Depending on principle of operation

Classification of relays.-

1- Electromagnetic Relays
  - Attracted armature
  - Balanced beam
  - Induction disc
  - Induction cup.

2. Directional Relays
  - Frequency relays
  - Undervoltage relays
  - Directional over current.

3. Differential Protection.-
  - Biased or percent differential
  - balanced voltage differential

4. Distance Relays
  - Impedance type
  - Reactance type
  - Mho type (admittance).

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Depending on type of principle used for operation, there are different types of relays-

1. Electromagnetic Relays

An electromechanical relay has one or more coils, movable elements, contact system, etc. The operation of such relay depends on whether the operating torque/force is greater than the restraining torque/force.

ie,

$$F = F_o - F_r \quad \text{OR} \quad T = T_o - T_r$$

where T, F = Net torque / force

T_o, F_o = Operating —"—

T_r, F_r = Restraining —"—.

* Relay operates when, $F_o > F_r$ or $T_o > T_r$

Attendance

The operating torque is produced by electromagnetic attraction / induction / thermal effect of electric current. The restraining torque is ~~prod~~ given by springs.

A] Attracted armature relay -

These are the simplest type of relays. It can be of any type like hinged armature type or plunger type.

These relays have coil or electromagnet energized by the coil. The coil is energized by the operating quantity such as current or voltage, which produces a magnetic flux, thereby creating a electromagnetic force. This force is proportional to the square of the flux in the ~~air~~ air gap or square of the current (if saturation is neglected)

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

where, F = Net force

K_1 = a constant.

I = current in operating coil

K_2 = restraining force

Attracted armature relays respond to both ac & dc because torque is proportional to I^2. These relays are fast ~~relays~~ operating & fast reset relays because of small length of travel & light moving parts.

The attracted armature relays operates on the principle of electromagnetic force produced which ~~operate~~ attracts the plunger or hinged armature. A restrai[ning] force is provided by means of springs so that the armature returns to its original position when the electromagnet is de-energized. Whenever the force developed by the electromagnet exceeds th[e] restraining force, the moving contact clo[ses]

Attendance

due to movement of the armature.

~~Induction Relays~~

~~Balanced beam relays~~

Applications of attracted armature relays.

- These have applications in a.c & dc equip.
- These are instantaneous relays & has no intentional time lags & are sensitive to starting currents, load fluctuations & current surges
- These can be designed to respond over/under current, over/under voltage usual applications are-
- Over current protection & time lag is obtained by using attracted armature relays in conjuction with a definite time lag relay.
- Differential protection where attracted arma. relay is used for differential protection
- Auxiliary relays

Balance beam relays

It consists of a horizontal beam pivoted centrally, with one armature attached to either side. There are two coils, one on each side. The beam remains in horizontal position till operating force become more than restraining force. The current in one coil gives operating force while the current in other coil gives restraining force.

The beam is given a ~~sligh~~ slight mechanical bias by means of spring or weight adjustment

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such that under normal conditions, the cont are open. When operating torque increase the beam tilts & the contacts closes.

Operating principle,

Neglecting spring effect, the net torque

$$T = K_1 I_1^2 - K_2 I_2^2$$

where, T = Net torque

I_1 = Current in operating coil

I_2 = current in restraining coil

K_1, K_2 — constant.

Under balance cond^n, net torque is ze

$$\therefore K_1 I_1^2 = K_2 I_2^2$$

$$\therefore \frac{I_1}{I_2} = \sqrt{\frac{K_2}{K_1}} = \text{constant.}$$

Attendance

Induction disc relays: Shaded pole structure.

These operates on principle of electromagnetic induction.

In this type of relay, a metal disc is allowed to rotate betn two electromagnets. The electromagnets are energized by alternating currents.

These are most widely used relays for protection of lines or apparatus. Operating force is developed ~~due~~ due to the interaction of two AC flux displaced in time & space in movable element (rotor). Depending on type of movable element (rotor), it is disc type or cup type relay.

The diag shown is most commonly used shaded pole type induction disc relay. This relay is generally activated by current flowing in a single coil placed on a magnetic core having an air gap. The main air gap flux caused because of the flow of current is split into two out of phase components by a shading ring, which is made up of copper that encircles the portion of the pole face in each pole. The air gap flux of shaded pole lags ~~behing~~ behind the flux of non-shaded pole. The rotor (moving disc) is pivoted in such a way that it rotates in the air gap betn the poles. The phase angle betn the two fluxes, piercing the disc, is decided at the design stage.

In most designs, the disc may rotate by as much as 280°. Also, the moving contact on the disc is so positioned that it meets the stationary contacts when the largest radius section of the disc is under electromagnet.

←

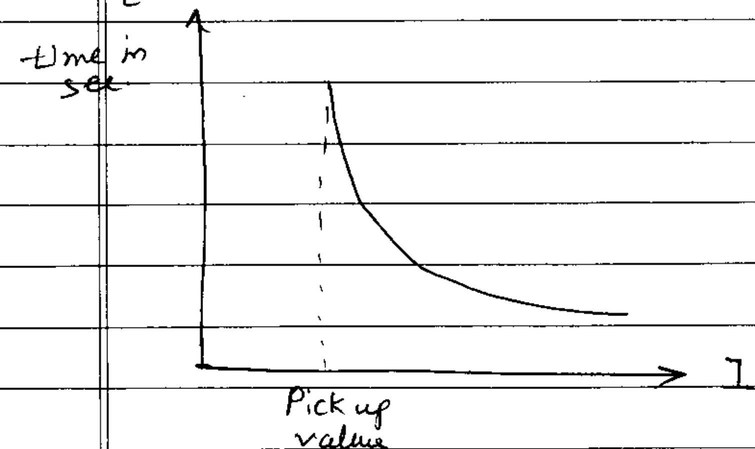
Induction disc relay- ~~watt hour meter structure~~
Continued →

The control torque is provided with the help of control spring attached to the disc spindle. With the movement of the disc towards closing of contacts, 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 increase in the area of the disc betn the poles of actuating quantity which causes increase in eddy currents & hence increase in electrical torque that just balances the increase in the control spring torque. The shape of the disc is not perfectly circular.

Modern induction disc relays are robust & reliable. The time - current characteristics of the relays are inverse characteristics, ie the time reduces as current increases.

The current settings can be changed by ta[king]
suitable number of turns. Higher current
setting will require smaller no. of turns.



The time setting can be changed by changing the relative position of contacts by adjusting the length of travel of moving contacts. This is known as time multiplier setting. The higher the time multiplier setting the greater is the operating time.

Attendance

Watt-hour meter type structure —

This structure gives the same results as given by a shaded pole type.

The construction is similar to watt-hr meter (energy meter).

It consists of an E-shaped electromagnet & a U-shaped electromagnet with a disc free to rotate in betn.

The E-shaped electromagnet carries two windings - pri. & secondary. The pri. wdg. carries relay current I_1 while sec. wdg. is connected to the windings of U-shaped electromagnet.

The pri. current induces emf in the sec. & so circulates a current I_2 in it. The flux ϕ_2 induced in the U-shaped magnet lags behind the flux ϕ_1 by an angle θ. The two fluxes ϕ_1 & ϕ_2 differing in phase by angle θ develop a driving torque in the disc proportional to $\phi_1 \phi_2 \sin\theta$.

Important feature of this relay is that its operation can be controlled by opening or closing the sec. wdg. ckt. If this ckt is opened, no torque will be developed & thus the relay can be made inoperative.

Induction Cup Relay -

This relay has, two, four or more electromagnets in stator. These are energized by relay coils. The rotating magnetic field is produced by the pair of relay coils. A rotor is a hollow metallic cylindrical ~~sq~~ cup that is arranged betⁿ two/four/eight electromagnets and a stationary iron core. The cup is free to move in the gap betⁿ the electromagnet & the stationary iron core.

The rotating field ~~produces~~ induces current into the ~~sq~~ cup, which then causes the cup to rotate in the same ~~direct~~ direction. The rotation depends upon the magnitude of the applied AC quantities & phase displacement betⁿ them.

~~In~~ Actually when disc of induction relay is replaced by aluminium cup, the inertia of rotating sys. is significantly reduced. Due to low mechanical inertia, the operating speed of cup relay is much higher than that of disc relay.

Attendance

The relay can be responsive to voltage or current. Similar structures are used in both cases.

A modern induction cup relay have an operating time of 0.010 sec.

Directional Relays

Active power in an electrical circuit
$$P = V \cdot I \cdot \cos\phi$$
where ϕ is angle betn V & I.

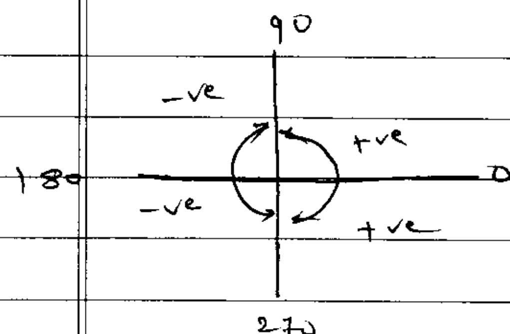
Reactive power is, $Q = V \cdot I \cdot \sin\phi$

For ϕ betn ~~90°~~ 270° & ~~270°~~ 90°, $\cos\phi$ is +ve

∴ Real power P is +ve

For $\phi = 90°$ and $180°$,
real power is zero.

For $\phi = 90°$ to $270°$, real power P is −ve.



Therefore, the power flow can be sensed by sensing the magnitude and sign of $VI\cos\phi$

Attendance

Directional Power Relay

The directional protection responds to flow of power in a definite direction with reference to location of CTs & PTs. Directional relays respond to the magnitude & sign (direction) of power applied at their terminals.

Induction disc type - watthour meter type construction can be modified to obtain directional feature. When directional feature is desired, the relay is provided with two actuating coils called current coil &

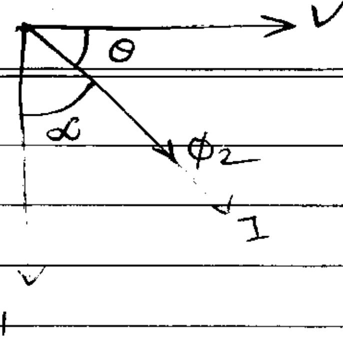
voltage coil. Induction cup relays having 4, 6, 8 pole construction are also used as directional relays.

The current coils of the relays are connected to the secondary of the CT. The voltage coils are connected to secondary of PTs. Depending on the phase angle betn current & voltage in the relay coils, the connection is called 30°, 60° or 90° connection.

The moving sys. of induction type directional relay comprises an aluminium sector and a contact which are fixed to a vertical spindle. The hair spring which is attached to the spindle at one end & to the main frame at the other, is equipped with a torsion setting device and serves two purposes.- (1) as control spring
(2) as electrical connection betn the moving contact & main frame.

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 moving disc can be adjusted & hence any desired time setting can be obtained.

The flux Φ_1 due to current in the potential coil will be nearly 90° lagging behind the applied vltg. V. The flux Φ_2 due to current coil will be nearly in phase with the operating current I.



The interaltion of fluxes ϕ_1 & ϕ_2 with the eddy currents induced in the disc produces a driving torque given by,

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

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

$$T \propto V \cdot I \sin(90 - \theta)$$
$$\propto VI\cos\theta$$
$\propto$ power in the ckt.

Attendance

$\therefore$ The direction of driving torque on the disc depends upon the direction of power flow in the ckt.

When the power in the ckt flows in the normal direction, the driving torque & the restraining torque (due to springs) help each other to not to turn away the moving contact ~~from~~ towards the fixed contacts. Consequently, the relay remains inoperative.

The reversal of current in the ckt. reverses the direction of driving torque on the disc. When the reversed driving torque is large enough, the disc rotates in the reverse direction & the moving contacts closes the trip ckt.

Directional Overcurrent Relay

Directional power relay is not suitable to use as directional overcurrent relay.

When a s.c. occurs, the sys. vltg. falls to a low value & there may be insufficient ~~tor~~ torque developed in the relay to cause its operation. This difficulty is overcome in the induction type directional overcurrent relay which is designed to be almost independent of sys. vltg. & p.f.

It consists of two relay elements mounted on a common case, namely, directional element and non-directional element.

Directional element – is a directional power relay which operates when power flows in a specific direction. The potential coil is connected to a PT & current coil is energized through a CT. This wdg. is carried over the upper magnet of the non-directional element. The trip contacts (1 & 2) of directional element are connected in series with the secondary ckt. of the overcurrent element. Therefore, the directional element must operate first (contacts 1 & 2 should close) in order to operate the overcurrent element.

Non-directional element – it is an overcurrent element. The spindle of the disc of this element carries a moving contact which closes the fixed contacts after the operation of directional element.

Operation – Under normal operating conditions, power flows in the normal direction in the ckt. Therefore the induction type directional ~~overcurrent~~ power relay does not operate (upper element), thereby keeping the overcurrent relay unenergized. However, when a s.c. occurs, there is a tendency for the current or power to flow in the reverse direction. When this happens, the disc of the upper element rotates to close contacts 1 & 2. This completes the ckt for the overcurrent element. The disk of this element rotates & moving contacts of it closes the trip ckt. This operates the ckt. breaker to isolate the faulty section.

Attendance

The arrangement is made in such a way that final tripping is not made till,

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 the overcurrent element.

Frequency Relay

The freq. of induced emf of syn. generators is maintained constant by constant speed. In case of overspeeding due to loss of load, or underspeeding due to increase in load, the freq. varies from normal value.

Freq. relays are used in generator protection. These are either electromagnetic or static relays. They can be either under freq. or over freq. relays.

Freq. relays are generally connected to the sec. of P.T. It monitors the freq. constantly. It has two pairs of coils which are connected in parallel to supply vltg. through impedances. The impedance vary with the freq. of supply. The impedances are tuned such that no torque is exerted on the cup rotor at rated freq. The torque exerted on the cup rotor will be clockwise or anticlockwise depending upon ~~the~~ whether the freq is more or less than the normal one.

The freq. setting can be varied by varying the position of sliding resistor. The pick-up sensitivity can be varied by adjusting the restraining spring.

Under-voltage Relay

Under-voltage protection is provided for A.C ckts, bus bars, motors, rectifiers, transformers, etc. Under-voltage relays are necessary for voltage control & reactive power control of network buses and load buses.

These relays can have inverse characteristic or instantaneous char. depending on design. In case of Inverse time undervoltage relays, operating time reduces with reduction in voltage.

Induction disc type construction is used for inverse undervoltage relays. The relay coil is energized by voltage to be measured either directly or through a P.T. The construction is similar to ~~us~~ usual induction relay or attracted armature relay. But the directions of torques on the movable element of relay are different. For ~~normal~~ voltage lower than normal, ~~voltage~~, the restraining torque reduces and the relay operates due to operating torque.

Attendance

Differential Protection (Relays)

A differential relay responds to vector difference betn two or more similar electrical quantities. Basic features are.–

i) it has at least two actuating quantities, eg, I_1, I_2.

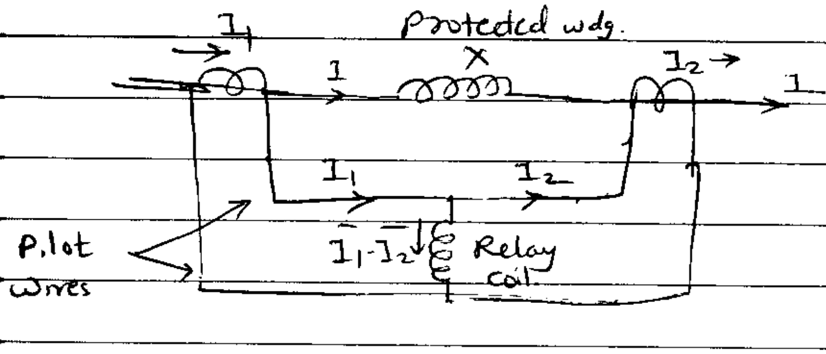
ii) The two or more actuating quantities should be similar

iii) The relay responds to the vector difference betn the two eg. $\bar{I}_1 - \bar{I}_2$ which includes magnitude & phase angle difference.

Most differential relays are current differential relays. These are used in,

- protection of generator, transformer
- protection of feeder, transmission lines
- — " — large motors
- Bus zone protection

To explain the principle,



X is the wdg. of protected machine. When there is no internal fault, the current entering in X is equal & in phase with current leaving X. These currents I_1 & I_2 circulate in the pilot wires. The polarity connections are such that currents I_1 & I_2 are in the same direction in pilot wires during normal conditions or external faults. Relay Operating coil is connected at the middle of pilot wires. Relay unit is of overcurrent type.

During normal conditions & external fault the protection sys. is balanced & the CT ratios are such that secondary currents are equal. These currents circulate in pilot wires. The vector differential current $I_1 - I_2$ which flows the relay coil is zero

ie $\bar{I}_1 - \bar{I}_2 = 0$ at normal condⁿ.

Hence relay does not operate.

When fault occurs in the protected zone, the current entering the protected winding is no more equal to the one leaving the winding because some current flows through the fault.

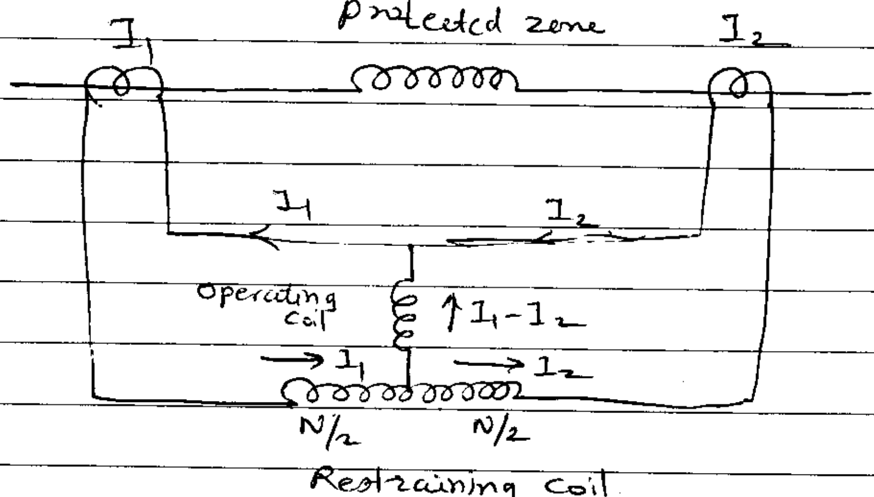
$\therefore \bar{I}_1 \neq \bar{I}_2$

$\therefore$ The difference $\bar{I}_1 - \bar{I}_2$ Flows through the relay operating coil and the relay operates if the operating torque is more than restraining torque

Attendance

Biased or Percent differential relay

It is the advanced form of differential protection relay. The only difference betⁿ them is the restraining coil. The restraining coil is used for overcoming the trouble arising out of differences in the current ratio for the high value of external s.c. current. That is, because of fault current, there is unbalance in the ratio of currents in the CTs.



In this relay the operating coil is connected to the midpoint of the restraining coil. The total ampere turns in the restraining coil becomes the sum of ampere turns in its two halves. ie, $\frac{I_1 N}{2} + \frac{I_2 N}{2}$ which gives the average restraining current of $\frac{I_1 + I_2}{2}$ in N turns.

Restraining coil produces the force which opposes the force due to Operating coil. The operating coil carries the differential current, ie $I_1 - I_2$ and restraining coil carries current proportional to $\frac{I_1+I_2}{2}$.

Normally current I_1 flows in N/2 part and

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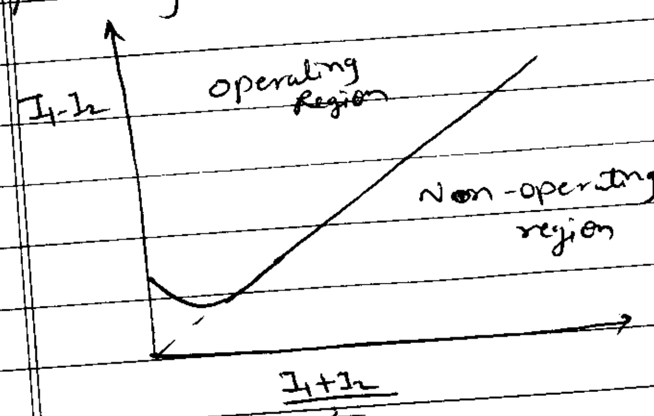
& current I_2 flows in other $N/2$ part. Hence effective ampere turns is $\frac{N}{2}(I_1+I_2)$
Hence total amount of current through restraining coil is $\frac{I_1+I_2}{2}$.
Under normal cond^n, force by restraining coil is greater than force produced by operating coil. Therefore relay doesn't operate. During fault cond^n, operating force becomes more than restraining force, hence relay operates.
The ratio of differential operating current to average restraining current is a fixed percentage. Hence the relay is called percentage differential relay.
Operating char.,



Distance Protection

Distance relays are double actuating quantity relay with one coil energized by voltage & the other by current. The torque produced is such that when V/I reaches below a set value, the relay operates.

During a fault in a T.L. the fault current increases & the voltage at fault point reduces. The ratio V/I is measured at ~~fault~~ the location of CT & PT. The voltage at PT location depends on distance betn the PT & the fault. If fault is nearer, measured voltage is lesser & vice versa. Hence assuming constant fault resistance, each value of V/I measured from relay location corresponds to distance betn relaying point & fault along the line. Hence such protection is called impedance protection or distance protection.

Distance protection is high speed protection & is simple to apply. It can be used as primary & backup protection. It is widely used in protection of T.L.

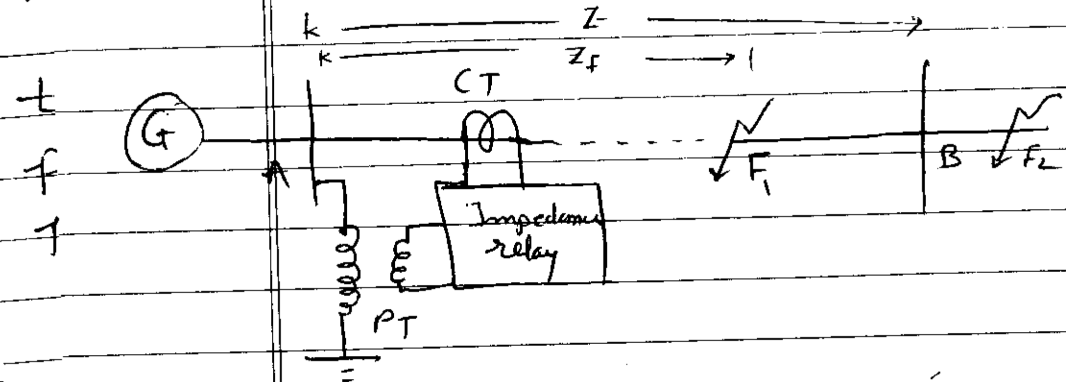
Impedance type distance relay

The relay measures the impedance of the faulty point. If it is less than the ~~relay~~ relay setting value, it operates.

In normal operating condition, the line vltg value is more than the current.

But when fault occurs, the current value increases & vtg reduces. This reduces the impedance value & relay operates.

Consider the impedance relay is placed on the T.L. for the protection of the line AB. Z is the impedance of the line in normal operating conditions.



Let F_1 fault occur in line AB. This fault decreases impedance below the relay setting value. The relay operates. If the fault is beyond the protective zone, the relay is inoperative.