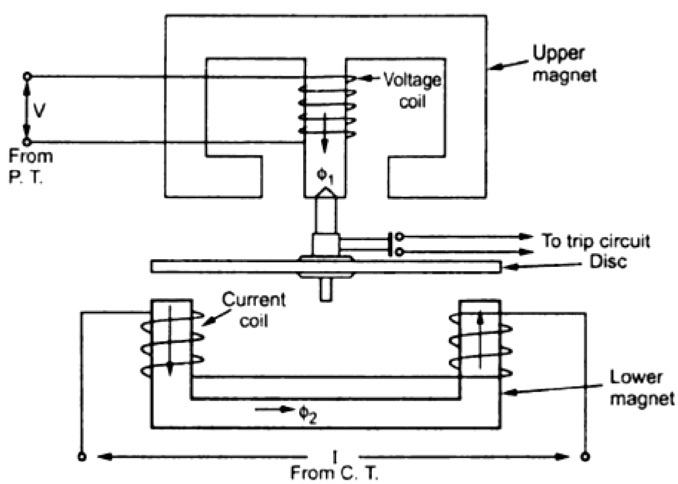
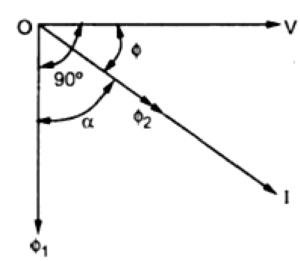
UNIT 2
Relay Application and Characteristics

In the previous unit we had studied about basics of Relays such as what is protection of power system? What types of protection we use? Why do we use Relays. In this unit we are going to cover constructional features of relays.

2.1 Direction Power Relay

This relay is used to protect against the power flow. If the power flow(which is generally considered as the direction of current flow) in the correct direction the relay do not trip but in any situation power start flowing in opposite direction then the relay will trip. In this relay amount of current do not matter a lot only direction of power flow is considered. The construction of this type of relay is similar to the watthour meter type relay the only difference is that the primary relay coil is fed from secondary of the P.T. and secondary relay coil is fed from the secondary of C.T. as shown in the figure. The C.T. and P.T. are associated with the same line which is to be protected.





The current coil of relay produces a flux $\emptyset_2$ which is in phase with the current I. the voltage coil produces the flux $\emptyset_1$which lag 90° from the voltage V. The current I lags the voltage V by an angle $\emptyset$. The angle between $\emptyset_1$and $\emptyset_2$ is α as shown in the phasor diagram.

The interaction of flux $\emptyset_1$and $\emptyset_2$ troduces the torque hence we can write,

$$T \propto \emptyset_1\emptyset_2 \sin\alpha$$

But $\emptyset_1 \propto V$ and $\emptyset_2 \propto I$

While $\alpha = 90 - \emptyset$

$$T \propto VI \sin(90 - \emptyset)$$

$$\boxed{T \propto VI \cos\emptyset \propto power\ in\ circuit}$$

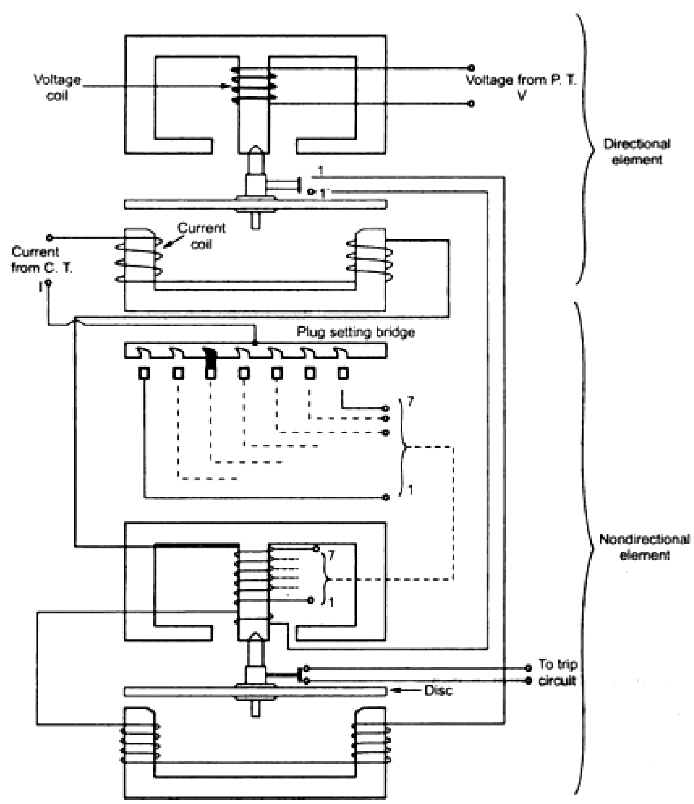
Under the normal working condition, the driving torque act in the same direction as that of restraining torque. This moves the moving contact away from the fixed tripping circuit contacts. Thus relay remains Inoperative as long as power flow is in one particular direction. As soon as the fault occur there is a current reversal this produces the torque in opposite direction and relay contacts move towards the trip contacts of the C.B. and closes the contact.

2.2 Directional Induction Type Overcurrent relay

In this type of relay the direction of power flow and the amount of fault cueernt both are considered. The construction of this type of relay is very simple and interesting. The Directional Induction Type Overcurrent relay uses two relay element mounted on a common case. These two elements are

- Directional power relay
- Induction type over current relay

These type of relays are connected in the manner as shown in the figure.

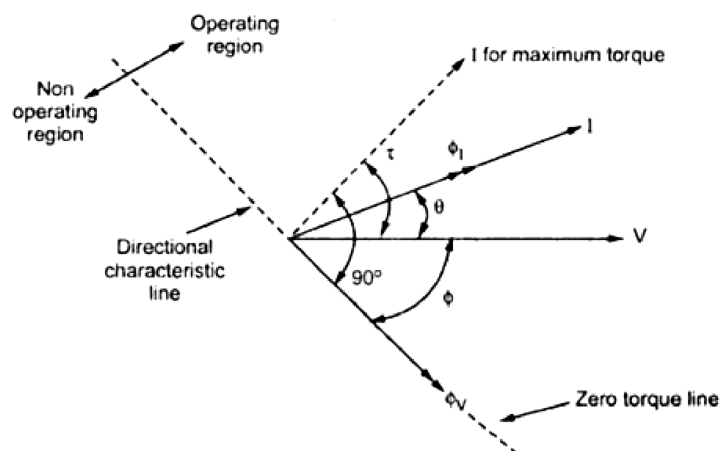


The upper relay is directional power relay and the lower relay is Overcurrent relay. The current coil of directional power relay is connected with primary coil of the over current relay. The secondary coil of over current relay is connected with the trip circuit of the directional power relay.

Its working is very simple. as we can see that the primary of overcurrent relay is already energized with current coil of directional relay. As soon as the current start flowing in reverse direction the directional relay works and closes the trip contacts which close the secondary coil circuit of Overcurrent relay. When the current increases from the per decided value the contacts of Overcurrent relay get closed and a trip signal is sent to C.B which further opens the contacts of CB.

Characteristic of Directional Induction Type Overcurrent relay:

The phasor diagram of the relay is given bellow. In this relay you can observe that the current I is leading voltage V by an angle θ. This is not naturally happen. We make an arrangement in the relay so that current I leads the voltage V.



The torque is proportional to the fluxes $\emptyset_V$, $\emptyset_1$ and sin of the angle between the two fluxes.

$$T \propto \emptyset_V \emptyset_1 \sin(\emptyset_V \hat{} \emptyset_1)$$

$$\propto \emptyset_V \emptyset_1 \sin(\theta + \emptyset)$$

Now $\emptyset_V \propto V$ and $\emptyset_1 \propto I$

$$T = KVI \sin(\theta + \emptyset)$$

Where K = Constant

This will be satisfied when the relay current I phasor lies along the $\emptyset_V$ phasor or in anti phase with $\emptyset_V$. The corresponding line is called zero torque line and is shown in figure.

2.3 Differentia Relays

The relays used in power system protection are of different types. Among them differential relay is very commonly used relay for protecting transformers and generators from localised faults. Differential relays are very sensitive to the faults occurred within the zone of protection but they are least sensitive to the faults that occur outside the protected zone. Most of the relays operate when any quantity exceeds beyond a predetermined value for example over current relay operates when current through it exceeds predetermined value. But the principle of differential relay is somewhat different. It operates depending upon the difference between two or more similar electrical quantities.

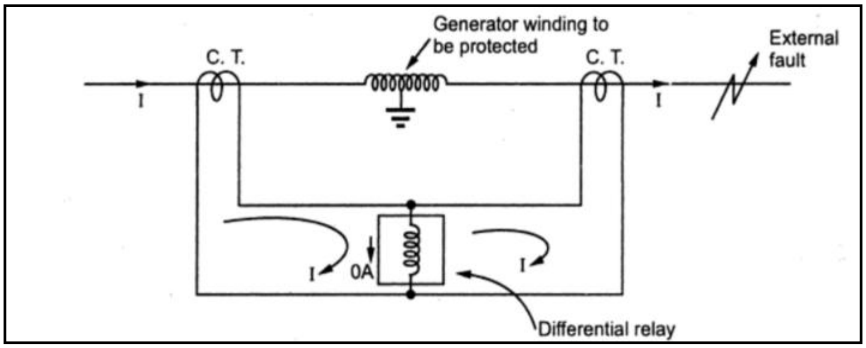
The differential relay is one that operates when there is a difference between two or more similar electrical quantities exceeds a predetermined value. In differential relay scheme circuit, there are two currents come from two parts of an electrical power circuit. These two currents meet at a junction point where a relay coil is connected. According to Kirchhoff Current Law, the resultant current flowing through the relay coil is nothing but summation of two currents, coming from two different parts of the electrical power circuit. The polarities and amplitude of both the currents are so adjusted that the phasor sum of these two currents, is zero at normal operating condition. Thereby there will be no current flowing through the relay coil at normal operating conditions. But due to any abnormality in the power circuit, if this balance is broken, that means the phasor sum of these two currents no longer remains zero and there will be non-zero current flowing through the relay coil thereby relay being operated.

2.4 Types of Differential Relay

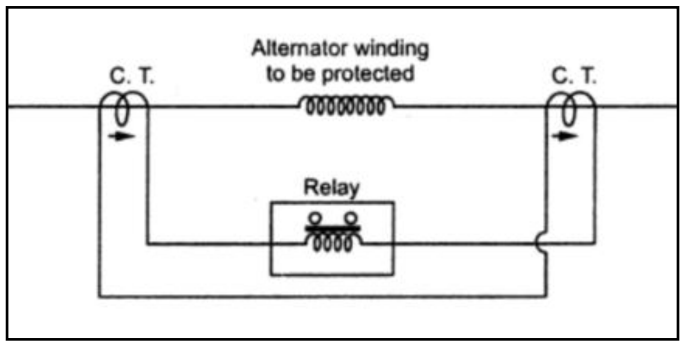
There are mainly two types of differential relay depending upon the principle of operation.

Current Balance Differential Relay:

In current differential scheme, there are two sets of current transformer each connected to either side of the equipment protected by differential relay. The ratio of the current transformers are so chosen, the secondary currents of both current transformers matches each other in magnitude. The polarity of current transformers are such that the secondary currents of these CTs opposes each other. From the circuit is clear that only if any nonzero difference is created between this to secondary currents, then only this differential current will flow through the operating coil of the relay. If this difference is more than the peak up value of the relay, it will operate to open the circuit breakers to isolate the protected equipment from the system.



Voltage Balance Differential Relay:

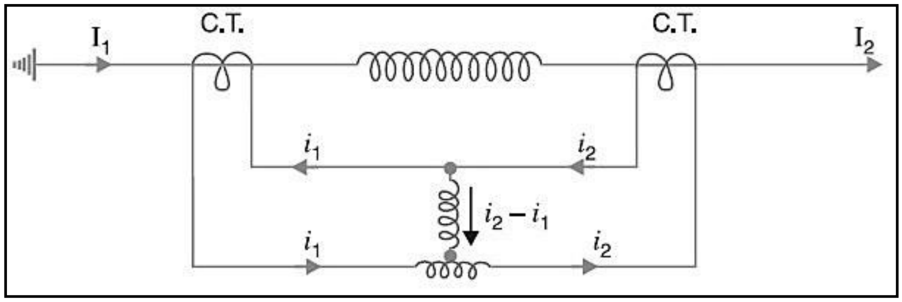


In this arrangement the current transformer are connected either side of the equipment in such a manner that EMF induced in the secondary of both current transformers will oppose each other. That means the secondary of the current transformers from both sides of the equipment are connected in series with opposite polarity. The differential relay coil is inserted somewhere in the loop created by series connection of secondary of current transformers as shown in the figure. In normal operating conditions and also in through fault conditions, the EMFs induced in both of the CT secondary are equal and opposite of each other and hence there would be no current flowing through the relay coil. But as soon as any internal fault occurs in the equipment under protection, these EMFs are no longer balanced hence current starts flowing through the relay coil thereby trips circuit breaker.

There are some disadvantages in the voltage balance differential relay such as A multy tap transformer construction is required to accurate balance between current transformer pairs. The system is suitable for protection of cables of relatively short length otherwise capacitance of pilot wires disturbs the performance. On long cables the charging current will be sufficient to operate the relay even if a perfect balance of current transformer achieved. These disadvantages can be eliminated from the system by introducing Translay system which is nothing but modified balance voltage differential relay system.

Percentage Differential Relay:

This is designed to response to the differential current in the term of its fractional relation to the current flowing through the protected section. In this type of relay, there are restraining coils in addition to the operating coil of the relay. The restraining coils produce torque opposite to the operating torque. Under normal and through fault conditions, restraining torque is greater than operating torque. Thereby relay remains inactive. When internal fault occurs, the operating force exceeds the bias force and hence the relay is operated. This bias force can be adjusted by varying the number of turns on the restraining coils. As shown in the figure below, if I_1 is the secondary current of CT_1 and I_2 is the secondary current of CT_2 then current through the operating coil is $I_1 - I_2$ and current through the restraining coil is $(I_1+ I_2)/2$. In normal and through fault condition, torque produced by restraining coils due to current $(I_1+ I_2)/2$ is greater than torque produced by operating coil due to current $I_1- I_2$ but in internal faulty condition these become opposite. And the bias setting is defined as the ratio of $(I_1- I_2)$ to $(I_1+ I_2)/2$



$$\text{Bias setting in percentage} = \frac{I_1 - I_2}{(I_1 + I_2)/2} \times 100\%$$

It is clear from the above explanation, greater the current flowing through the restraining coils, higher the value of the current required for operating coil to be operated. The relay is called percentage relay because the operating current required to trip can be expressed as a percentage of through current.

2.5 Distance Protection

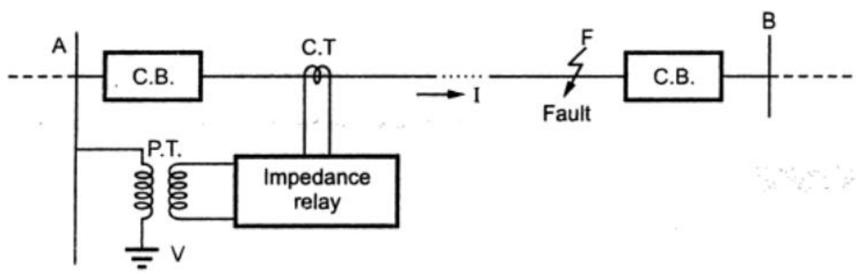
Distance relays respond to the voltage and current, i.e., the impedance, at the relay location. The impedance per mile is fairly constant so these relays respond to the distance between the relay location and the fault location.

As the power systems become more complex and the fault current varies with changes in generation and system configuration, directional overcurrent relays become difficult to apply and to set for all contingencies, whereas the distance relay setting is constant for a wide variety of changes external to the protected line.

There are three general distance relay types. Each is distinguished by its application and its operating characteristic.

- Impedance relay which is based on measurement of impedance Z
- Reactance relay which is based on measurement of reactance X
- Admittance or Mho relay which is based on measurement of component of admittance Y.

Impedance Relay:



The working principle of distance relay or impedance relay is very simple. There is one voltage element from potential transformer and an current element fed from current transformer of the system. The deflecting torque is produced by secondary current of CT and restoring torque is produced by voltage of potential transformer. In normal operating condition, restoring torque is more than deflecting torque. Hence relay will not operate. But in faulty condition, the current becomes quite large whereas voltage becomes less. Consequently, deflecting torque becomes more than restoring torque and dynamic parts of the relay starts moving which ultimately close the No contact of relay. Hence clearly operation or working principle of distance relay, depends upon the ratio of system voltage and current. As the ratio of voltage to current is nothing but impedance a distance relay is also known as impedance relay.

The operation of such relay depends upon the predetermined value of voltage to current ratio. This ratio is nothing but impedance. The relay will only operate when this voltage to current ratio becomes less than its predetermined value. Hence, it can be said that the relay will only operate when the impedance of the line becomes less than predetermined impedance (voltage / current). As the impedance of a transmission line is directly proportional to its length, it can easily be concluded that a distance relay can only operate if fault is occurred within a predetermined distance or length of line.

Torque equation:

The positive torque is produced by the current element is proportional to I^2 while the negative torque produced by the voltage element is proportional to V^2.

Let control spring effect produces a constant torque of $-K_3$.

$$T = K_1 I^2 - K_2 V^2 - K_3$$

Where K_1 and K_2 are the constants, ehile V and I are r.m.s. values.

At the balance point when the relay is on the vaerge of operating the3 net torque is zero hence we can write'

$$0 = K_1 I^2 - K_2 V^2 - K_3$$

$$K_2 V^2 = K_1 I^2 - K_3$$

Deviding both side by $K_2 I^2$,

$$(V/I)^2 = (K_1/K_2) - (K_3/K_2 I^2)$$

$$Z^2 = (K_1/K_2) - (K_3/K_2 I^2)$$

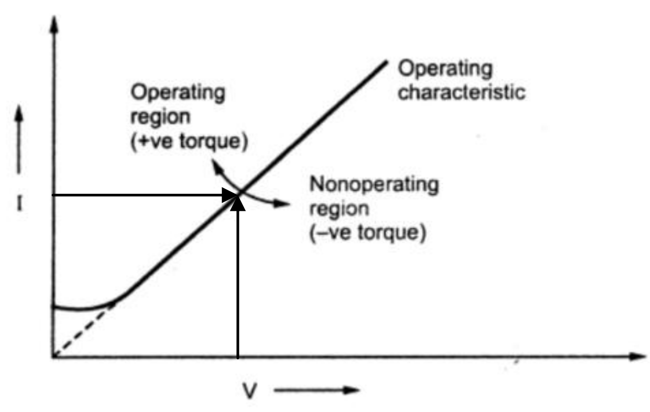
$$Z = \sqrt{\frac{K_1}{K_2} - \frac{K_3}{K_2 I^2}}$$

Generally the spring effect is neglected as its effect is dominant at low current which generally do not occur in practice. So with $K_3 = 0$,

$$Z = \sqrt{\frac{K_1}{K_2}}$$

$$= \frac{V}{I}$$

Operating characteristic:



As we know that the impedance relay will trip when the impedance of the line becomes low then a pre defined value. For a particular fault position, the ratio (V/I) i.e. impedance is constant. Which is shown by straight line in the above figure. The value of Z changes according to the fault position. If the fault occur near the relay then the value of fault current is high hence the impedance (V/I) is less. As the fault position moves away from the relay location the value of fault current becomes low hence increasing the value of impedance (V/I).

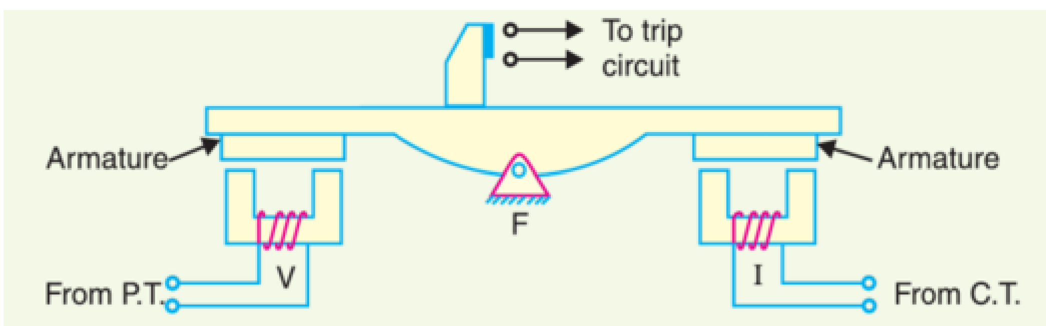
2.6 Types of Distance or Impedance Relay

There are mainly two **types of distance relay**-

- **Definite distance relay**.
- **Time distance relay**.

Let us discuss one by one.

Definite Distance Relay:



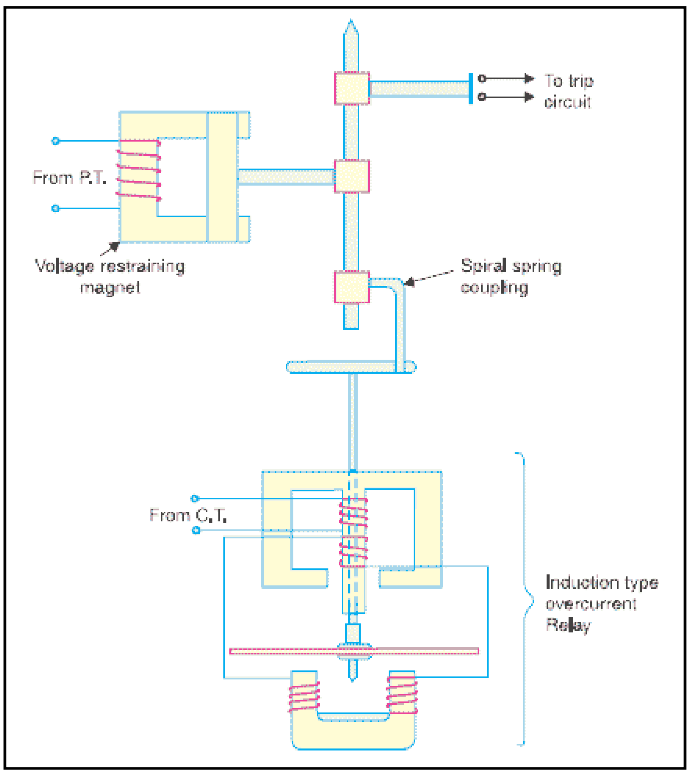
This is simply a variety of balance beam relay. Here one beam is placed horizontally and supported by hinge on the middle. One end of the beam is pulled downward by the magnetic force of voltage coil, fed from potential transformer attached to the line. Other end of the beam is pulled downward by the magnetic force of current coil fed from current transformer connected in series with line. Due to torque produced by these two downward forces, the beam stays at an equilibrium position. The torque due to voltage coil, serves as restraining torque and torque due to current coil, serves as deflecting torque.

Under normal operating condition restraining torque is greater than deflecting torque. Hence contacts of this distance relay remain open. When any fault is occurred in the feeder, under protected zone, voltage of feeder decreases and at the same time current increases. The ratio of voltage to current i.e. impedance falls below the pre-determined value. In this situation, current coil pulls the beam more strongly than voltage coil, hence beam tilts to close the relay contacts and consequently the circuit breaker associated with this impedance relay will trip.

Time Distance Impedance Relay:

This delay automatically adjusts its operating time according to the distance of the relay from the fault point. The time distance impedance relay not only be operated depending upon voltage to current ratio, its operating time also depends upon the value of this ratio. That means.

$$Operating\ time\ T \propto \frac{Voltage}{Current} \propto Impedance \propto Distance\ along\ transmission\ line$$



The relay mainly consists of a current driven element like double winding type induction over current relay. The spindle carrying the disc of this element is connected by means of a spiral spring coupling to a second spindle which carries the bridging piece of the relay contacts. The bridge is normally held in the open position by an armature held against the pole face of an electromagnet excited by the voltage of the circuit to be protected.

Operating Principle of Time Distance Impedance Relay:

During normal operating condition the attraction force of armature fed from PT is more than force generated by induction element, hence relay contacts remain in open position when a short circuit fault occurs in the transmission line, the current in the induction element increases. Then the induction in the induction element increases. Then the induction element starts rotating. The speed of rotation of induction elements depends upon the level of fault i.e. quantity of current in the induction element. 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.

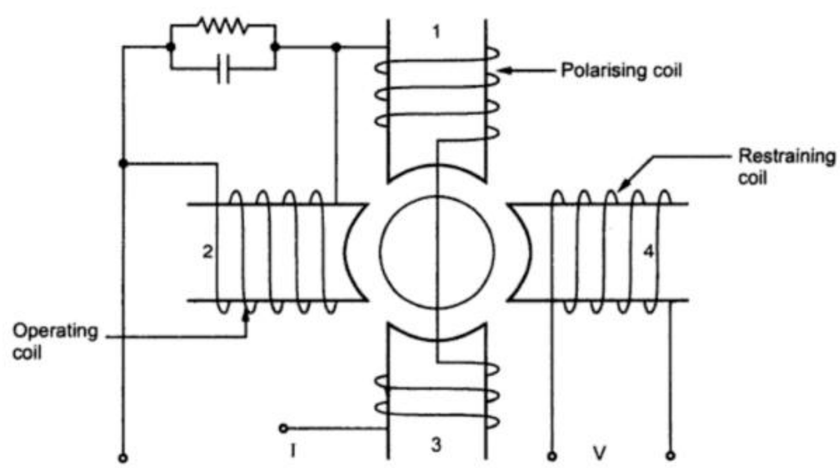
The angle through which the disc travels the disc travel before relay operate depends upon the pull of the voltage excited magnet. The greater the pull, the greater will be the travel of the disc. The pull of this magnet depends upon the line voltage. The greater the line voltage the greater the pull hence longer will be the travel of the disc i.e. operating time is proportional to V.
Again, speed of rotation of induction element approximately proportional to current in this element. Hence, time of operation is inversely proportional to current.

Reactance Relay:

In this relay the operating torque is produced by current while the restraining torque due to a current voltage directional relay. The overcurrent element develops the positive torque. And directional unit produces negative torque.

Thus the reactance relay is an overcurrent relay with the directional resistant.

Construction:



In this relay a 4 pole induction cup type relay is shown. In which there are three windings. First is operating coil, second is Polarizing coil and third is restraining coil. The operating and polarizing coil is fed from C.T. The current flows through the polarising coil then further through operating coil. The restraining coil is separately supplied with the P.T.

The operating torque is produced by the interaction of fluxes with polorising coil (which is proportional to "I") and flux produced by operating coil(Which is also proportional to "I"). hence the operating torque is directly proportional to I^2. The restraining torque is produced by the interaction of the fluxes produced by Polarizing(which is proportional to "I") coil and restraining coil(Which is proportional to voltage from P.T. i.e. "V") hence the restraining torque is proportional to $VI\cos(\theta - \tau)$.

Torque Equation:

The net torque negelectiog the effect of spring is given by,

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

At balance point net torque is zero,

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

$$K_1 I^2 = K_2 VI\cos(\theta - \tau)$$

Dividing both side by I^2.

$$K_1 = K_2 (V/I) \cos(\theta - \tau)$$

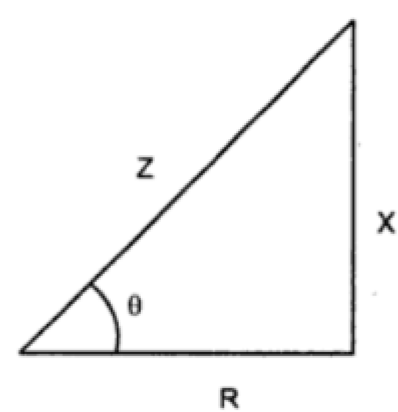
$$K_1 = K_2 Z\cos(\theta - \tau)$$

Adding capacitor, the torque angle is adjusted as 90°,

$$K_1 = K_2 Z\cos(\theta - \tau)$$

$$K_1 = K_2 Z\sin\theta$$

$$Z\sin\theta = \frac{K_1}{K_2}$$



Consider an impedance triangle shown in fig.

$$Z \sin\theta = X = Reactance$$

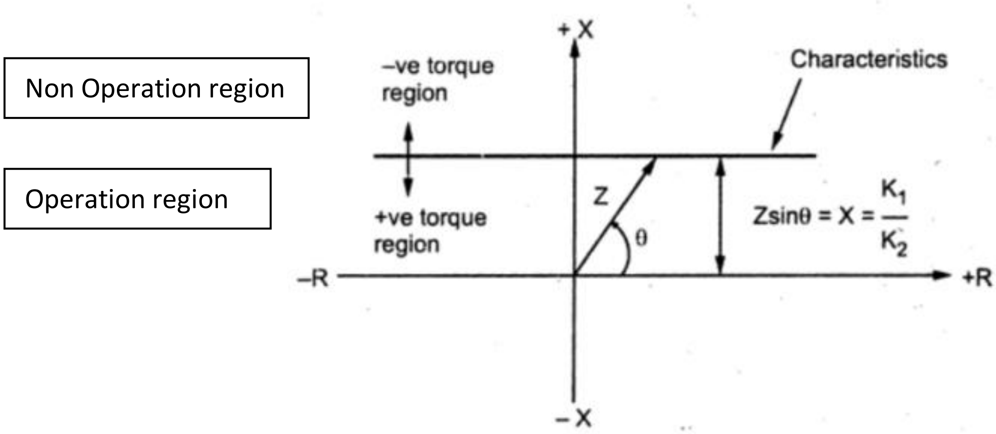
$$Z \cos\theta = R = Resistance$$

$$\boxed{X = \frac{K_1}{K_2} = constant}$$

Thus the relay operates only on the reactance only. The constant X means a straight line parallel to X axis on R-X diagram.

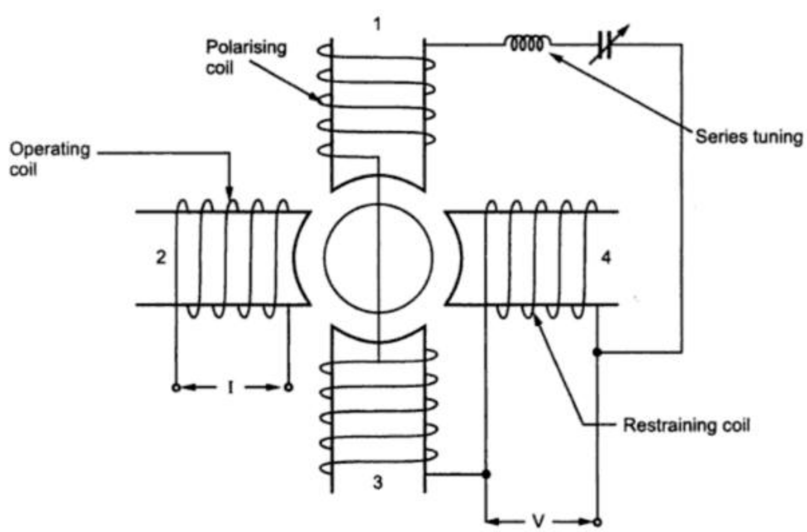
Operating Characteristic:

The operating characteristic of the relay is a straight line parallel to x axis.



The relay will operate when the value of Z $\sin\theta$ is less then the predetermined value i.e. for any point bellow the line shown in the figure. The region above the characteristic line is non operating region.

Admittance Relay:



The construction of the admittance relay is similar to the reactance relay. The main differende in the reactance relay and Mho relay is that the polarizing coil is common with voltage coil instead of current coil. The construction of the Mho relay is given in the figure bellow.

The operating torque is produced by V and I element while the restraing torque is produced by the voltage element. Thus an admittance relay is voltage restrained directional relay. The operating torque is produced by the interaction of the fluxes due to the windings carried by the poles 1, 2 and 3. While the restraining torque is produced by the interaction of the fluxes due to the windings carried by the poles 1,3 and 4.

Thus the restraining torque is V^2 while the operating torque is proportional to the product of voltage and current (VI). The torque angle is adjusted using series tuning circuit.

Torque Equation

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

K^3 = control spring effect

Generally control spring effect is negelected ($K_3 = 0$)

And at balance net torqure is also zero.

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

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

Divided by VI

$$K_1 \cos(\theta - \tau) = K_2 \frac{V^2}{VI}$$

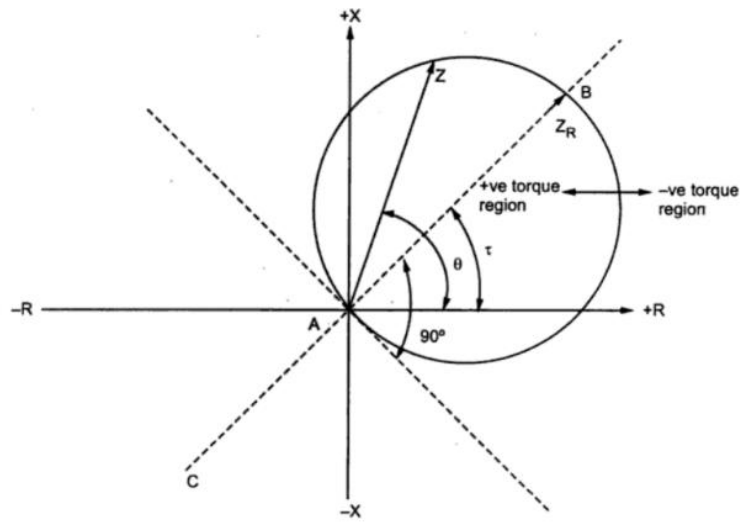
$$K_1 \cos(\theta - \tau) = K_2 \frac{V}{I}$$

$$\frac{K_1}{K_2}\cos(\theta - \tau) = Z$$

This is the equation of a circle having diameter K_1/K_2. Passing through the origin. And this constant K_1/K_2 is the ohomic setting of this relay.

Operating characterstic

As seen from the torque equation, the characterstic of this relay is a circle passing through origin when diameter as K_1/K_2.



2.7 Difference Between Impedance Relay, Mho Relay, Reactance Relay

- impedance relay is not inherently directional but can b made so, by using a directional unit with it. Reactance relay on other hand doesn't have directional feature nor can be made directional using directional unit mho relay incorporates features of reactance relay with an addition that it is inherently directional. Other difference lies in their application i.e. Reactance relay is used for short transmission lines, Mho relay is used for long transmission lines and Impedance is used for medium length lines........

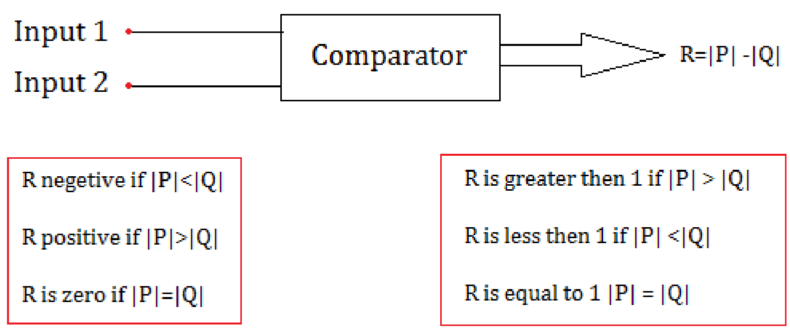
- We know about that impedance relay having operating torque produced by the current, restraining torque produced by the voltage. In the reactance relay operating torque is produced by the current, restraining torque is produced by the current and voltage. In the mho relay operating torque by the voltage and current, restraining torque is produced by the voltage. Impedance relay used in the medium transmission line. Reactance relay used for the small transmission line.mho relay used in the long transmission line.

2.8 Comparator

Comparators are the device which is generally used in static relays to make decision about operation of the relay. Comparator compares the input quantity with any reference value or compares between two or more input quantity. It is the main part of the static relays. There are basically two types of comparator namely amplitude comparator and Phase comparator.

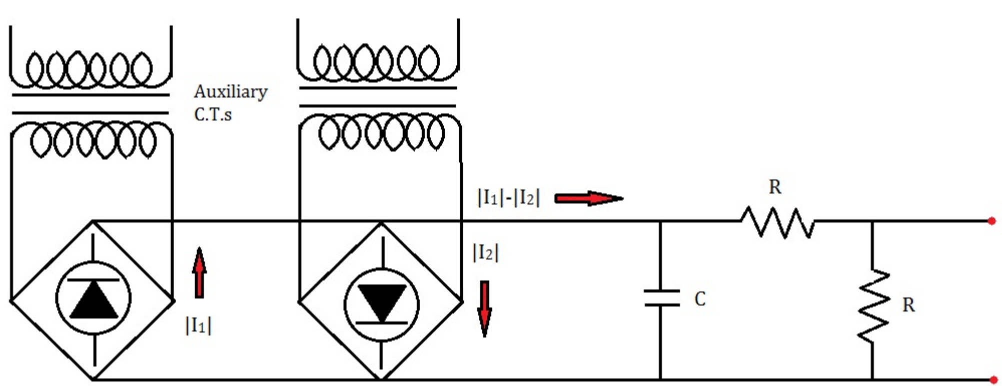
Amplitude comparator

An amplitude comparator compares the amplitude of the two input quantities, irrespective of phase angle of the quantities. The figure shows the basic operation of an amplitude comparator. In some comparators the ratio of amplitude is obtained and resultant is decided based on the value of the ratio.



Rectifier bridge comparator

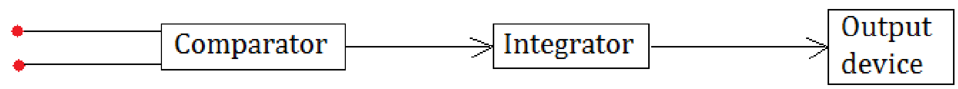
The input to the comparator are sinusoidal current derived from auxiliary current transformer. The rectifiers are connected in current opposition. Both the inputs are rectified from bridge rectifier. If the value of current in first rectifier is $|I_1|$ and in second rectifier is $|I_2|$ then the resultant current $|I| = |I_1|-|I_2|$ will flow from the circuit. If the value of I is sufficient



enough to energize the relay coil, the relay will trip.

Integrating type Amplitude comparator

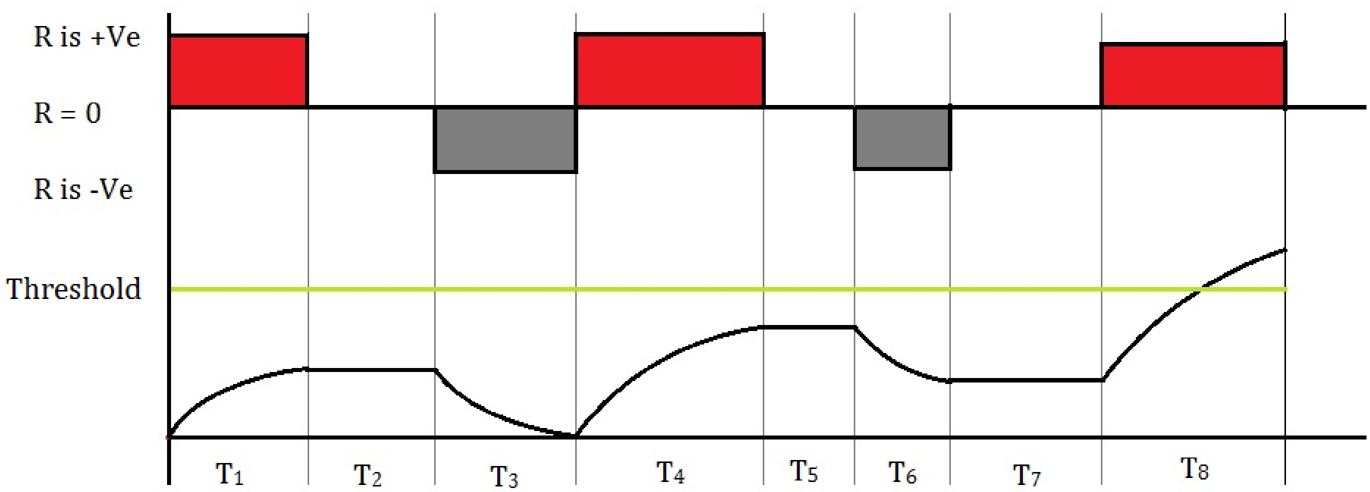
In such types of comparator, the output of the comparator is given to an integrator and circuit integrates the output with time. When such an integrated value reaches the threshold value, the output relay operates.



An integrator consists of a capacitor. Depending on the value of the comperator, capacitor charges and discharges.

If |R|=|P|-|Q|

Then depending upon the value of R the capacitor charges or discharges. If for the positive value of R capacitor charges then for negative value of R capacitor discharges.



In the above figure the working of amplitude comparator is shown.

1. During T_1 The R is +ve and capacitor charges to a certain level

2. During T_2 the R is Zero hence capacitor nither charges nor discharges i.e. the value of voltage remain unchanged w.r.t. previous position. It is shown by straight line in the period T_{2+}
3. During T_3 R is negative and capacitor discharges. Because the period T_1 and T_3 is equal so capacitor discharges compelitely.
4. During period T_4 capacitor again charges but this time the period of T_4 is greater then T_1 so capacitor charges to higher level than from T_1.
5. During period T_5 R is zero so there is no change inn capacitor value
6. During period T_6 r is negative hence capacitor discharges but do not completely because there is a difference in the period of T_4 and T_6. Capacitor charges for a long time during T_4 and discharges for a short time during T_6.
7. During period T_7 capacitor remains unchanged
8. During period T_8 Capacitor again charges and the voltage across capacitor becomes greater than the threshold voltage this will generate a trip signal and relay will operate.

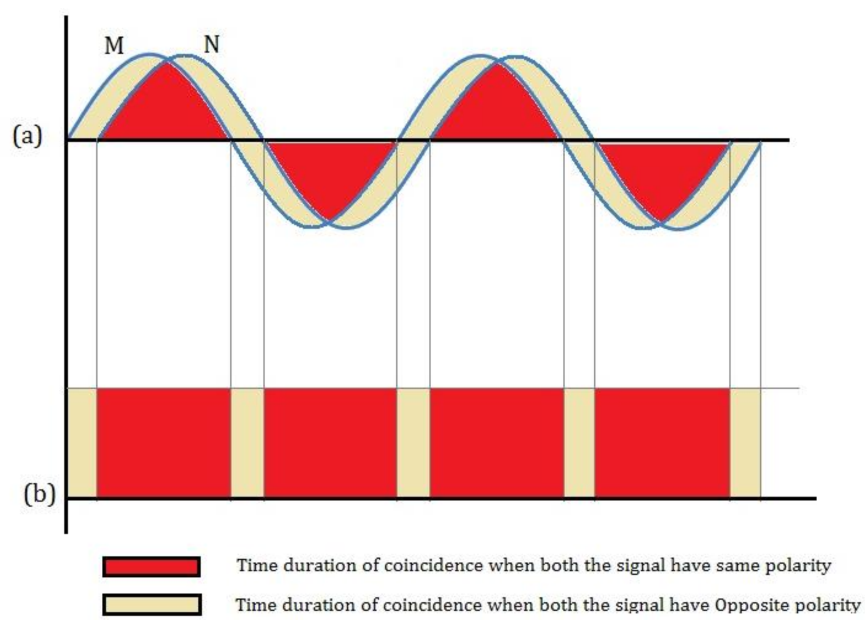
Phase Comparator

As amplitude comparator compares the amplitude of input signals, phase comparators compares the phase angle between the two input quantities. Phase comparison can be made in a number of different ways. Some important techniques are described below.

- Coincidence type phase comparator
- Vector product phase comparator

Coincidence Type Phase Comparator

In this technique the period of coincidence is measured when both the inputs are +ve or -ve simultaneously. In other words the period of coincidence of positive polarities of two input signals is measured and compares with a predetermined angle; usually 90°.The figure shows the period of



coincidence represented by an angle α. If the two input signals have the phase difference of θ the period of co incidence α = 180 – θ. If θ is less than 90°, α will be greater than 90°. The relay is required to trip when θ is 90°, i.e. α > 90°. Thus, the phase comparator circuit is design to send a trip signal when θ > 90°. The red color interval is the period of coincidence while the brown color interval is the period of non coincidence. The brown color is indicated by θ while the red color is indicating by α.

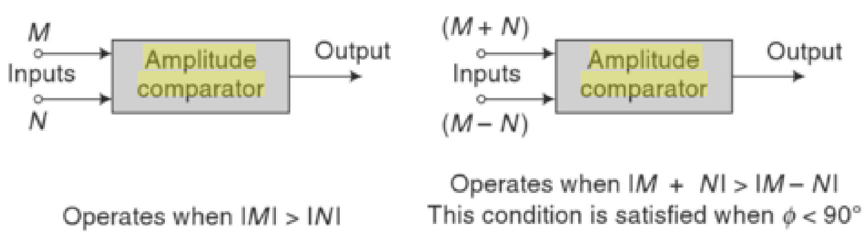
Vector Product Phase Comparators

You have to cover this topic by yourself.

- Take reference from book BADRI RAM page no. 61 (Operating principles and Relay construction)

2.9 Duality in comparators

We can use the amplitude comparator as a amplitude comparator as well as Phase comparator just modifying by the Input signals. The same can be done with the phase comparator. This property of the comparator is known as duality.



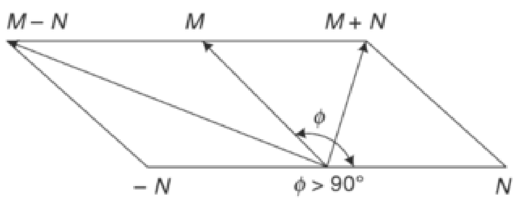
Here a amplitude comparator is given in which two inputs are M and N. amplitude comparator simply compares the amplitude of both the inputs. In this case we represent the amplitude by vector scale. If vector length of M > N then, amplitude of M is greater than N and vice versa.

Now How to use Amplitude comparator as a Phase comparator?

For this purpose you need to modify the input signals. We apply (M+N) and (M-N) instead of simply applying M and N. In this case comparator compares the vector length of (M+N) and (M - N).

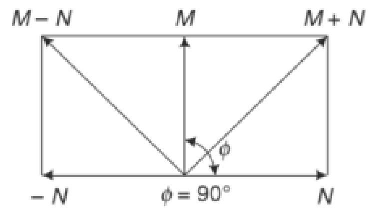
- If (M+N) > (M-N) then the phase angle between M and N is less Then 90°

- If (M+N) < (M-N) then the phase angle between M and N is greater Then 90°
- If (M+N) = (M-N) then the phase angle between M and N is equal to 90°



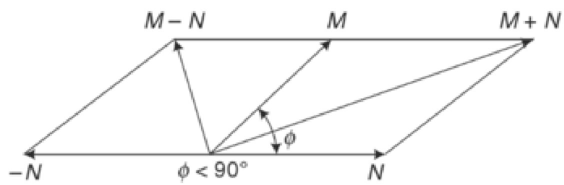
Comparison: (M + N) < (M − N)

(a)



Comparison: (M + N) = (M − N)

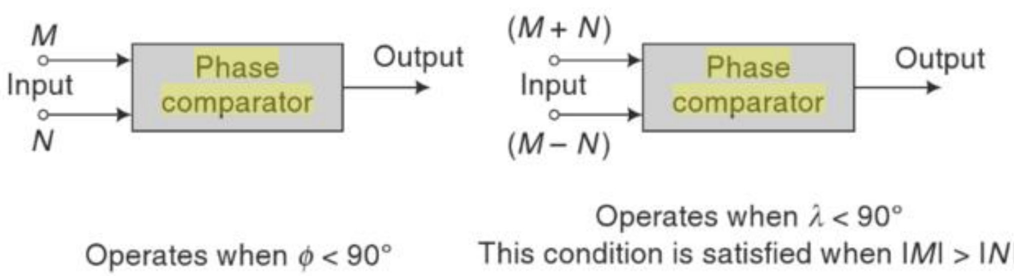
(b)



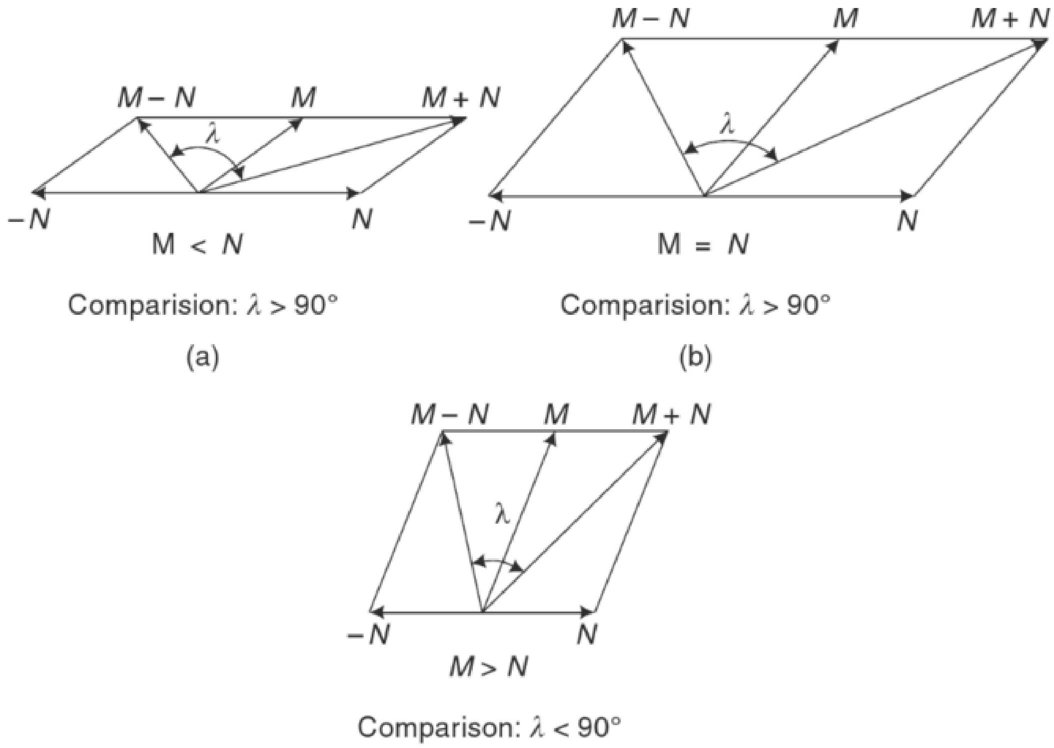
Comparison: (M + N) > (M − N)

In the same way Phase comparator can be used for amplitude comparison too.

There are two input M and N. A phase comparator simply compares the phase between M and N. but by applying the given modification the phase comparator can be sued as a amplitude comparator.



- If the phase difference between (M+N) and (M-N) is greator then 90° then N > M
- If the phase difference between (M+N) and (M-N) is equal to 90° then N = M
- If the phase difference between (M+N) and (M-N) is less then 90° then N < M



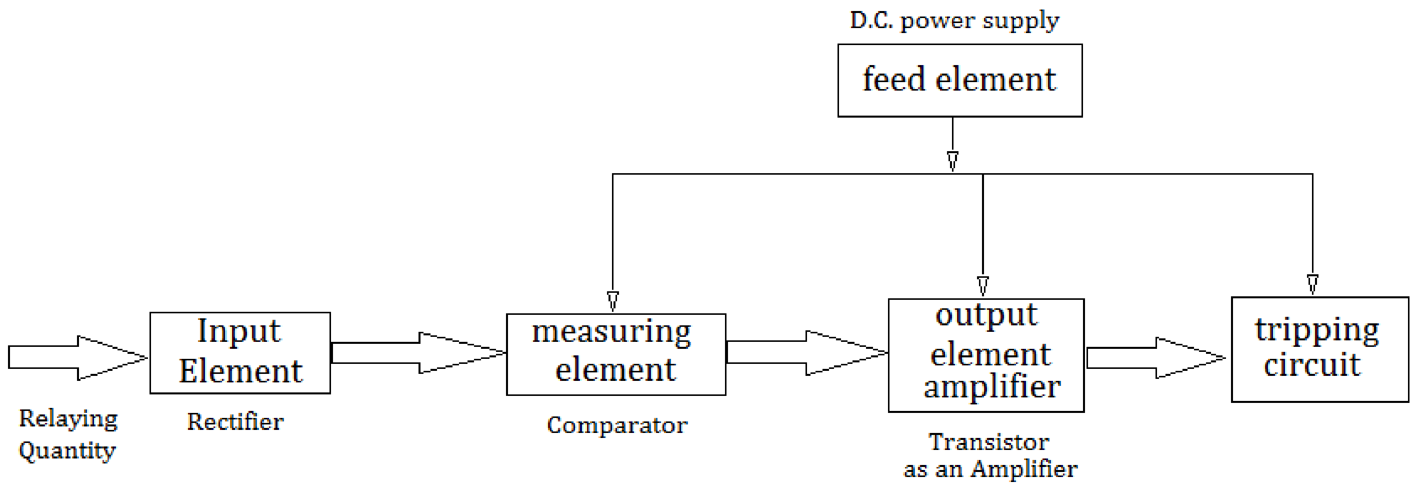
2.10 Static Relays

The term *'static'* implies that the relay has no moving parts. This is not strictly the case for a static relay, as the output contacts are still generally attracted armature relays. In a protection relay, the term 'static' refers to the absence of moving parts to create the relay characteristic.

SSRs (solid-state relays) have no movable contacts. SSRs are not very different in general operation from mechanical relays that have movable contacts. SSRs, however, employ semiconductor switching elements, such as thyristors, triacs, diodes, and transistors. The greatest feature of SSRs is that SSRs do not use switching contacts that will physically wear out.

2.11 Basic Element of Static Relay

The figure shows the block diagram of a static relay indicating its basic elements.



Input Element

It is the element which accepts the Input from the outer environment. It may be the output from C.T. or P.T. or the output from the transducer. Thus an electronic circuit such as rectifier is required as an input element to get the input signal in a convenient form before applying it to a measuring element.

Measuring Element

It is the heart of the static relay. It is the main device or circuit which is used for the comparison between two or more quantity. Comparator compares the input and generate the output signals to trip the relay. In the case of differential relay the two quantity would be current or voltage entering or leaving the protected zone. In the case of Overcurrent relays the entering quantity into the comparator are compared with reference value and based on the result of comparison the relay operates.

Output Element

The signals obtained from the measuring element are required to be amplified before applying to the tripping signal. The output element is an amplifier. Some times this element not only amplifies the signal but multiplies them or combines them with other signals to delay them.

Feed Element

The measuring element uses electronic circuit consisting transients, diodes etc. The output element uses transients as an amplifier. All these components, circuit along with the tripping circuit require D.C. supply for the proper functioning. The feed element provides the D.C. voltage required by the various element.

2.12 Comparison of Static And Electromagnetic Relays

The Solid Static relays use ***analogue electronic devices*** instead of magnetic coils and mechanical components to create the relay characteristics. The measurement is carried out by static circuits consisting of comparators, level detectors, filter etc while in a conventional electromagnetic relay it is done by comparing operating torque (*or force*) with restraining torque (*or force*). The relaying quantity such as voltage/current is rectified and measured. The static relays are commonly using the transistor circuits and called transistor relays. This is because the transistor cab be used as an amplifier device as well as a switching devices

2.13 Advantages of Static Relays over Conventional Electromagnetic Relays

- Low Weight
- Required Less Space which results in panel space saving.
- Arc less switching
- No acoustical noise.
- Multi-function integration.
- Fast response.
- Long life (*High Reliability*): more than 109 operations
- High Range of Setting compared to electromechanical Relay
- More Accurate compared to electromechanical Relay
- Low Electromagnetic Interference.
- Less power consumption.
- Shock and vibration resistant
- No contact bounce
- Microprocessor compatible.
- No moving contacts; hence associated problems of arcing, contact bounce, erosion, replacement of contacts.
- No gravity effect on operation of static relays. Hence can be used in vessels ie, ships, aircrafts etc.

- A single relay can perform several functions like over current, under voltage, single phasing protection by incorporating respective functional blocks. This is not possible in electromagnetic relays.
- Static relay is compact.
- Superior operating characteristics and accuracy.
- Static relay can think , programmable operation is possible with static relay.
- Effect of vibration is nil, hence can be used in earthquake-prone areas.
- Simplified testing and servicing. Can convert even non-electrical quantities to electrical in conjunction with transducers.
- Static Relay burden is less than Electromagnetic type of relays. Hence error is less.

2.14 Limitations of Static Relays

- Auxiliary voltage requirement for Relay Operation.
- Static relays are sensitive to voltage transients which are caused by operation of breaker and isolator in the primary circuit of CTs and PTs.
- Serious over voltage is also caused by breaking of control circuit, relay contacts etc. Such voltage spikes of small duration can damage the semiconductor components and also cause mal operation of relays.
- Temperature dependence of static relays: The characteristics of semiconductor devices are affected by ambient temperature.
- Highly sophisticated isolation and filter circuits are required to be built into the relay design to take care of electromagnetic interference and transient switching disturbances in the power system.
- Highly reliable power supply circuits are required.
- Effect of environmental conditions like humidity, high ambient temperature, dust accumulation on PCB leading to tracking.
- The component failure.
- Non availability of fault data.
- Characteristic variations with passage of time.

Important Question

- Why directional features provided for impedance relay cannot be used for reactance relay?
- Discuss about the phase and amplitude comparator in detail.
- What is distance relay? Draw its characteristics. How is directional feature added with over current relay? Why is it required?
- Compare a static relay with electromagnetic relays.
- Describe different types of distance relays used for protection of transmission lines. Which one is best and why?
- Explain the working principle of electromagnetic induction type relays. What is use of shading ring?
- Realize Mho relay characteristic using static comparator.
- Discuss about the main components of Static relays.
- Discuss the various types of phase comparators used in static relays.
- What do you mean by Duality in comparators.

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