UNIT –II

ELCTROMAGNETIC PROTECTION

In a power system consisting of generators, transformers, transmission and distribution circuits, it is inevitable that sooner or later some failure will occur somewhere in the system. When a failure occurs on any part of the system, it must be quickly detected and disconnected from the system.

There are two principal reasons for it. Firstly, if the fault is not cleared quickly, it may cause unnecessary interruption of service to the customers. Secondly, rapid disconnection of faulted apparatus limits the amount of damage to it and prevents the effects of fault from spreading into the system. The detection of a fault and disconnection of a faulty section or apparatus can be achieved by using fuses or relays in conjunction with circuit breakers. A fuse performs both detection and interruption functions automatically but its use is limited for the protection of low-voltage circuits only.

For high voltage circuits (say above 3·3 kV), relays and circuit breakers are employed to serve the desired function of automatic protective gear.

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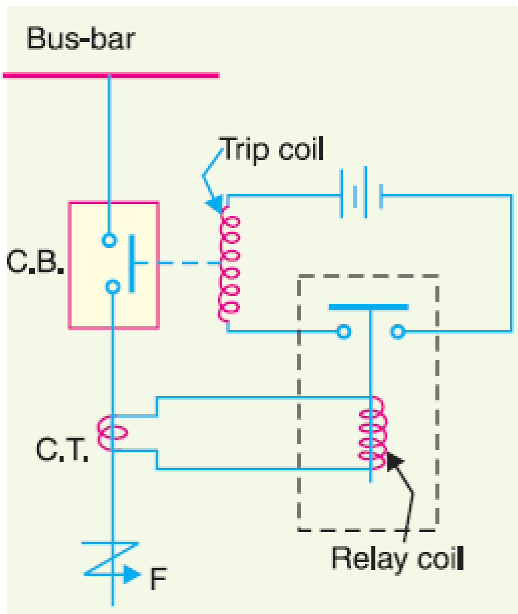


Operation Steps:

- When a short circuit occurs at point F on the transmission line, the current flowing in the line increases to an enormous value.
- This results in a heavy current flow through the relay coil, causing the relay to operate by closing its contacts.
- This in turn closes the trip circuit of the breaker, making the circuit breaker open and isolating the faulty section from the rest of the system.

In this way, the relay ensures the safety of the circuit equipment from damage and normal working of the healthy portion of the system.

Fundamental Requirements of Protective Relaying:

The principal function of protective relaying is to cause the prompt removal from service of any element of the power system. In order that protective relay system may perform this function satisfactorily, it should have the following qualities:

selectivity (ii) speed (iii) sensitivity (iv) reliability (v) simplicity (vi) economy

1. Selectivity:

It is the ability of the protective system to select correctly that part of the system in trouble and disconnect the faulty part without disturbing the rest of the system. The system can be divided into the following protection zones:

(a) generators (b) low-tension switchgear (c) transformers

(d) high-tension switchgear (e) transmission lines

It may be seen in the previous Fig. that there is certain amount of overlap between the adjacent protection zones.

For a failure within the region where two adjacent zones overlap, more breakers will be opened than the minimum necessary to disconnect the faulty section. But if there were no overlap, a failure in the region between zones would not lie in either region and, therefore, no breaker would be opened. For this reason, a certain amount of overlap is provided between the adjacent zones.

2- Speed:

The relay system should disconnect the faulty section as fast as possible for the following reasons:

(a) Electrical apparatus may be damaged if they are made to carry the fault currents for a long time.

(b) A failure on the system leads to a great reduction in the system voltage. If the faulty section is not disconnected quickly, then the low voltage created by the fault may shut down consumers’ motors and the generators on the system may become unstable.

(c) The high speed relay system decreases the possibility of development of one type of fault into the other more severe type.

3- Sensitivity.

It is the ability of the relay system to operate with low value of actuating quantity.

Sensitivity of a relay is a function of the volt-amperes input to the coil of the relay necessary to cause its operation.

4- Reliability. It is the ability of the relay system to operate under the pre-determined conditions.

5- Simplicity. The relaying system should be simple so that it can be easily maintained. Reliability is closely related to simplicity. The simpler the protection scheme, the greater will be its reliability.

6- Economy.

The most important factor in the choice of a particular protection scheme is the economic aspect. Sometimes it is economically unjustified to use an ideal scheme of protection and a compromise method has to be adopted. As a rule, the protective gear should not cost more than 5% of total cost. However, when the apparatus to be protected

is of utmost importance (e.g.generator, main transmission line etc.), economic considerations are often subordinated to reliability.

Basic Relays

Most of the relays used in the power system operate by virtue of the current and/or voltage supplied by current and voltage transformers connected in various combinations to the system element that is to be protected. Through the individual or relative changes in these two quantities, faults signal their presence, type and location to the protective relays. Having detected the fault, the relay operates the trip circuit which results in the opening of the circuit breaker and hence in the disconnection of the faulty circuit.

The electro-mechanical relays work on the following two main operating principles:

(i) Electromagnetic attraction

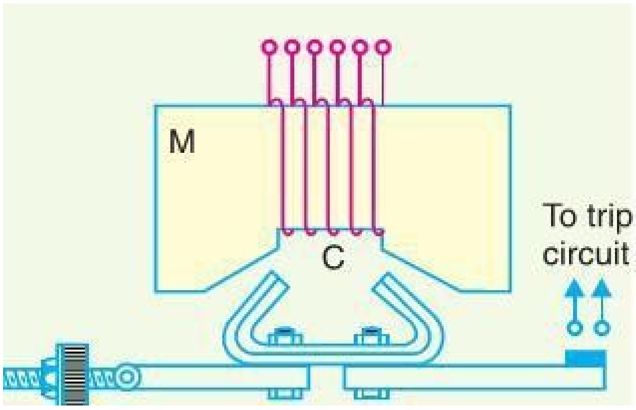
(ii) Electromagnetic induction

Electromagnetic Attraction Relays :

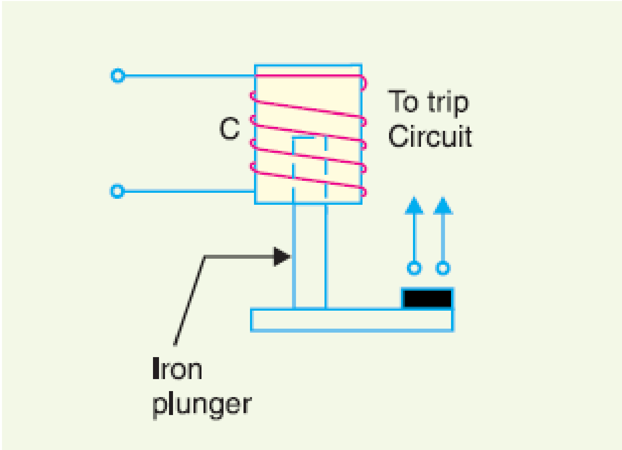
Electromagnetic attraction relays operate by virtue of an armature being attracted to the poles of an electromagnet or a plunger being drawn into a solenoid. Such relays maybe actuated by D.C. or A.C. quantities.

(*i*) Attracted armature type relay. Fig. 21.3 shows the schematic arrangement of anattracted armature type relay. It consists of a laminated electromagnet *M* carrying a coil *C* and a pivoted laminated armature. The armature is balanced by a counterweight and carries a pair of spring contact fingers at its free end. Under normal operating conditions, the current through the relay coil *C* is such that counterweight holds the armature in the position shown. However, when a short circuit occurs, the current through the relay coil increases sufficiently and the relay armature is attracted upwards. The contacts on the relay armature bridge a pair of stationary contacts attached to the relay frame. This completes the trip circuit which results in the opening of the circuit breaker and, therefore, in the disconnection of the faulty circuit.

The minimum current at which the relay armature is attracted to close the trip circuit is called *pickup* current. It is a usual practice to provide a number of tappings on the relay coil so that the number of turns in use and hence the setting value at which the relay operates can be varied.



(*ii*) Solenoid type relay. Fig. 21.4 shows the schematic arrangement of a solenoid type relay.It consists of a solenoid and movable iron plunger arranged as shown. Under normal operatingconditions, 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.



(*iii*) Balanced beam type relay. Fig. 21.5 shows the schematic arrangement of a balancedbeam 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. How-ever, when a fault occurs, the current through the re-lay 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.

Induction Relays:

Electromagnetic induction relays operate on the principle of induction motor and are widely used for protective relaying purposes involving a.c. quantities. An induction relay essentially consists of a pivoted aluminum disc placed in two alternating magnetic fields of the same frequency but displaced in time and space. The torque is produced in the disc by the interaction of one of the magnetic fields with the currents induced in the disc by the other.

To understand the production of torque in an induction relay, refer to the elementary arrangement shown in Fig. below (i). The two A.C. fluxes φ2 and φ1 differing in phase by an angle α induce e.m.f.s' in the disc and cause the circulation of eddy currents I_2 and I_1 respectively. These currents lag behind their respective fluxes by 90 Referring to Fig. below (ii) where the two A.C. fluxes and induced currents are shown separately for clarity let

$$\phi_1 = \phi_{1max} \sin \omega t$$
$$\phi_2 = \phi_{2max} \sin (\omega t + \alpha)$$

Where φ_1 and φ_2 are the instantaneous values of fluxes and φ_2 leads φ_1 by an angle α.

Assuming that the paths in which the rotor currents flow have negligible self-inductance, the rotor currents will be in phase with their voltages.

When current flows in a wire, and an external magnetic field is applied across that flow, the wire experiences a force perpendicular both to that field and to the direction of the current flow. A left hand can be held, as shown in the illustration, so as to represent three mutually orthogonal axes on the thumb, first finger and middle finger.

Each finger is then assigned to a quantity (mechanical force, magnetic field and electric current). The right and left hand are used for generators and motors respectively.

$$i_1 \propto \frac{d\phi_1}{dt} \propto \frac{d}{dt}(\phi_{1max} \sin \omega t)$$

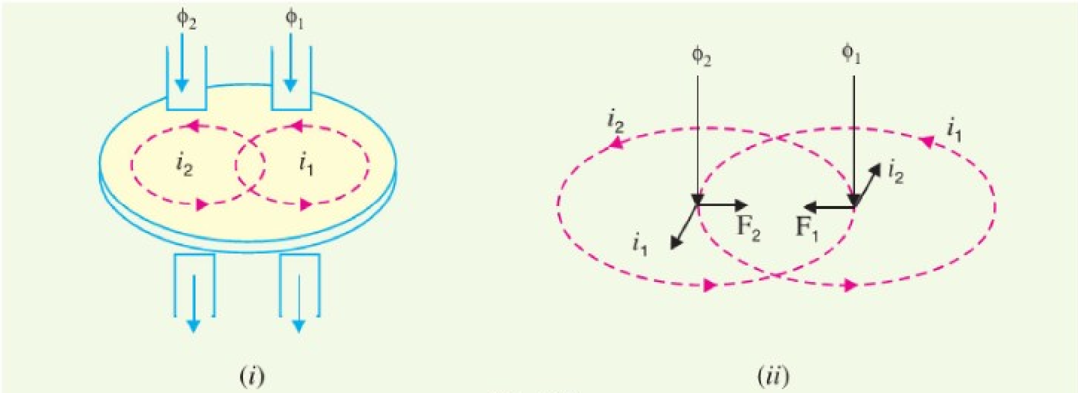


Fig. 21.6

$$\propto \phi_{1max} \cos \omega t$$

and $$i_2 \propto \frac{d\phi_2}{dt} \propto \phi_{2max} \cos(\omega t + \alpha)$$

Now, $$F_1 \propto \phi_1 i_2 \quad \text{and} \quad F_2 \propto \phi_2 i_1$$

Net force F at the instant considered is

$$\begin{aligned} F &\propto F_2 - F_1 \\ &\propto \phi_2 i_1 - \phi_1 i_2 \\ &\propto \phi_{2max} \sin(\omega t + \alpha)\, \phi_{1max} \cos \omega t - \phi_{1max} \sin \omega t\, \phi_{2max} \cos(\omega t + \alpha) \\ &\propto \phi_{1max}\, \phi_{2max} [\sin(\omega t + \alpha) \cos \omega t - \sin \omega t \cos(\omega t + \alpha)] \\ &\propto \phi_{1max}\, \phi_{2max} \sin \alpha \\ &\propto \phi_1\, \phi_2 \sin \alpha \qquad \ldots(i) \end{aligned}$$

The following points may be noted from exp. (*i*) :

(*a*) The greater the phase angleαbetween the fluxes, the greater is the net force applied to thedisc. Obviously, the maximum force will be produced when the two fluxes are 90^o out of phase.

(*b*) The net force is the same at every instant. This fact does not depend upon the assumptionsmade in arriving at exp. (*i*).

(*c*) The direction of net force and hence the direction of motion of the disc depends upon whichflux is leading.

The following three types of structures are commonly used for obtaining the phase difference in the fluxes and hence the operating torque in induction relays:

(*i*) shaded-pole structure

(*ii*) watthour-meter or double winding structure (***iii***) induction cup structure

(i) shaded-pole structure:

The general arrangement of shaded-pole structure is shown in Fig. below It consists of a pivoted aluminum disc free to rotate in the air-gap of an electromagnet. One half of each pole of the magnet is surrounded by a copper band known as shading ring. The alternating flux φs in the shaded portion of the poles will, owing to the reaction of the current induced in the ring, lag behind the flux φu in the unshaded portion by an angle α. These two

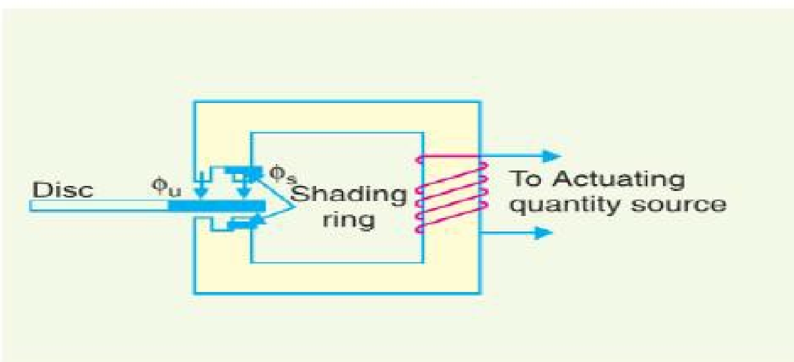
a.c. fluxes differing in phase will produce the necessary torque to rotate the disc. As proved earlier, the driving torque T is given by:

$$T \propto \phi_s \phi_u \sin \alpha$$

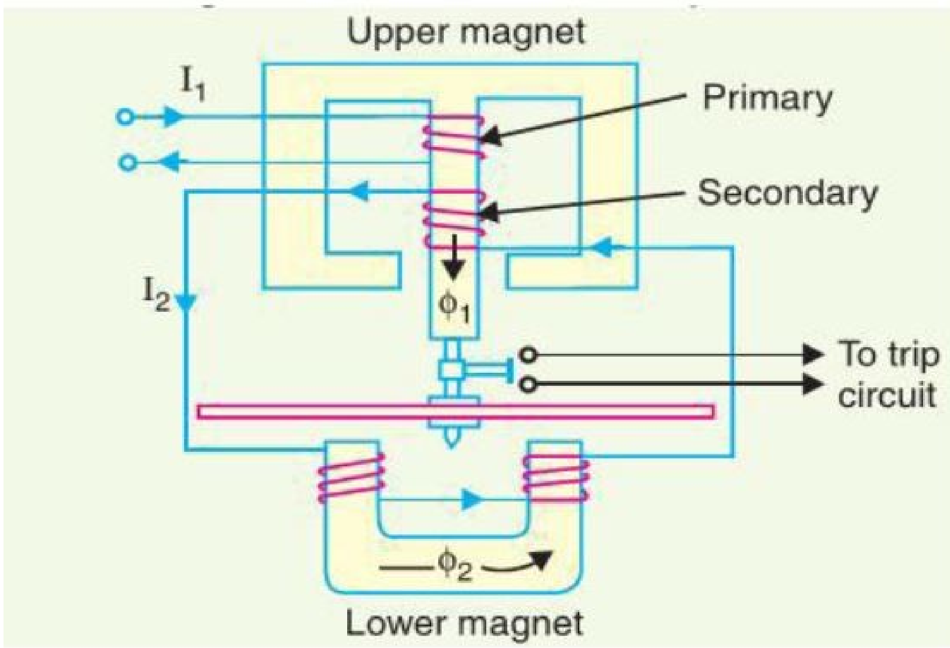
Assuming the fluxes ϕ_s and ϕ_u to be proportional to the current I in the relay coil,

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

This shows that driving torque is proportional to the square of current in the relay coil.



(ii) Watthour-meter structure. This structure gets its name from the fact that it is used in watt-hour meters. The general arrangement of this type of relay is shown in Fig. It consists of a pivoted aluminium disc arranged to rotate freely between the poles of two electromagnets. The upper electromagnet carries two windings ; the pirmary and the secondary. The primary winding carries the relay current I_1 while the secondary winding is connected to the winding of the lower magnet. The primary current induces e.m.f. in the secondary and so circulates a current I_2 in it. The flux φ_2 induced in the lower magnet by the current in the secondary winding of the upper magnet will lag behind φ_1 by an angle α . The two fluxes $\varphi_1$and φ_2 differing in phase by α will produce a driving torque on the disc proportional to φ_1 ,$\varphi_2$and $\sin \alpha$.



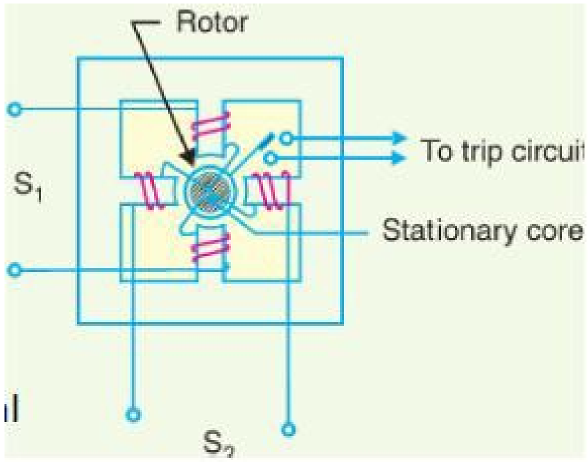
An important feature of this type of relay is that its operation can be controlled by opening or closing the secondary winding circuit. If this circuit is opened, no flux can be set by the lower magnet however great the value of current in the primary winding may be and consequently no torque will be produced. Therefore, the relay can be made inoperative by opening its secondary winding circuit.

(iii) Induction cup structure

Fig. shows the general arrangement of an induction cup structure. It most closely resembles an induction motor, except that the rotor iron is stationary, on 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 driving torque. If φ 1 and $\varphi 2$ represent the fluxes produced by the respective pairs of poles, then torque produced is proportional to $\varphi 1$ $\varphi 2$ sin α 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 Watt-hour meter structures.

Therefore, this type of relay has very high speed and may have an operating time less then 0·1 second.



Relay timing:

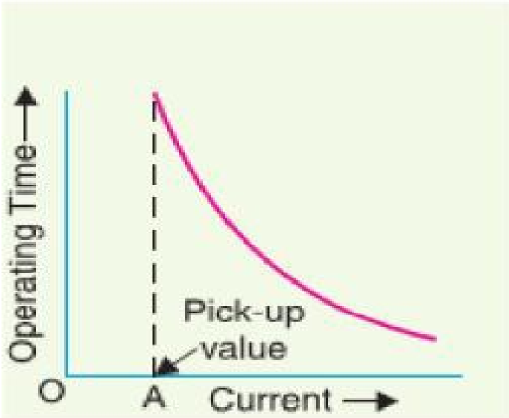
An important characteristic of a relay is its time of operation. By ‘the time of operation’ is meant length of the time from the instant when the actuating element.

(i) Instantaneous relay:

An instantaneous relay is one in which no intentional time delay is provided. In this case, the relay contacts are closed immediately after current in the relay coil exceeds the minimum calibrated value. Fig. below shows an instantaneous solenoid type of relay.ment is energized to the instant when the relay contacts are closed. e.g. one-cycle would be 1/50 second in a 50-cycle system.

(ii) Inverse-time relay:

An inverse-time relay is one in which the operating time is approximately inversely proportional to the magnitude of the actuating quantity. Fig.shows the time-current characteristics of an inverse current relay.



(a) In an induction relay, the inverse-time delay can be achieved by positioning a permanent magnet (known as a drag magnet) in such a way that relay disc cuts the flux between the poles of the magnet. When the disc moves, currents set up in it produce a drag on the disc which slows its motion.

(b) In other types of relays, the inverse time delay can be introduced by oil dashpot or a time limit fuse. Fig. previously shows an inverse time solenoid relay using oil dashpot. The piston in the oil dashpot attached to the moving plunger slows its upward motion. At a current value just equal to the pickup, the plunger moves slowly and time delay is at a maximum. At higher values of relay current, the delay time is shortened due to greater pull on the plunger.

The inverse-time characteristic can also be obtained by connecting a time-limit fuse in parallel with the trip coil terminals as shown in previous fig, The shunt path formed by time-limit fuse is of negligible impedance as compared with the relatively high impedance of the trip coil. Therefore, so long as the fuse remains intact, it will divert practically the whole secondary current of CT from the trip oil. When the secondary current exceeds the current carrying capacity of the fuse, the fuse will blow and the whole current will pass through the trip coil, thus opening the circuit breaker.

(iii) Definite time lag relay:

In this type of relay, there is a definite time elapse between the instant of pickup and the closing of relay contacts. This particular time setting is independent of the amount of current through the relay coil ; being the same for all values of current in excess of the pickup value. It may be worthwhile to mention here that practically all inverse-time relays are also provided with definite minimum time feature in order that the relay may never become instantaneous in its action for very long overloads.

Important Terms

It is desirable to define and explain some important terms much used in connection with relays.
(i) Pick-up current. It is the minimum current in the relay coil at which the relay starts to operate. So long as the current in the relay is less than the pick-up value, the relay does not operate and the breaker controlled by it remains in the closed position.

However, when the relay coil current is equal to or greater than the pickup value, the relay operates to energize the trip coil which opens the circuit breaker.

(ii) Current setting. It is often desirable to adjust the pick-up current to any required value. This is known as current setting and is usually achieved by the use of tapping on the relay operating coil. The taps are brought out to a plug bridge as shown in Fig. below, the plug bridge permits to alter the number of turns on the relay coil. This changes the torque on the disc and hence the time of operation of the relay.
∴ Pick-up current = Rated secondary current of C.T. ×Current setting

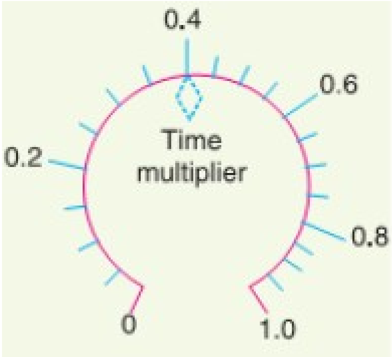
For example, suppose that an over current relay having current setting of 125% is connected to a supply circuit through a current transformer of 400/5. The rated secondary current of C.T. is 5 amperes. Therefore, the pick-up value will be 25% more than 5 A i.e. 5 ×1·25 = 6·25 A. It Means that with above current setting, the relay will actually operate for a relay coil current equal to or greater than 6·25 A.

Plug-setting multiplier (P.S.M.): It is the ratio of fault current in relay coil to the pick-up current.

For example, suppose that a relay is connected to a 400/5 current transformer and set at 150%. With a primary fault current of 2400 A, the plug-setting multiplier can be calculated as under:
Pick-up value = Rated secondary current of *CT* Current setting = 5 * 1·5 =7·5 A
Fault current in relay coil =2400*5/400 = 30 A P.S.M = 30/7.5 =4

(iv) Time-setting multiplier. A relay is generally provided with control to adjust the time of operation. This adjustment is known as time-setting multiplier. The time-setting dial is calibrated from 0 to 1 in steps of 0.05 sec (see Fig. below).

These figures are multipliers to beused to convert the time derived from time/P.S.M. curve into the actualoperating time. Thus if the time setting is 0·1 and the time obtained from the time/P.S.M. curve is 3 seconds, then actual relay operating time = 3 ×0·1 = 0·3 second. For instance, in an induction relay, the time of operation is controlled by adjusting the amount of travel of the discfrom its reset position to its pickup position. This is achieved by the adjustment of the position of amovable backstop which controls the travel of the disc and thereby varies the time in which the relaywill close its contacts for given values of fault current. A so-called “time dial” with an evenly divided scale provides this adjustment. The actual time of operation iscalculated by multiplying the time setting multiplier with the time obtained from time/P.S.M. curve of the relay.



Functional Relay Types:

Most of the relays in service on power system today operate on the principle of electromagnetic attraction or electromagnetic induction. Regardless of the principle involved, relays are generally classified according to the function they are called upon to perform in the protection of electric power circuits.

For example, a relay which recognizes over current in a circuit (i.e. current greater than that which can be tolerated) and initiates corrective measures would be termed as an over current relay irrespective of the relay design. Similarly an overvoltage relay is one which recognizes overvoltage in a circuit and initiates the corrective measures. Although there are several types of special function relays, only the following important types will be discussed:

(i) Induction type over current relays

(ii) Induction type reverse power relays

(iii) Distance relays

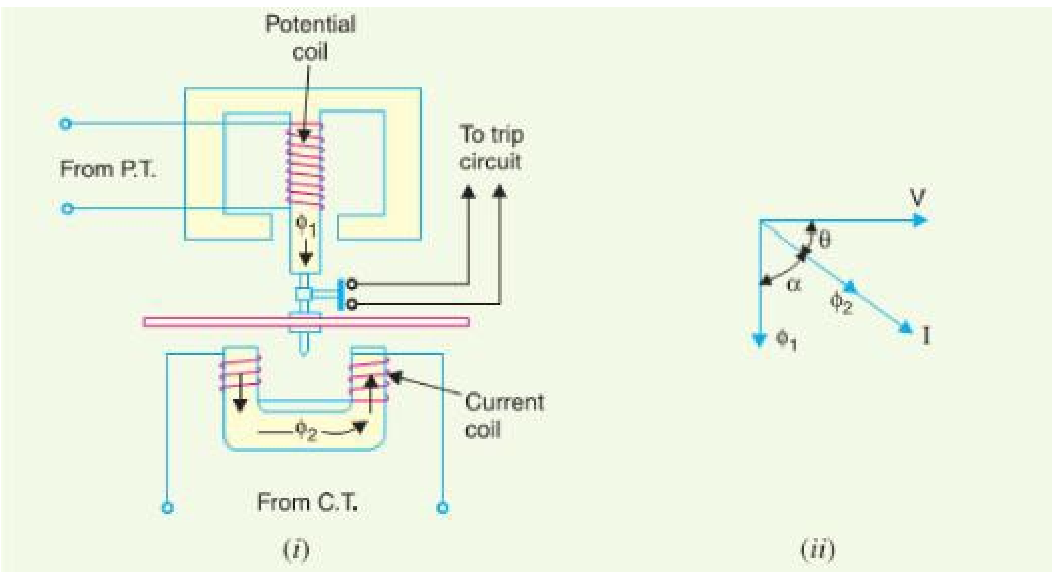
(iv) Differential relays

Induction Type Directional Power Relay

This type of relay operates when power in the circuit flows in a specific direction. Unlike a non-directional over current relay, a directional power relay is so designed that it obtains its operating torque by the interaction of magnetic fields derived from both voltage and current source of the circuit it protects.

Thus 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. Constructional detailsFig. below shows the essential parts of a typical induction type directional power relay.

It consists of an aluminum disc which is free to rotate In between the polesof two electromagnets. The upper electromagnet carries a winding (called potential coil) on the central limb which is connected through a potential transformer (P.T.) to the circuit voltage source.



The lower electromagnet has a separate winding (called current coil) connected to the secondary of C.T. in the line to be protected. The current coil is provided with a number of tappings connected to the plug setting bridge (not shown for clarity).

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 pre-set 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.

Operation: The flux φ 1 due to current in the potential coil will be nearly 90º lagging behind the applied voltage V. The flux φ2 due to current coil will be nearly in phase with the operating current I [See vector diagram in fig.].

The interaction of fluxes φ 1and φ2 with the eddy currents induced in the disc produces a driving torque given by :

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

$$\text{Since} \quad \phi_1 \propto V, \quad \phi_2 \propto I \quad \text{and} \quad \alpha = 90 - \theta$$

$$T \propto V I \sin(90 - \theta)$$

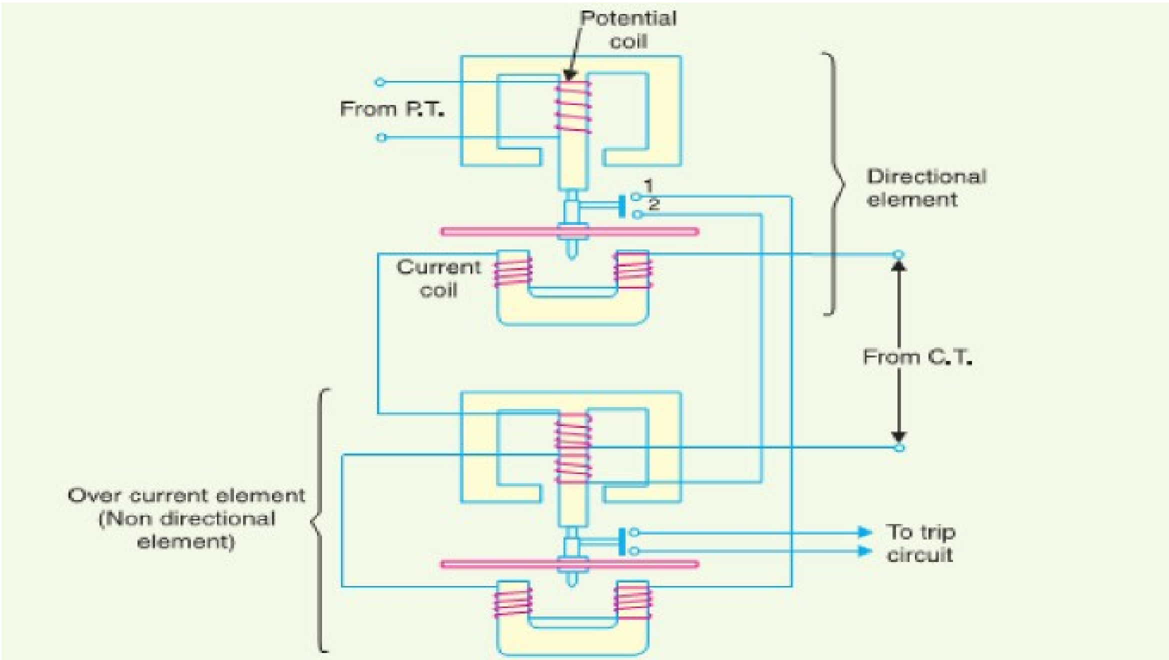
$$\propto V I \cos\theta$$

$$\propto \text{power in the circuit}$$

It is clear that the direction of driving torque on the disc depends upon the direction of power flow in the circuit to which the relay is associated. When 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 from the fixed contacts. Consequently, the relay remains inoperative. However, the reversal of current in the circuit reverses the direction of driving torque on the disc. When the reversed driving torque is large enough, the disc rotates in the reverse direction and the moving contact closes the trip circuit. This causes the operation of the circuit breaker which disconnects the faulty section.

Induction Type Directional Over current Relay:

The directional power relay discussed above is unsuitable for use as a directional protective relay under short-circuit conditions. When a short circuit occurs, the system voltage falls to a low value and there may be insufficient torque developed in the relay to cause its operation. This difficulty is overcome in the directional over current relay which is designed to be almost independent of system voltage and power factor.



Constructional details:

Fig. Shows the constructional details of a typical induction type directional over current relay. It consists of two relay elements mounted on a common case viz.(i)directional element and (ii) non-directional element.

(i) Directional element. It is essentially a directional power relay which operates when power flows in a specific direction. The potential coil of this element is connected through a potential transformer (P.T.) to the system voltage.

(ii) Non-directional element. It is an Over current element similar in all respects to a non-directional over current relay.

Operation.

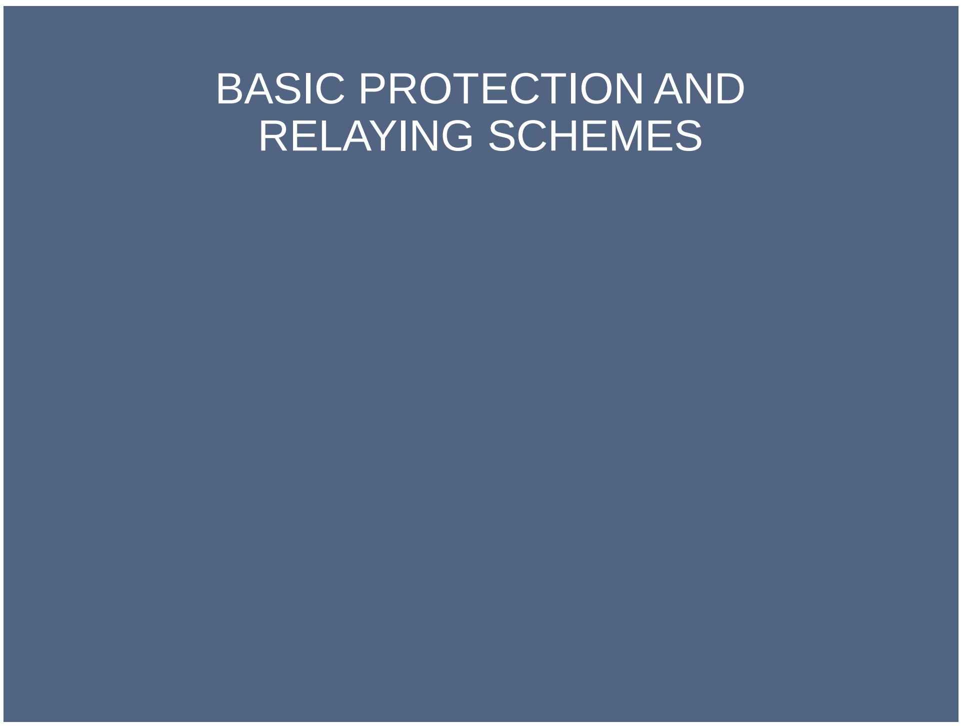
Under normal operating conditions, power flows in the normal direction in the circuit protected by the relay. Therefore, directional power relay (upper element) does not operate, thereby keeping the over current element (lower element) un-energized. However, when a short-circuit occurs, there is a tendency for the current or power to flow in the reverse direction. Should this happen, the disc of the upper element rotates to bridge the fixed contacts 1 and 2. This completes the circuit for over current element. The disc of this element rotates and the moving contact attached to it closes the trip circuit. This operates the circuit breaker which isolates the faulty section.

The two relay elements are so arranged that final tripping of the current controlled by them is not made till the following conditions are satisfied:

(i) Current flows in a direction such as to operate the directional element.

(ii) Current in the reverse direction exceeds the pre-set value.

(iii) Excessive current persists for a period corresponding to the time setting of over current element.



Differential Relays:

Most of the relays discussed so far relied on excess of current for their operation. Such relays are less sensitive because they cannot make correct distinction between heavy load conditions and minor fault conditions. In order to overcome this difficulty, differential relays are used.

A **differential relay** *is one that operates when the phasor difference of two or more similar electrical quantities exceeds a pre-determined value.*

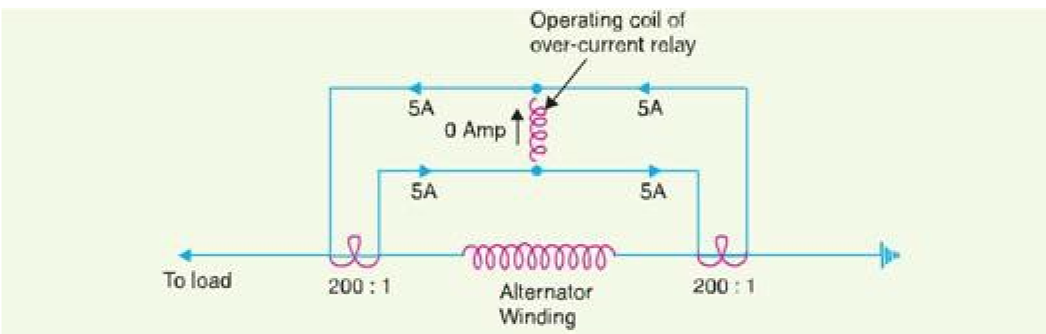
Thus a current differential relay is one that compares the current entering a section of the system with the current leaving the section. Under normal operating conditions, the two currents are equal but as soon as a fault occurs, this condition no longer applies. The difference between the incoming and outgoing currents is arranged to flow through the operating coil of the relay. If this differential current is equal to or greater than the pickup value, the relay will operate and open the circuit breaker to isolate the faulty section.

It may be noted that almost any type of relay when connected in a particular way can be made to operate as a differential relay. In other words, it is not so much the relay construction as the way the relay is connected in a circuit that makes it a differential relay. There are two fundamental systems of differential or balanced protection *viz.*

(i) Current balance protection ***(ii)*** Voltage balance protection

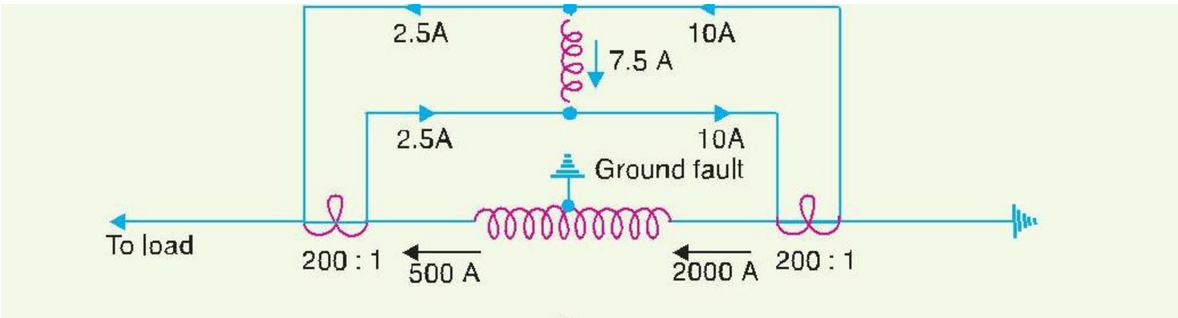
Current Differential Relay

Fig. shows an arrangement of an overcurrent 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 secondaries 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 the over current relay is connected across the CT secondary circuit. This differential relay compares the current at the two ends of the alternator winding



Under normal operating conditions, suppose the alternator winding carries a normal current of 1000 A. Then the currents in the two secondaries of CT's are equal [See Fig.].

These currents will merely circulate between the two CT's and no current will flow through the differential relay. Therefore, the relay remains inoperative. If a ground fault occurs on the alternator winding as shown in Fig. (*i*), 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.



(i)

Disadvantages

(*i*) The impedance of the pilot cables generally causes a slight difference between the currents atthe two ends of the section to be protected. If the relay is very sensitive, then the small differential current flowing through the relay may cause it to operate even under no fault conditions.

(*ii*) Pilot cable capacitance causes incorrect operation of the relay when a large through-currentflows.

(*iii*) Accurate matching of current transformers cannot be achieved due to pilot circuitimpedance. The above disadvantages are overcome to a great extent in biased beam relay.

Distance or Impedance Relays

The operation of the relays discusssed so far depended upon the magnitude of current or power in the protected circuit. However, there is another group of relays in which the operation is governed by the ratio of applied voltage to current in the protected circuit. Such relays are called distance or im-pedance relays. In an impedance relay, the torque produced by a current element is opposed by the torque produced by a voltage element. The relay will operate when the ratio *V/I* is less than a pre-determined value.

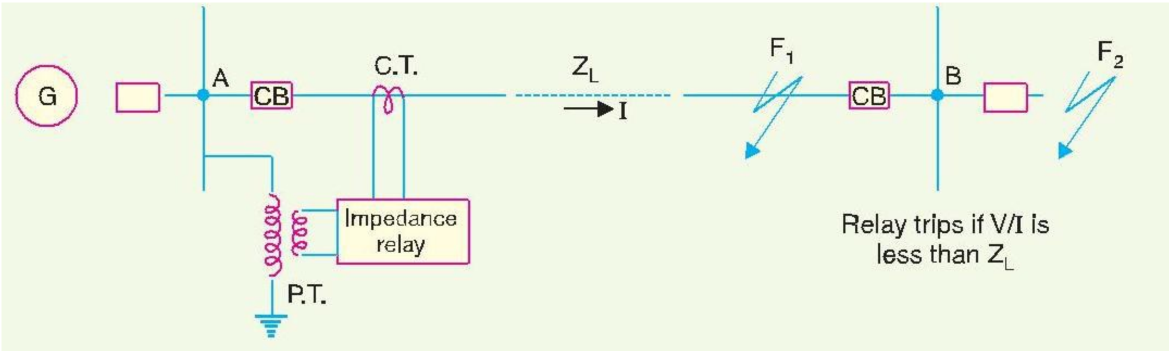


Fig. illustrates the basic principle of operation of an impedance relay. The voltage element of the relay is excited through a potential transformer (P.T.) from the line to be protected. The current element of the relay is excited from a current transformer (C.T.) in series with the line. The portion *AB* of the line is the protected zone. Under normal operating conditions, the impedance of the pro-tected zone is Z_L. The relay is so designed that it closes its contacts whenever impedance of the protected section falls below the pre-determined value *i.e.* Z_L in this case.

Now suppose a fault occurs at point F_1 in the protected zone. The impedance Z (= V /I) between the point where the relay is installed and the point of fault will be less than Z_L and hence the relay operates. Should the fault occur beyond the protected zone (say point F_2), the impedance Z will be greater than Z_L and the relay does not operate.

Types. A distance or impedance relay is essentially an ohmmeter and operates wheneverthe impedance of the protected zone falls below a pre-determined value. There are two types of distance relays in use for the protection of power supply, namely ;

(*i*) *Definite-distance relay*which operates instantaneously for fault upto a pre-determined distance from the relay.

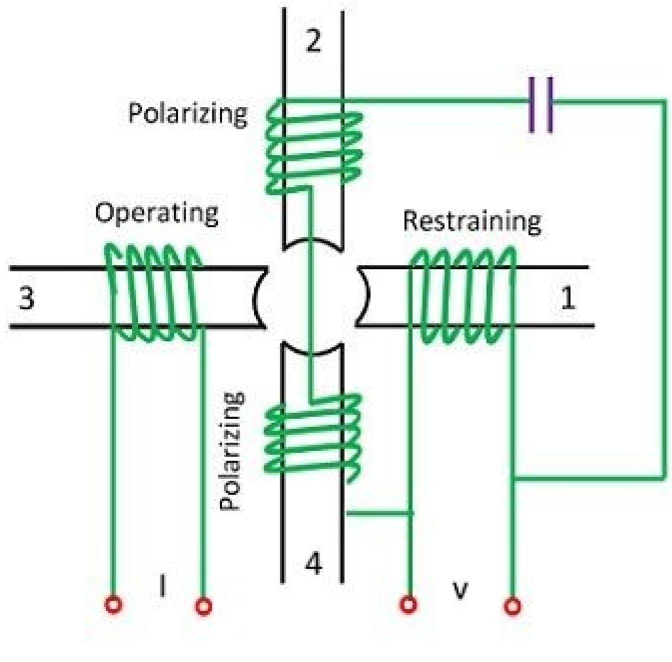
(*ii*) *Time-distance relay*in which the time of operation is proportional to the distance of fault fromthe relay point. A fault nearer to the relay will operate it earlier than a fault farther away from the relay.

It may be added here that the distance relays are produced by modifying either of two types of basic relays; the balance beam or the induction disc.

Mho Relay:

A mho Relay is a high-speed relay and is also known as the admittance relay. In this relay operating torque is obtained by the volt-amperes element and the controlling element is developed due to the voltage element. It means a mho relay is a voltage controlled directional relay.

A mho relay using the induction cup structure is shown in the figure below. The operating torque is developed by the interaction of fluxes due to pole 2, 3, and 4 and the controlling torque is developed due to poles 1, 2 and 4.



Schematic Diagram of Mho Relay

If the spring controlling effect is indicated by –K3, the torque equation becomes,

$$T = K_1 VI cos(\theta - 90°) - K_3$$

Where θ and τ are defined as positive when I lag behind V. At balance point, the net torque is zero, and hence the equation becomes

$$K_1 VI cos(\theta - \tau) - K_2 V^2 - K_3 = 0$$

$$\frac{K_1}{K_2}\text{Cos}(\theta-\tau)-\frac{K_3}{K_2VI}=\frac{V}{I}=Z$$

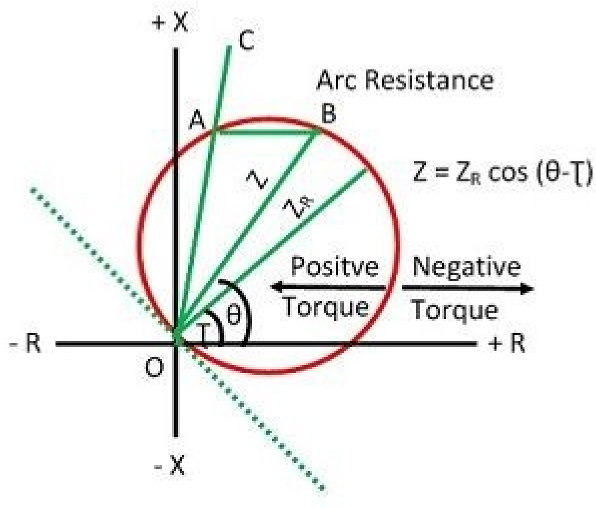
$$Z=\frac{K_1}{K_2}\text{Cos}\,(\theta-\tau)$$

If the spring controlled effect is neglected i.e., k3 = 0.

Operating Characteristic of Mho Relay:

The operating characteristic of the mho relay is shown in the figure below. The diameter of the circle is practically independent of V and I, except at a very low magnitude of the voltage and current when the spring effect is considered, which causes the diameter to decrease. The diameter of the circle is expressed by the equation as

ZR= K1 / K2 = ohmic setting of the relay

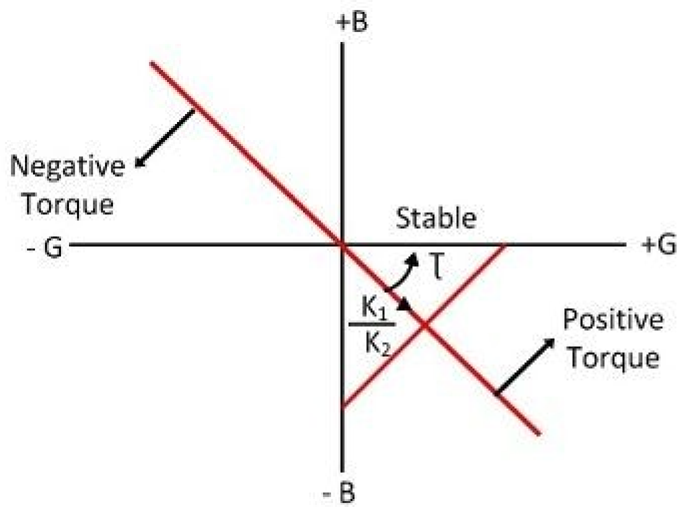


Operating Characteristic of Mho Relay

The relay operates when the impedance seen by the relay within the circle. The operating characteristic showed that circle passes through the origin, which makes the relay naturally directional. The relay because of its naturally directional characteristic requires only one pair of contacts which makes it fast tripping for fault clearance and reduces the VA burdens on the current transformer.

The impedance angle of the protected line is normally 60º and 70º which is shown by line OC in the figure. The arc resistance R is represented by the length AB, which is horizontal to OC from the extremity of the chord Z. By making the τ equal to, or little less lagging than Θ, the circle is made to fit around the faulty area so that the relay is insensitive to power swings and therefore particularly applicable to the protection of long or heavily loaded lines.

For a given relay the τ is constant, and the admittance phasor Y will lie on the straight line. The characteristic of mho relays on the admittance diagram is, therefore, a straight line and is shown in the figure below.



Characteristic of Mho Type Relay on Admittance Diagram

Mho relay is suitable for EHV/UHV heavily loaded transmission lines as its threshold characteristic in Z-plane is a circle passing through the origin, and its diameter is ZR. Because of this, the threshold characteristic is quite compact enclosing faulty area compactly and hence, there is lesser chance to operate during power swing and also it is directional.