6^{TH} SEM (ELECTRICAL ENGG.)

SWITCHGEAR AND PROTECTIVE DEVICES

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PROTECTION OF ELECTRICAL POWER EQUIPMENTS AND LINES

Protection of Alternators:

Some of the important faults which may occur on an alternator are :

(*i*) failure of prime-mover
(*ii*) failure of field
(*iii*) overcurrent
(*iv*) overspeed
(*v*) overvoltage
(*vi*) unbalanced loading
(*vii*) stator winding faults

(*i*) Failure of prime-mover. When input to the prime-mover fails, the alternator runs as a synchronous motor and draws some current from the supply system. This motoring conditions is known as "inverted running".

(*ii*) Failure of field: It is sufficient to rely on the control room attendant to disconnect the faulty alternator manually from the system bus-bars.

(*iii*) Overcurrent. It occurs mainly due to partial breakdown of winding insulation or due to overload on the supply system.

(*iv*) Overspeed. The chief cause of overspeed is the sudden loss of all or the major part of load on the alternator.

(*v*) Over-voltage. The field excitation system of modern alternators is so designed that overvoltage conditions at normal running speeds cannot occur. However, overvoltage in an alternator occurs when speed of the prime-mover increases due to sudden loss of the alternator load.

(*vi*) Unbalanced loading. Unbalanced loading means that there are different phase currents in the alternator. Unbalanced loading arises from faults to earth or faults between phases on the circuit external to the alternator.

(*vii*) Stator winding faults. These faults occur mainly due to the insulation failure of the stator windings. The main types of stator winding faults, in order of importance are :

(*a*) fault between phase and ground.
(*b*) fault between phases
(*c*) inter-turn fault involving turns of the same phase winding

The stator winding faults are the most dangerous and are likely to cause considerable damage to the expensive machinery. Therefore, automatic protection is absolutely necessary to clear such faults in the quickest possible time in order to minimise the extent of damage.

Differential Protection of Alternators:

The most common system used for the protection of stator winding faults employs circulating-current principle. In this scheme of protection, currents at the two ends of the protected section are compared. Under normal operating conditions, these currents are equal but may become unequal on the occurrence of a fault in the protected section. The difference of the currents under fault conditions is arranged to pass through the operating coil of the relay. The relay then closes its contacts to isolate protected section from the system. This form of protection is also known as ***Merz-Price circulating current scheme*.**

Schematic arrangement: The schematic arrangement of current differential protection for a 3-phase alternator. Identical current transformer pairs *CT*1 and *CT*2 are placed on either side of each phase of the stator windings. The secondaries of each set of current transformers are connected in star ; the two neutral points and the corresponding terminals of the two star groups being connected together by means of a four-core pilot cable. Thus there is an independent path for the currents circulating in each pair of current transformers and the corresponding pilot *P*. The relay coils are connected in star, the neutral point being connected to the current-transformer common neutral and the outer ends one to each of the other three pilots. In order that burden on each current transformer is the same, the relays are connected across equipotential points of the three pilot wires and these equipotential points would naturally be located at the middle of the pilot wires. The relays are generally of electromagnetic type and are arranged for instantaneous action since fault should be cleared as quickly as possible.

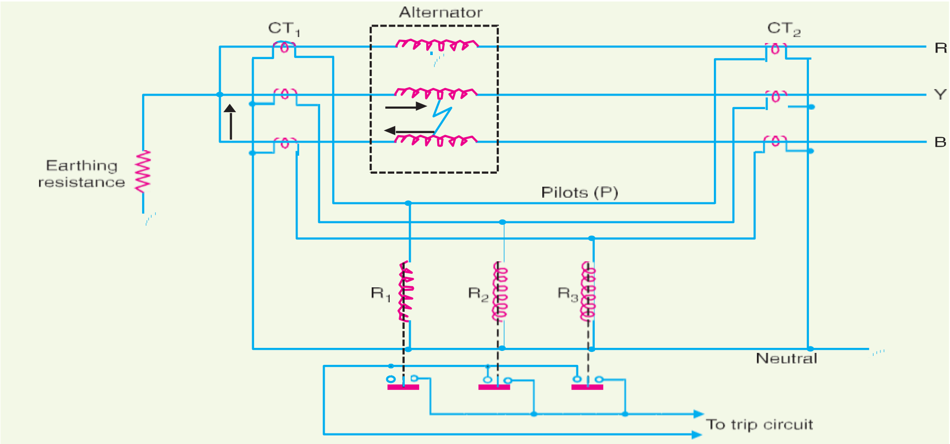

Fig. 22.2

Operation: The relays are connected in shunt across each circulating path. Therefore, the circuit of Fig. 22.2 can be shown in a simpler form in Fig. 22.3.

Under normal operating conditions, the current at both ends of each winding will be equal and hence the currents in the secondaries of two CTs connected in any phase will also be equal. Therefore, there is balanced circulating current in the pilot wires and no current flows through the operating coils (*R*1, *R*2 and *R*3) of the relays. When an earth-fault or phase-to-phase fault occurs, this condition no longer holds good and the differential current flowing through the relay circuit operates the relay to trip the circuit breaker.

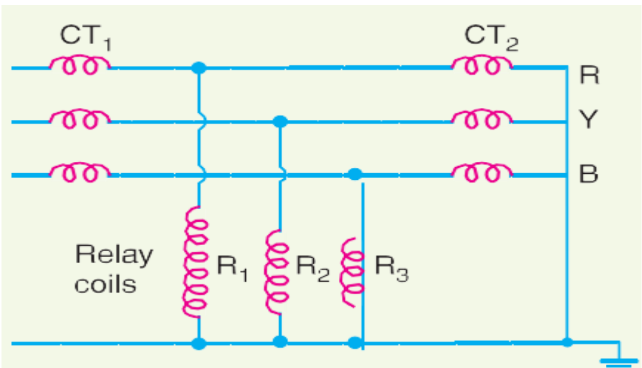

Fig. 22.3

Balanced Earth-fault Protection:

In small-size alternators, the neutral ends of the three-phase windings are often connected internally to a single terminal. Therefore, it is not possible to use Merz-Price circulating current principle described above because there are no facilities for accommodating the necessary current transformers in the neutral connection of each phase winding. Under these circumstances, it is considered sufficient to provide protection against earth-faults only by the use of balanced earth-fault protection scheme. This scheme provides no protection against phase-to-phase faults, unless and until they develop into earth-faults, as most of them will.

Schematic arrangement: The schematic arrangement of a balanced earth-fault protection for a 3-phase alternator. It consists of three line current transformers, one mounted in each phase, having their secondaries connected in parallel with that of a single current transformer in the conductor joining the star point of the alternator to earth. A relay is connected across the transformers secondaries. The protection against earth faults is limited to the region between the neutral and the line current transformers.

Operation: Under normal operating conditions, the currents flowing in the alternator leads and hence the currents flowing in secondaries of the line current transformers add to zero and no current flows through the relay. Also under these conditions, the current in the neutral wire is zero and the secondary of neutral current transformer supplies no current to the relay. If an earth-fault develops at $F2$ external to the protected zone, the sum of the currents at the terminals of the alternator is exactly equal to the current in the neutral connection and hence no current flows through the relay. When an earth-fault occurs at $F1$ or within the protected zone, these currents are no longer equal and the differential current flows through the operating coil of the relay. The relay then closes its contacts to disconnect the alternator from the system.

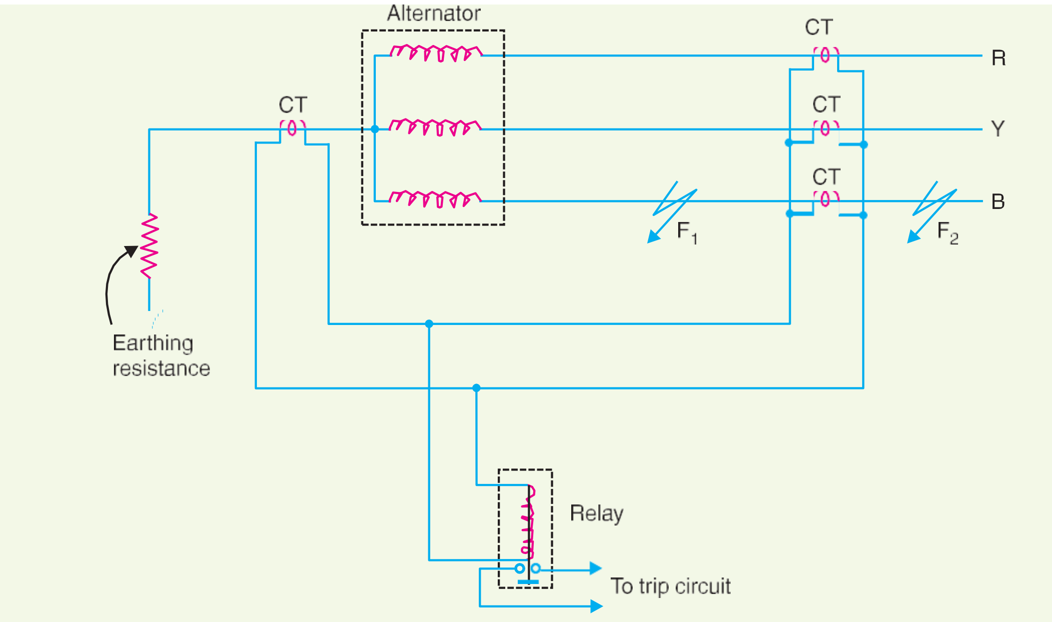

Fig. 22.6

Protection Systems for Transformers:

Transformers are static devices, totally enclosed and generally oil immersed. Small distribution transformers are usually connected to the supply system through series fuses instead of circuit breakers. Consequently, no automatic protective relay equipment is required.

Power transformers may suffer only from :

(*i*) open circuits

(*ii*) overheating

(*iii*) winding short-circuits *e.g.* earth-faults, phase-to-phase faults and inter-turn faults.

The principal relays and systems used for transformer protection are :

(*i*) *Buchholz devices* providing protection against all kinds of incipient faults *i.e*. slow-developing faults such as insulation failure of windings, core heating, fall of oil level due to leaky joints etc.

(*ii*) *Earth-fault relays* providing protection against earth-faults only.

(*iii*) *Overcurrent relays* providing protection mainly against phase-to-phase faults and overloading.

(*iv*) *Differential system* (or circulating-current system) providing protection against both earth and phase faults.

Buchholz Relay:

Buchholz relay is a gas-actuated relay installed in oil immersed transformers for protection against all kinds of faults.
It is used to give an alarm in case of incipient (*i.e.* slow-developing) faults in the transformer and to disconnect the transformer
from the supply in the event of severe internal faults. It is usually installed in the pipe connecting the conservator to the main tank.

Construction:
It takes the form of a domed vessel placed in the connecting pipe between the main tank and the conservator. The device has two elements. The upper element consists of a mercury type switch attached to a float. The lower element contains a mercury switch mounted on a hinged type flap located in the direct path of the flow of oil from the transformer to the conservator. The upper element closes an alarm circuit during incipient faults whereas the lower element is arranged to trip the circuit breaker in case of severe internal faults.

Operation:
The operation of Buchholz relay is as follows:
(*i*) In case of incipient faults within the transformer, the heat due to fault causes the decomposition of some transformer oil in the main tank. The products of decomposition contain more than 70% of hydrogen gas. The hydrogen gas being light tries to go into the conservator and in the process gets entrapped in the upper part of relay chamber. When a predetermined amount of gas gets accumulated, it exerts sufficient pressure on the float to cause it to tilt and close the contacts of mercury switch attached to it. This completes the alarm circuit to sound an alarm.
(*ii*) If a serious fault occurs in the transformer, an enormous amount of gas is generated in the main tank. The oil in the main tank rushes towards the conservator *via* the Buchholz relay and in doing so tilts

the flap to close the contacts of mercury switch. This completes the trip circuit to open the circuit breaker controlling the transformer.

Advantages

(*i*) It is the simplest form of transformer protection.

(*ii*) It detects the incipient faults at a stage much earlier than is possible with other forms of protection.

Disadvantages

(*i*) It can only be used with oil immersed transformers equipped with conservator tanks.

(*ii*) The device can detect only faults below oil level in the transformer. Therefore, separate protection is needed for connecting cables.

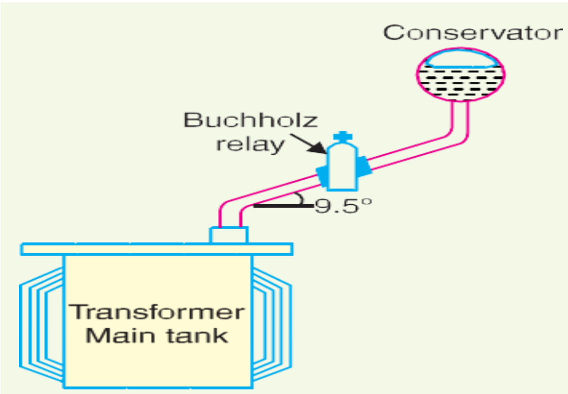

Fig. 22.11

Busbar Protection:

Busbars in the generating stations and sub-stations form important link between the incoming and outgoing circuits. If a fault occurs on a busbar, considerable damage and disruption of supply will occur unless some form of quick-acting automatic protection is provided to isolate the faulty busbar. The busbar zone, for the purpose of protection, includes not only the busbars themselves but also the isolating switches, circuit breakers and the associated connections. In the event of fault on any section of the busbar, all the circuit equipment connected to that section must be tripped out to give complete isolation.

The two most commonly used schemes for busbar protection are:

(*i*) Differential protection **(*ii*)** Fault bus protection (*i*) **Differential protection:**The basic method for busbar protection is the differential scheme in which currents entering and leaving the bus are totalised. During normal load condition, the sum of these currents is equal to zero. When a fault occurs, the fault current upsets the balance and produces a differential current to operate a relay.

The busbar is fed by a generator and supplies load to two lines. The secondaries of current transformers in the generator lead, in line 1 and in line 2 are all connected in parallel. The protective relay is connected across this parallel connection. All *CT*s must be of the same ratio in the scheme regardless of the capacities of the various circuits. Under normal load conditions or external fault conditions, the sum of the currents entering the bus is equal to those leaving it and no current flows through the relay. If a fault occurs within the protected zone, the currents entering the bus will no longer be equal to those leaving it. The difference of these currents will flow through the relay and cause the opening of the generator, circuit breaker and each of the line circuit breakers.

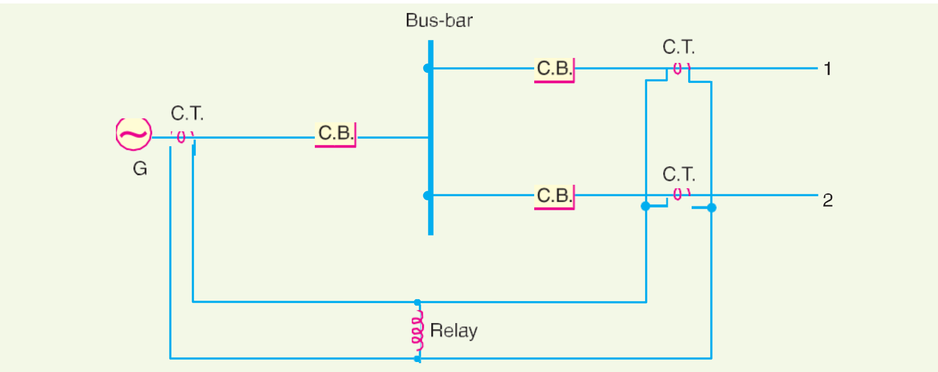

Fig. 23.1

Fault Bus protection. It is possible to design a station so that the faults that develop are mostly earth-faults. This can be achieved by providing earthed metal barrier (known as *fault bus*) surrounding each conductor throughout its entire length in the bus structure. With this arrangement, every fault that might occur must involve a connection between a conductor and an earthed metal part. By directing the flow of earth-fault current, it is possible to detect the faults and determine their location. This type of protection is known as fault bus protection. Fig. 23.2 show the schematic arrangement of fault bus protection. The metal supporting structure or fault bus is earthed through a current transformer. A relay is connected across the secondary of this CT. Under normal operating conditions, there is no current flow from fault bus to ground and the relay remains inoperative. A fault involving a connection between a conductor and earthed supporting structure will result in current flow to ground through the fault bus, causing the relay to operate. The operation of relay will trip all breakers connecting equipment to the bus.

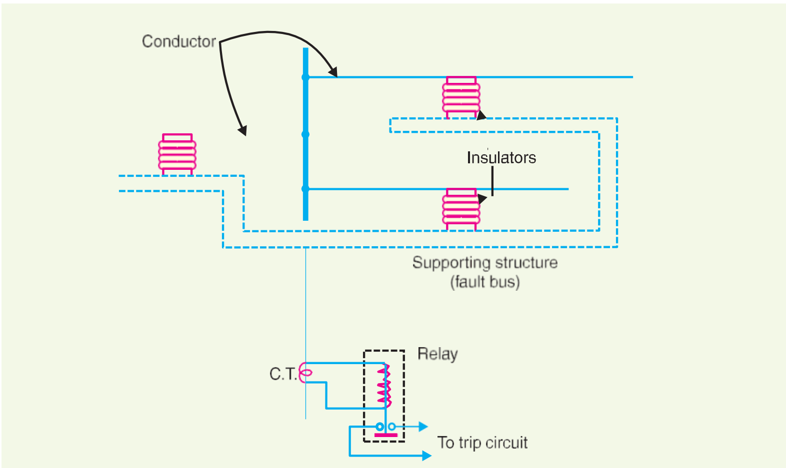

Fig. 23.2

Protection of Transmission Lines:

The common methods of transmission line protection are:

(*i*) Time-graded overcurrent protection

(*ii*) Differential protection

(*iii*) Distance protection

<u>Differential Pilot-Wire Protection:</u>

The differential pilot-wire protection is based on the principle that under normal conditions, the current entering one end of a line is equal to that leaving the other end. As soon as a fault occurs between the two ends, this condition no longer holds and the difference of incoming and outgoing currents is arranged to flow through a relay which operates the circuit breaker to isolate the faulty line. There are several differential protection schemes in use for the lines.

Merz-Price voltage balance system:

The single line diagram of Merz-Price voltage balance system for the protection of a 3-phase line is shown. Identical current transformers are placed in each phase at both ends of the line. The pair of *CTs* in each line is connected in series with a relay in such a way that under normal conditions, their secondary voltages are equal and in opposition *i.e.* they balance each other.

Under healthy conditions, current entering the line at one-end is equal to that leaving it at the other end. Therefore, equal and opposite voltages are induced in the secondaries of the *CT*s at the two ends of the line. The result is that no current flows through the relays. Suppose a fault occurs at point *F* on the line as shown in Fig. 23.8. This will cause a greater current to flow through *CT*1 than through *CT*2. Consequently, their secondary voltages become unequal and circulating current flows through the pilot wires and relays. The circuit breakers at both ends of the line will trip out and the faulty line will be isolated.

Advantages

(*i*) This system can be used for ring mains as well as parallel feeders.

(*ii*) This system provides instantaneous protection for ground faults. This decreases the possibility of these faults involving other phases.

(*iii*) This system provides instantaneous relaying which reduces the amount of damage to overhead conductors resulting from arcing faults.

Disadvantages

(*i*) Accurate matching of current transformers is very essential.

(*ii*) If there is a break in the pilot-wire circuit, the system will not operate.

(*iii*) This system is very expensive owing to the greater length of pilot wires required.

(*iv*) In case of long lines, charging current due to pilot-wire capacitance* effects may be sufficient
to cause relay operation even under normal conditions.

(*v*) This system cannot be used for line voltages beyond 33 kV because of constructional difficulties in matching the current transformers.

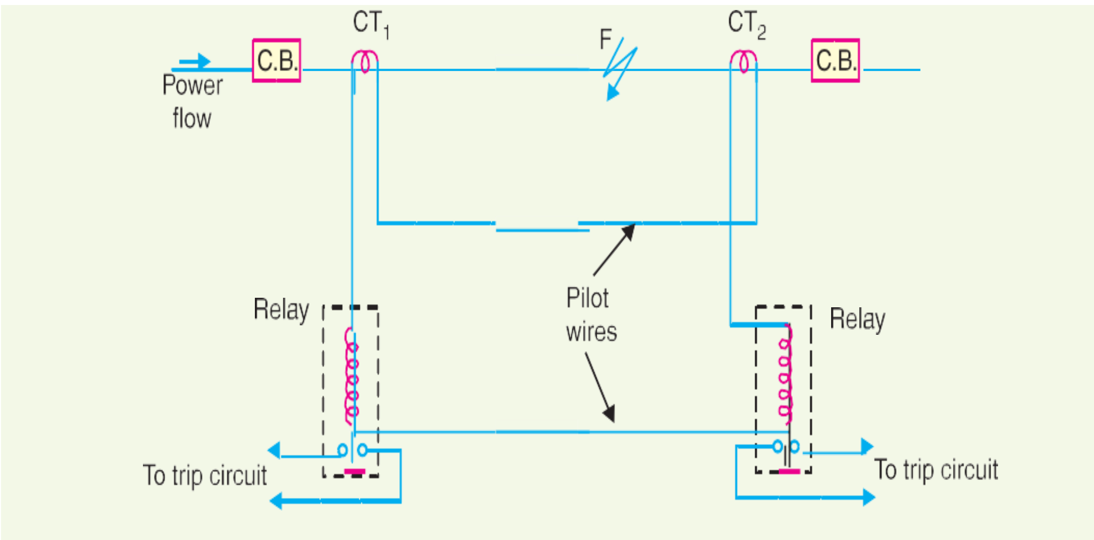

Fig. 23.8

PROTECTION AGAINST OVERVOLTAGE AND LIGHTNING

Voltage surge and Cause of overvoltage:

A sudden rise in voltage for a very short duration on the power system is known as a voltage surge or transient voltage. Transients or surges are of temporary nature and exist for a very short duration (a few hundred μ*s*) but they cause over voltages on the power system. They originate from switching and by lightning striking a transmission line.

Causes of Overvoltages:

The overvoltages on a power system may be broadly divided into two main categories *viz*.

1. Internal causes

a. Switching surges **b.** Insulation failure

c. Arcing ground **d.** Resonance

2. External causes *i.e*. lightning

1.Internal Causes of Overvoltages:

Internal causes of overvoltages on the power system are primarily due to oscillations set up by the sudden changes in the circuit conditions. This circuit change may be a normal switching operation such as opening of a circuit breaker, or it may be the fault condition such as grounding of a line conductor.

a.Switching Surges:

i.Case of an open line: During switching operations of an unloaded line, travelling waves are set up which produce overvoltages on the line.

ii.Case of a loaded line: Overvoltages will also be produced during the switching operations of a loaded line. Suppose a loaded line is suddenly interrupted. This will set up a voltage of 2 *Zn I* across the break (*i.e*. switch) where *i* is the instantaneous value of current at the time of opening of line and *Zn* is the natural impedance of the line.

iii.Current chopping: Current chopping results in the production of high voltage transients across the contacts of the air blast circuit breaker. Air-blast circuit breakers retain the same extinguishing power irrespective of the magnitude of this current. When breaking low currents (*e.g.* transformer magnetising current) with air-blast breaker, the powerful de-ionising effect of air-blast causes the current to fall abruptly to zero well before the natural current zero is reached. This phenomenon is called current chopping and produces high transient voltage across the breaker contacts. Overvoltages due to current chopping are prevented by resistance switching.

b. Insulation Failure: The most common case of insulation failure in a power system is the grounding of conductor (*i.e*. insulation failure between line and earth) which may cause overvoltages in the system.

c. Arcing ground. In the early days of transmission, the neutral of three phase lines was not earthed to gain two advantages. Firstly, in case of line-to-ground fault, the line is not put out of action. Secondly, the zero sequence currents are eliminated, resulting in the decrease of interference with communication lines. Insulated neutrals give no problem with short lines and comparatively low voltages. However, when the lines are long and operate at high voltages, serious problem called *arcing ground* is often witnessed. The arcing ground produces severe oscillations of three to four times the normal voltage.
The phenomenon of intermittent arc taking place in line-to-ground fault of a 3ϕ system with consequent production of transients is known as **arcing ground.**
The transients produced due to arcing ground are cumulative and may cause serious damage to the equipment in the power system by causing breakdown of insulation. Arcing ground can be prevented by earthing the neutral.

d. Resonance. Resonance in an electrical system occurs when inductive reactance of the circuit becomes equal to capacitive reactance. Under resonance, the impedance of the circuit is equal to resistance of the circuit and the p.f. is unity. Resonance causes high voltages in the electrical system.

2. External Causes(LIGHTNING):
An electric discharge between cloud and earth, between clouds or between the charge centres of the same cloud is known as **lightning.** Lightning is a huge spark and takes place when clouds are charged to such a high potential (+ve or −ve) with respect to earth or a neighbouring cloud that the dielectric strength of neighbouring medium (air) is destroyed.

The uprush of warm moist air from earth, the friction between the air and the tiny particles of water causes the building up of charges. When drops of water are formed, the larger drops become positively charged and the smaller drops become negatively charged. When the drops of water accumulate, they form clouds, and hence cloud may possess either a positive or a negative charge, depending upon the charge of drops of water they contain. The charge on a cloud may become so great that it may discharge to another cloud or to earth and this discharge is called as lightning.

Mechanism of Lightning Discharge:

When a charged cloud passes over the earth, it induces equal and opposite charge on the earth. As the charge acquired by the cloud increases, the potential between cloud and earth increases and, therefore, gradient in the air increases. When the potential gradient is sufficient (5 kV*/cm to 10 kV/cm) to break down the surrounding air, the lightning stroke starts.

i. As soon as the air near the cloud breaks down, a streamer called *leader streamer or pilot streamer* starts from the cloud towards the earth and carries charge with it. The leader streamer will continue its journey towards earth as long as the cloud, from which it originates feeds enough charge to it to maintain gradient at the tip of leader streamer above the strength of air. If this gradient is not maintained, the leader streamer stops and the charge is dissipated without the formation of a complete stroke.

ii. In many cases, the leader streamer continues its journey towards earth until it makes contact with earth or some object on the earth. As the leader streamer moves towards earth, it is accompanied by points of luminescence which travel in jumps giving rise to stepped leaders. The velocity of stepped leader exceeds one-sixth of that of light and distance travelled in one step is about 50 m. It may be noted that stepped leaders have sufficient luminosity and give rise to first visual phenomenon of discharge.

iii. The path of leader streamer is a path of ionisation and , therefore, of complete breakdown of insulation. As the leader streamer reaches near the earth, a *return streamer* shoots up from the earth o the cloud, following the same path as the main channel of the downward leader. The action can be compared with the closing of a switch between the positive and negative terminals; the downward leader having negative charge and return streamer the positive charge. This phenomenon causes a sudden spark called lightning.

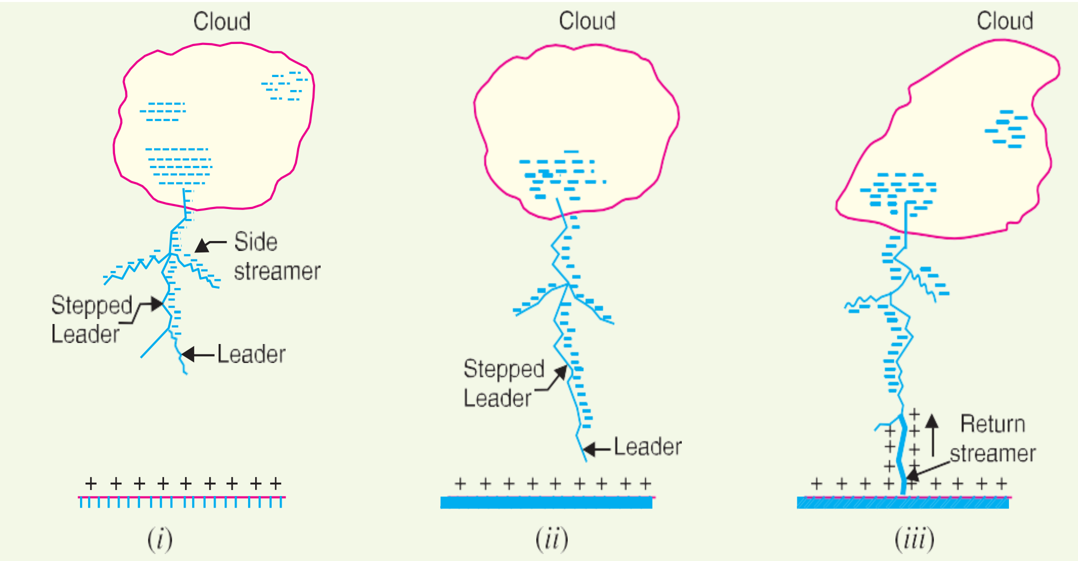

Fig. 24.4

Types of Lightning Strokes:

1. Direct stroke. In the direct stroke, the lightning discharge (*i.e.* current path) is directly from the cloud to the subject equipment *e.g*. an overhead line. From the line, the current path may be over the insulators down the pole to the ground. The overvoltages set up due to the stroke may be large enough to flashover this path directly to the ground. The direct strokes can be of two types *viz*.

(i) Stroke *A* and (*ii*) stroke *B*

(i)In **stroke *A***, the lightning discharge is from the cloud to the subject equipment *i.e*. an overhead line. The cloud will induce a charge of opposite sign on the tall object (*e.g.* an overhead line in this case). When the potential between the cloud and line exceeds the breakdown value of air, the lightning discharge occurs between the cloud and the line.

(*ii*) In **stroke *B***, the lightning discharge occurs on the overhead line as a result of stroke *A*

between the clouds. There are three clouds *P*, *Q* and *R* having positive, negative and positive charges respectively. The charge on the cloud *Q* is bound by the cloud *R*. If the cloud *P* shifts too near the cloud *Q*, then lightning discharge will occur between them and charges on both these clouds disappear quickly. The result is that charge on cloud *R* suddenly becomes free and it then discharges rapidly to earth.

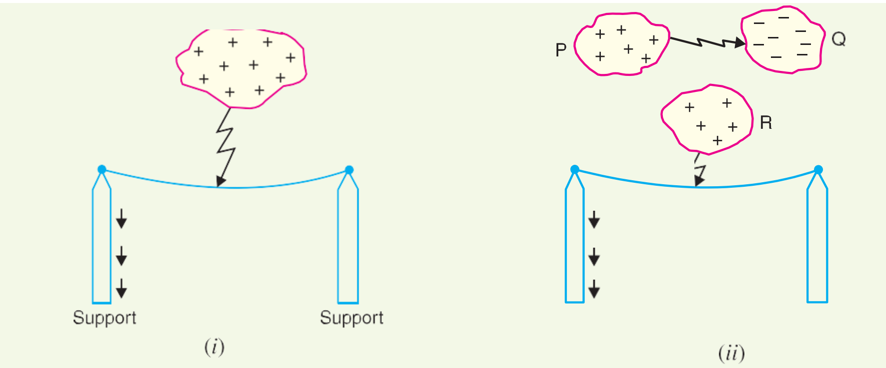

Fig. 24.5

2.Indirect stroke. Indirect strokes result from the electrostatically induced charges on the conductors due to the presence of charged clouds. A positively charged cloud is above the line and induces a negative charge on the line by electrostatic induction.

This negative charge, however, will be only on that portion of the line right under the cloud and the portions of the line away from it will be positively charged. The induced positive charge leaks slowly to earth *via* the insulators. When the cloud discharges to earth or to another cloud, the negative charge on the wire is isolated as it cannot flow quickly to earth over the insulators. The result is that negative charge rushes along the line is both directions in the form of travelling waves.

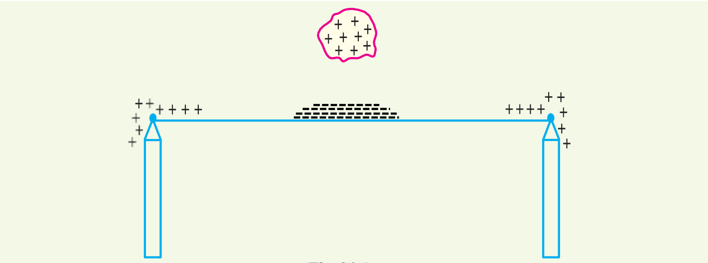

Fig. 24.6

Harmful Effects of Lightning:

(*i*) The travelling waves produced due to lightning surges will shatter the insulators and may even wreck poles.

(*ii*) If the travelling waves produced due to lightning hit the windings of a transformer or generator, it may cause considerable damage. The inductance of the windings opposes any sudden passage of electric charge through it. Therefore, the electric charges "piles up" against the transformer (or generator). This induces such an excessive pressure between the windings that insulation may breakdown, resulting in the production of arc.

(*iii*) If the arc is initiated in any part of the power system by the lightning stroke, this arc will set up very disturbing oscillations in the line. This may damage other equipment connected to the line.

Lightning Arresters:

A **lightning arrester** *or a* **surge diverter** *is a protective device which conducts the high voltage surges on the power system to the ground.*

It consists of a spark gap in series with a non-linear resistor. One end of the diverter is connected to the terminal of the equipment to be protected and the other end is effectively grounded. The length of the gap is so set that normal line voltage is not enough to cause an arc across the gap but a dangerously high voltage will break down the air insulation and form an arc. The property of the non-linear resistance is that its resistance decreases as the voltage (or current) increases and vice-versa.

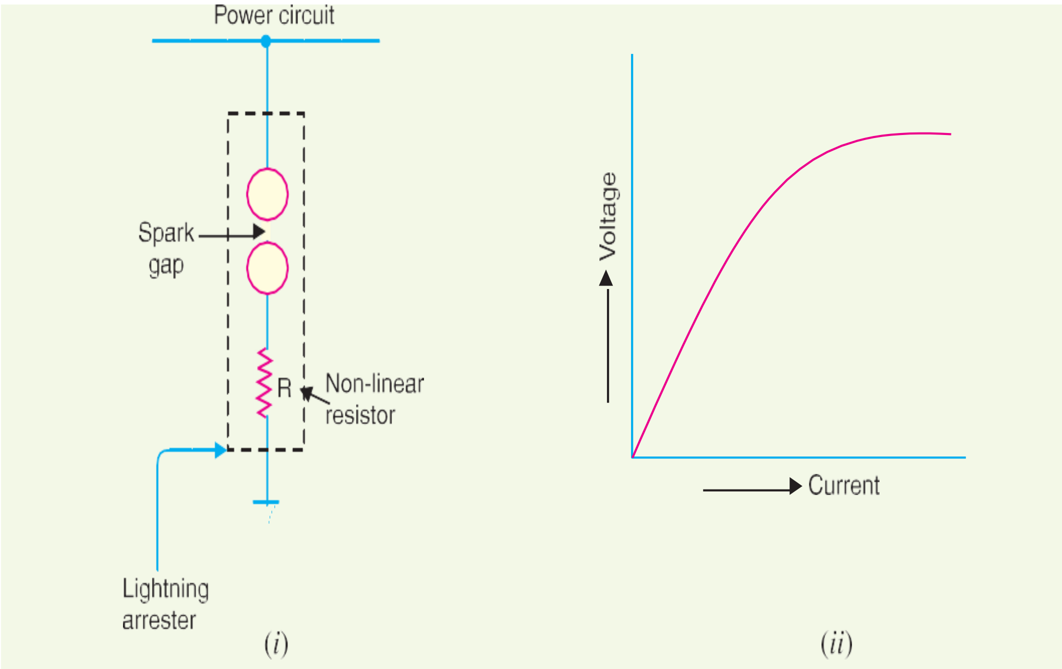

Fig. 24.8

Types of Lightning Arresters:

1.Rod Gap Arrester. It is a very simple type of diverter and consists of two 1·5 cm rods which are bent at right angles with a gap inbetween as shown in Fig. 24.9. One rod is connected to the line circuit and the other rod is connected to earth. The distance between gap and insulator (*i.e*. distance *P*) must not be less than one-third of the gap length so that the arc may not reach the insulator and damage it. Generally, the gap length is so adjusted that breakdown should occur at 80% of spark- over voltage in order to avoid cascad- ing of very steep wave fronts across the insula- tors. The string of insulators for an overhead line on the bushing of transformer has frequently a rod gap across it.

Under normal operating conditions, the gap remains non-conducting. On the occurrence of a high voltage surge on the line, the gap sparks over and the surge current is conducted to earth. In this way, excess charge on the line due to the surge is harmlessly conducted to earth.

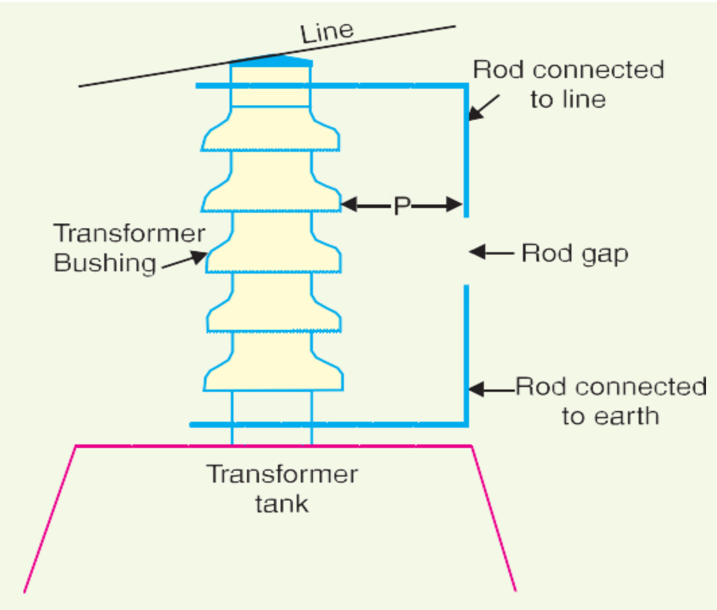

Fig. 24.9

2.Horn Gap Arrester: It consists of two horn shaped metal rods *A* and *B* separated by a small air gap. The horns are so constructed that distance between them gradually increases towards the top as shown. The horns are mounted on porcelain insulators.

One end of horn is connected to the line through a resistance *R* and choke coil *L* while the other end is effectively grounded. The resistance *R* helps in limiting the follow current to a small value. The choke coil is so designed that it offers small reactance at normal power frequency but a very high reactance at transient frequency. Thus the choke does not allow the transients to enter the apparatus to be protected. The gap between the horns is so adjusted that normal supply voltage is not enough to cause an arc across the gap.

Under normal conditions, the gap is non-conducting *i.e*. normal supply voltage is insufficient to initiate the arc between the gap. On the occurrence of an overvoltage, spark-over takes place across the *small gap *G*. The heated air around the arc and the magnetic effect of the arc cause the arc to travel up the gap. The arc moves progressively into positions 1, 2 and 3. At some position of the arc (perhaps position 3), the distance may be too great for the voltage to maintain the arc. Consequently, the arc is extinguished. The excess charge on the line is thus conducted through the arrester to the ground.

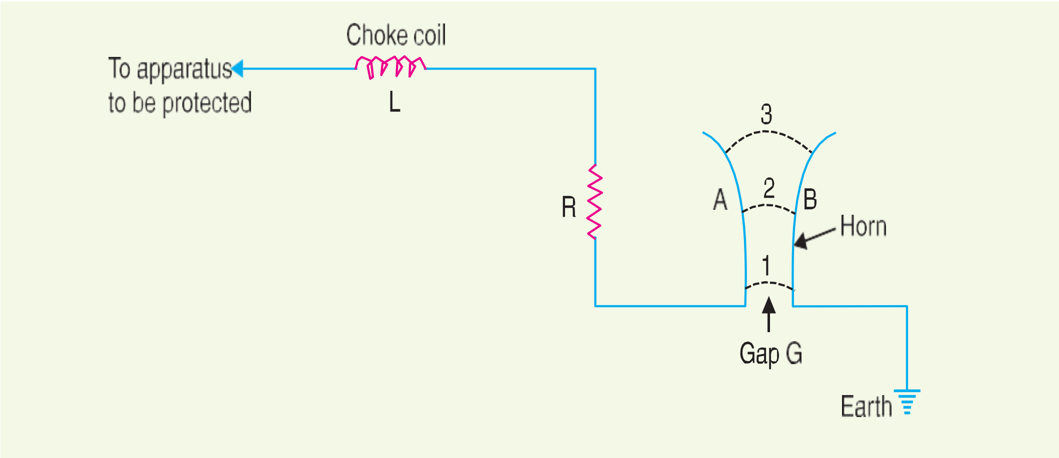

Fig. 24.10

3.Valve type arrester: Valve type arresters incorporate non-linear resistors and are extensively used on systems operating at high voltages.

It consists of two assemblies (*i*) series spark gaps and (*ii*) non-linear resistor discs (made of material such as thyrite or metrosil) in series. The non-linear elements are connected in series with the spark gaps. Both the assemblies are accommodated in tight porcelain container.

(*i*) The spark gap is a multiple assembly consisting of a number of identical spark gaps in series. Each gap consists of two electrodes with a fixed gap spacing. The voltage distribution across the gaps is linearised by means of additional resistance elements (called grading resistors) across the gaps. The spacing of the series gaps is such that it will withstand the normal circuit voltage. However, an overvoltage will cause the gap to breakdown, causing the surge current to ground via the non-linear resistors.

(*ii*) The non-linear resistor discs are made of an inorganic compound such as Thyrite or Metrosil. These discs are connected in series. The non-linear resistors have the property of offering a high resistance to current flow when normal system voltage is applied, but a low resistance to the flow of high-surge currents. In other words, the resistance of these non-linear elements decreases with the increase in current through them and *vice-versa*.

Under normal conditions, the normal system voltage is insufficient to cause the breakdown of air gap assembly. On the occurrence of an overvoltage, the breakdown of the series spark gap takes place and the surge current is conducted to earth *via* the non-linear resistors. Since the magnitude of surge current is very large, the non-linear elements will offer a very low resistance to the passage of surge. The result is that the surge will rapidly go to earth instead of being sent back over the line. When the surge is over, the non-linear resistors assume high resistance to stop the flow of current.

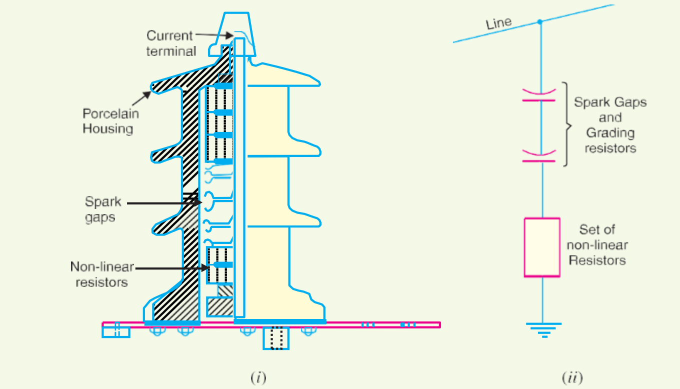

Fig. 24.13

Surge Absorber:

A **surge absorber** *is a protective device which reduces the steepness of wave front of a surge by absorbing surge energy*

Types of Surge Absorber:

1.A condenser connected between the line and earth can act as a surge absorber. Since the reactance of a condenser is inversely proportional to frequency, it will be low at high frequency and high at low frequency. Since the surges are of high frequency, the capacitor acts as a short circuit and passes them directly to earth. However, for power frequency, the reactance of the capacitor is very high and practically no current flows to the ground.

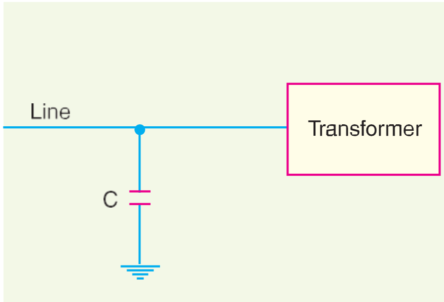

Fig. 24.14

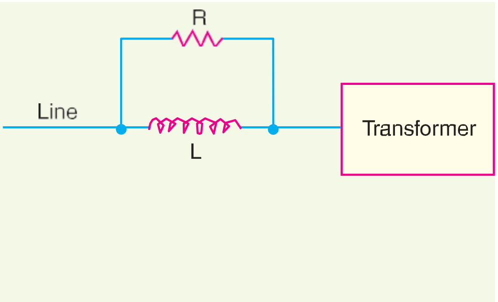

Fig. 24.15

2. Another type of surge absorber consists of a parallel combination of choke and resistance connected in series with the line as shown in Fig. 24.15. The choke offers high reactance to surge frequencies ($X_L = 2\pi f L$). The surges are, therefore, forced to flow through the resistance R where they are dissipated.

3. It is called Ferranti surge absorber. It consists of an air cored inductor connected in series with the line. The inductor is surrounded by but insulated from an earthed metallic sheet called dissipator. This arrangement is equivalent to a transformer with short-circuited secondary. The inductor forms the primary whereas the dissipator forms the short-circuited secondary. The energy of the surge is used up in the form of heat generated in the dissipator due to transformer action. This type of surge absorber is mainly used for the protection of transformers.

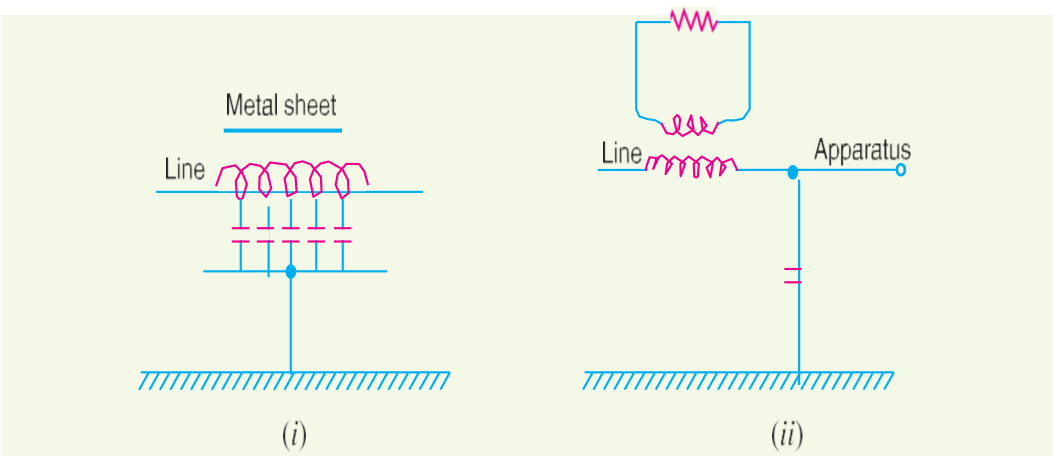

Fig. 24.17

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STATIC RELAYS

ADVANTAGES OF STATIC RELAYS:

1.Moving parts and contacts are greatly reduced.

2.High degree of accuracy.

3.High speed of operation.

4.Low power consumption.

5.Static relays are very compact.

6.Resetting time and overshoots can be reduced.

7.Static relays have superior characteristics and accuracy.

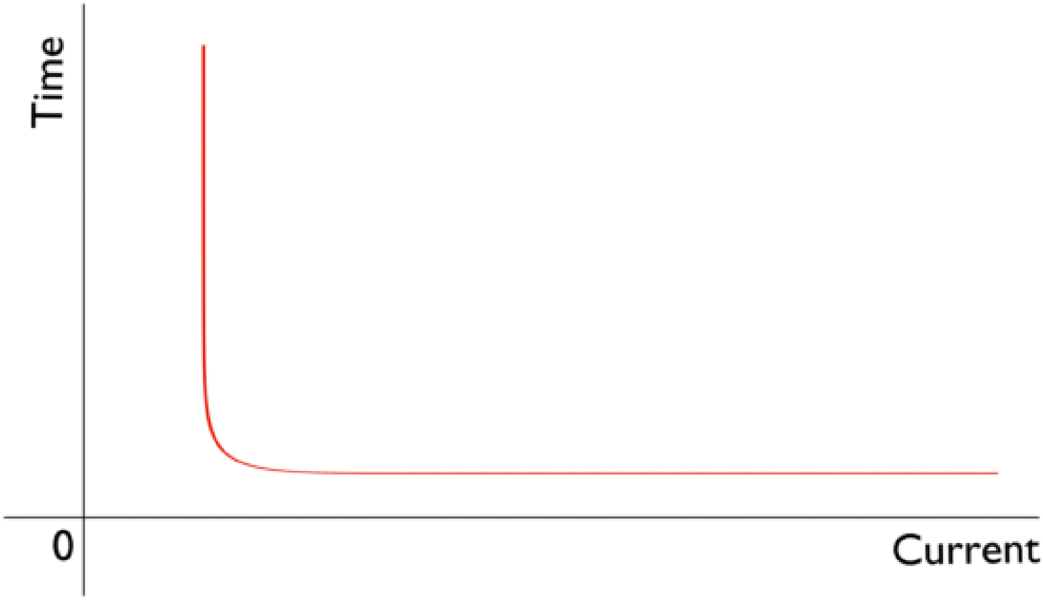
8.Simplified testing and servicing is possible.

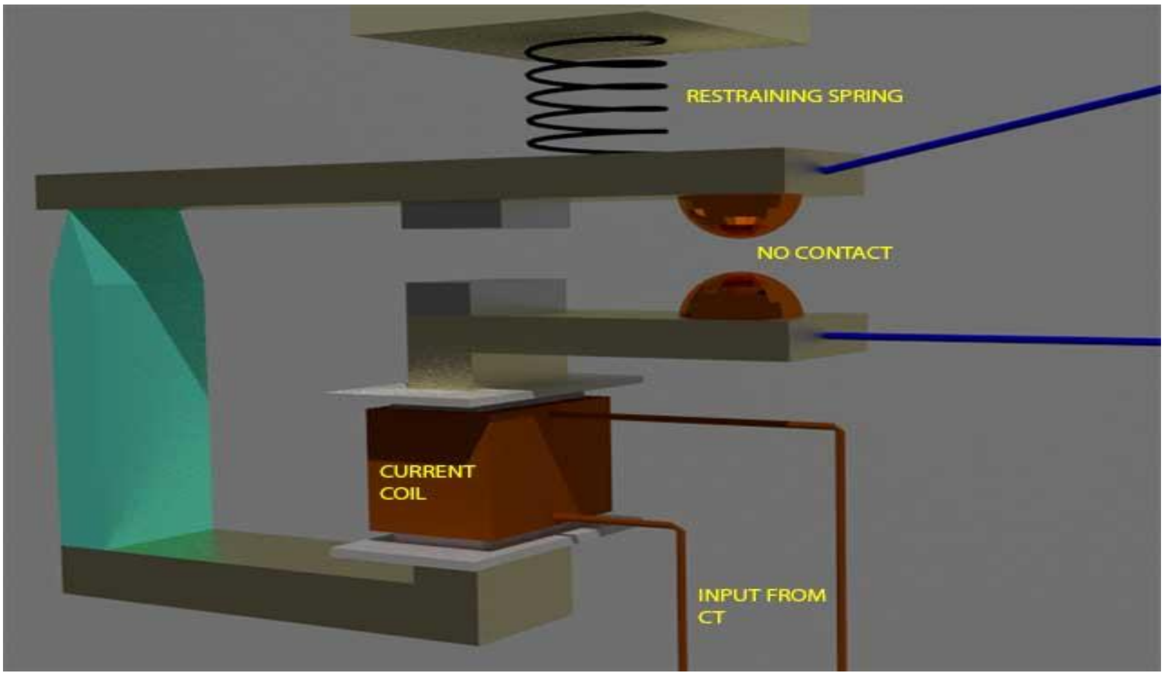
INSTANTANEOUS OVERCURRENT RELAY:

A magnetic core is wound by a current coil. A piece of iron is so fitted by hinge support and restraining spring in the relay, that when there is not sufficient current in the coil, the NO contacts remain open. When the current in the coil crosses a preset value, the attractive force becomes enough to pull the iron piece towards the magnetic core, and consequently, the no contacts get closed.

We refer the pre-set value of current in the relay coil as pickup setting current. This relay is referred as instantaneous over current relay, as ideally, the relay operates as soon as the current in the coil gets higher than pick upsetting current. There is no intentional time delay applied. But there is always an inherent time delay which we cannot avoid practically. In practice, the operating time of an

instantaneous relay is of the order of a few milliseconds.

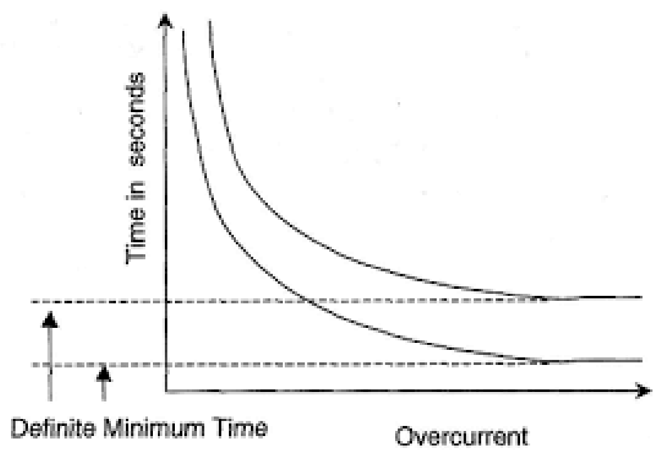




PRINCIPLE OF IDMT (INVERSE DEFINITE MINIMUM TIME) RELAY:

IDMT Relay are protection relays used on transmission lines to see that line current does not exceed safe values and if it exceeds then circuit breaker is triggered.

Ideal inverse time characteristics cannot be achieved, in an overcurrent relay. As the current in the system increases, the secondary current of the current transformer is increased proportionally. The secondary current enters the relay current coil. But when the CT becomes saturated, there would not be a further proportional increase of CT secondary current with increased system current. From this phenomenon, it is clear that from trick value to certain range of faulty level, an inverse time relay shows specific inverse characteristic. But after this level of fault, the CT becomes saturated and relay current does not increase further with increasing faulty level of the system. As the relay current does not increase further, there would not be any further reduction in time of operation in the relay. We define this time as the minimum time of operation. Hence, the characteristic is inverse in the initial part, which tends to a definite minimum operating time as the current becomes very high. That is why the relay is referred as inverse definite minimum time over current relay or simply IDMT relay.



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