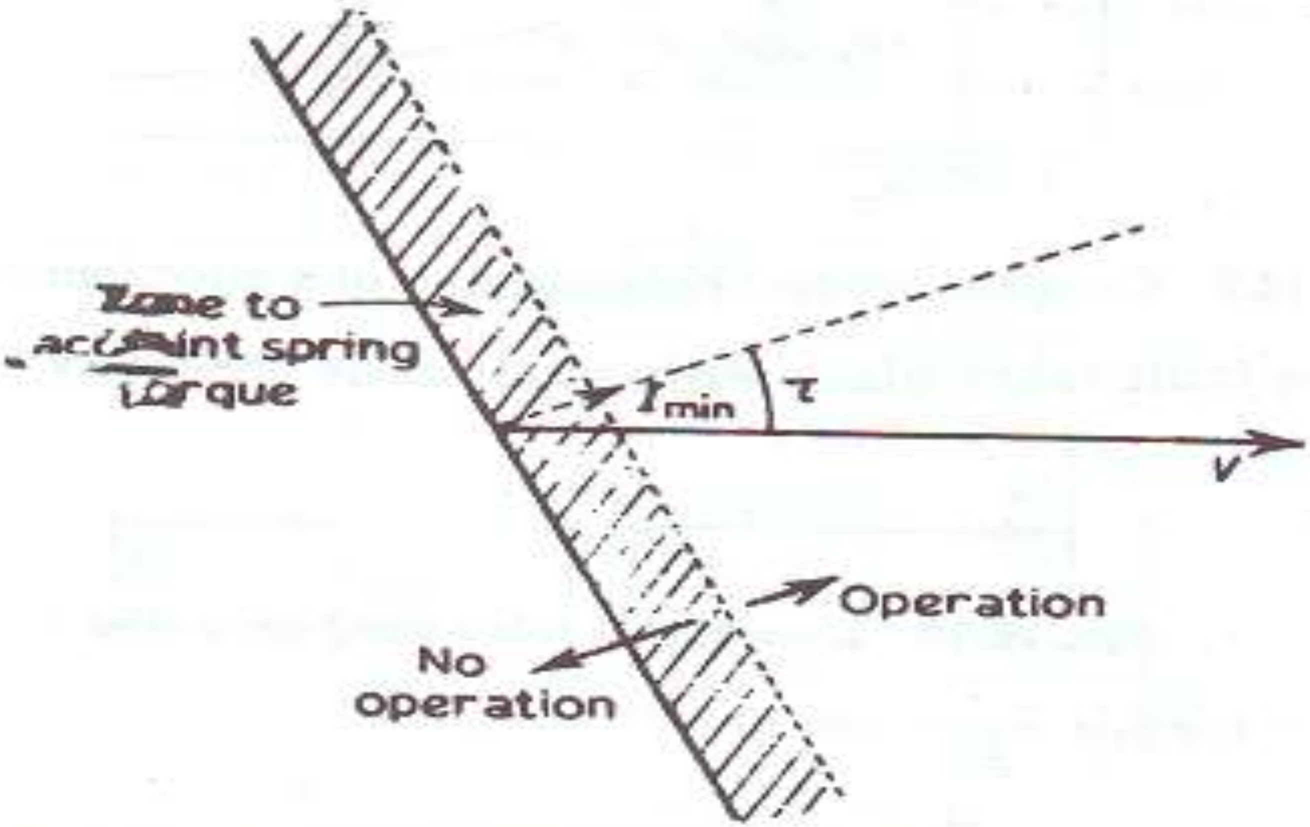


Fig. 14.12 Polar characteristic of directional relay

The zone between the dotted line and the line parallel to it corresponds to the spring torque. If the current vector lies within these lines the torque developed is less than the spring torque and hence the relay does not operate. If the current crosses the dotted line the spring torque is less than the operating torque and hence the relay operates. This relay is almost independent of voltage and power factor of the system.

INDUCTION TYPE DIRECTIONAL POWER RELAY

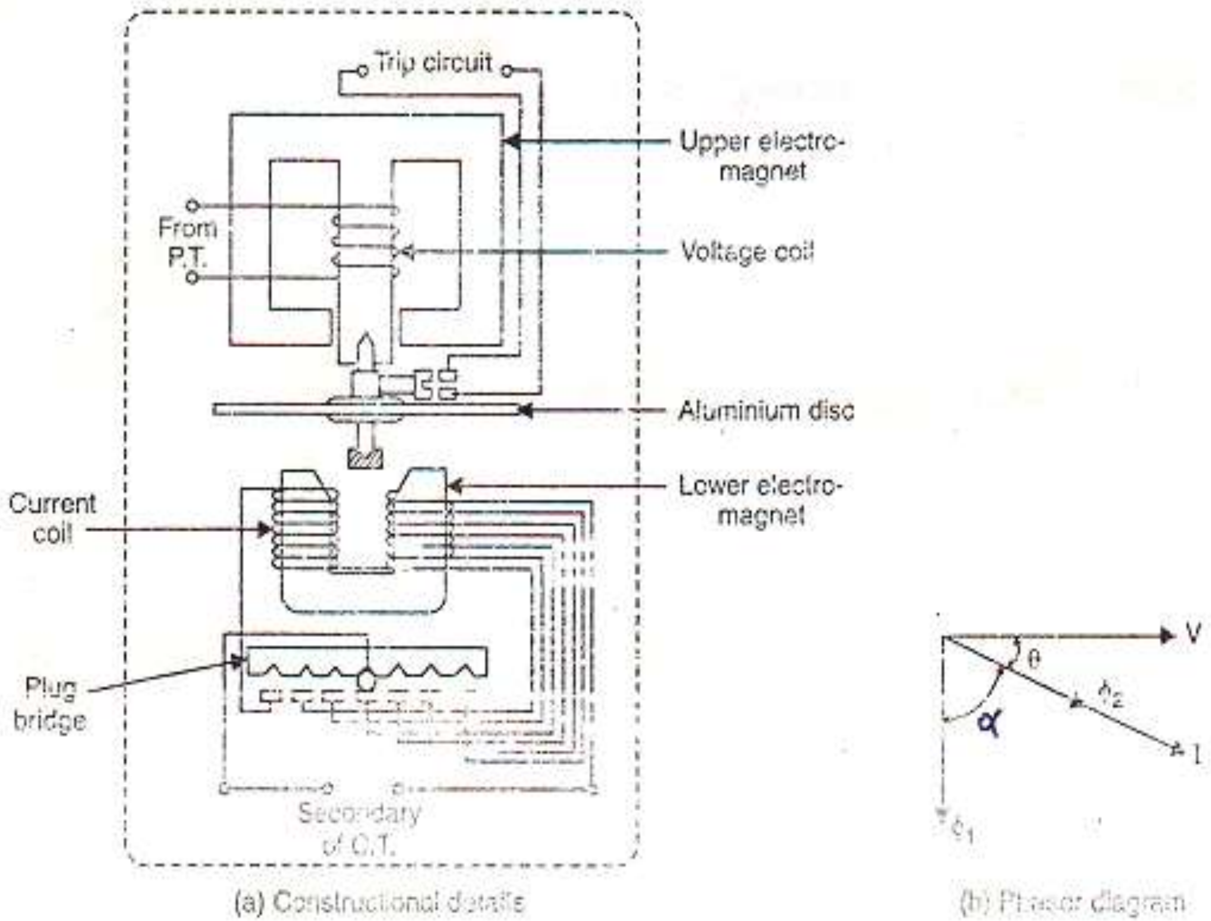


Fig. 23.17. Induction type directional power relay.

- **Principle** : It operates when power in the circuit flows in a specific direction. This type of relay, unlike a non-directional overcurrent relay (where the driving torque is due to the interaction of magnetic fields derived from current in the relay winding), is so designed that it obtains its operating torque by interaction of magnetic fields derived from both voltage and current source of the circuit it protects.

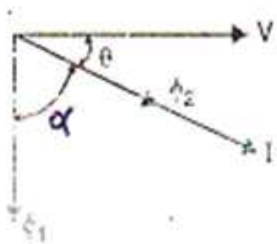
- This type of relay is essentially a wattmeter and the direction of the torque set up in the relay depends upon the direction of the current relative to the voltage with which it is associated.

- **Construction**: It consists of an aluminium disc which is free to rotate between the poles of two electromagnets. The upper electromagnet carries a winding, (called potential coil) on the central limb which is connected through a P.T. (Potential transformer) to the circuit voltage source. The lower electromagnet has a separate winding (called current coil) connected to the secondary of C.T (current transformer) in the line to be protected.

- The current winding is provided with tappings which are connected to the plug bridge, this permits to have any desired current setting. The restraining torque is provided by a spiral spring.

  The spindle of the disc carries a moving contact which bridges two fixed contacts when the disc has rotated through a preset angle. By adjusting this angle, the travel of the moving disc can be adjusted and hence any desired time-setting can be given to the relay.

- **Working** : refer fig (b). The flux ϕ1 due to current in the potential coil will lag behind the applied voltage V by nearly 90 deg. The flux ϕ2 due to the current coil will be nearly in phase with the operating current I. The interaction of fluxes ϕ1 & ϕ2 with eddy currents induced in the disc produces a driving torque which is given by



(b) Phasor diagram

$$T \propto \phi_1 \phi_2 \sin \alpha$$

Also, $\phi_1 \propto V, \phi_2 \propto I$ and $\alpha = 90° - \theta$

$$\therefore \quad T \propto VI \sin(90° - \theta)$$

$$\propto VI \cos\theta$$

$\propto$ power in the circuit

- Obviously the direction of driving torque on the disc depends upon the direction of power flow in the circuit to which the relay is associated.
- If the power in the circuit flows in the normal direction, the driving torque and the restraining torque (due to spring) help each other to turn away the moving contact form the fixed contacts and consequently the relay does not operate.

- However, when the current in the circuit reverses the direction of driving torque on the disc also reverses. When the reversed driving torque is large enough, the disc rotates in the reverse direction and the moving contact closes the trip circuit. Subsequently the circuit breaker operates and the faulty section is isolated.

UNIVERSAL TORQUE EQUATION

- Torque developed by current winding = $K_1 I^2$
- Torque developed by voltage winding = $K_2 V^2$
- If both current and voltage windings are employed

  $T = K_3\ VI \cos(\theta - \tau)$

  Where θ = angle between V and I, and

  τ = value of torque angle (known as relay maximum torque angle); it is the design constant of the relay

- When all the elements are present

  $T = K_1 I^2 + K_2 V^2 + K_3\ VI\cos(\theta - \tau) + K$

  Where

  k_1, k_2, k_3 = tap settings or constants of I and V, and

  K = mechanical constraints due to spring or gravity.

- By assigning plus or minus signs to some of the terms and letting others be zero and sometimes adding some terms having a combination of voltage and current, the operating characteristics of all types of relays can be obtained.
- For example, for over-current relay K2 = 0, K3 = 0 and the spring torque will be -K. Similarly, for directional relay, K1 = 0, K2 = 0.

DISTANCE RELAYS

- Impedance relays
- Reactance relays
- Mho relays

IMPEDANCE RELAY

- From the universal torque equation putting K3 = 0 and giving negative sign to voltage term, it becomes
- $T = K_1 I^2 - K_2 V^2$ (neglecting spring torque)
- This means the operating torque is produced by the current coil and restraining torque by the voltage coil, which means that an impedance relay is a voltage restrained over–current relay.

- For the operation of the relay the operating torque should be greater than the restraining torque, i.e.

$$K1I^2 > K2V^2$$

$$V^2/I^2 < K1/K2$$

$$Z < \sqrt{K1/K2}$$

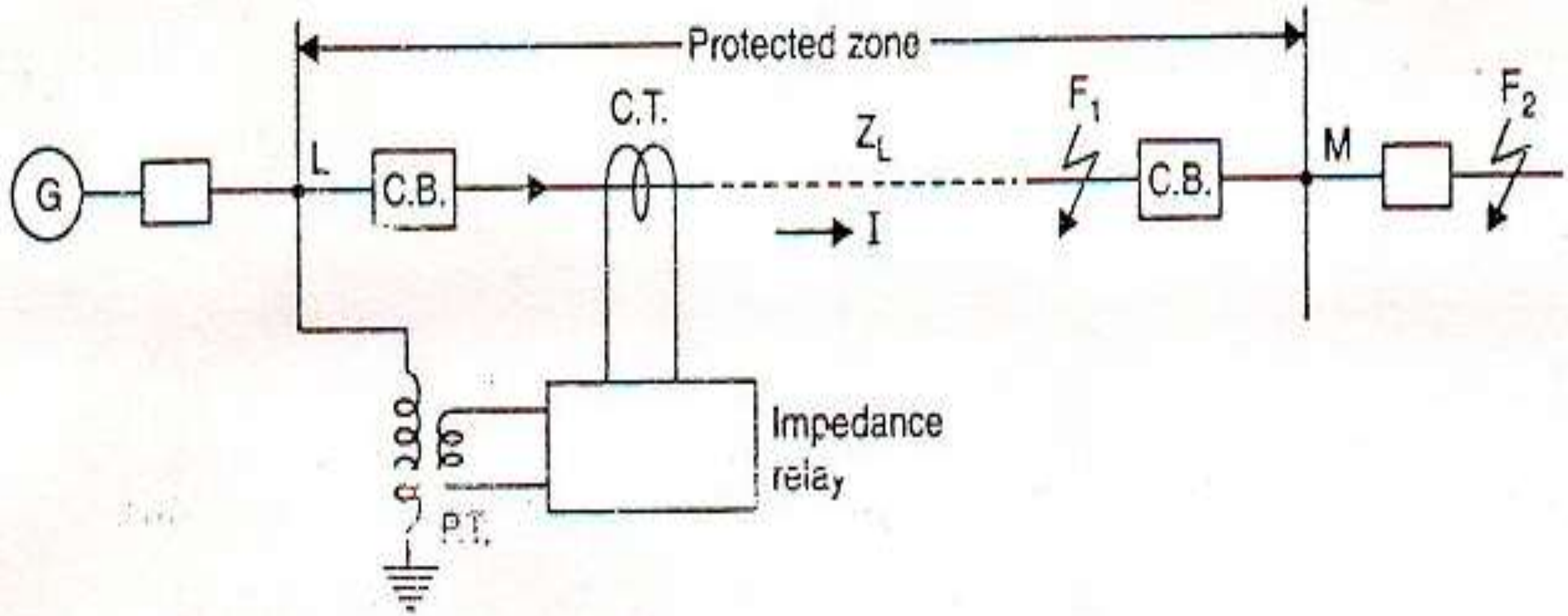
$$Z < \text{constant (designed impedance)}$$

- This means that the impedance relay will operate only if the impedance seen by the relay is less than a prespecified value (design impedance). At threshold condition

$$Z = \sqrt{K1/K2}$$

- Impedance relay is an ohmmeter and operates whenever the impedances of the protected zone falls below a predetermined value.

- Working : The relay operates when the ratio V/I is less than the predetermined value



G = Generator   P.T. = Potential transformer

C.B. = Circuit breaker   C.T. = Current transformer

F_1, F_2 = Faults (location)

Fig. 23.29. Basic principle of operation of an impedance relay.

- The voltage element of the relay is excited through a P.T from the line to be protected. The current element of the relay is excited from a C.T in series with the line. The portion LM (ZL) of the line is the protected zone.

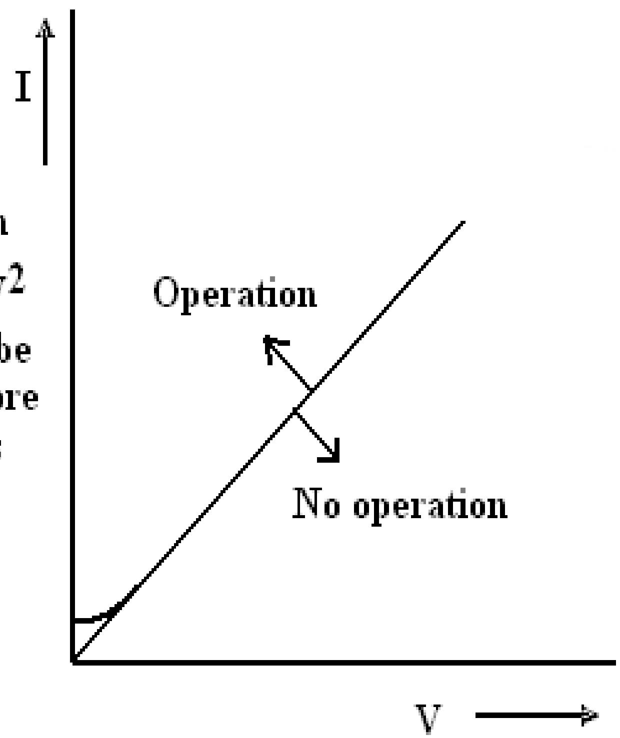
- On the occurrence of the fault at point F1 in the protected zone, the impedance Z (=V/I, V and I being substation voltage and the fault current respectively) between the point where the relay is installed and the point of fault being less than ZL, the relay will operate. However, the relay will not operate if the fault occurs beyond the protected zone (say point F2), since Z is greater than ZL at this point.

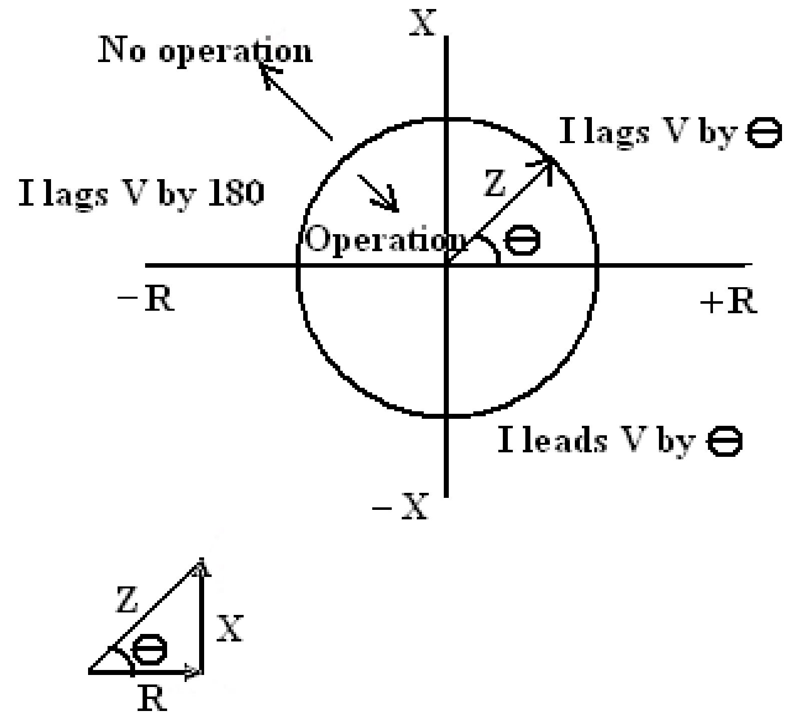
- Operating characteristic of Impedance relay on VI and R-X diagram

For operation

$K_1 I^2 > K_2 V^2$

i.e, I should be more therefore operation is towards increasing current.



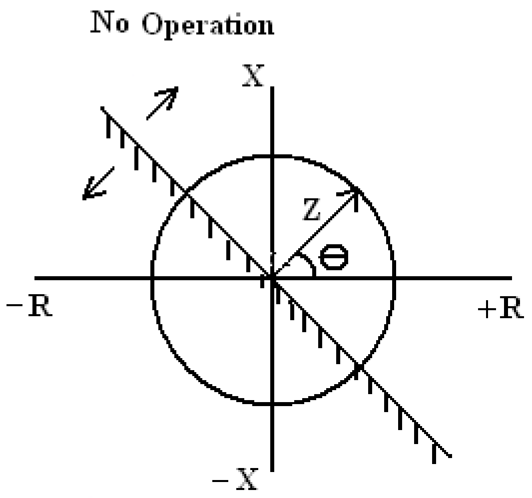


- The initial bend in the V-I characteristic is due to the presence of spring torque
- Form R-X diagram it is clear that if the impedance as seen by the relay lies within the circle the relay will operate; otherwise, it will not.
- In case the two were in phase, the Z vector would have coincided with +R -axis. In case the current was lagging the voltage by 180°, the Z vector would coincide with –R -axis.

- The impedance relays normally used as high speed relays.
- These relays may use a balance beam structure or an induction cup structure.

- It is to be noted here that -R-axis does not mean here negative resistance axis but the one as explained. When I lags behind V, the Z vector lies in the upper semi-circle and Z lies in the lower when I leads the voltage. Since the operation of the relay is independent of the phase relation between *V* and *I*, the operating characteristic is a circle and hence it is a non-directional relay.
- The directional property to the impedance relay can be given by using the impedance relay along with a directional unit.

This means the impedance unit will operate only when the directional unit has operated



It is clear that if the impedance vector as seen by the relay lies in a zone indicated by the thick line, the relay will operate, otherwise it will not.

TYPES OF IMPEDANCE RELAY

(1). Definite-distance relay

(2). Time-distance relay

DEFINITE DISTANCE RELAY

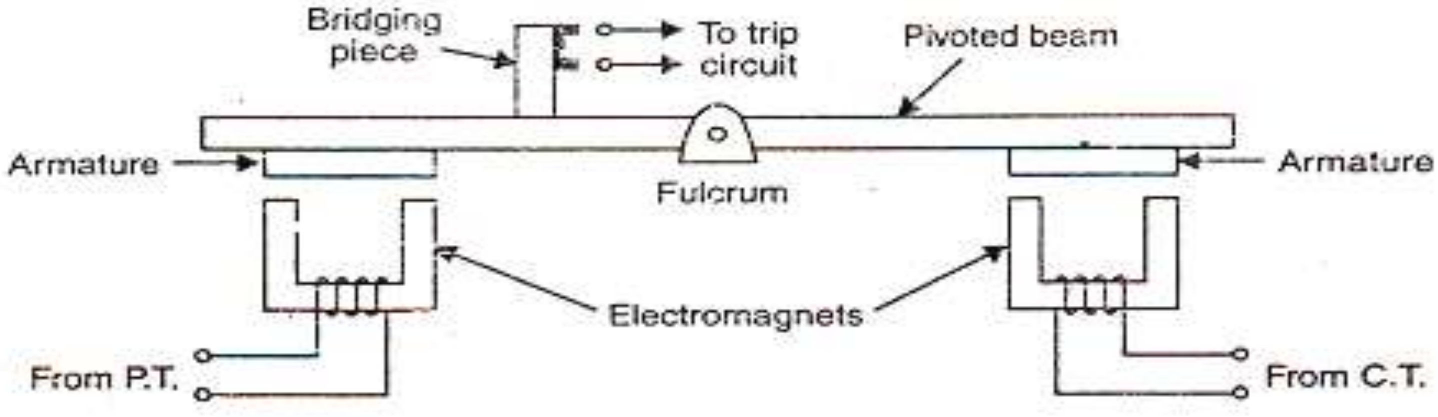


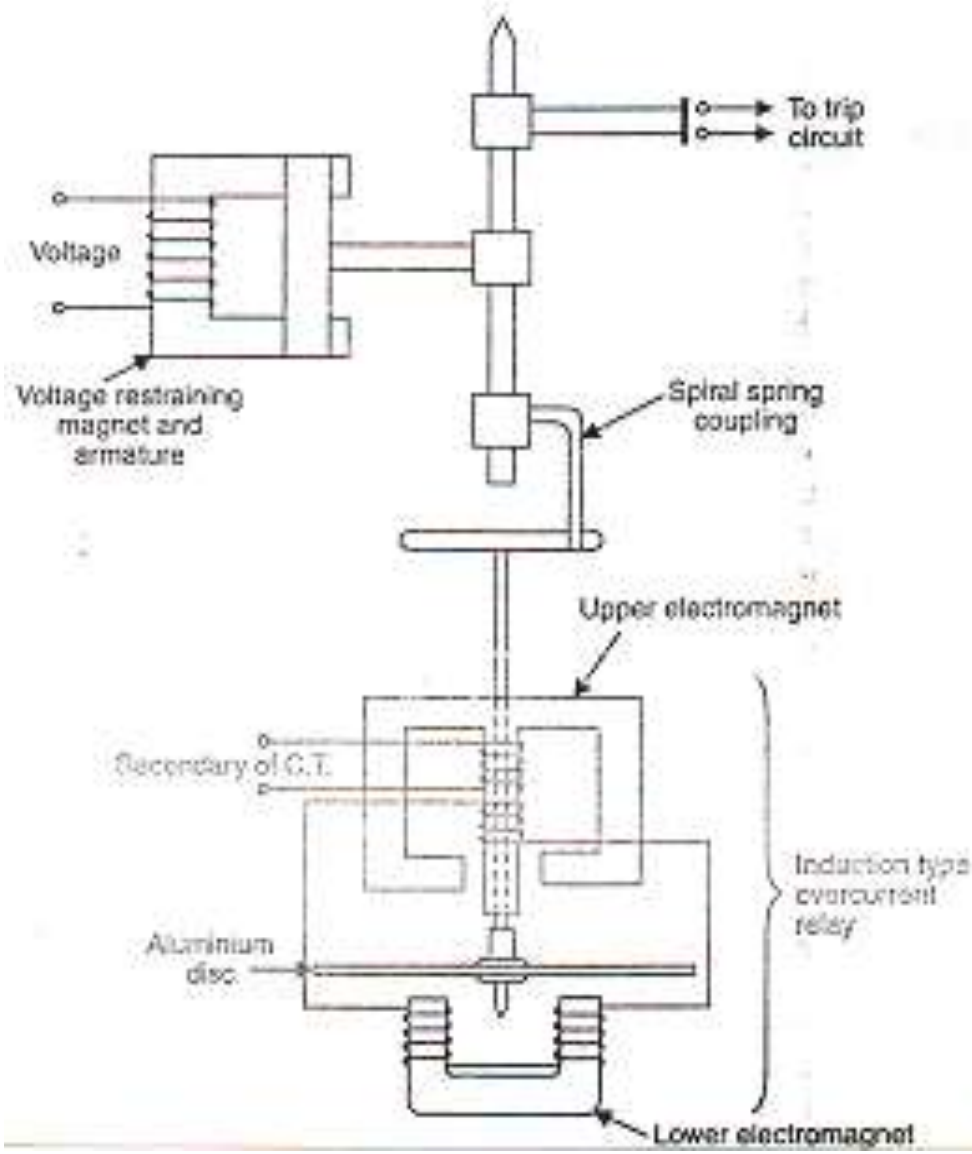
Fig. 23.30 Schematic arrangement of a definite-distance type impedance relay.

Construction : It consists of a pivoted beam and two electromagnets energized respectively by a voltage transformer (P.T) and current transformer (C.T) in the protected circuit. The armature of the two electromagnets are mechanically coupled to the beam on the opposite sides of the fulcrum. The beam is provided with a bridging piece for the trip contacts. The design of the relay is such that the torques produced by the two electromagnets are in opposite direction.

- **Working** : When the operating conditions are normal the pull due to voltage magnet is greater (because current I corresponds to normal load) than that of the current element. Therefore, the relay contacts remain open. However when ever a fault takes place in the protected zone, the applied voltage to the relay decreases whereas the current increases. Consequently, the ratio V/I falls below the pre-determined value, and the pull of the current element exceeds that due to the voltage element, thereby causing the beam to tilt in a direction to complete the trip circuit.
- That is $V^2/I^2 < K1/K2$

$$Z < \sqrt{K1/K2}$$

TIME DISTANCE IMPEDANCE RELAY



This type of relay automatically adjusts its operating time according to the distance of the relay from the fault point i.e., operating time, T ∝ V/I ∝ Z ∝ distance

- **Construction** :

i). it consists of a metallic disc usually made of aluminium or copper which is capable of rotating between two electromagnets upper magnet and lower magnet. The upper magnet has two separate windings similar to that of over-current relay. The primary winding is connected to the secondary of the current transformer (C.T) connected to the line to be protected. The windings have a number of tappings (not shown) so as to vary the current settings, the tappings are connected to a plug bridge. The secondary winding on the upper electromagnet is connected in series with the winding on the lower electromagnet. The currents in the secondary are due to electromagnetic induction. By this arrangement leakage fluxes of upper and lower magnets are sufficiently displaced in space and phase to set up a rotational torque on the induction disc, as in the shaded pole induction disc motor.

ii). The torque is controlled by a permanent magnet (not shown). The controlling or breaking torque cause by a permanent magnet varies directly as the driving torque.

iii). The spindle which carries the induction disc is shown connected by means of a spiral coupling to the second spindle which carries the bridging piece or the moving contacts or the relay trip contacts. The bridge is normally held in the open position by an armature held against the pole face of an electromagnet energized by the voltage of the line. In actual practice the spindle carrying the induction disc is attached to the inner end of the spiral spring through a geared counter shaft in order to obtain the required characteristic for the relay operating time

- **WORKING** :

i). When the operating conditions are normal the pull exerted by the armature is more than that of the induction element and thus the trip circuit contacts remain open.

ii). Whenever the fault occurs, the disc of the induction current element starts to rotate at a speed depending upon the operating current. As the rotation of the disc proceeds, the spiral spring coupling is wound up till the tension of the spring is sufficient to pull the armature away from the pole face of the voltage excited magnet. As soon it occurs, the spindle carrying the armature and bridging piece moves rapidly in response to the tension of the spring and the trip contacts are closed. Consequently, the circuit breaker opens and the fault section is isolated.

The rotational speed of the disc, neglecting the effect of control spring, is proportional to the operating current. Also the time of operation of relay is directly proportional to the pull of the voltage-excited magnet and hence to the line voltage V at the point where the relay is connected. Thus in this type of relay the time required is directly proportional to the line voltage V and inversely proportional to current i.e., the operational time of the relay varies as V/I i.e., Z – distance.

REACTANCE RELAY

- In this relay the operating torque is obtained by current and the restraining torque due to a current voltage directional element. This means, a reactance relay is an over-current relay with directional restraint.
- $T = K_1I^2 - K_3\ VI\cos(\theta - \tau)$

- The directional element is so designed that its maximum torque angle is 90 deg. i,e., τ = 90 deg in the universal torque equation will be

$$T = K_1 I^2 - K_3 VI \cos(\theta - \tau)$$

$$= K_1 I^2 - K_3 VI \cos(\theta - 90) = K_1 I^2 - K_3 VI \sin\theta$$

For the operation of the relay

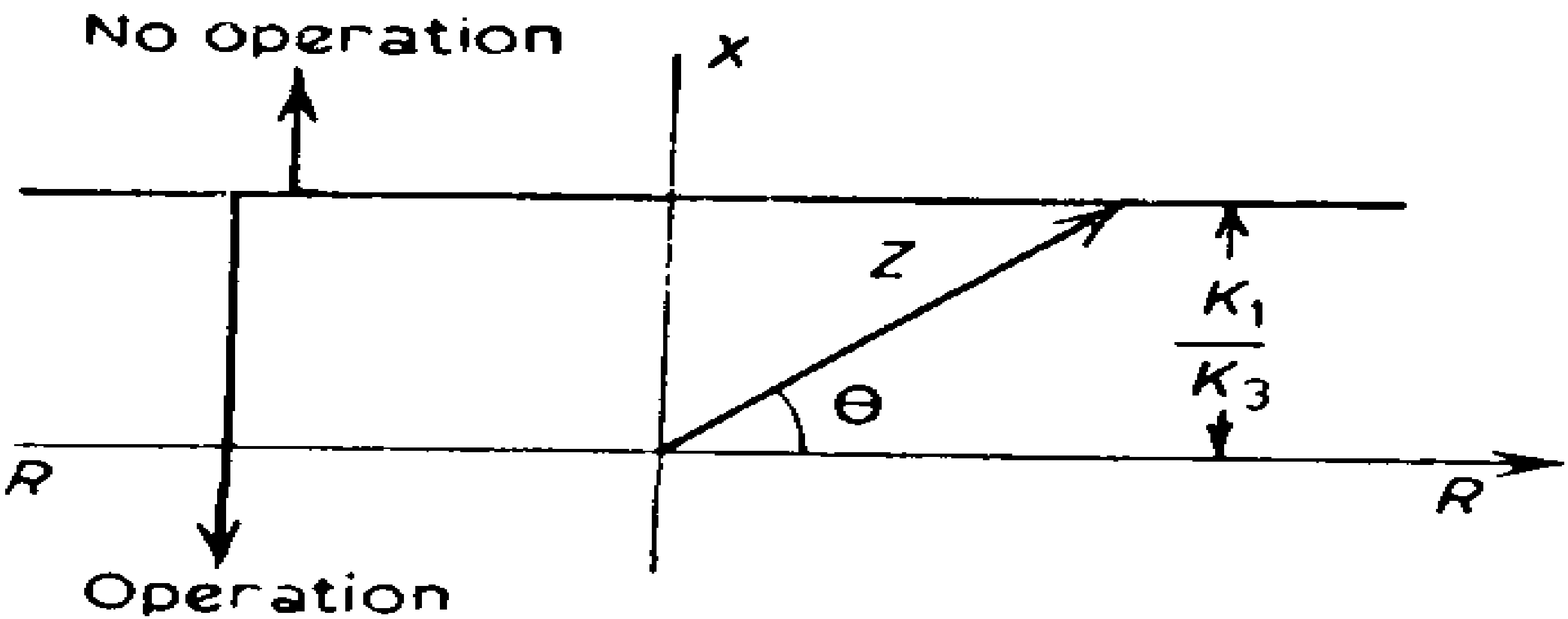
$$K_1 I^2 > K_3 VI \sin\theta$$

$$VI/I^2 \sin\theta < K_1/K_3$$

$$Z \sin\theta < K_1/K_3$$

$$X < K_1/K_3$$

- For operation the reactance seen by the relay should be smaller than the designed reactance
- The characteristic is shown in fig



- The resistance component of the impedance has no effect on the operation of the relay. It responds only to the reactance component of the impedance.
- The relay will operate for all impedances whose heads lie below the operating characteristic whether below or above the R-axis.
- The relay that is used to give directional feature to the reactance relay, is known as mho relay or admittance relay.

- The structures used for the reactance relay are
    1. Induction cup.
    2. Double-Induction loop structure

INDUCTION CUP

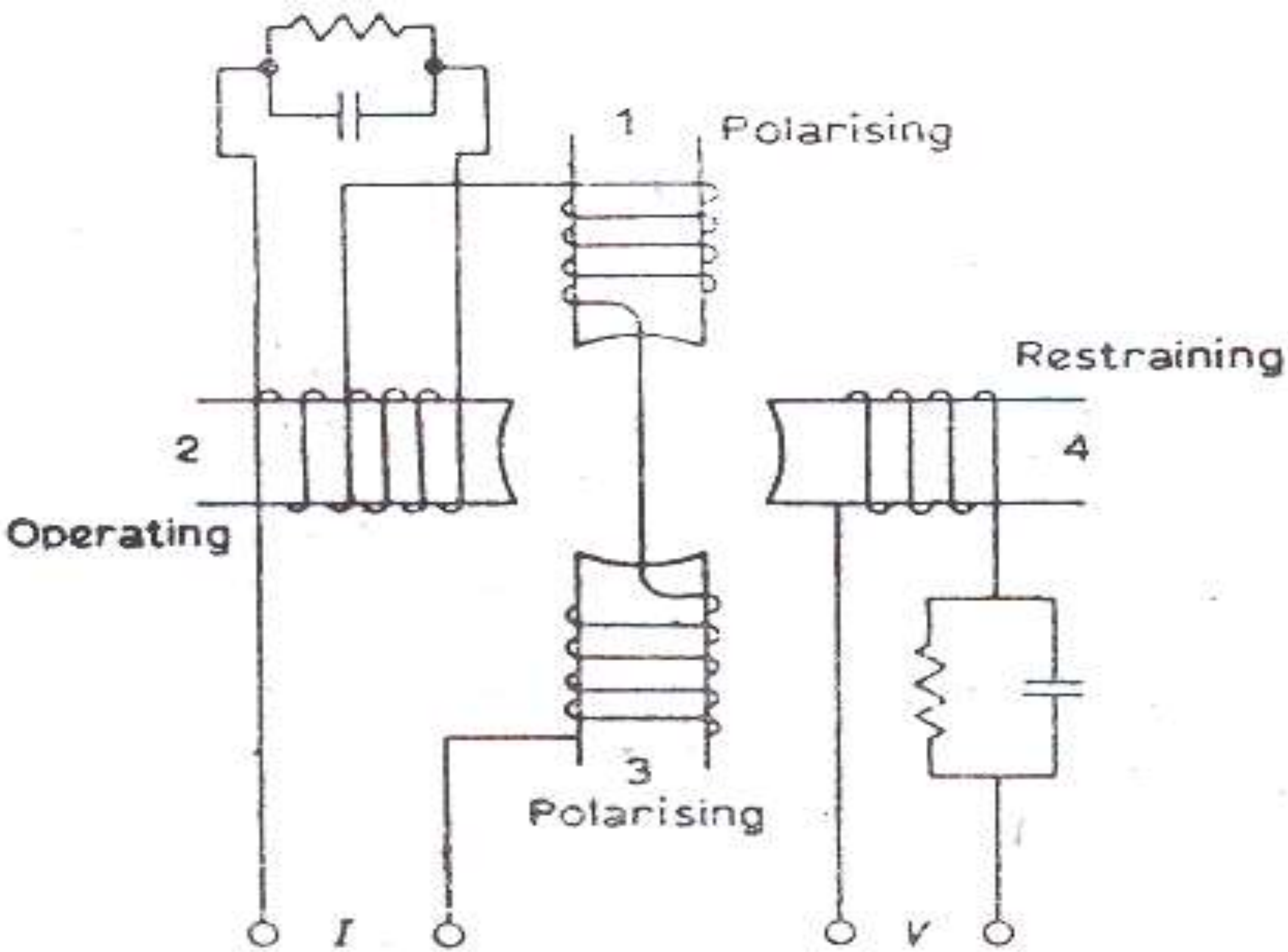


Fig. 14.17 Schematic diagram of a reactance relay

- **Construction** : It has a 4 pole structure. This has operating, polarizing and restraining coils. The operating torque is produced by the interaction of fluxes due to the windings carrying current coils, i.e. interaction of fluxes of poles 1, 2 and 3 and the restraining torque is developed due to the interaction of fluxes due to the poles 1, 3 and 4. The operating torque will be proportional to I^2 and the restraining torque proportional to VI cos (θ - 90°). The desired maximum torque angle is obtained with the help of R-C circuits as shown in Fig.

MHO RELAY (Offset Impedance)

- From the universal torque equation

$$T = K_3\, VI \cos(\theta - \tau) - K_2 V^2$$

For the operation of the relay

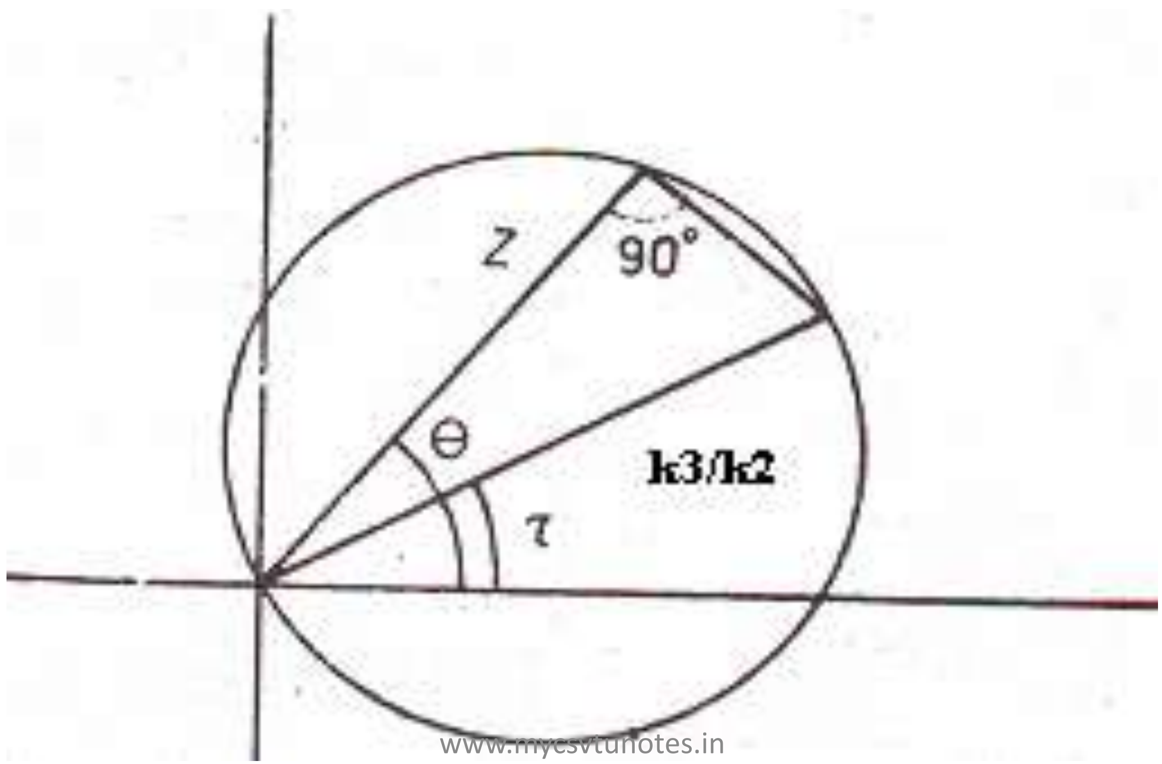
$$K_3\, VI \cos(\theta - \tau) > K_2 V^2$$

$$V^2/VI < K_3 / K_2 \cos(\theta - \tau)$$

$$Z < K_3 / K_2 \cos(\theta - \tau)$$

- In this relay the operating torque is obtained by the V-I element and restraining torque due to the voltage element. This means a mho relay is a voltage restrained directional relay.

- This characteristic, when drawn on impedance diagram it is a circle passing through the origin. The relay operates when the impedance seen by the relay falls within this circle.



- The relay is inherently directional.
- The impedance angle of the protected line is normally 60° to 70°.
- The relay is an accurate measuring device and does not operate during power swing which may occur on long or heavily loaded lines.

- The operating torque is produced by the interaction of fluxes due to poles 1,2 and 3 and the restraining torque due to poles 1,3 and 4.

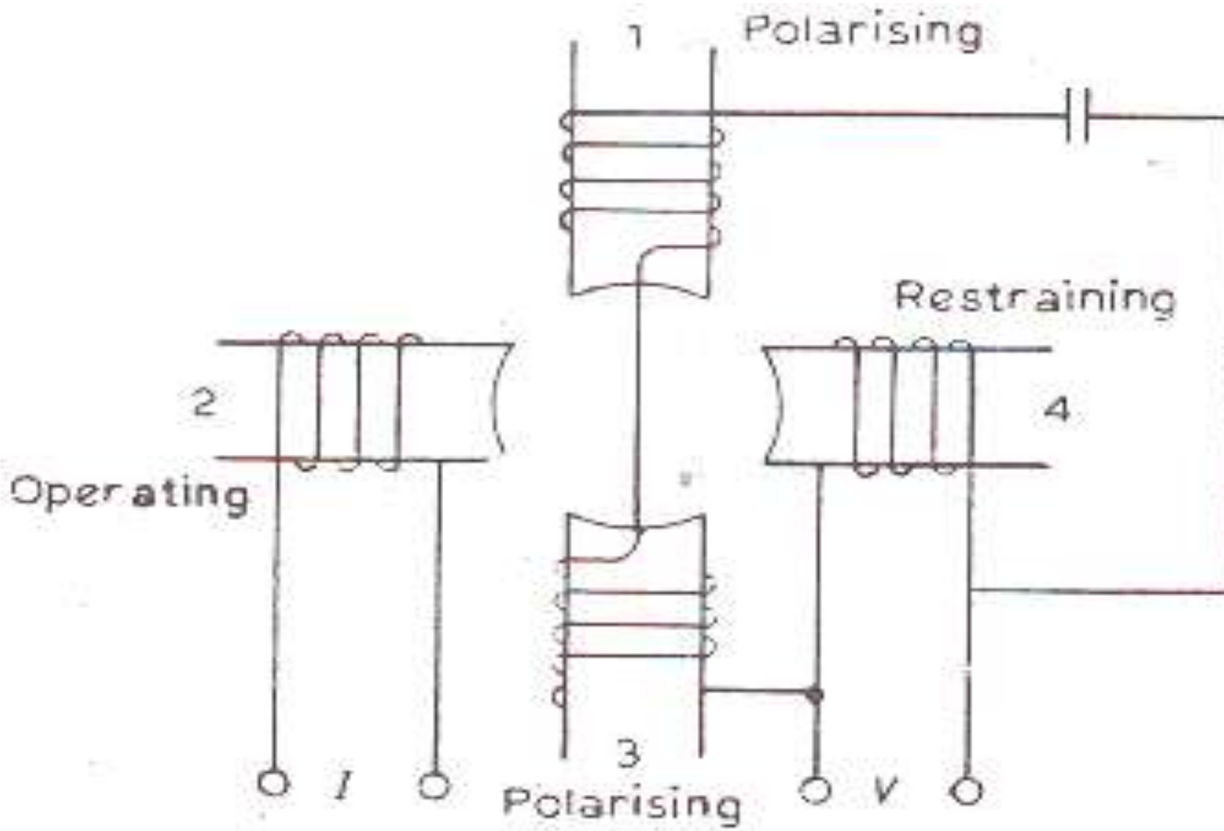
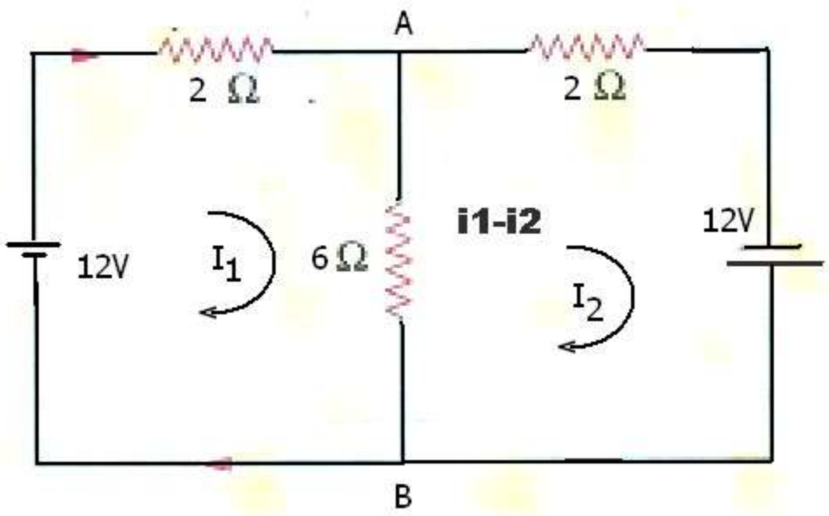
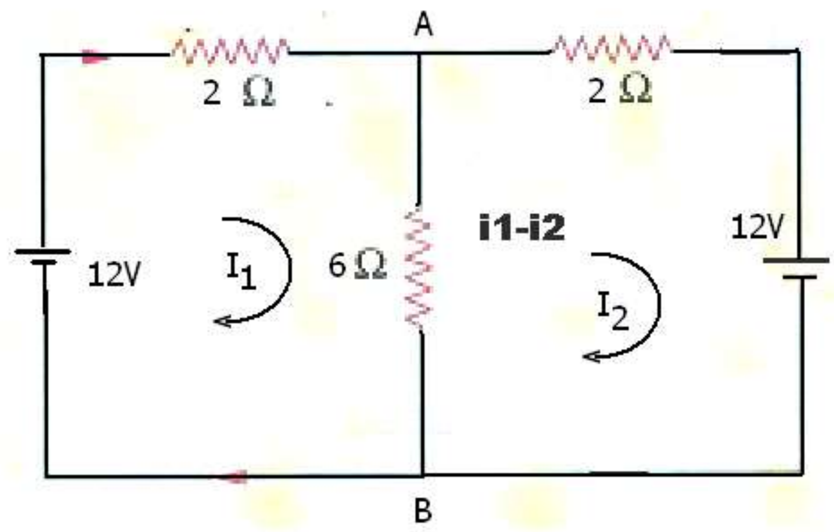


Fig. 14.20 Schematic diagram of a mho relay

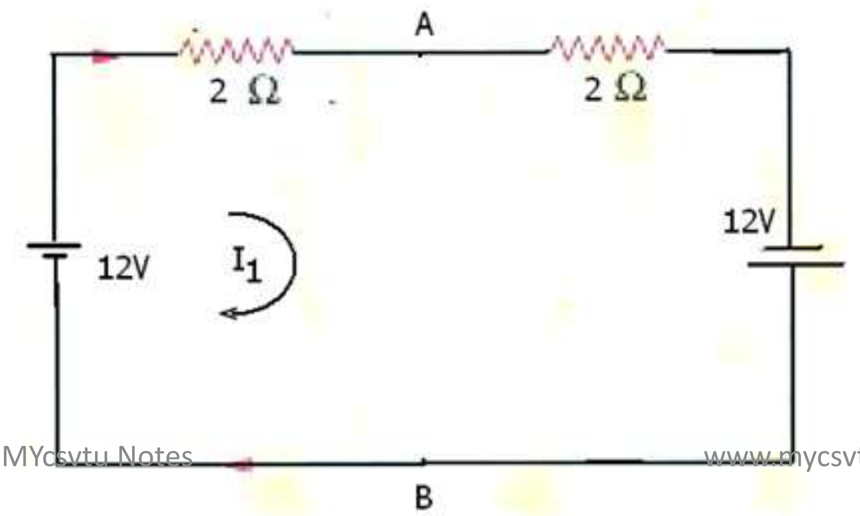
Base for Differential Relay





I1 = 6A, I2 = 6A

I1 = 0.857A, I2 = - 0.857A



DIFFERENTIAL RELAY

- It is used in unit protection.
- It is an over current relay (usually IDMT relay).
- The differential relay is one that operates when the vector difference of two or more similar electrical quantities exceeds a pre-determined value.

DIFFERENTIAL RELAY

- Differential relay, should have:

  (1) Two or more similar electrical quantities

  (2) These quantities should have phase displacement (normally approx. 180°), for the operation of the relay.

- The two fundamental systems of differential or balanced protection are :

  i). Current balance protection.

  ii). Voltage balance protection.

CURRENT DIFFERETIAL PROTECTION TYPE

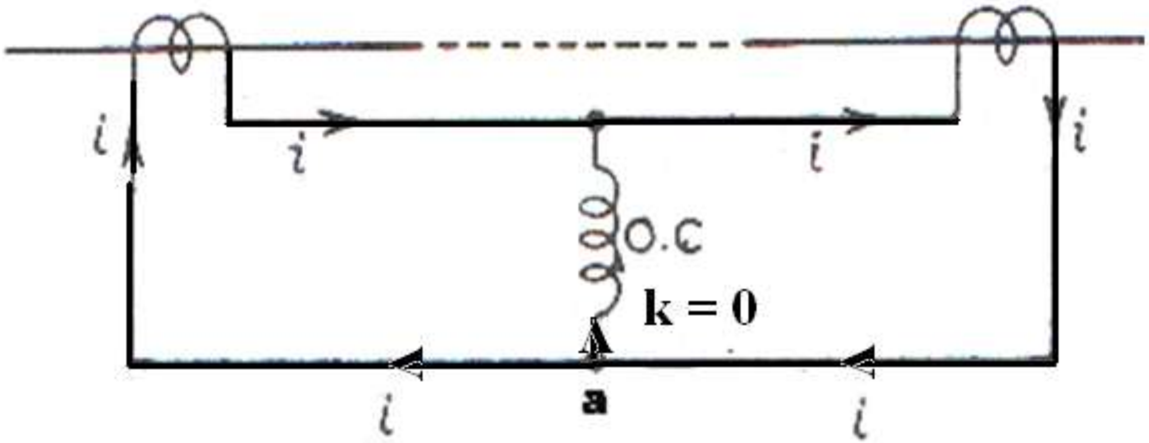


fig a

- CTs are connected in series with the help of pilot wires.
- The relay operating coil is connected between the mid-points (equipotential points) of the pilot wire.

- The voltage induced in the secondary of the CTs will circulate a current through the combined impedance of the pilot wires and the CTs. In case the operating coil is not connected between the equipotential points, there will be difference current through the operating coil of the relay and this may result in mal-operation of the relay.
- This relay should operate when fault is between two CT’s, but should not operate when the fault is outside the CT zone. This is known as “Unit Protection”.

- For external fault

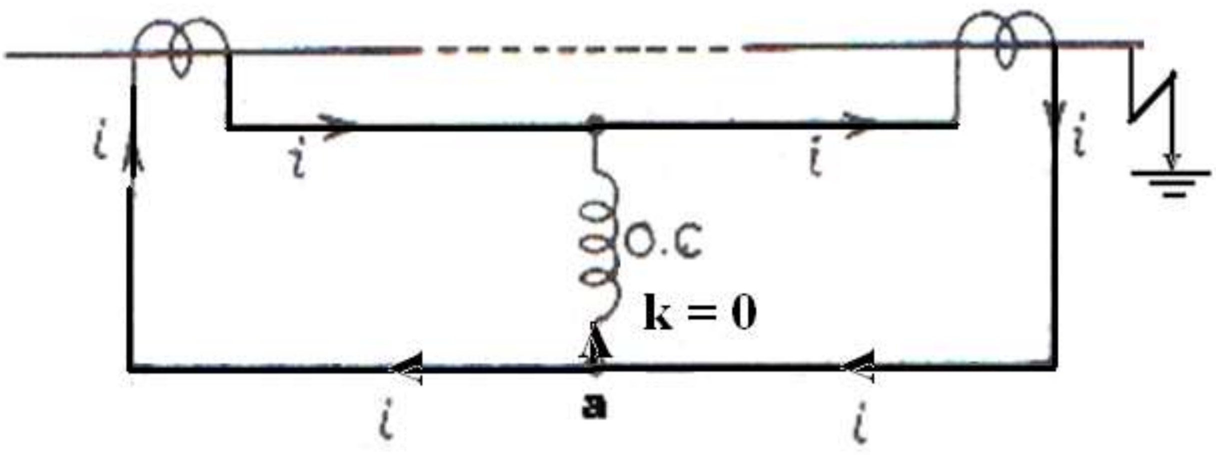


fig a

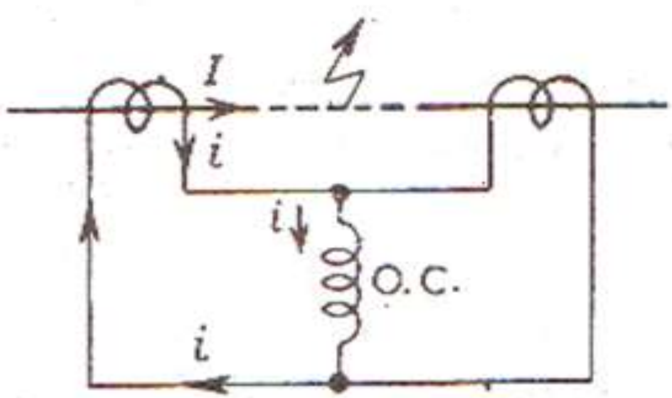
KCL at a

i = i + k

k = 0

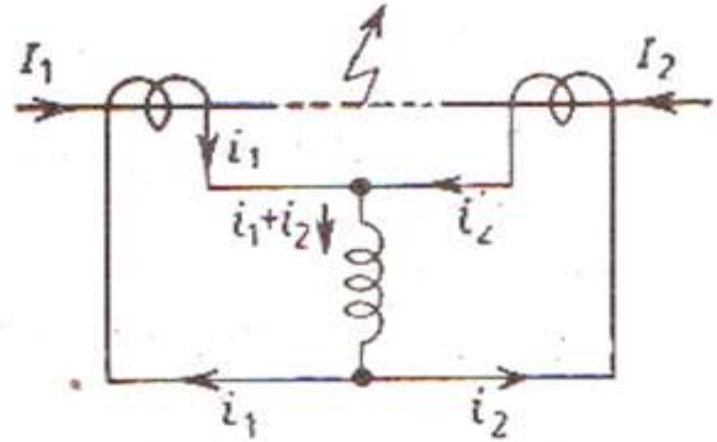
- Current is same in both the winding, therefore difference current is zero & relay does not operate.

- For internal fault :



Singly fed

(c)



Doubly fed

(d)

- Difference current will flow through operating coil & relay will operate.
- This is known as MERZ-PRICE protection.

- **BIASED DIFFERENTIAL PROTECTION OR PERCENTAGE DIFFERENTIAL PROTECTION**

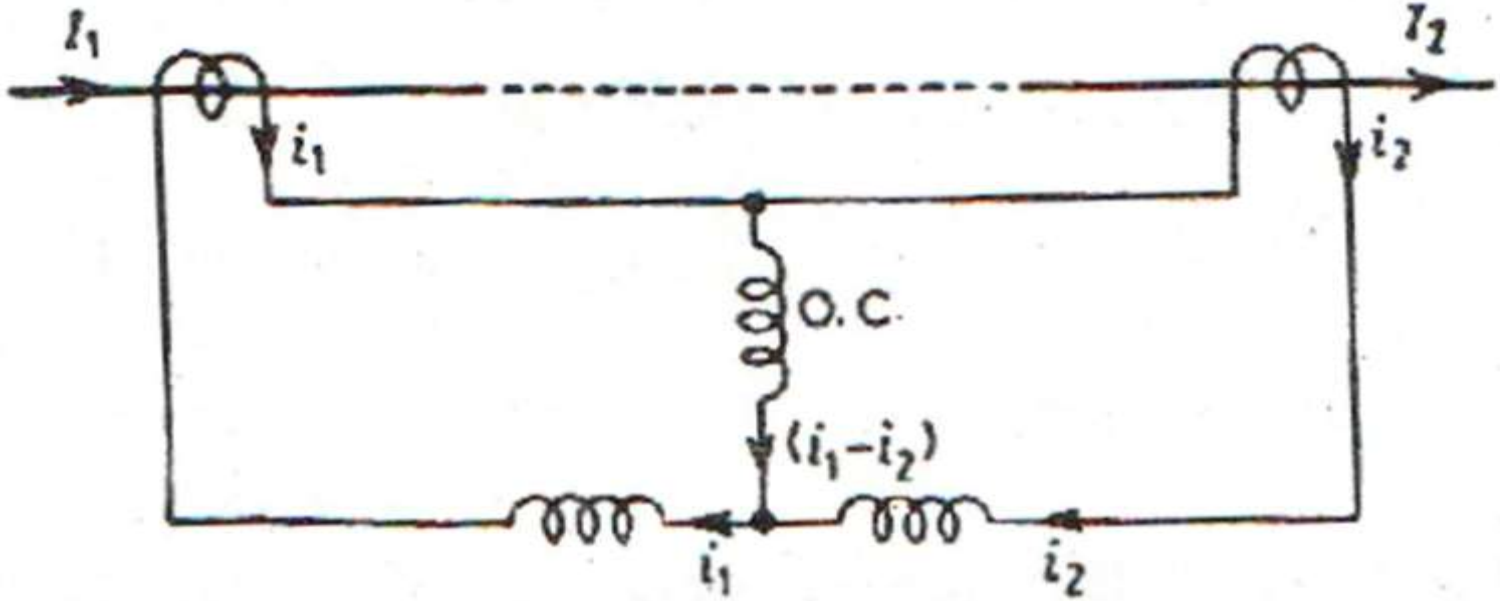


fig e Percentage differential protection

- In above cases CT's were assumed identical, but in practice this is not true. Suppose the two CT's under normal conditions differ in their magnetic properties slightly in terms of different amounts of residual magnetism or in terms of unequal burden on the two CT's, one of the CT's will saturate earlier during short circuit currents (offset i.e., it contains d.c components) and thus the two CT's will transform their primary current differentially even for a through fault condition. To accommodate these features, the relay is biased, known as biased differential protection or percentage differential protection as shown in fig (e)

- **Construction**: The relay consists of an operating coil and a restraining coil. The operating coil is connected to the mid-point of the restrained coil. The operating current is a variable quantity because of the restraining coil. Normally, no current flows through the operating coil under through fault condition, but owing to the dissimilarities in CT's, the differential current through the operating coil is (i1 – i2) and the equivalent current in the restraining coil is (i1 + i2)/2

- Torque developed by operating coil

  To α (i1 – i2) no

  Where no is number of turns in the operating coil

- The torque due to restraining coil

  T α (i1 + i2)/2. nr

  Where nr is the number of turns in the restraining coil

- At balance
- (i1 – i2) no = (i1 + i2)/2. nr

$$\frac{i_1 - i_2}{(i_1 + i_2)/2} = \frac{n_r}{n_0}$$

- Operating characteristic

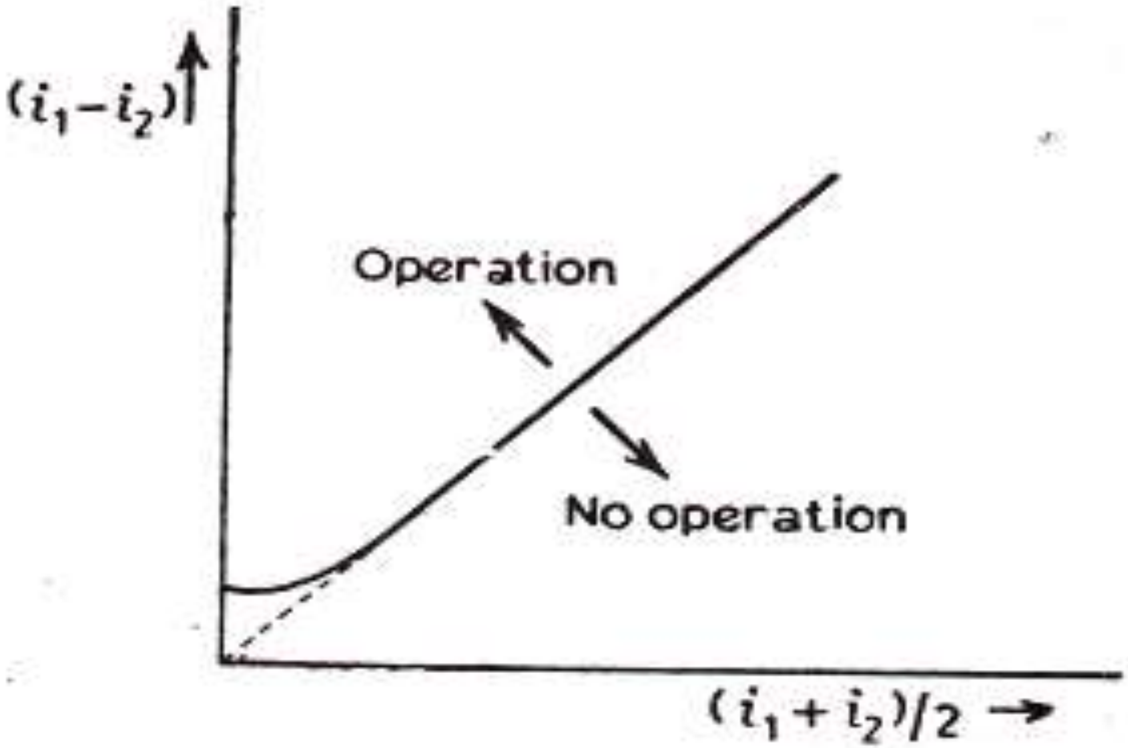


Fig. 14.27 **Operating characteristic of a percentage differential relay**

- It is clear that except for the effect of the control spring at low currents, the ratio of the differential operating current to the average restraining current is a fixed percentage. This is why it is known as percentage differential relay.

VOLTAGE BALANCE RELAY

- Two CT's are connected at either end in phase opposition.

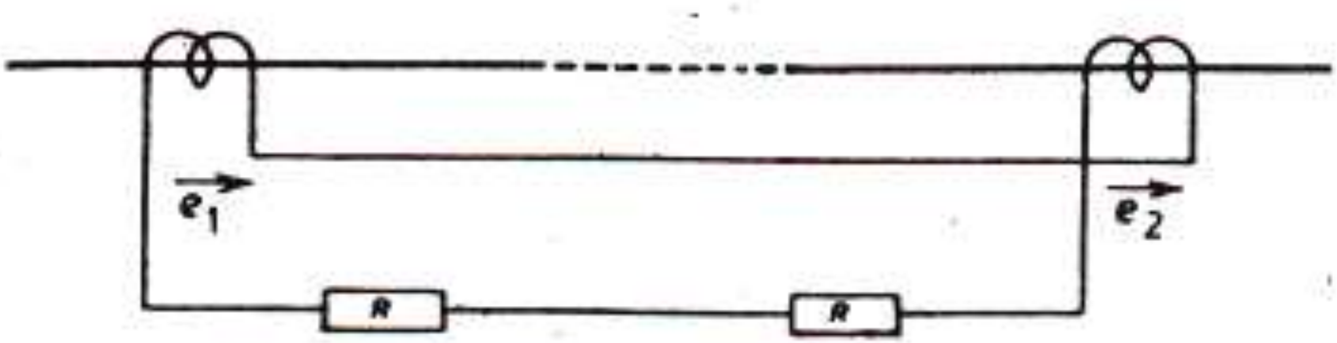
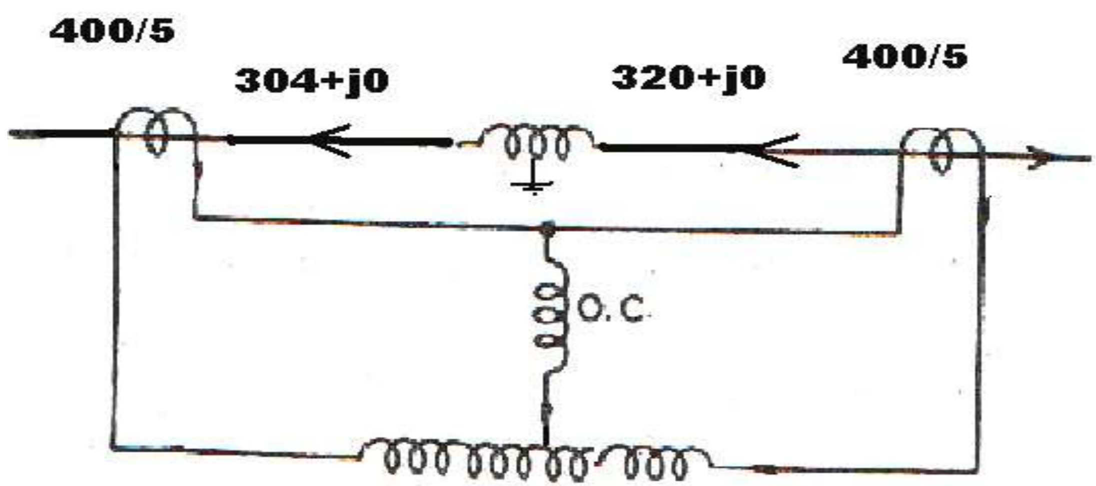


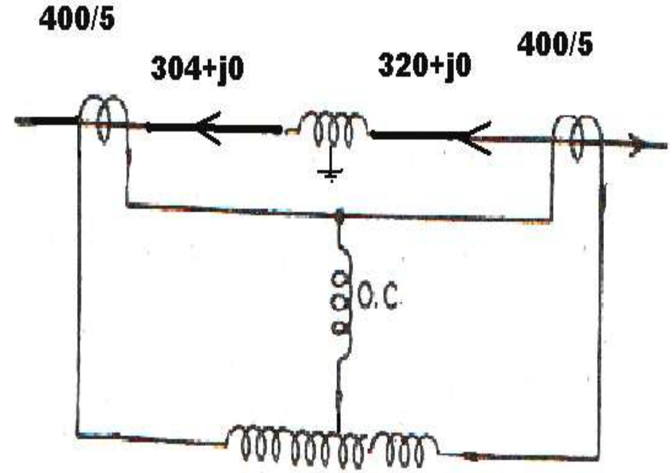
Fig. 14.28 Voltage balance protection

- Under normal/healthy conditions equal currents (I1 = I2) flow in both the 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 ever fault occurs in the protected zone, the currents in the two primaries will differ from one another (i,e,. I1 not equal to I2) and their secondary voltages will no longer be in balance. Consequently, a circulating current will flow through the operating coil, causing the trip circuit to close

- Q. Fig. shows percentage differential relay applied to the protection of an alternator winding. The relay has a 0.1 amp mimimum pick up and 10% slope of characteristic (I1 – I2) Vs (I1 + I2)/2. A high resistance ground fault occurred near the grounded neutral end of the generator winding while generator is carrying load. As a consequence the currents flowing at each end of the winding are shown in fig. Assuming C.T ratios of 400/5 amperes, will the relay operate the trip of the breaker.





- Sol: %age differential relay

$$I1 - I2 = (320+j0) - (304+j0) = 16$$

$$I1 + I2 = (320+j0) + (304+j0) = 624$$

Current in operating coil = $\frac{16 \times 5}{400} = 0.2$ A

Current in restraining coil = $\frac{1 \times 624 \times 5}{2 \times 400} = 3.9$ A

With 10% slope operating current corresponding to 3.9 A in restraining coil = 0.39 A.

Since the actual current in the operating coil is 0.2 A therefore the relay will not trip the circuit breaker.

- **Slope = operating current/ restraining current = 0.1 x 3.9 = 0.39 A.**

1992

- Q1. (a). Draw the schematic diagram of a Reactance Relay and Mho Relay and explain in brief how these relays function.

  (b). Describe the various types of constructions of attracted armature relays. Why can it operate on a.c and d.c ? State its salient features.

  (c). Describe the construction, principle of operation and application of an

  (i). Induction disc

  (ii). Induction cup relay. what is the ratio of reset to pick-up value in case of these relay ? and Explain why ratio of reset to pick-up should be high? (wadhwa p-370 induction cup relay)

1993

- Q1.(a). Why directional relay used along with reactance relay is a MHO relay ?

  (b). Why MHO relay has got directional property.

  (c). Explain how operating region of reactance relay on –x axis is indefinite.

1995

- Q1.(a). Derive the torque expression of a directional relay and describe how it can be converted to directional power unit.

  (b). On an impedance diagram explain what is meant by +R, -R, +X and –X.

  (c). Explain why pick-up value of instantaneous over current relay is greater than reset value.

  (d). For plotting operating characteristic of IDMT relay current is plotted as multiples of pickup value. Explain why?
- Q2. (a). Give the contact circuit for 3 zone impedance relay and explain its operation.

  (b). A 3 phase short circuit fault is most dangerous to the power system. Why ?

  (c). Which distance relay is most affected by power swings? Explain with suitable diagram.

- Q3. Under what system conditions over-current relays are not adequate for protection of EHV transmission lines? Explain the significance of source impedance in selecting a particular type of relay. (other than over-current). Suggest relays for a range of (source/line) impedance ratios (0-36).
- Q4. Explain the meaning of terms as applied to 'Distance' protection of transmission lines:

  i). Zone switching.

  ii). Delta-wye switching

  iii). Complete (Full) switching

  Give the number of measuring units (relays) for providing a 3 stepped characteristics.

- Q5. (a). Why directional relay used along with reactance is a mho relay?

  (b). Why Mho relay has got directional property ?

  (c). Explain how operating region of reactance relay on – X axis is indefinite.

Q6. (a). Discuss clearly operation of differential relay for system fed at both ends, for internal and through faults.

  (b). How a directional unit can be converted to power directional relay ?

  (c). Why seal-in-relay is used along the main relay to control the trip circuit ?

1997

- Q1. (a). Draw the diagram of instantaneous over-current relay.

  (b). Explain the cause of overreach of the relay.

  (c). Prove that for 100% offset in fault current the minimum value of overreach is 2.

Q2. (a). Develop the torque expression of a directional relay.

  (b). Draw and explain the operating characteristic of a relay.

  (c). What is meant by 30° connection ? Where is it used and why ? How is the connection done ?

- Q3. (a). The slope of percentage differential relay used for the protection of stator winding is 10%. A high resistance ground fault occurs on one phase winding. As a consequence the currents at the two ends of phase are 320 + j0 and 340 + j0 amps. If the C.T ratios are 400/5 amp, will the relay trip the C.B ?

  (b). Explain the terms under-reach and overreach of distance relays. Discuss the three step distance protection considering these two terms.

  (c). Draw the diagram of directional relay using four polar structure.

- Q4. (a). Derive the expression for electromagnetic torque developed. Draw VI characteristic of the relay and explain the nature of curve.

  (b). How 30° connections are done to the relay ? Why and where are these connections used ?

  (c). Draw and explain the operation of trip circuit.

  (d). Discuss the phenomena of snap action in an instantaneous over-current relay.

  (e). A power system element fed at both ends is protected by percentage differential relay. Explain how the relay responds only to fault occurring on the power system and is unaffected by through fault.

1998

- Q1. (a). Explain in brief the desirable features of a protective relay listing them in order of merit.

  (b). What are limitations of plain over-current relays ?

  (c). List the various Distance Relay Protection schemes for transmission line protection. Which relay characteristic shape is considered to be best and why ? (Irrespective of line length).

Q2. (a). “The bias setting in the differential protection for a transformer is higher than that in generator protection.” Give brief explanation with usual ranges of operating quantity and restraining quantity (in % of current of setting).

(b). Describe a protection unit scheme for an Extra High Voltage transmission line which uses “UNIT” as well as “NON-UNIT” schemes of protection. Complete your answer by giving the relay (trip contacts) connection diagram for a three section line.

2000

- Q1. (a). Explain how distance relays are superior to over-current relays for protection of transmission lines.

2002

- Q1. (a). What is meant by an instantaneous relay?
- (b). Draw the diagram of instantaneous over-current relay.

(c). Why does this relay suffer from the drawback of over reach ?

(d). Prove that with 100% offset in fault current, over reach of instantaneous over current relay exceeds twice the protected section. What is the remedy to this drawback ?

- Q2. (a). Discuss the following :

  (i). Seal in relay

  (ii). Trip circuit

  (iii). Stability ratio

DEC-JAN.2006 – 07

- Q1.(A). What is the need for protective relaying in power system and state its basic requirement.
- (b). Explain the term Directional. Give the constructional features, principle of working and characteristics of directional relays.
- (c). Define the terms (i). Plug setting multiplier (ii). Time setting in connection with IDMT relays. How plug setting control the pick-up of the relay?

  Determine the time of operation of 1A, 3sec over current relay having plug setting of 125% and time multiplier of 0.6. The supplying C.T is rated 400:1 A and fault current is 4000A. The relay characteristic curve is

PSM	1.3	2	4	8	10	20
Time of Operation	30	10	5	3.3	3	2.2

NOV. 2007

Q1 a). Describe a directional over current relay with neat sketch. Explain where and why would u prefer directional over current relay ?

b). Explain the various time-current characteristics of over current relays stating their areas of applications. How these characteristics are achieved in practice for an electromagnetic relay ?

c). Explain the following terms with reference to the protective relaying :

i). Reach of the relay

ii). Seal in relay

iii). Through fault stability

iv). Unit system of protection