SGP Important Questions

UNIT-I: Circuit Breakers

1. Briefly discuss the different methods of arc interruption in case of circuit breakers?

Ans: There are two methods for the arc interruption.

A. High Resistance method, B. Low Resistance (or) Current Zero Interruption

A. **High resistance method**:

The high resistance method uses the process to increase the effective resistance of the arc with the time so that the current is reduced to such a value that heat produce by it is not sufficient to produce the arc.

The resistance of the arc can be increased by the following ways.

- Cooling of arc: The arc resistance can be increased by adding the neutral or cold air between the contacts.
- Increasing the length of arc: The resistance of the arc can be increased by increasing the mean length between the contacts. This decreases the voltage gradient of the contact and the arc phenomenon can be reduces. But this process is not practical because this increases the length of the contacts for the high voltage system.
- Reducing the cross section area: The cross section of the arc can be reduced by having the small contact surface area or letting the arc pass through the small hole to reduce the arc. This process can help to reduce the voltage necessary to maintain the arc.

- Splitting the arc: This is the best method of increasing the resistance of the arc. The arcs so formed are splitted into the small channels to reduce the effect of it. The provision of splitter is designed in the circuit breaker and the formed arc passes through it to form the series of arc into the splitter. This increases the mean length of the arc and the cooling is better.

B. **Low Resistance or the Current Zero interruption**:

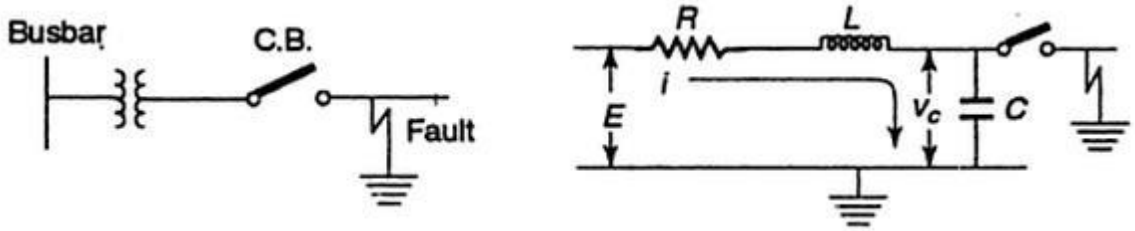
This method is applicable only for the AC supply system because in AC current crosses zero for every half cycle. In this process when the current reaches the zero value it

has the minimum effect and the fresh air is supplied to turn down the arc. This method is widely used in the modern circuit breaker. It can be done by any of the following methods:

- Lengthening of the gap: The dielectric strength is proportional to the length of gap so that lengthening by rapid operating of the contacts is an obvious procedure. The permissible arc length is limited, however by other considerations ex: arc energy etc.
- Increasing the pressure in the vicinity of the arc: By increasing the pressure the density of the particle constituting the discharge also increases. The increased density of particle causes higher rate of deionization and thus the dielectric strength of the medium between the contacts is increased.
- Cooling: If the particle is allowed to cool the natural combination of ionized particles will take place more rapidly resulting increase in dielectric strength of the medium. Cooling by conduction to adjacent parts e.g. baffles or by the use of gas such as hydrogen that has as high diffusion and great absorption rate is, therefore, effective.
- Blast effect: By blowing a stream of air through the arc, ionized particles between the contacts are swept away and replaced by unionized particles, the dielectric strength of the medium can be increased considerably. This can be achieved by forcing the cool un-ionized gas or liquid in to the contact space. These unionized particles increase the dielectric strength of the medium.

2. Explain the concepts of recovery voltage and re striking voltages and derive the expression for RV and RRRV.

Ans: When the circuit breaker is closed, the short circuit current flows through R, L and the contacts of the circuit breaker.



When the circuit breaker contacts are opened and the arc is extinguished, the current is diverted through the capacitance C, which results in transient condition. The inductance and the capacitance form a series oscillatory circuit. The voltage across the capacitance rises and oscillates. The natural frequency of oscillation is given by

$$f_n = \frac{1}{2\pi\sqrt{LC}}$$

The voltage across the capacitance which is the voltage across the contacts of the circuit breaker can be calculated in terms of L, C, f and system voltage. The mathematical expression for transient condition is as follows.

$$L\frac{di}{dt} + \frac{1}{C}\int idt = V_m coswt$$

Since the natural frequency oscillation is a fast phenomenon, it persists for only for a small period of time. During this short period which is of interest, the change in the power frequency term is very little and, hence negligible, because $coswt \approx 1$.

Hence $V_m coswt$ can assumed to remain constant at Vm.

$$L\frac{di}{dt} + \frac{1}{C}\int idt = V_m$$

$$i = \frac{dq}{dt} = \frac{d(C\ V_c)}{dt}$$

$$\frac{di}{dt} = \frac{d^2(C\ V_c)}{dt} = C\frac{d^2(V_c)}{dt}$$

$$\frac{1}{C}\int idt = \frac{q}{C} = V_C$$

$$LC\frac{d^2V_C}{dt^2} + V_C = V_m$$

Take laplace transform on both sides,

$$(LCS^2 + 1)V_C(s) = \frac{V_m}{S}$$

$$V_c(s) = \frac{V_m}{S\,(LCS^2+1)} = \frac{V_m}{LCS(s^2+\frac{1}{LC})}$$

$$V_c(s) = \frac{w_n^2 V_m}{S\,(S^2+w_n^2)} = \frac{w_n\,V_m}{s}\left(\frac{w_n}{(S^2+w_n^2)}\right)$$

where $\omega_n = \frac{1}{\sqrt{LC}}$

Taking inverse laplace transform

$$V_C(t) = w_n V_m \int_0^t \sin w_n t = w_n V_m \left[\frac{-\cos w_n t}{w_n}\right]_0^t$$

As $V_c(t) = 0$ at t =0, constant t = 0,

$$V_c(t) = V_m(1-\cos\omega_n t)$$

This is the expression for restriking voltage.

The maximum value of restriking voltage occurs at $t= \frac{\pi}{\omega_n} = \pi\sqrt{LC}$

Hence the maximum value of restriking voltage = $2V_m$.

Rate of rise of Restriking voltage $= \frac{d}{dt}[V_m(1-\cos\omega_n t)]$

RRRV = $V_m \omega_n \sin\omega_n t$

3. Discuss the Air blast Circuit breakers and its advantages.

Ans: In the air blast circuit breakers the arc interruption takes place to direct a blast of air, at high pressure and velocity, to the arc. Dry and fresh air of the air blast will replace the ionized hot gases within the arc zone and the arc length is considerably increased. Consequently the arc may be interrupted at the first natural current zero. In air blast circuit breakers, the contacts are surrounded by compressed air. When the contacts are opened the compressed air is released in forced blast through the arc to the atmosphere extinguishing the arc in the process. A compressor plant is necessary to maintain high air pressure in the receiver.

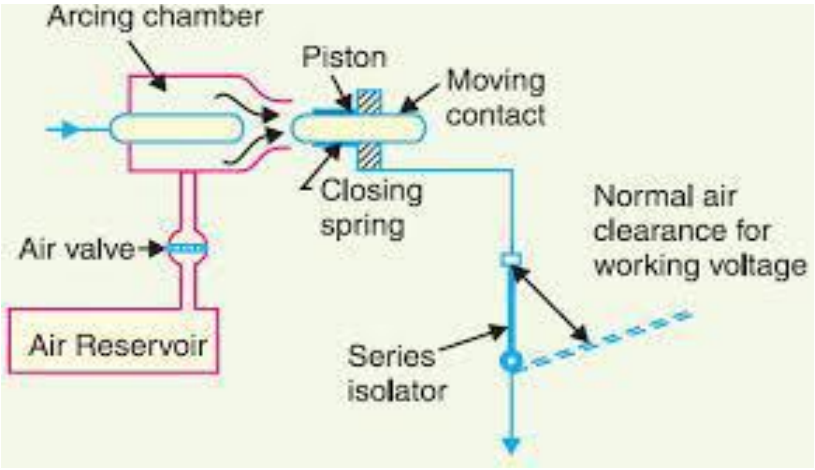
Two types of air blast circuit breakers are

i. Axial air blast circuit breaker

ii. Cross Blast air circuit breaker

Axial-blast air circuit breaker:

The fig shows the essential components of axial blast air circuit breaker. The fixed and moving contacts are held in closed position by spring pressure under normal conditions. The air reservoir is connected to the arcing chamber through an air valve. This valve remains closed under normal conditions but opens automatically by tripping impulse when a fault occurs on the system.



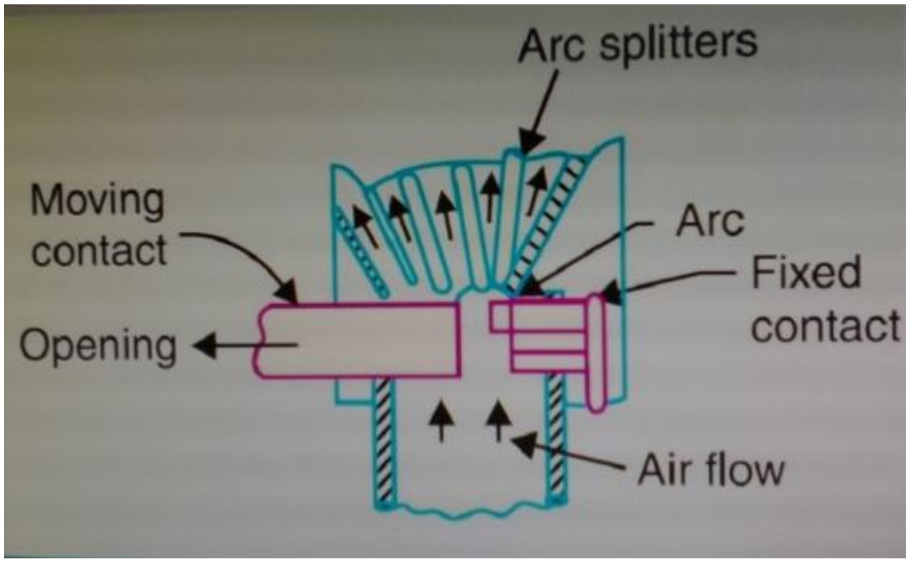
When a fault occurs the tripping impulse causes the opening of the air valve which connects the circuit breaker reservoir to the arcing chamber. The high pressure air entering the arcing chamber pushes away the moving contact against spring pressure.

The moving contact is separated and an arc is struck. At the same time, high pressure air blast flows along the arc and takes away the ionised gases along with it. Consequently, the arc is extinguished and current flow is interrupted.

It may be noted that in such circuit breakers, the contact separation required for interruption is generally small about 1.75 cm. Such a small gap may constitute inadequate clearance for the normal service voltage. Therefore, an isolating switch is incorporated as part of this type of circuit breaker. This switch opens immediately after fault interruption to provide necessary clearance for insulation.

Cross Blast air circuit breaker

In this type of circuit breaker, an air blast is directed at right angles to the arc. The cross-blast lengthens and forces the arc into a suitable chute for arc extinction. Figure below shows the parts of a typical cross blast air circuit breaker.



When the moving contact is withdrawn, an arc is struck between the fixed and moving contacts. The high pressure cross-blast forces into a chute consisting of an arc splitters and baffles. The splitters serve to increase the length of the arc and baffles give improved cooling. The result is that arc is extinguished and flow of current is interrupted. Since the blast pressure is same for all currents, the inefficiency at low currents is eliminated. The final gap for interruption is great enough to give normal insulation clearance so that series isolating switch is not necessary.

4. Explain different types of SF_6 Circuit breakers with neat diagrams.

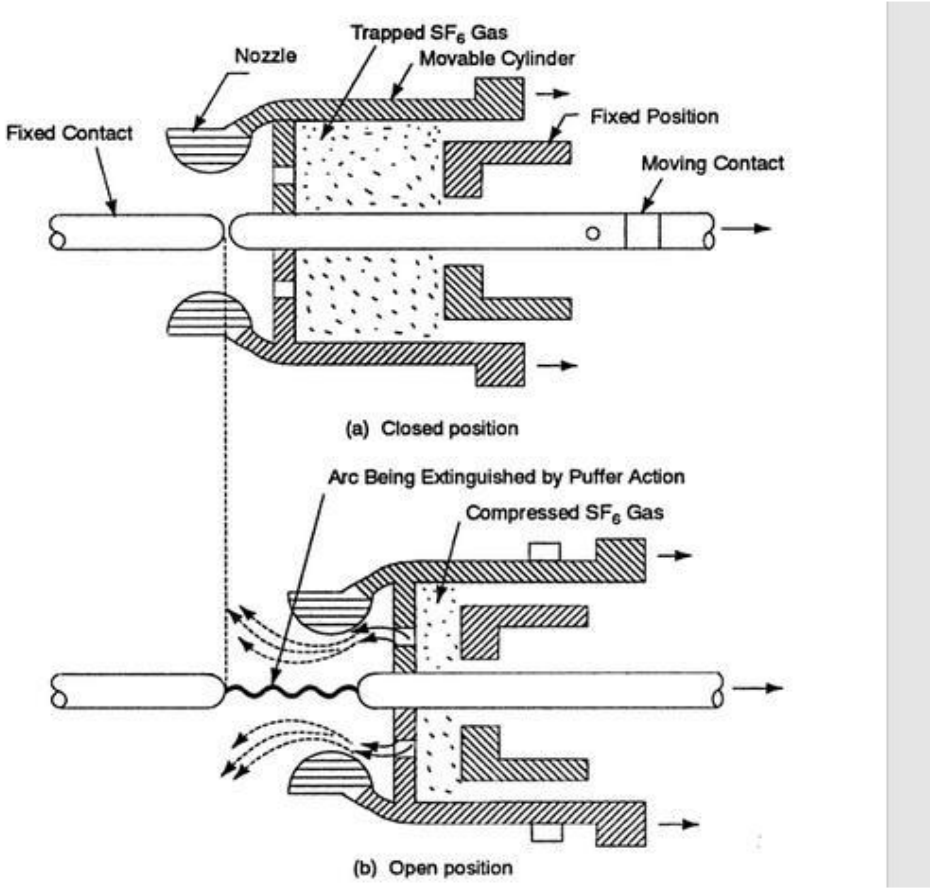
Ans: SF6 Circuit Breaker:

Sulphur Hexafluoride symbolically written as SF_6 is a gas which satisfies the requirements of an ideal arc interrupting medium. So SF_6 is extensively used these days as an arc interrupting medium in circuit breakers ranging from 3 kv upto 765 kv class. In addition to this SF_6 is used in many electrical types of equipment for insulation. Here first we discuss in brief,

some of the essential properties of SF_6 which is the reason of it's extensive use in circuit breakers.

Puffer type:

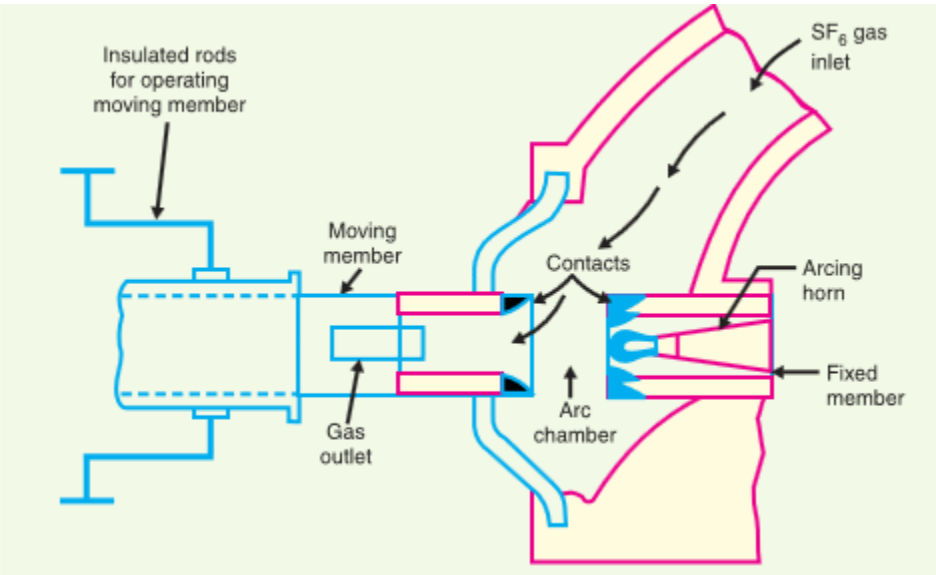
As illustrated in the figure the breaker has a cylinder and piston arrangement. Here the piston is fixed but the cylinder is movable. The cylinder is tied to the moving contact so that for opening the breaker the cylinder along with the moving contact moves away from the fixed contact (Fig-A(b)). But due to the presence of fixed piston the SF_6 gas inside the cylinder is compressed. The compressed SF_6 gas flows through the nozzle and over the electric arc in axial direction. Due to heat convection and radiation the arc radius reduces gradually and the arc is finally extinguished at current zero. The dielectric strength of the medium between the separated contacts increases rapidly and restored quickly as fresh SF_6 gas fills the space. While arc quenching, small quantity of SF_6 gas is broken down to some other fluorides of sulphur which mostly recombine to form SF_6 again. A filter is also suitably placed in the interrupter to absorb the remaining decomposed by-product.



The gas pressure inside the cylinder is maintained at around 5 kgf per sq. cm. At higher pressure the dielectric strength of the gas increases. But at higher pressure the SF_6 gas liquify at higher temperature which is undesired. So heater is required to be arranged for automatic control of the temperature for circuit breakers where higher pressure is utilised. If the SF_6 gas will liquify then it loses the ability to quench the arc.

Non-Puffer type :

Working: In the closed position of the breaker, the contacts remain surrounded by SF_6 gas at a pressure of about 2.8 kg/cm^2. When the breaker operates, the moving contact is pulled apart and an arc is struck between the contacts. The movement of the moving contact is synchronized with the opening of a valve which permits SF_6 gas at 14 kg/cm^2 pressure from the reservoir to the arc interruption chamber. The high pressure flow of SF_6 rapidly absorbs the free electrons in the arc path to form immobile negative ions which are ineffective as charge carriers. The result is that the medium between the contacts quickly builds up high dielectric strength and causes the extinction of the arc. After the breaker operation *(i.e.,* after arc extinction), the valve is closed by the action of a set of springs.



Advantages:

1. Due to the superior arc quenching property of SF_6, they have very short arcing time.
2. Since the dielectric strength of SF_6 gas is 2 to 3 times that of air, they can interrupt much larger currents.

1. The closed gas enclosure keeps the interior dry so that there is no moisture problem.
2. There is no risk of fire in such breakers because SF_6 gas is non-inflammable.

6. There are no carbon deposits. So insulation problems are eliminated.
7. They can withstand high RRRV. So the problem of current chopping is reduced.

Disadvantages

1. SF_6 breakers are costly due to the high cost of SF_6.
2. Since SF_6 gas has to be reconditioned after every operation of the breaker, additional equipment is required for this purpose.
3. Condenses at low temperatures (10°C)
4. Sealing problems. Imperfect joints lead to leakage of SF6 gas.
5. SF6 gas is suffocating to some extent. In case of leakage in the breaker tank, SF6 gas being heavier than air settles in the surroundings and may lead to suffocation of the operating personnel. However, it is non-poisonous.
6. Arced SF6 gas is poisonous and should not be inhaled or let-out.
7. Influx of moisture in the breaker is very harmful to SF6 gas circuit breakers.

1. Discuss about the Vacuum Circuit breakers and its advantages.

Ans: Principle:

When the contacts of the breaker are opened in vacuum (10 -7 to 10 -5 torr), an arc is produced between the contacts by the ionization of metal vapours of contacts. The arc is quickly extinguished because the metallic vapours, electrons, and ions produced during arc condense quickly on the surfaces of the circuit breaker contacts, resulting in quick recovery of dielectric strength. As soon as the arc is produced in vacuum, it is As illustrated in the figure the breaker has a cylinder and piston arrangement. Here the piston is fixed but the cylinder is movable. The cylinder is tied to the moving contact so that for opening the breaker the cylinder

Construction:

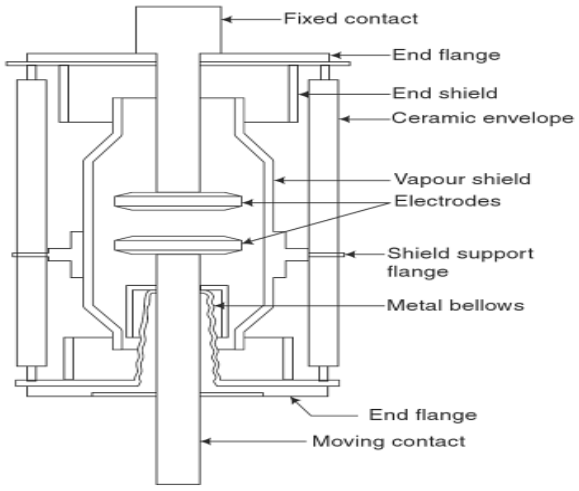


Fig shows the parts of a typical vacuum circuit breaker. It consists of fixed contact, moving contact and arc shield mounted inside a vacuum chamber. The movable member is connected to the control mechanism by stainless steel bellows .This enables the permanent sealing of the vacuum chamber so as to eliminate the possibility of leak .A glass vessel or ceramic vessel is used as the outer insulating body. The arc shield prevents the deterioration of the internal dielectric strength by preventing metallic vapours falling on the inside surface of the outer insulating cover.

Working:

When the breaker operates the moving contacts separates from the fixed contacts and an arc is struck between the contacts. The production of arc is due to the ionization of metal ions and depends very much upon the material of contacts. The arc is quickly extinguished because the metallic vapours, electrons and ions produced during arc are diffused in short time and seized by the surfaces of moving and fixed members and shields. Since vacuum has very fast rate of recovery of dielectric strength, the arc extinction in a vacuum breaker occurs with a short contact separation.

Advantages:

a. They are compact, reliable and have longer life.
b. There are no fire hazards
c. There is no generation of gas during and after operation

d. They can interrupt any fault current. The outstanding feature of a VCB is that it can break any heavy fault current perfectly just before the contacts reach the definite open position.

e. They require little maintenance and are quiet in operation

f. Can withstand lightning surges

g. Low arc energy

Low inertia and hence require smaller power for control mechanism.

2. Explain the principle & operation of Oil circuit breakers.

Ans: Minimum oil circuit breaker:

It uses minimum amount of oil. In such circuit breakers oil is used only for arc extinction, the current conducting parts are insulated by air or porcelain or organic insulating material.

Construction

There are two chambers in a minimum oil circuit breaker, the oil in each chamber is separated from each other. The main advantage of this is that low oil is required and oil in second chamber won't get polluted. Upper chamber is called the circuit breaker chamber and lower one is called the supporting chamber. Circuit breaking chamber consists of moving contact and fixed contact. Moving contact is connected with a piston its just for the movement of the contact and no pressure build due to its motion.There are two vents on fixed contact they are axial vent for small current produced in oil due to heating of arc and radial vents for large currents. The whole device is covered using Bakelite paper and porcelain for protection. Vents are placed in a turbulator.

Operation

Under normal operating conditions, the moving contacts remain engaged with the upper fixed contact. When a fault occurs, the moving contact is pulled down by the tripping springs and an arc is struck. The arc vapourises oil and produces gases under high pressure. This action constrains the oil to pass through a central hole in the moving contact and results in forcing series of oil through the respective passages of the turbulator. The process of turbulation is orderly one, in which the sections of arc are successively quenched by the effect of separate streams of oil ,moving across each section in turn and bearing away its gases.

A low oil circuit breaker has following advantages compared to bulk oil circuit breaker

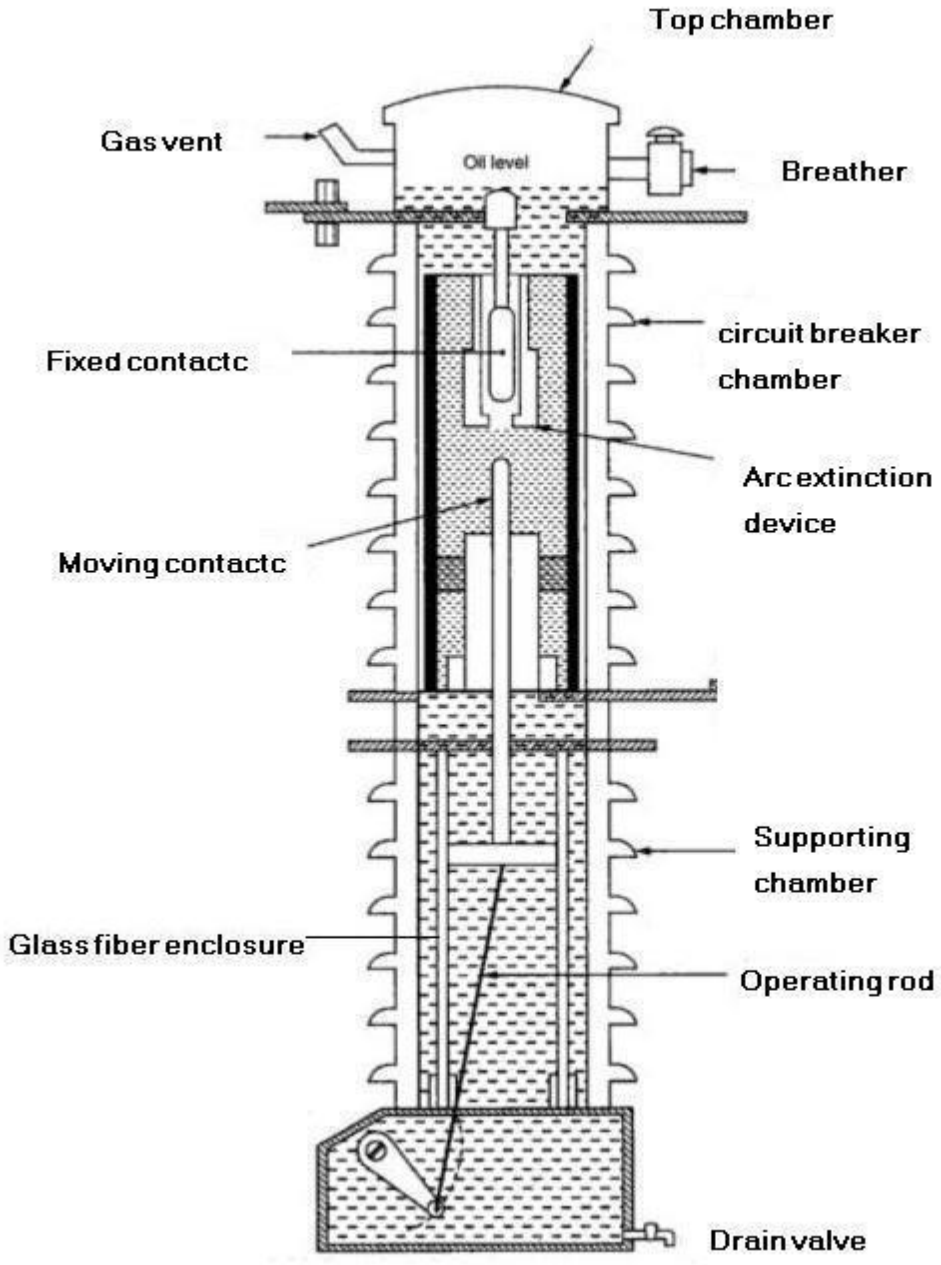
1. It requires lesser quantity of oil

2. It requires smaller space
3. There is reduced risk of fire

A low oil circuit breaker has following disadvantages compared to bulk oil circuit breaker

1. Due to smaller quantity of oil,the degree of carbonisation is increased
2. There is a difficulty of removing the gases from the contact space in time

The dielectric strength of oil deteriorates rapidly due to high degree of carbonisation.



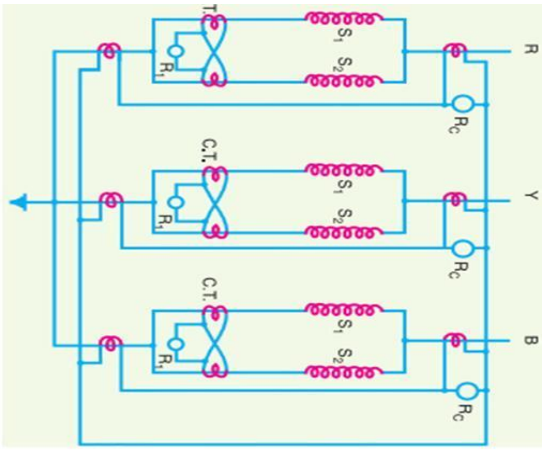
UNIT – III: Generator Protection & Transformer Protection

1. Explain stator inter-turn protection of Alternators.

Ans: Stator Inter-Turn Protection:

Merz-price circulating-current system protects against phase-to-ground and phase-to-phase faults. It does not protect against turn-to-turn fault on the same phase winding of the stator. It is because the current that this type of fault produces flows in a local circuit between the turns involved and does not create a difference between the currents entering and leaving the winding at its two ends where current transformers are applied. However, it is usually considered unnecessary to provide protection for inter-turn faults because they invariably develop into earth-faults.

In single turn generator there is no necessity of protection against inter-turn faults. However, inter-turn protection is provided for multi-turn generators such as hydro-electric generators. These generators have double-winding armatures as they carry very heavy currents. The relays R_C provide protection against phase-to-ground and phase-to-phase faults whereas relays R_1 provide protection against inter-turn faults.

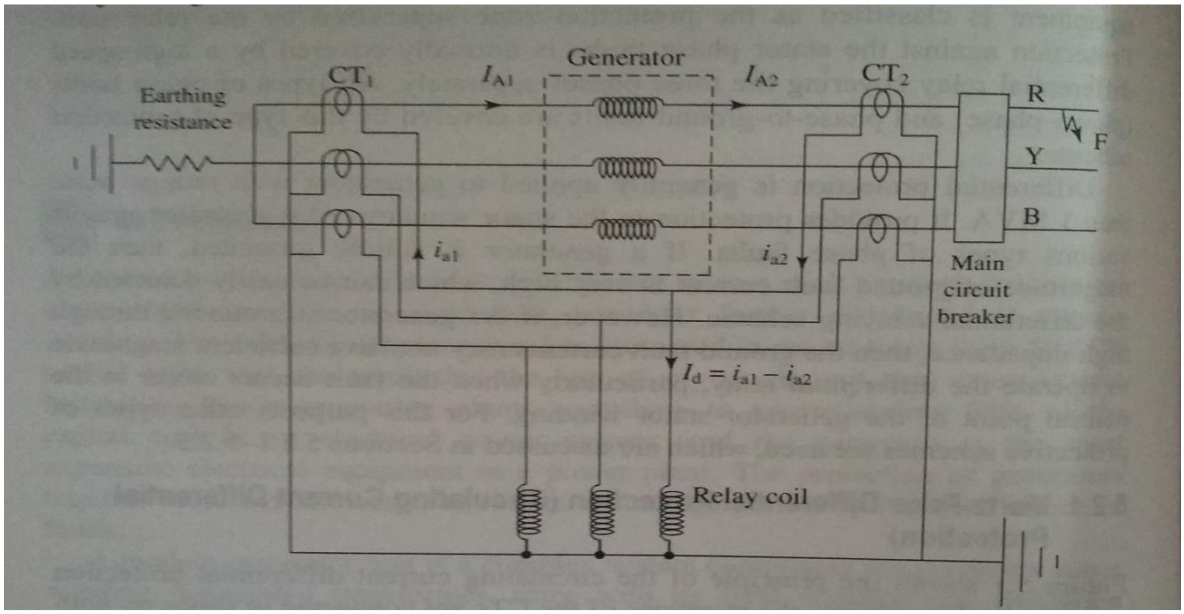


Two current transformers are connected on the circulating-current principle. Under normal conditions, the currents in the stator windings S_1 and S_2 are equal and so will be the currents in the secondaries of the two CTs. The secondary current round the loop then is the same at all points and no current flows through the relay R_I. If a short-circuit develops between adjacent turns, say on S_1, the currents in the stator windings S_1 and S_2 will no longer be equal. Therefore, unequal currents will be induced in the secondaries of CTs and the difference of these two currents flows through the relay R_I. The relay then closes its contacts to clear the generator from the system.

2. Explain Merz-Price circulating current scheme employed for the protection of Alternators.

Ans: In merz-price differential protection the primaries of the CTs are connected in series on the both side of each phase winding of the generator. The secondaries of the CTs are connected in additive manner to pass the circulating currents through a closed path. The differential relay constantly checks on the secondary sides of CTs as to whether the incoming current of a phase winding is equal to the respective outgoing current of the same winding.

The directions of currents passing through the secondary side of the CTs are shown in fig. If the currents on the primary sides , that is, IA1 and IA2, have the same magnitude, then the secondary side currents, ia1 and ia2 will also have the same magnitude, considering that CTs on both sides have same turns ratio and have identical characteristics. If there is a significant difference in currents (Id) on both sides of the windings, then this indicates a fault in the protection zone of the stator winding of the generator. Hence the differential relay trips if the value of Id exceeds a predetermined value (relay setting). On the other hand, during external faults, the differential relay remains stable and does not initiate a trip signal.



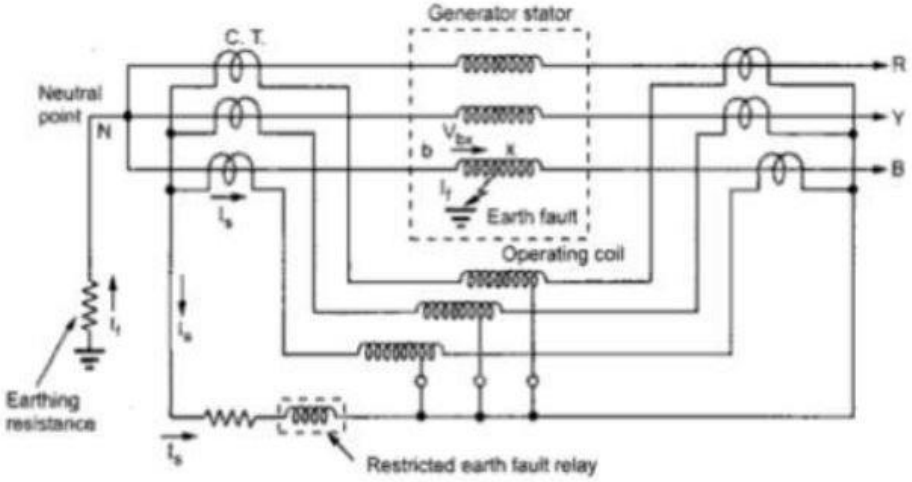
If the CTs are identical in nature, then the functioning the differential relay is straightforward. However, in practice, it is impossible to achieve CTs with identical saturation characteristics. Hence, the secondary currents of the CTs are unequal even though the primary currents are same. This current widely known as spill current. This spill current passes through the relay and may mal-operate the relayif the value exceeds the setting of the relay. This is possible particularly in case of heavy through fault conditions. Moreover, if the length of the

connecting wires (pilot wires) is unequal , then the value of the spill current increases. In order to avoid mal-operation of the differential relay in those situations, a stabilizing resistance is connected in series with the realy. However , incorporation of the stabilizing resistance reduces the sensitivity of the relay during an internal fault.

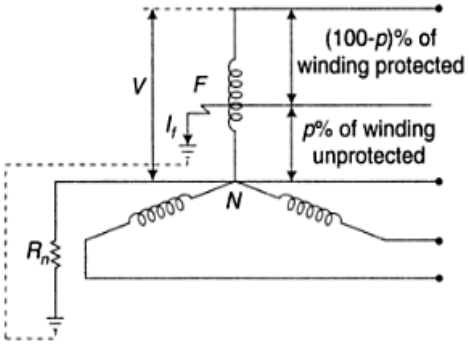
3. Explain restricted earth fault protection.

Ans: Restricted Earth Fault Protection:

When the neutral is solidly grounded, it is possible to provide protection to complete winding of the generator against ground faults. However, the neutral is grounded through resistance to limit ground fault currents. With resistance grounding it is not possible to protect the complete winding against ground faults. The percentage of winding protected depends on the value of the neutral grounding resistor and the relay setting. The usual practice is to protect 80 to 85% of the generator winding against ground fault. The remaining 15-20% from neutral end is left unprotected. The relay setting for the differential protection is determined by the value of the neutral grounding resistor and the percentage of winding to be protected. If the ground fault occurs at the point F of the generator winding, the voltage V_{FN} is available to drive the ground-fault current I_f through the neutral to ground connection. If the fault point F is nearer to the neutral point N, the forcing voltage V_{FN}, will be relatively less. Hence, ground fault current I_f will reduce. It is not practicable to keep the relay setting too sensitive to sense the ground fault currents of small magnitudes. Because, if the relay is made too sensitive, it may respond during through faults. The percentage of winding that is left unprotected;



$$\frac{p}{100} = \frac{V_{ph}}{R_n I_f}$$



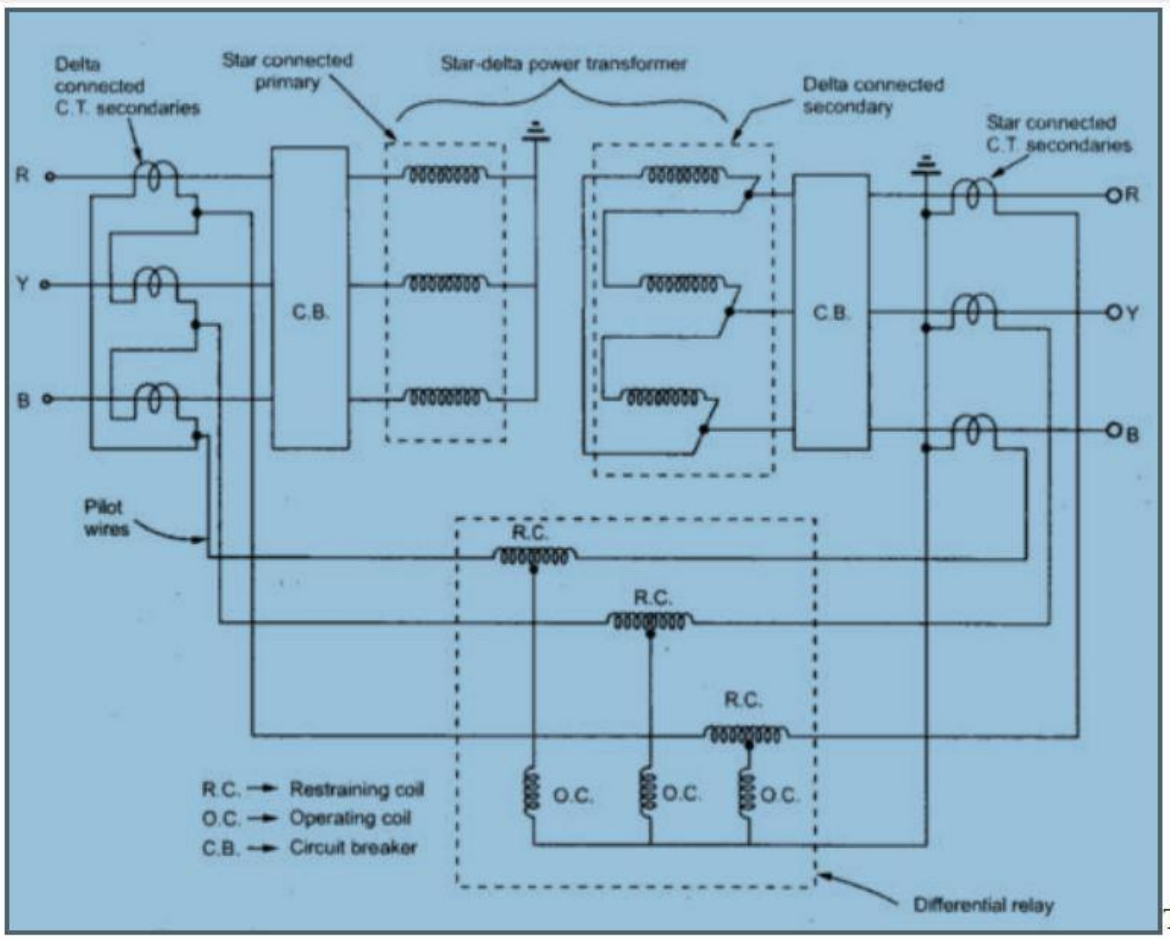
1. Explain the percentage differential protection for star/delta transformer with relevant diagrams showing all essential details. Discuss its advantages over simple differential protection.

Ans: Transformer differential protection:

Basic discussions related to the Merz-Price Scheme and its limitations which are taken care by the biased differential scheme.

a. Transformation ratio
b. Current Transformer Connections
c. Bias to cover tap-changing facility and CT mismatch
d. Magnetization Inrush

Power Transformer Connections		C. T. Connections	
Primary	Secondary	Primary	Secondary
Star	Delta	Delta	Star
Delta	Delta	Star	Star
Star	Star	Delta	Delta
Delta	Star	Star	Delta



The star point of the power transformer primary as well as the star connected C.T. secondaries must be grounded. The restraining coils are connected across the C.T. secondary windings while the operating coils are connected between the tapping points on the restraining coils and the star point of C.T. secondaries.

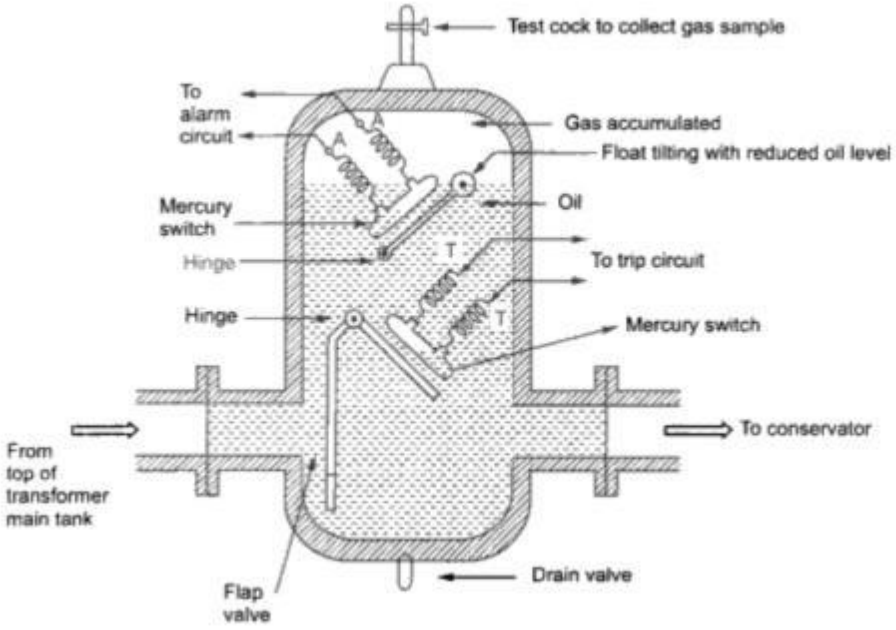
With the proper selection of turns ratio of C.T.s the coils are under balanced condition during normal operating conditions. The C.T. secondaries carry equal currents which are in phase under normal conditions. So no current flows through the relay and the relay is inoperative. It is important to note that this scheme gives protection against short circuit faults between the turns i.e. interturn faults also. This is because when there is an interturn fault, the turns ratio of power transformer gets affected. Due to this the currents on both sides of the power transformer become unbalanced. This causes an enough differential current which floes through the relay and the relay operates.

2. What is Buchholz relay? Explain its working principle with a neat sketch.

Ans: Buchholz Relay:

Operation:

There are many types of internal faults such as insulation fault, core heating, bad switch contacts, faulty joints etc. which can occur. When the fault occurs the decomposition of oil in the main tank starts due to which the gases are generated. As mentioned earlier, major component of such gases is hydrogen. The hydrogen tries to rise up towards conservator but in its path it gets accumulated in the upper part of the Buchholz relay. Through passage of the gas is prevented by the flap valve.



When gas gets accumulated in the upper part of housing, the oil level inside the housing falls. Due to which the hollow float tilts and closes the contacts of the mercury switch attached to it. This completes the alarm circuit to sound an alarm. Due to this operator knows that there is some incipient fault in the transformer. The transformer is disconnected and the gas sample is tested. The testing results give the indication, what type of fault is started developing in the transformer. Hence transformer can be disconnected before grows into a serious one. The alarm circuit does not immediately disconnect the transformer but gives only an indication to the operator. This is because sometimes bubbles in the oil circulating system may operate the alarm circuit even though actually there is no fault. However if a serious fault such as internal short circuit between phases, earth fault inside the tank etc. occurs then the considerable amount of gas gets generated. In that case, due to a fast reduction in the level of oil, the pressure in the tank increases. Due to this the oil rushes towards the conservator. While doing so it passes through the relay where flap valve is present. The flap valve

gets deflected due to the rushing oil and operates the mercury switch, thereby energizing the trip circuit which opens the circuit breaker of transformer is totally disconnected from the supply. The connecting pipe between the tank and the conservator should be as straight as possible and should slope upwards conservator at a small angle from the horizontal. This angle should be around 100. For the economic considerations, Buchholz relays are not provided for the transformer having rating below 500 KVA.

Advantages:

The various advantages of the Buchholz relay are,

1. Normally a protective relay does not indicate the appearance of the fault. It operates when fault occurs. But Buchholz relay gives an indication of the fault at very early stage, by anticipating the fault and operating the alarm circuit. Thus the transformer can be taken out of service before any type of serious damage occurs.
2. It is the simplest protection in case of transformers.

Limitations:

The various limitations of the Buchholz relay are

1. Can be used only for oil immersed transformers having conservator tanks.
2. Only faults below oil level are detected.
3. Setting of the mercury switches cannot be kept too sensitive otherwise the relay can operate due to bubbles, vibration, earthquakes mechanical shocks etc.

UNIT - IV: Feeder and Bus bar Protection

1. Describe in detail the protection of Radial, parallel feeder and ring mains.

Ans: The conditions required for this protection are where time lag is permitted and where instantaneous operation is not necessary. A few important applications are discussed below

(i) Radial Feeder Protection:

The characteristic features of radial system are that power can flow only in one direction from generator or supply end to load. This arrangement has the drawback that continuity of supply cannot be maintained at the receiving end in the event of occurrence of fault. In a radial system when numbers of feeders are connected in series is shown in fig.7.1. It is desired that the smallest possible part of the system should be off. This can be conveniently achieved by time graded protection. The settings of the relays on a number of series connected feeder circuit are so arranged that a time interval of not less than 0.4sec is obtained between relay panels. Relays located adjacent to the supply source are given a maximum time setting and those at the remote end of the feeder branch operate practically instantaneously. Standard relays have a definite minimum time range adjustable between 0 to 2 sec and with this range it is generally possible to secure selective operative of six relay points in series.

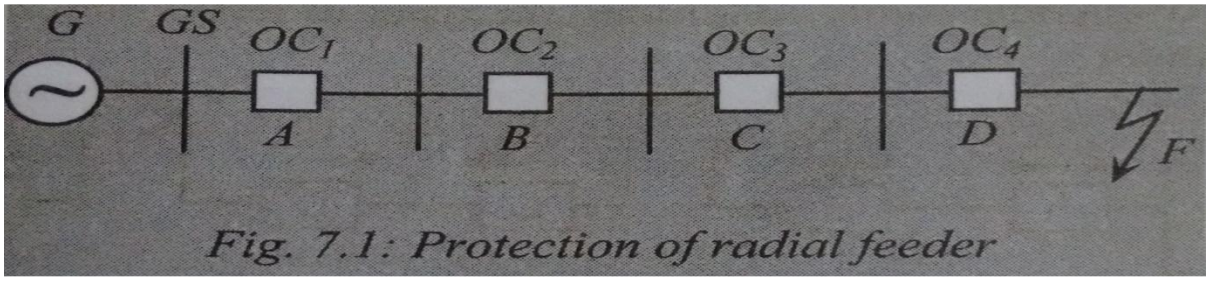


Fig. 7.1: Protection of radial feeder

Consider a scheme in the fig.7.1 in which a generating station(GS) supplies three transformer substations SS,, SS,, SS3 in series . If a fault occurs on the far side of SS3 it is obvious that only the over current relay D should operate and not any of the others and consequently the time taken to operate D should be less than of that of any of the others. Similarly the time taken should increase progressively as the generating station is approached and this is the principle of plain time grading. Here it is assumed that under remote end fault conditions all relays will be operating on the flat portion of their characteristic curve. For

example under such conditions the operating time right varies from 0.4 sec for D to 1.6 sec for A.

(ii) Parallel feeder Protection:

The parallel feeder system is usually an extension to the radial system, when owing to increase in power demand, it is found necessary to supplement the supply of the major distributing substations by duplicate feeders or where at any particular point on the system it is considered necessary to provide an alternate supply source to maintain continuity of supply. When a fault occurs on any one feeder, say feeder-2, the current will be fed to the fault as shown in fig. 7.2 by the arrows.

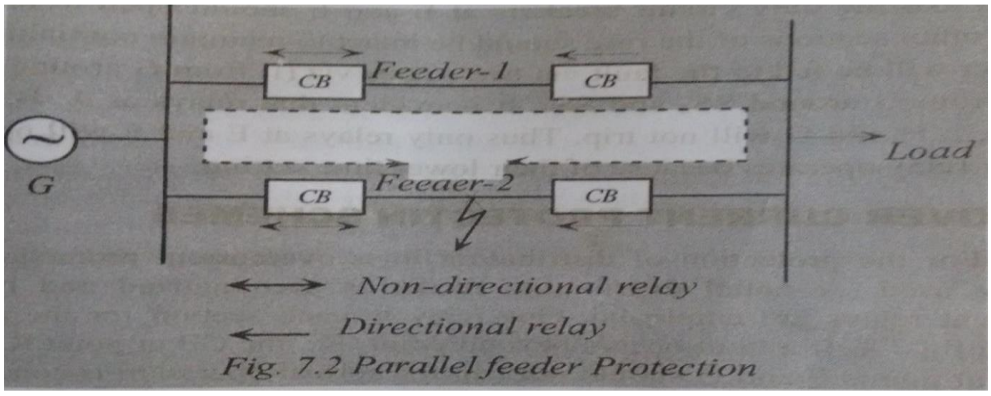


Fig. 7.2 Parallel feeder Protection

It is to be seen that as far as the relays near the source are concerned, the direction, where as the direction of the relay near the load end of the fault feeder is reversed. Therefore, for proper coordination the relays near the source end are non-directional relays whereas relays near the load end are directional relays. The direction of the current for which the directional relay will operate is indicated by the corresponding arrow heads. In this case as soon as fault takes place in feeder-2, the directional relay in feeder -1 corresponds to load current and after some time the non directional relay in feeder-2 will operate, thereby isolating feeder-2 from the source.

(iii) Protection of Ring mains:

The ring main system, which is extensively used in the modern distribution systems comprises simply of connecting a number of substations in series with the first and last having a feeder connected to the same power source. The advantage of this method is that fact alternative power supplies are available at each substation which gives a large measure of security in

maintaining continuity of supply.

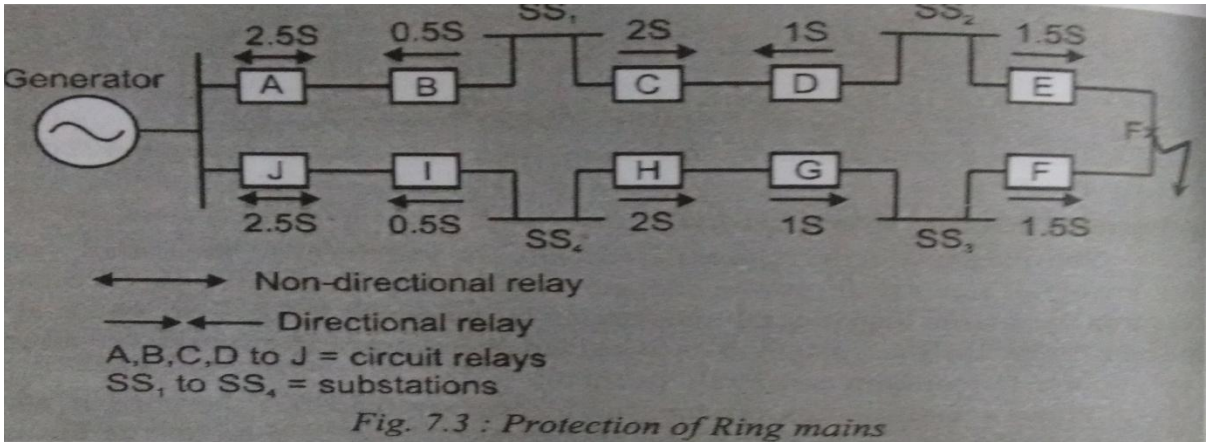


Fig. 7.3 : Protection of Ring mains

A typical ring main system consisting of one generator (G) and four substations (SS1, SS2, SS3 and SS4) is shown in fig. 7.3. Since the power can flow in both directions in this arrangement, therefore, it is necessary to grade in both directions around the ring and also to use directional relays. In order to isolate only faulty section of the ring under faulty conditions, the types of relays and their time settings should be as under.

(i) The two lines leaving the generating station should be equipped with a non directional over current relays (relays at A to J)

(ii) At each sub-station, reverse power or directional relays should be placed in both incoming and outgoing lines (relays at B, C, D, E, F, G, H)

(iii)There should be relative proper time setting of the relays.

Suppose fault occurs at F as shown in fig.7.3 for ensuring the selectivity it is desired that the only circuit breakers at E and F should open to clear the fault where as other sections of the ring should be intact to maintain continuity of supply. The power will be fed to the fault via two routes viz (i) from G around SS, and SS, and (ii) from G around SS4 and SS3. It is evident that relays at A, B, C and D as well as J, I, H and G will not trip. Thus only relays at E and F will operate before any other relay operates because of their lower time setting.

2. Explain about the over current protection of feeders with relevant connection diagram.

Ans: Time-Graded System:

Definite time over current relay is employed in this scheme. For a fault current definite

time over current relay operates. Starts a timing unit which trips the CB after a preset time, which is independent of the fault current. The relays operating time is adjusted in increasing order from the tail end of the feeder, as shown in fig. 7.4.

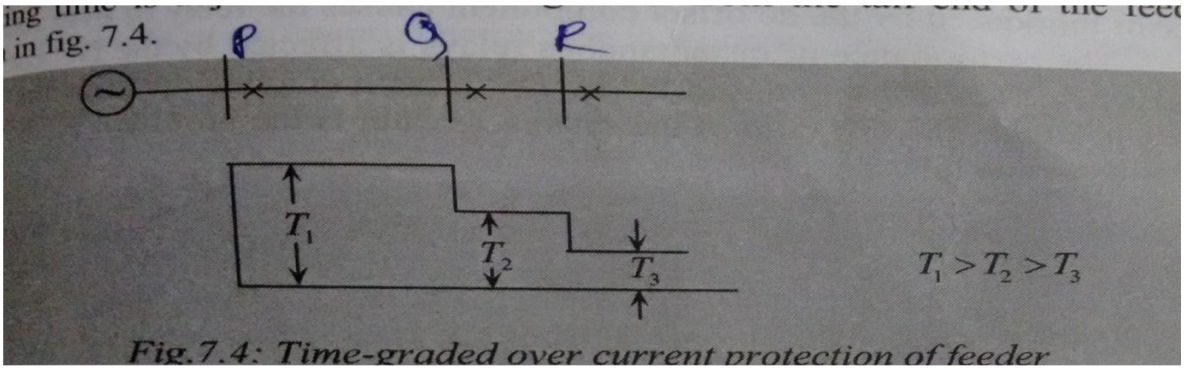


Fig.7.4: Time-graded over current protection of feeder

The protection is provided at the sending end of each substation P,Q,R which are indicated by the vertical lines and the crosses represents the location of relays. When a fault occurs beyond 'R.' the CB at `R' operates first, since relay at R comes into action as fault current flows through it and the protection at point Q and P acts as a back up protection i.e., if the relay or CB at R fails then the relay, at Q will operate and CB at Q will trip. Therefore, it can be observed that if a fault occurs then the relay nearer to that fault with operate first then any other relay.

The time of operation of the relays various locations is so adjusted that the relay farthest from the source will have minimum time of operation and as it approaches towards the source the operating time increases. This is the main drawback of grading the relays in this way because it is required that the more severe a fault is, lesser should be the operating time of the relays where as in this scheme the operating time increases. This system of protection is suitable for a system whose impedance between the substations is low. It means that the fault current is generally the same if a fault occurs on any section of the feeder.

Current-Graded System:

This type of grading is done on a system where the fault current varies appreciably with the location of fault. This means as we go towards the source the fault current increases. With this lf the relays are set to pick at a progressively higher current towards the source. then the draw back of the long time delay that occurs in case of time graded systems can be partially overcome. This is known as current grading. For the protecting of different sections of the

feeder, the operating time of the relays is kept same as shown in fig.7.5

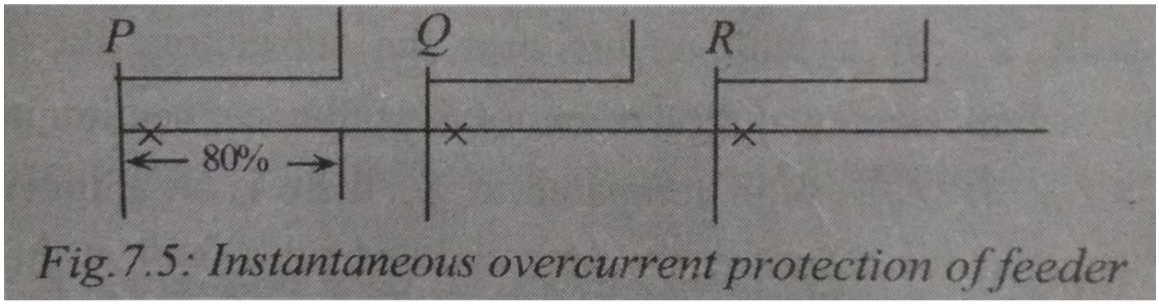


Fig.7.5: Instantaneous overcurrent protection of feeder

If fault in between Q and R, the relay at Q should trip. But it shout not operate for faults beyond point R. Similarly, the relays at point P should trip for fault between points P and Q. The relay at R should trip for faults beyond R. This operation is not achieved due to the following reasons.

- The fault current magnitude cannot be accurately calculated as the parameters of the circuit may, not be known.

- During a fault, there is a transient condition and the performance of the relays is not accurate.

This scheme cannot protect the entire feeder, this system is not used alone. It may be used in conjunction with IDMT relays, as shown in fig. The performance of instantaneous relays is affected by the DC component of transients. The error introduced by the DC offset component causes the relay of over reach. The performance of instantaneous relays is affected by the DC component of transients. The error introduced by the DC off set component causes the relay to overreach. Higher the X/R ratio of the system, greater is the problem, A DC filter is used to overcome this problem.

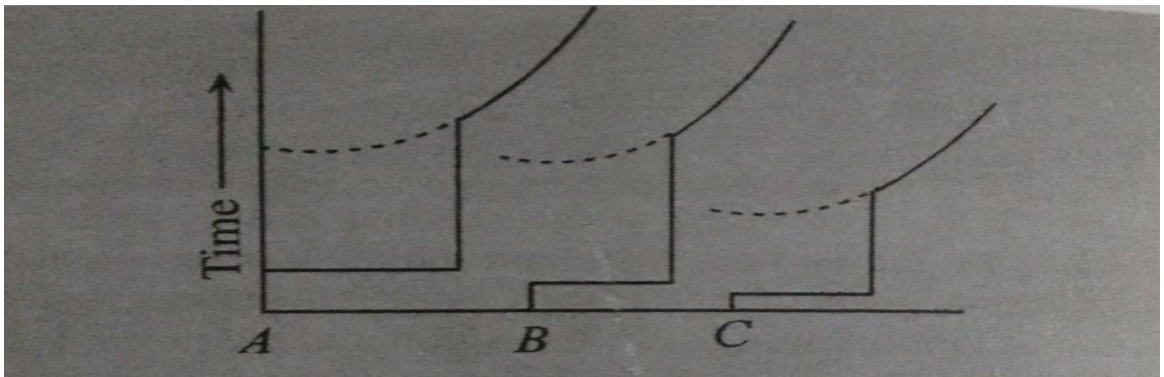


Fig 7.6 Combined instantaneous and I.D.M.T. protection

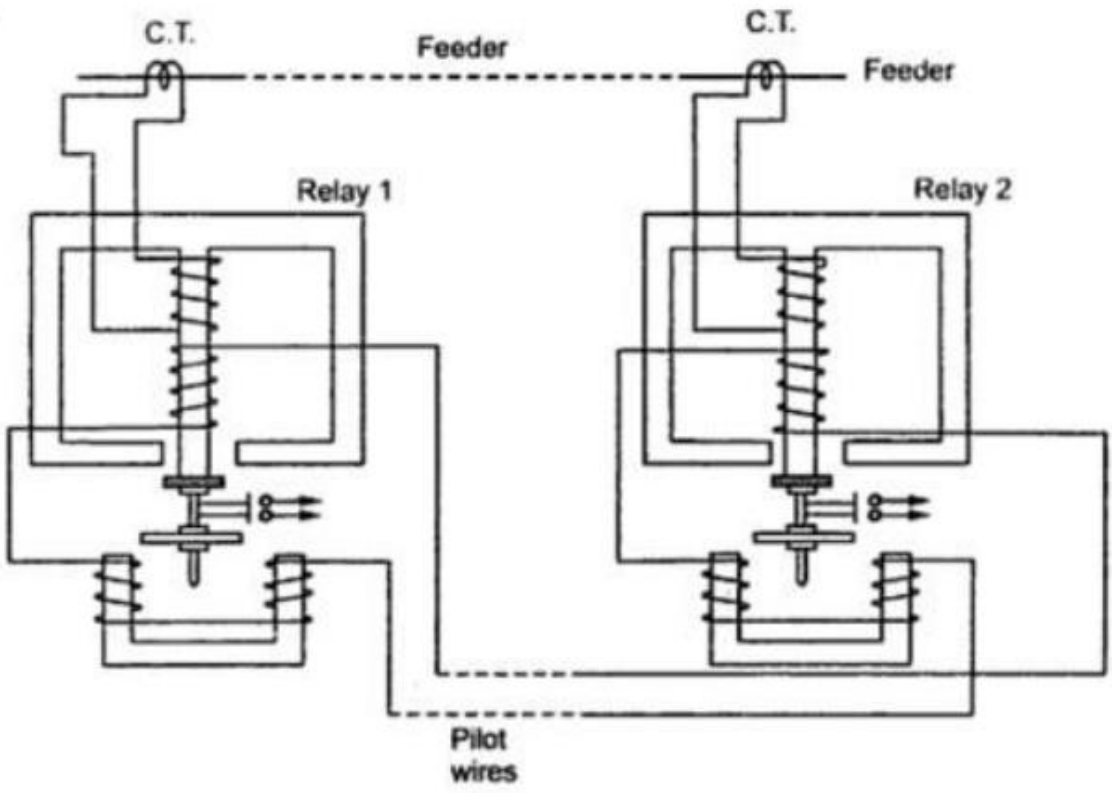
In the USA an instantaneous relay, employing induction Cup type construction is used for this purpose as it is less sensitive to the D.0 offset component. This arrangement also provides a high reset to pick-up ratio, more than 90%. The current-graded scheme is used where the impedance between substations is sufficient to create a margin of difference in fault currents. For such a system Zs is smaller compared to Zi. The advantage of this system as compared to the graded scheme is that the operating time is less near the power source.

1. Describe the protection scheme of a single feeder using Translay relay.

Ans: Translay Scheme :

The translay relay is another type of differential relay. The arrangement is similar to over current relay but the secondary winding is not closed on itself. Additionally copper ring or copper shading bands are provided on the central limb as shown in the figure below.

In this scheme, two such relays are employed at the two ends of feeder as shown in the figure below.



The secondaries of the two relays are connected to each other using pilot wires. The connection is such that the voltages induced in the two secondaries oppose each other. The copper coils are used to compensate the effect of pilot wire capacitance currents and unbalance between two currents transformers.

Under normal operating conditions, the current at the two ends of the feeder is same. The primaries of the two relays carry the same currents inducing the same voltage in the secondaries. As these two voltages are in opposition, no current flows through the two secondaries circuits and no torque is exerted on the discs of both the relays. When the fault occurs, the currents at the two ends of the feeder are different. Hence unequal voltages are induced in the secondaries. Hence the circulating current flows in the secondary circuit causing torque to be exerted on the disc of each relay. But as the secondaries are in opposition, hence torque in one relay operates so as to close the trip circuit while in other relay the torque restricts the operation. Care must be taken so that, at least one relay operates under the fault condition. Role of copper ring: Mainly relays may operate because of unbalance in the current transformers. The copper rings are so adjusted that the torque due to current induced in the copper ring due to primary winding of relay is restraining and do not allow the disc to rotate. It is adjusted just to neutralize the effect of

unbalance existing between the current transformers. The copper rings also neutralize the effect of pilot capacitive currents. Though the feeder current is same at two ends, a capacitive current may flow in the pilots. This current leads the secondary voltage by 90o. The copper rings are adjusted such that no torque is exerted on the disc, due to such capacitive pilot currents. Therefore in this scheme the demerits of pilot relaying scheme is somewhat taken care of.

The advantages of this scheme are,

1. Only two pilot wires are required.
2. The cost is very low.
3. The current transformers with normal design can be employed.
4. The capacitive effects of pilot wire currents do not affect the operation of the relays.

4. Explain about the three zone distance relay protection.

Ans: Three zone distance relay protection:

Operation:

Consider fig.7.14 which consists of two line sections i.e., AB and CD, it is desired to provide distance protection scheme. The protection scheme is divided into three zones. Let us assume the three-zones are Z_{1a}, Z_{2a} and Z_{3a} for relay at bus A.

First Zone:

First zone Z_{1a} corresponds to approximately 80% 1ength of the line AB. It is a high speed is used for the primary protection of the protected line. It is to be noted here that the first zone is extended only up to 80% and not 100% length of the line-as the relay impedance measurement will not be very accurate towards the end of the line especially "when the current is offset. If the relay operates for a fault beyond the-protected line, this phenomenon is called "over reach". Overreach may occur due to transient during the fault condition.

Second Zone:

Second zone Z_{2a} for relay at A covers the remaining 20% length of the line AB and 20% of adjoining line. In case of a fault in this section relay at A will operate when the time elapsed corresponds to the ordinate Z_{2a}. The main idea of the second zone is to provide protection for the remaining 20% section of the line AB. in case of an arcing fault in section AB which adds to the impedance of the line as seen by the relay at A, the adjustment is such that the relay at A will see & that impedance is second zone and will operate. This is why the second zone is extended into the adjoining line. The second zone unit operates after a certain time delay. Its operating time is usually 0.2sec to 0.5sec.

Third zone:

The third zone unit at A provides back up protection for faults in the line CD, i.e., if there is a fault in the line CD and if some reason the relay at C fails to operate then relay at A will provide backup protection. The time delay for the third zone is usually 0.4sec to 1sec.

In case the feeder is being fed from both the ends and let the fault takes place in the 2nd zone of line AB(20% of the line AB), the relay at B will operate instantaneously where as the fault lies in the second zone of the relay at A. This is undesirable from stability point of view and it is desirable to avoid this delay. This is made possible when the relay at B gives an interruption signal at A in order to trip the breaker quickly rather than waiting for zone 2 tripping.

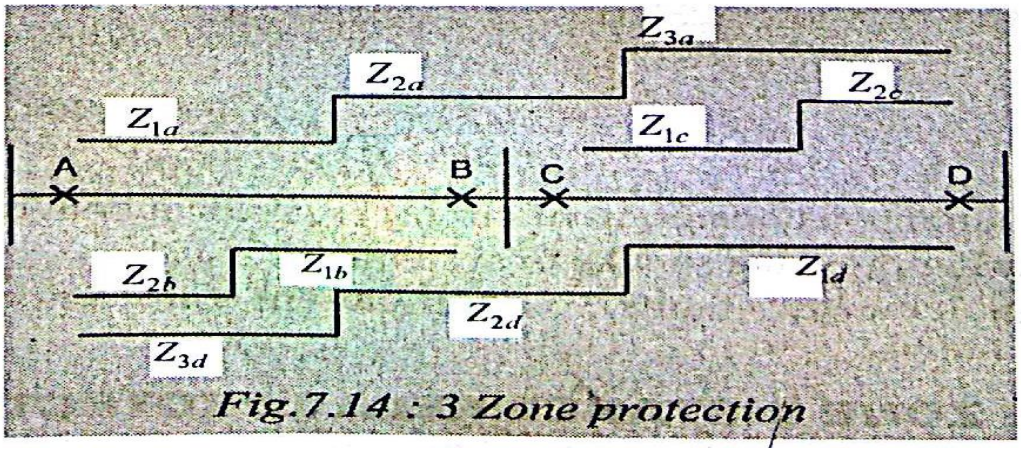


Fig.7.14 : 3 Zone protection

5. Explain about carrier current protection.

Ans: On long lines carrier pilot relaying is cheaper and more reliable than pilot wire relaying even though the terminal equipment is more expensive and more complicated than that required for use with pilot relays. The essential difference between this scheme and voltage balance pilot wire systems is that in the former, only the phase angles of the current at the two ends of the feeder are compared instead of actual currents used in the latter case. This phase angle decides whether the fault is internal or external.

There are different methods of carrier current protection and basic forms of carrier protection are (i) phase comparison protection and (ii) Directional comparison protection

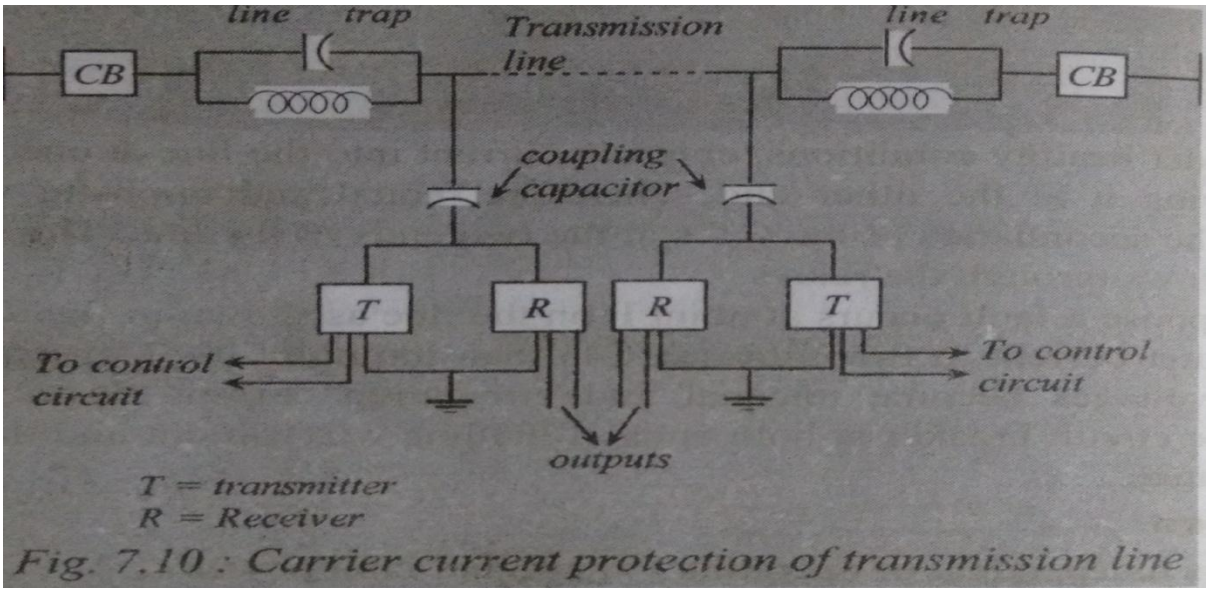


Fig. 7.10 : Carrier current protection of transmission line

Carrier phase comparing Relaying:

Fig.7.11 shows the principle elements of equipment at both ends of a transmission line using carrier pilot. The transmission line CT's feed a network that transforms the CT output currents into a signal phase sinusoidal output voltage, the voltage is applied to a carrier current transmitter and to a comparer. The comparer control the operation of an auxiliary relay for the tripping of the transmission line circuit breaker. These elements provide means for transmitting and receiving carrier current signals for comparing at each end the relative phase relations of the transmission line control at both ends of the line. The line CT's are so connected that their secondary currents are 180degrees out of phase \N hen normal current is flowing in the feeder. For an external fault at D in fig.7.12, the directions of current flow are 180 degrees out of phase as for normal operation.

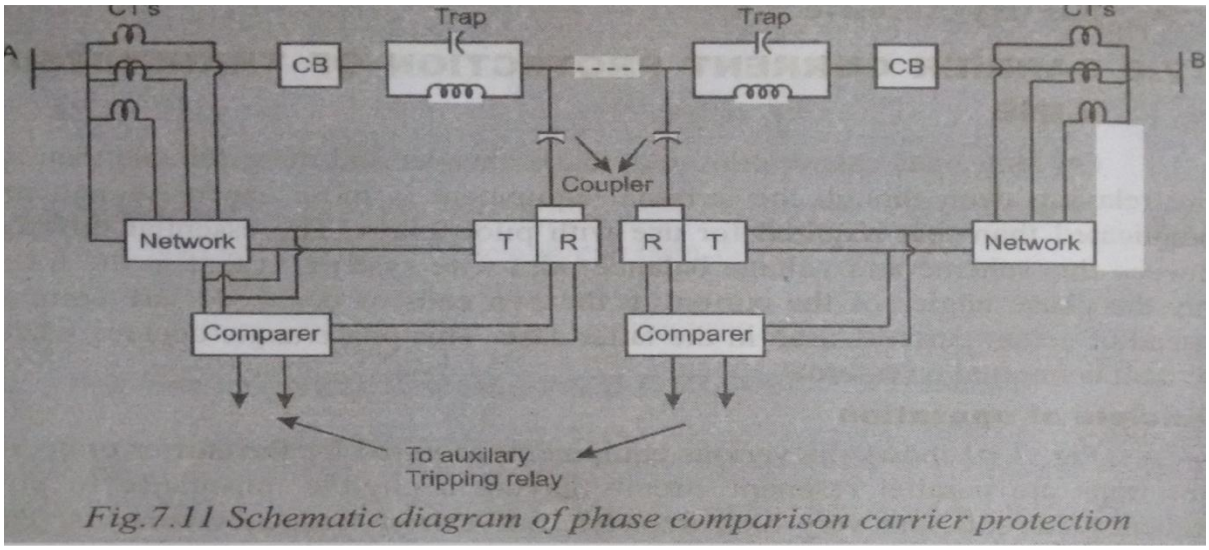


Fig.7.11 Schematic diagram of phase comparison carrier protection

Since an AC voltage is used to control the transmitter, carrier current is transmitted only during the half cycles of the voltage when the polarity is positive. The carrier current signals transmitted from A and B are displaced in time so that there is always a carrier current signal from one end or the other. There is no operation of the relay.

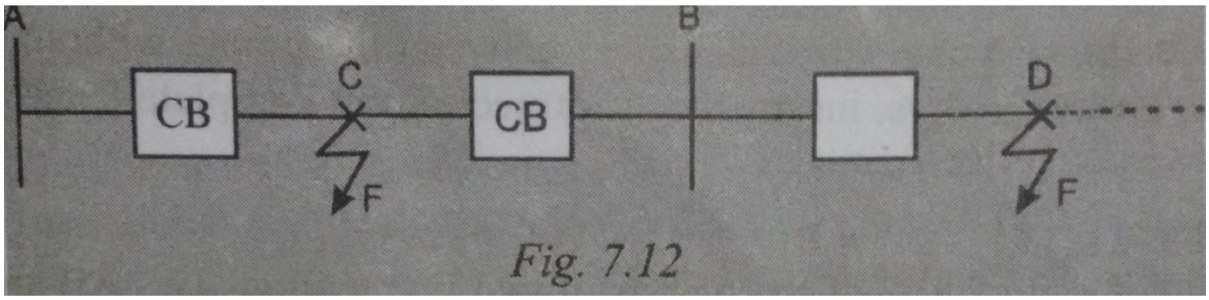


Fig. 7.12

For internal fault at C, currents are fed from both ends, the phase between the secondary currents is zero and a tripping signal is transmitted. Phase comparison relay acts to block tripping at both terminals wherever the carrier current signals are displaced in time to that there is little or no time interval when a signal is riot being transmitted from one end or the other. When the carrier current signals are in phase, tripping will occur whenever there is sufficient short circuit current flowing. Fig. 7.13 explains the operation of carrier phase protection.

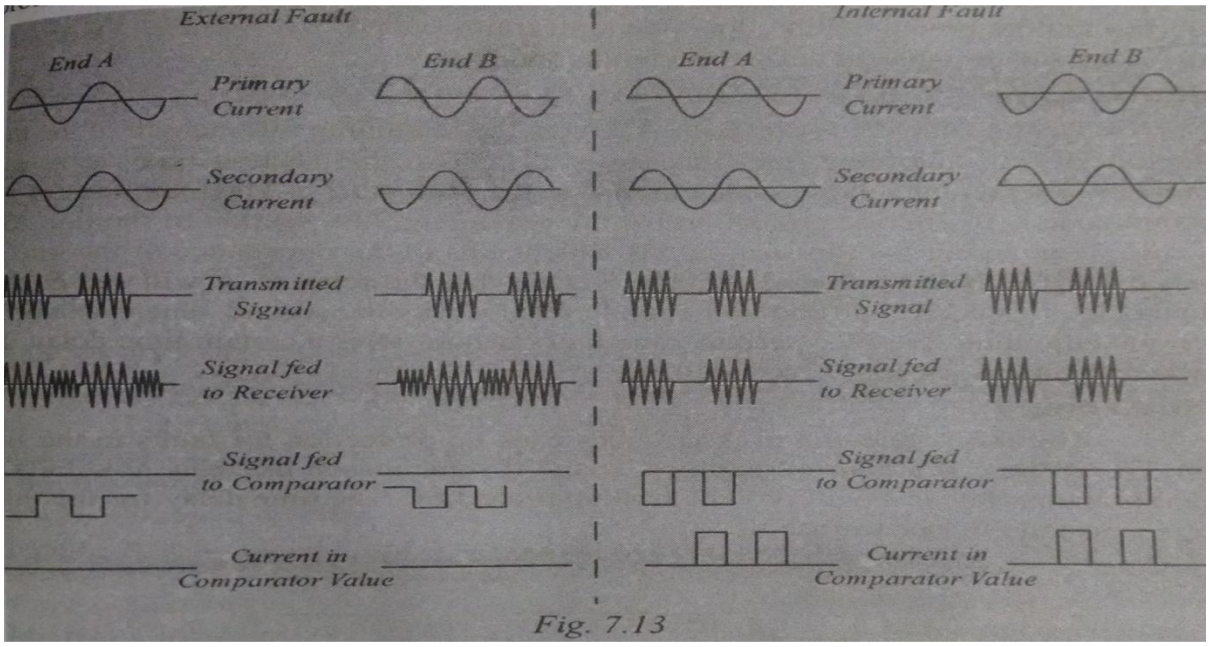


Fig. 7.13

4. Discuss about various schemes of protection of bus bars.

Ans: Differential protection:

Differential protection of bus bar is extensively employed in modem power station or

substations. In differential protection system the currents entering and leaving the bus bar are totalized. During normal operating or external fault conditions, the sum of these currents is zero. When the fault occurs, the fault currents upset the balance and develops a differential current which operates the relay. The schematic arrangement of this protection to station bus bar is shown in fig. The secondaries of CTs in the generator load in line -1 and line-2 are connected in parallel. The protective relay is connected across this parallel connection. Regardless of the capacities of the various circuits, all CT's must be of the same ratio in the scheme. When 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 opening of generator circuit breaker and each of the line circuit breaker.

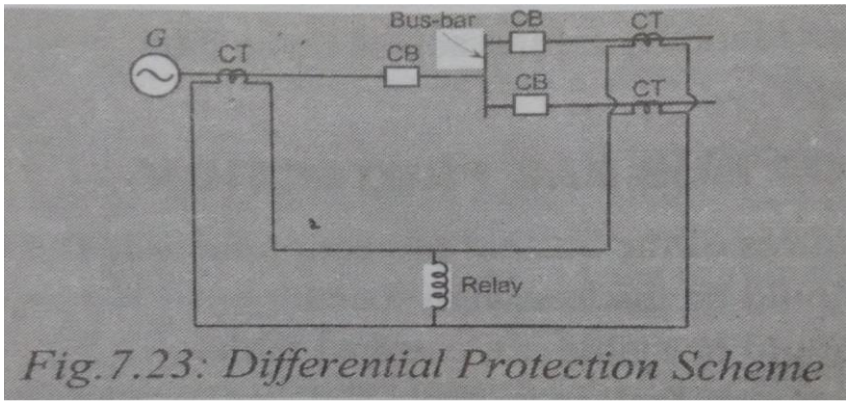


Fig.7.23: Differential Protection Scheme

Limitations:

(i) The circuit is complicated due to sectionalizing
(ii) Due to large load variation setting of relays require a change
(iii) Under external fault condition there might be a mal-operation, this is due to the saturation of one of the CT due to DC components in fault current.

iv) Under external fault conditions differential (spill) current is caused due to the left over magnetism is cores of the CT's and also the difference in the primary current of the CT's will cause a differential current.

To overcome the problem of C.T saturation and to improve the stability without intentional time delay, the following protection schemes have been developed.

(i) Biased differential bus zone protection
(ii) High impedance bus zone protection
(iii) High impedance voltage differential bus zone protection.

UNIT – V: Static and Digital Relays

1. What are the advantages and disadvantages of static relays over electro mechanical relays?

Ans: Advantages of static relays:

i. The consumption in case of static relay is usually is much lower than that in case of their electro-mechanical equivalents. Hence burden on the instrument transformers is reduced and their accuracy is increased, possibility of use of air gaped CTs is there , problems arising out of CT saturation are eliminated, and there is an overall reduction in cost of CTs and PTs.
ii. Quick response, long life, shock proof, fewer problems of maintenance, high reliability and high degree of accuracy.
iii. Absence of moving contacts and associated problems of arcing, contact bounce, erosion, replacement of contacts etc.
iv. Quick reset action a high reset value of overshoot can be easily achieved because of absence of mechanical inertia and thermal storage.
v. There is no effect of gravity on operation of static relays and therefore they can be installed in vessels, aircrafts etc.
vi. Ease of providing amplification enables greater sensitivity to be obtained.
vii. Use of printed or integrated circuits avoids wiring errors and facilitates rationalization of batch products.
viii. Static relays are very compact. A single static relay can perform several functions. The space required for installation of protective relays and control relays etc, are reduced.
ix. The characteristics of static relays are accurate and superior. They can be altered within certain range as per protection needs.
x. Static relays assisted by power line carrier can be employed for remote back-up and network monitoring.
xi. Static relays can be designed for repeated operations. This is possible because of absence of moving parts in measuring circuits.
xii. The risk of unwanted tripping is less with static relays.
xiii. Static relays are quite suitable for earth quake prone areas, ships, vehicles, locomotives, aero planes etc. This is because of high resistance to shock and vibration.
xiv. The static relays are provided with integrated features for self monitoring, easy testing and servicing. Defective module can be replaced easily.
xv. A static protection control and monitoring system can perform several functions such as protection, monitoring, measurement, memory, indication, data communication etc.

Limitations of static relays:

i. Auxiliary dc supply is required. However, this drawback is not very important as auxiliary dc

supply can be obtained from station battery supply and conveniently changed as per local needs.

ii. Static relays are sensitive voltage spikes or voltage transients. Special measures are taken to avoid such problem.

iii. The characteristics of static relays are influenced by ambient temperature and ageing. However, temperature can be provided by using thermistor circuits and digital measuring techniques etc. While ageing can be minimized by pre-soaking for a several at a relatively high temperature.

iv. The reliability of the system depends upon the large number of small components and their electrical connections.

v. The static relays have low short-time over-load capacity compared with electro-magnetic relays.

vi. Static relay characteristic is likely to be affected by the operation of the output device but this is not so in case of electro-magnetic relay because its operation is based on the comparison between operating torques/forces.

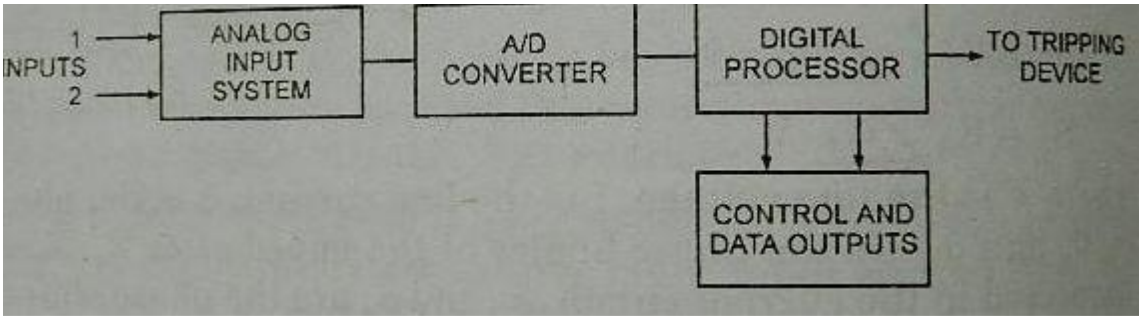
vii. Highly trained person are required for their servicing.

viii. Static relays are not very robust in construction and affected by surrounding interference.

2. Explain microprocessor based digital relay?

Ans: Microprocessor based digital relays:

With the fast development in fast scale integrated (LSI) technology, sophisticated and fast microprocessors are now available. With the rapid growth of modern complex large power system networks, fast, accurate and reliable protective schemes are essential . Microprocessor based schemes are becoming more and more popular for power system several protection as they offer attractive compactness and flexibility. They reduce the number of types of relay units. An interface employing op-amps, analog multiplexer analog-digital (A/D) converter voltage comparators and passive elements have been developed to provide the characteristics of various types of relays such as definite time relays, Inverse time over current relays, phase comparators relays and reverse power relays etc.



A block diagram of a microprocessor based digital programmable static relay is shown in figure.

The three phase A.C. quantities received from the power system through CTs PTs are sampled simultaneously or sequentially at uniform time intervals (4 to 32 samples per cycle).they are then converted into the digital form through an A/D converter and transfer to digital processor. digital signals are in the form of coded square pulses which represents discrete data .the signals are in binary form .the microprocessor/digital processor being set with the recommended values compares the dynamic inputs and decides accordingly to generate trip /alarm signal to the output device.

Microprocessor based relays have numerous advantages .they have a very small burden on the CTs and PTs .saturation can be avoided by using air gap CT having a limited output, they can process and display the signals very efficiently, accurately and in a fastest possible manner .due to their programmable characteristics ,they can be applied extensively in the protection of electrical power systems .moreover one microprocessor unit may be able to perform relaying function of systems .microprocessor relays are more reliable and secure to relay engineers because they can alert the user to a mal function before a false trip or failure to trip occurs .however the microprocessor should be properly shielded from external influences and the system earthing must be very good from which they receive their control voltage.

3. **Explain and draw the block diagram of static over current relay.**
4. **Explain the operation of static Impedance relay with its characteristics?**
5. **Explain the operation of static Reactance relay with its characteristics?**
6. **Explain the operation of static Mho relay with its characteristics?**