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Model Question Paper

Sub: Protection of Power Systems (8EX3A) **Sem: VIII**

1. **Explain the nature and causes of faults. Discuss the consequences of faults on power system.**

A. Faults caused by either insulation failures or by conducting path failures. The failure of insulation results in short circuits which are very harmful as they may damage some equipment of the power system. Most of the faults on transmission and distribution lines are caused by overvoltages due to lightning or switching surges, or by external conducting objects falling on overhead lines. Over voltages due to lightning or switching surges cause flash over on the surface of insulators resulting in short circuits. Some insulators get punctured or break. Birds also may cause faults on overhead lines if their bodies touch one of the phases and the earth wire. If the conductors are broken there is a failure of the conducting path and the conductor becomes open circuited. if the broken conductor falls to the ground, it results in a short circuit. Unbalanced currents flowing in rotating machines setup harmonics, there by heating missions in short periods of time. Therefore unbalancing of the lines is not allowed in the normal operation of power system.

Consequences of faults:

Heavy short circuit current may cause damage to equipment or any other element of the system due to overheating and high mechanical forces setup due to heavy current
Arcs associated with short circuits may cause fire hazards. Search files resulting from arcing may destroy the faulty element of the system.
There may be a reduction in the supply voltage of the healthy feeders, resulting in the loss of industrial loads.
Short circuits may cause the unbalancing supply voltages and currents there by heating rotating machines.

2. **Explain the differences between protection CT and measurement CT.**

A. The CT using for protection will have to carry the fault currents which are 10 times the normal full load current thats why it is designed at much bellow the saturation point (knee) inorder to aviod saturation. These CTs have to protect against fault hence these CTs are not supposed to saturate during fault current and they should transform secondary current exectly replica of fault current. For example class 5P20 means 5=% error, P = protection class, 20 means 20 times of rated current means when 20 times of rated current is flowing through CT the error in sec. current may be +/- 5%.

The CT used for metering will have to carry only full load current thats why it is designed near to knee point. as per accuracy concern the metering Ct should be more accurate under normal operating condition i.e under normal operating condition the pretection CT accuracy not important. It will function up to full load current only then it will be saturated. It will not follow the CTR Above the full load curent. Take the example of a train, if boggies are connected to engine it will follow the speed of engine but if coupling is broken boggies will not follow the engine.

3. **A 1200/5 , 400V CT is connected on the 1000/5 tap. What is the maximum secondary burden that can be used and we can maintain rated accuracy at 20 times rated symmetrical secondary current?**

A. The secondary voltage V_S corresponding to the tap 1000/5,

V_S =(1000/1200)*400=333V

Secondary current I_S=20*5=100A

$V_S=I_S*(R_S+R_B)$

from calibration curve.

333 = 100(0.51+R_B)

Secondary burden = 3.33 - 0.51 = 2.72Ω

4. **Discuss the classification of protective relays based on their speed of operation.**

A. Protective relays can be generally classified by their speed of operation follows.

(i) Instantaneous relays
(ii) Time delay relay
(iii) High speed relay
(iv) Ultra high speed relays

Instantaneous relays:

In this relays, no intentional time delay is introduced to slow down their response. These relays of operate as soon as a secure decision is made

Time delay relays:

In this relays and intentional time delay is introduced between the relay decision time and the initiation of the trip action.

High speed relays:

These relays offer rate in less than a specified time the specified time in present practice is 60 milliseconds.

Ultra high speed relays:

To disturb is not included in the relay standard but these relays a commonly operate within 5 milliseconds

5. **What you understand by a zone of protection? Discuss various zones of protection for a modern power system.**

A. A Power system contains generators, Transformers, bus bars, transmission and distribution lines etc. There is a separate protective scheme for each piece of equipment or element of the power system such as generator protection, Transformer protection, transmission line protection and busbar protection etc. The system is divided into a number of zones for protection. A productive zone covers one or at the most two elements of a power system. A protective zones are planned in such a way that the entire power system is collectively covered by them and thus no part of the system is left unprotected. Adjacent protective zones must overlap each other, haircut failing which your fault on the boundary of the zones may not lie in any of the zones, and hence no circuit breaker would trip. Thus the overlapping between the adjacent zones is unavoidable. If a fault occurs in the overlapping zone in a properly protected scheme, more circuit breaker then the minimum necessary to isolate the faulty element of the system would trip.

If a fault occurs in a particular zone it is the duty of the primary release of the zone to isolate the faulty element the primary really is the first line of defence if due to any reason the primary relay fails to operate there is a backup protective scheme to clear the fault as a second line of defence.

The causes of of failures of protective scheme may be due to the failure of various elements. The reliability of protective scheme should at least be 95%. With proper design installation and maintenance of the relays, circuit breakers, trip mechanisms AC and DC wiring etc. a very high degree reliability can be achieved. The backup relays are made independent of those factors which might cause primary release to fail. A backup relay operates after a time delay to give primary relay sufficient time to operate. When a backup relay operates larger part of the power system is disconnected from the power source but this is unavoidable. As far as possible a back up relay should be placed at a different station. Sometimes a local backup is also used. It should be located in such a way that it does not employ components common with the primary relays which are to be backed up. There are three types of backup relays:

(i) Remote backup

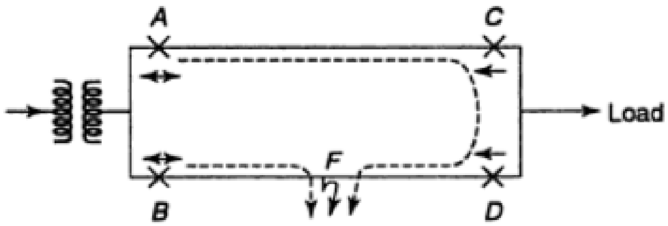
(ii) Relay backup

(iii) Breaker backup

6. Explain the overcurrent protective schemes for feeders.

A. An over current protective scheme for parallel feeders:

At the sending end of the feeders non directional relays are required. At the other end of the feeders directional overcurrent relays are required. The arrow mark for the directional release place it it is C and D indicate that the relay will operate if current flows in the direction flow by the arrow. If your fault occurs at F, the directional relay at D trips, as the direction of the current is reversed. The relay at C does not trip, as the current flows in the normal direction. The relay at B trips for your fault at F. Does the faulty feeder is isolated and the supply of the healthy feeder is maintained.



If non directional relays are used at C and D, both Reliance placed at C and D will trip for your fault at F. This is not desired as healthy feeder is also tripped. Due to this very reason relays at C and D are directional overcurrent relays. For fault at feeders the direction of current at A and B does not change and hence relay is used at A and B are non directional.

7. Discuss the protection employed against loss of excitation of an alternator

A. When the excitation of a generator is lost it speeds up slightly and operates as an induction generator. Round rotor generator do not have damper windings and hence they are not suitable for Such an operation. The router is overheated quickly due to heavy induced current in the rotor iron. The rotors of salient pole generator so not over heated because they have damper windings which carry induced currents. The starters of both salient and the non salient pole generators overheated due to wattless current drawn by the Machines as magnetizing current from the system. The stator overheating does not occur as quickly as rotor overheating. A large machine May upset the system stability because it draws reactive power from the system when it runs as induction generator where it supplies reactive power when it runs as a generator. A machine provide with a quick acting automatic voltage regulator and connected to very large system may run for several minutes as an induction generator without harm.

Field failure may be caused by the failure of excitation normal operation faulty field breaker. A protective scheme employing offset more or directional impedance relay having characteristics is recommended for large modern generators. When a generator loses it's exaltation, the locus of the equivalent generator impedance moves from the first quadrant to the fourth quadrant, irrespective of initial conditions. They relay trips the field breaker and the generator disconnected from the system.

8. State the different types of protection schemes employed in generators

A. A generator is the most important and costly equipment in a power system. As it is accompanied by Prime mover, excitation system, voltage regulator, cooling system, etc., its protection becomes very complex and elaborate. It is subjected to more types of troubles then any other equipment. Modern generating set is generally provided with the following protective schemes.

(i) Stator protection

(a) percentage differential protection

(b) protection against stator inter-turn faults

(c) stator overheating protection

(ii) Rotor protection

(a) field ground fault protection

(b) loss of excitation protection

(c) protection against rotor overheating because of unbalanced three phase stator currents

(iii) Miscellaneous

(a) over voltage protection

(b) overspeed protection

(c) protection against motoring

(d) protection against vibration

(e) bearing overheating protection

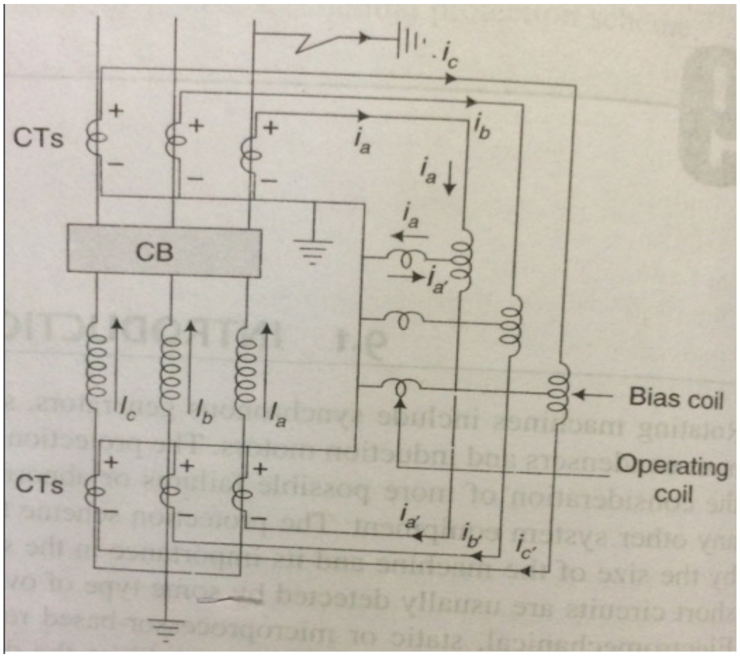
(f) protection against auxiliary failure

(g) protection against voltage regulator failure

9. Enumerate the Relaying schemes which are employed for the protection of a modern alternator

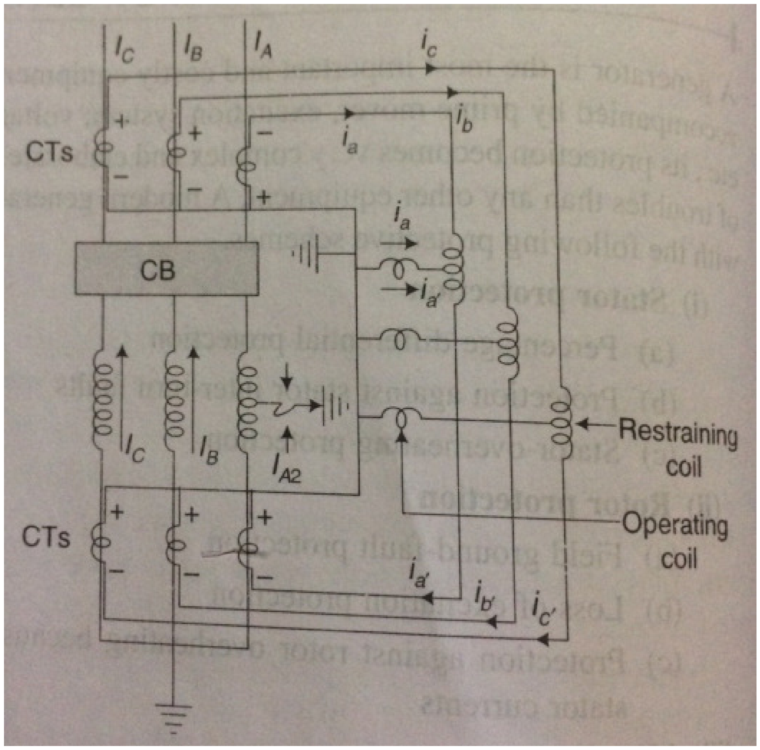
A. Percentage differential protection

The schematic diagram of percentage differential protection is shown in figure.



External fault

It is used for the protection of generators above 1MW. It protects against winding faults, i.e. Phace to phace and phase to ground faults. This is also called biased the differential protection or longitudinal differential protection. The polarity of the secondary voltage of CT is at a particular moment for an external fault has been shown in the figure. In the operating coil the current sent by the upper CT is called by the current sent by the lower CT and the relay does not operate. For an internal fault the polarity of the secondary voltage of the upper CT is reversed. Now the operating coil carries the sum of the current sent by upper CT and the lower CT and it operates under trips the circuit breaker.



Internal fault

The percentage differential protection does not respond to the external faults and overlords. It provides complete protection against phace to phace faults it provides protection against ground fault to about 80 to 85% the generator windings. It does not provide protection to 100 percent of the winding because it is influenced by the magnitude of the earth fault current which depends upon the method of neutral grounding. When the neutral is grounded through an impedance, the differential protection supplemented by sensitive earth fault relays.

Due to the difference in the magnetizing currents of the upper and the Lower CT is the current through the operating coil will not be zero even under normal loading conditions or during external fault conditions. Therefore to provide stability on external faults bias coils are provided the relay is set to operate, not at a different current but at a certain percentage of the through current. To obtain the required amount of biasing a suitable ratio of the restraining coil turns to operating coil turns is provided. High speed percentage differential relay is having visible ratio or percentage slope characteristics or preferred the setting of the bias coils varies from 5% to 50% and that of the relay coil from 10% to 100% of the full load current.

10. Describe the construction and operation of the HRC cartridge fuse. What are its dvantages and disadvantages

A. The HRC fuses cope with increasing rupturing capacity on the distribution system and overcome the serious disadvantages supported by the semi enclosed rewirable fuses.

In an HRC fuse, element surrounded by an inter Arc quenching medium is completely enclosed in an outer body of ceramic material having good mechanical strength. The unit in which the fuse element is enclosed is called fuse link. The fuse link is replaced when it blows off. An HRC fuse consists of cylindrical body of ceramic material usually steatite, pure silver element, pure quartz powder, brass end-caps and copper contact blades. The fuse element is fitted inside the ceramic body and the space within the body surrounding the element is completely filled with pure powered quartz. The ends of the fuse element arc connected to the metal end-caps which are screwed to the ceramic body by means of special forged screws. End contacts are welded to the metal end-caps. The contact blades ate bolted on the stationary contacts on the panel.

The fuse element is either pure silver of bimetalic in nature. Normally, the fuse element has two or more sections joined together by means of a tin joint.

When the fuse carries normal rated current, the heat energy generated is not sufficient to melt the fuse element. But when a fault occurs, the fuse element melts before the fault current reaches its first peak.

Advantages of HRC fuses:

(i) Capability of clearing high values of fault currents

(ii) Fast operation

(iii) Non-deterioration for long periods

(iv) No maintenance needed

(v) Reliable discrimination

(vi) Consistent in performance

(vii) Cheaper than other circuit interrupting devices

(viii) Current limitation by cut-off action

(ix) Inverse time current characteristics

Disadvantages of HRC fuses

(i) It requires replacement after each operation.

(ii) Inter locking is not possible.

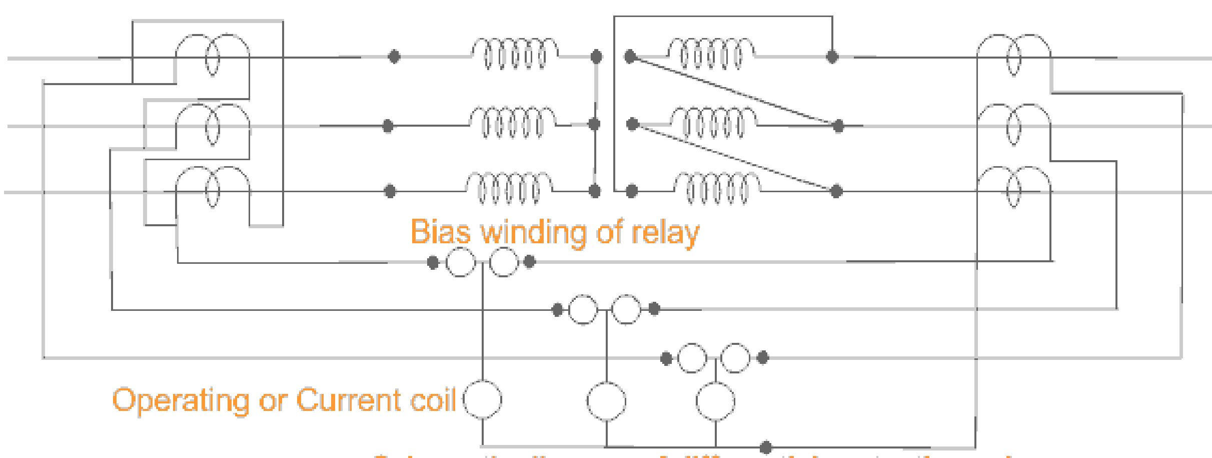
(iii) It produces overheating of the adjacent contacts.

Q 11. Explain Percentage Differential protection for transformers.

Sol. Generally Differential protection is provided in the electrical power transformer rated more than 5MVA.The Differential Protection of Transformer has many advantages over other schemes of protection. The faults occur in the transformer inside the insulating oil can be detected by Buchholz relay. But if any fault occurs in the transformer but not in oil then it can not be detected by Buchholz relay. Any flash over at the bushings are not adequately covered by Buchholz relay. Differential relays can detect such type of faults. Moreover Buchholz relay is provided in transformer for detecting any internal fault in the transformer but Differential Protection scheme detects the same in more faster way. The differential relays normally response to those faults which occur in side the differential protection zone of transformer.

Differential Protection Scheme in a Power Transformer

Principle of Differential Protection scheme is one simple conceptual technique. The differential relay actually compares between primary current and secondary current of power transformer, if any unbalance found in between primary and secondary currents the relay will actuate and inter trip both the primary and secondary circuit breaker of the transformer. Suppose you have one transformer which has primary rated current I_p and secondary current I_s. If you install CT of ratio $I_p/1A$ at the primary side and similarly, CT of ratio $I_s/1A$ at the secondary side of the transformer. The secondaries of these both CTs are connected together in such a manner that secondary currents of both CTs will oppose each other. In other words, the secondaries of both CTs should be connected to the same current coil of a differential relay in such an opposite manner that there will be no resultant current in that coil in a normal working condition of the transformer. But if any major fault occurs inside the transformer due to which the normal ratio of the transformer disturbed then the secondary current of both transformers will not remain the same and one resultant current will flow through the current coil of the differential relay, which will actuate the relay and inter trip both the primary and secondary circuit breakers. To correct phase shift of current because of star-delta connection of transformer winding in the case of three-phase transformer, the current transformer secondaries should be connected in delta and star as shown here.



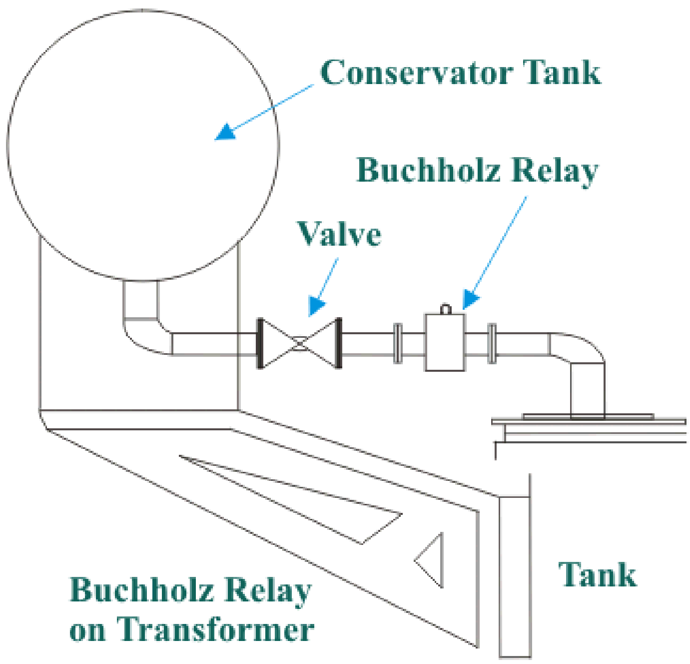
Schematic diagram of differential protection scheme

At maximum through fault current, the spill output produced by the small percentage unbalance may be substantial. Therefore, **differential protection of transformer** should be provided with a proportional bias of an amount which exceeds in effect the maximum ratio deviation.

Q 12. Explain working principle of Buchholz relay.

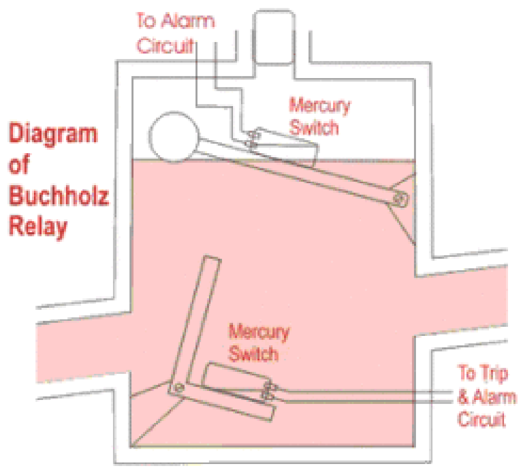
Sol. Construction of Buchholz Relay

Buchholz relay in transformer is an oil container housed the connecting pipe from main tank to conservator tank. It has mainly two elements. The upper element consists of a float. The float is attached to a hinge in such a way that it can move up and down depending upon the oil level in the Buchholz relay Container. One mercury switch is fixed on the float. The alignment of mercury switch hence depends upon the position of the float. The lower element consists of a baffle plate and mercury switch. This plate is fitted on a hinge just in front of the inlet (main tank side) of Buchholz relay in transformer in such a way that when oil enters in the relay from that inlet in high pressure the alignment of the baffle plate along with the mercury switch attached to it, will change.



In addition to these main elements a Buchholz relay has gas release pockets on top. The electrical leads from both mercury switches are taken out through a molded terminal block. The Buchholz relay working principle of is very simple. Buchholz relay function is based on very simple mechanical phenomenon. It is mechanically actuated. Whenever there will be a minor internal fault in the transformer such as an insulation faults between turns, break down of core of transformer, core heating, the transformer insulating oil will be decomposed in different hydrocarbon gases, CO_2 and CO. The gases produced due to decomposition of transformer insulating oil will accumulate in the upper part the Buchholz container which causes fall of oil level in it. Fall of oil level means lowering the position of float and thereby tilting the mercury switch. The contacts of this mercury switch are closed and an alarm circuit energized. Sometime due to oil leakage on the main tank air bubbles may be accumulated in the upper part the Buchholz container which may also cause fall of oil level in it and alarm circuit will be energized. By collecting the accumulated gases from the gas release pockets on the top of the relay and by analyzing them one can predict the type of fault in the transformer. More severe types of faults, such as short circuit between phases or to earth and faults in the tap changing equipment, are accompanied by a surge of oil which strikes the baffle plate and causes the mercury switch of the lower element to close. This switch energized the trip circuit of the circuit breakers associated with the transformer and immediately isolate the faulty transformer from the rest of the electrical power system by inter tripping the circuit breakers associated with both LV and HV sides of the transformer. This is how **Buchholz relay functions**.

The **Buchholz relay operation** may be actuated without any fault in the transformer. For instance, when oil is added to a transformer, air may get in together with oil, accumulated under the relay cover and thus cause a false Buchholz relay operation.



That is why mechanical lock is provided in that relay so that one can lock the movement of mercury switches when oil is topping up in the transformer. This mechanical locking also helps to prevent unnecessary movement of breakable glass bulb of mercury switches during transportation of the Buchholz relays. The lower float may also falsely operate if the oil velocity in the connection pipe through, not due to internal fault, is sufficient to trip over the float. This can occurs in the event of external short circuit when over currents flowing through the winding cause overheated the copper and the oil and cause the oil to expand.

Q 13. A generator winding is protected by using a percentage differential relay whose characteristics is having a slope of 10%. A ground fault occurred near the terminal end of the generator winding while generator is carrying load. As a consequence, the currents flowing at each end of the winding are shown in the fig. Assuming CT ratios of 500/5 A, the relay operate to trip the circuit breakers.

Solution: Given: $I_1 = 240 + j0$, $I_2 = 220 + j0$, and CT ratio = 400/5

Therefore, CT secondary currents will be

$$I_{1s} = \frac{(240 + j0) \times 5}{400} \text{ A} = 3 + j0 \text{ A}$$

$$I_{2s} = \frac{(220 + j0) \times 5}{400} \text{ A} = 2.75 + j0 \text{ A}$$

Differential operating current $(I_d) = I_{1s} - I_{2s} = 3 - 2.75 = 0.25$ A

(i.e. current in the operating coil)

$$\text{Restraining current } (I_r) = \frac{(I_{1s} + I_{2s})}{2} = \frac{(3 + 2.75)}{2} = 2.875 \text{ A}$$

(i.e. the current in the restraining coil)

Slope of the characteristic, $K = 10\% = 0.1$

The differential operating current required for the operation of the relay corresponding to current of 2.875 A in the restraining coil $= KI_r = 0.1 \times 2.875 = 0.2875$ A. Since the actual current in the operating coil is 0.25 A, the relay will not operate to trip the circuit breaker.

Q 14. Explain in detail about Bus-bar Protection system.

Sol. In early days only conventional over current relays were used for **busbar protection**. But it is desired that fault in any feeder or transformer connected to the busbar should not disturb busbar system. In viewing of this time setting of busbar protection relays are made lengthy. So when faults occurs on busbar itself, it takes much time to isolate the bus from source which may came much damage in the bus system. In recent days, the second zone distance protection relays on incoming feeder, with operating time of 0.3 to 0.5 seconds have been applied for **busbar protection**. But this scheme has also a main disadvantage. This scheme of protection can not discriminate the faulty section of the busbar. Now days, electrical power system deals with huge amount of power. Hence any interruption in total bus system causes big loss to the company. So it becomes essential to isolate only faulty section of busbar during bus fault. Another drawback of second zone distance protection scheme is that, sometime the clearing time is not short enough to ensure the system stability. To overcome the above mentioned difficulties, differential busbar protection scheme with an operating time less than 0.1 sec., is commonly applied to many SHT bus systems.

Current Differential Protection

The scheme of busbar protection, involves, Kirchoff's current law, which states that, total current entering an electrical node is exactly equal to total current leaving the node. Hence, total current entering into a bus section is equal to total current leaving the bus section. The principle of differential busbar protection is very simple. Here, secondaries of CTs are connected parallel. That means, S_1 terminals of all CTs connected together and forms a bus wire. Similarly S_2 terminals of all CTs connected together to form another bus wire. A tripping relay is connected across these two bus wires.

Here, in the figure above we assume that at normal condition feed, A, B, C, D, E and F carries current I_A, I_B, I_C, I_D, I_E and I_F. Now, according to Kirchoff's current law, $I_A + I_B + I_C + I_D + I_E + I_F = 0$ Essentially all the CTs used for differential busbar protection are of same current ratio. Hence, the summation of all secondary currents must also be equal to zero. Now, say current through the relay connected in parallel with all CT secondaries, is i_R, and i_A, i_B, i_C, i_D, i_E and i_F are secondary currents. Now, let us apply KCL at node X. As per KCL at node X,

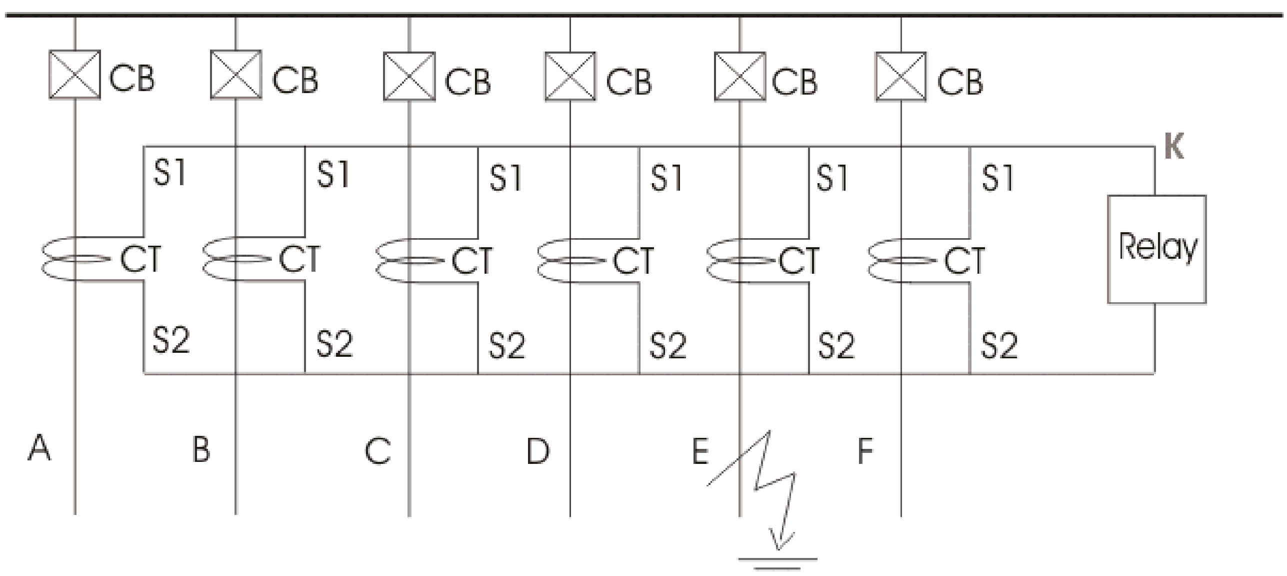
$$i_R + i_A + i_B + i_C + i_D + i_E + i_F = 0$$

$$\Rightarrow i_R + (i_A + i_B + i_C + i_D + i_E + i_F) = 0$$

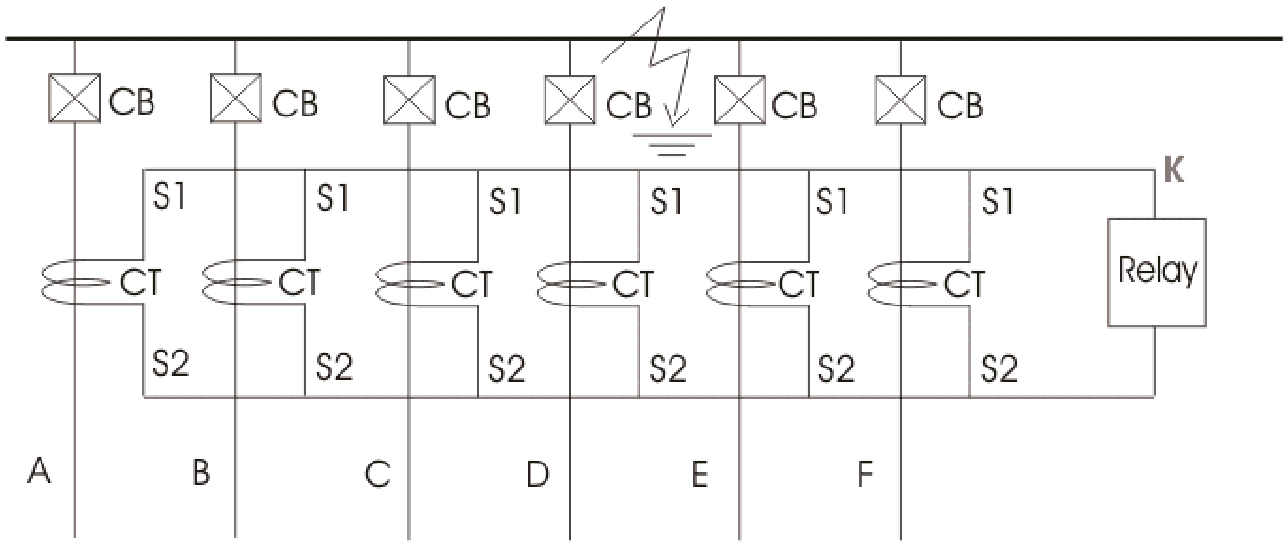
$$\Rightarrow i_R + (\textit{Sum of all secondary currents}) = 0$$

$$\Rightarrow i_R + 0 = 0\,[\textit{As sum of all secondary currents is zero}]$$

So, it is clear that under normal condition there is no current flows through the **busbar protection** tripping relay. This relay is generally referred as Relay 87. Now, say fault is occurred at any of the feeders, outside the protected zone. In that case, the faulty current will pass through primary of the CT of that feeder. This fault current is contributed by all other feeders connected to the bus. So, contributed part of fault current flows through the corresponding CT of respective feeder. Hence at that faulty condition, if we apply KCL at node K, we will still get, $i_R = 0$.



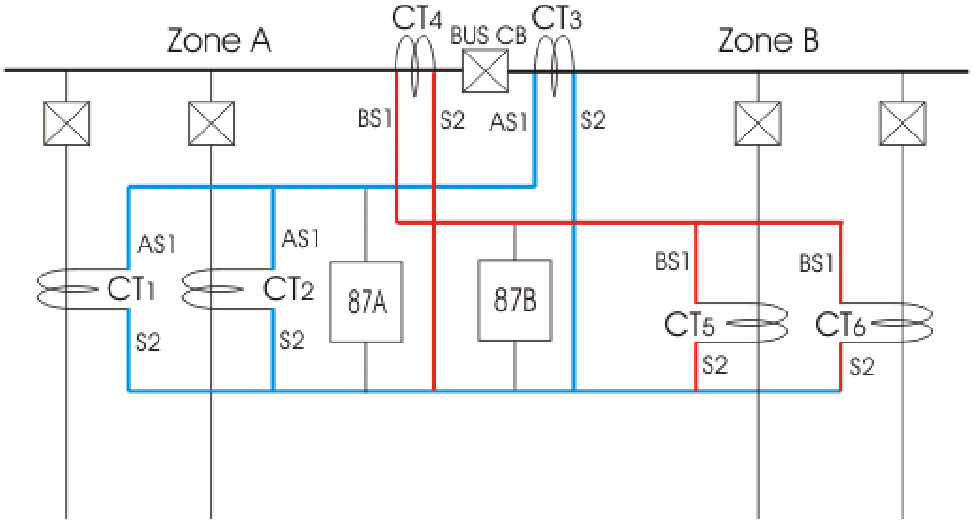
That means, at external faulty condition, there is no current flows through relay 87. Now consider a situation when fault is occurred on the bus itself. At this condition, also the faulty current is contributed by all feeders connected to the bus. Hence, at this condition, sum of all contributed fault current is equal to total faulty current. Now, at faulty path there is no CT. (in external fault, both fault current and contributed current to the fault by different feeder get CT in their path of flowing).



The sum of all secondary currents is no longer zero. It is equal to secondary equivalent of faulty current. Now, if we apply KCL at the nodes, we will get a non zero value of i_R. So at this condition current starts flowing through 87 relay and it makes trip the circuit breaker corresponding to all the feeders connected to this section of the busbar. As all the incoming and outgoing feeders, connected to this section of bus are tripped, the bus becomes dead. This differential busbar protection scheme is also referred as current differential protection of busbar.

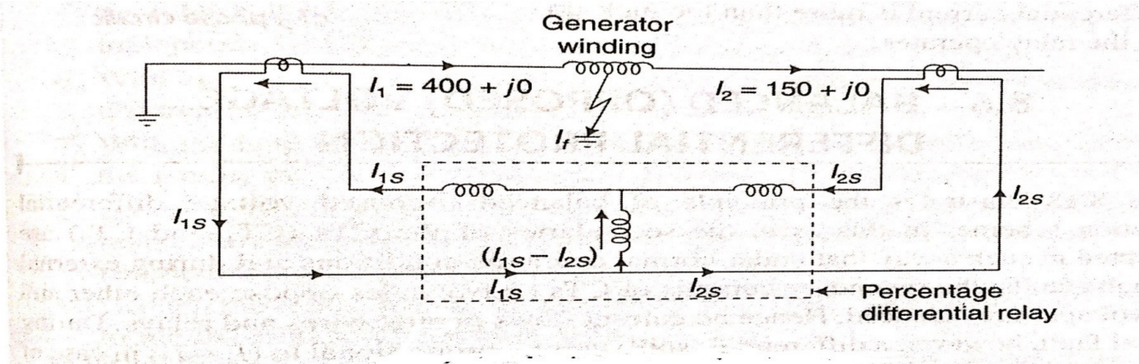
Differential Protection of Sectionalized Bus

During explaining working principle of current differential protection of busbar, we have shown a simple non sectionalized busbar. But in moderate high voltage system electrical bus sectionalized in than one sections to increase stability of the system. It is done because, fault in one section of bus should not disturb other section of the system. Hence during bus fault, total bus would be interrupted. Let us draw and discuss about protection of busbar with two sections.



Here, bus section A or zone A is bounded by CT_1, CT_2 and CT_3 where CT_1 and CT_2 are feeder CTs and CT_3 is bus CT. Similarly bus section B or zone B is bounded by CT_4, CT_5 and CT_6 where CT_4 is bus CT, CT_5 and CT_6 are feeder CT. Therefore, zone A and B are overlapped to ensure that, there is no zone left behind this busbar protection scheme. A SI terminals of CT_1, 2 and 3 are connected together to form secondary bus ASI; BSI terminals of CT_4, 5 and 6 are connected together to form secondary bus BSI. S_2 terminals of all CTs are connected together to form a common bus S_2. Now, busbar protection relay 87A for zone A is connected across bus ASI and S_2. Relay 87B for zone B is connected across bus BSI and S_2. This section busbar differential protection scheme operates in some manner simple current differential protection of busbar. That is, any fault in zone A, with trip only CB_1, CB_2 and bus C_B. Any fault in zone B, will trip only CB_5, CB_6 and bus CB. Hence, fault in any section of bus will isolate only that portion from live system. In current differential protection of busbar, if CT secondary circuits, or bus wires is open the relay may be operated to isolate the bus from live system. But this is not desirable.

Q. 15 Fig below shows percentage differential relay applied to the protection of a generator winding. The relay has a 0.1 A minimum pick-up and 10% slope of its operating characteristic on $(I_{1s} + I_{2s})/2$ verses $(I_{1s} - I_{2s})$ diagram. A high resistance ground fault occurred near the grounded neutral end of the generator winding while generator is carrying load. As a consequence, the currents flowing at each end of the winding is shown in the fig. Assuming CT ratio of 400/5 A, will the relay operate to trip the breaker.



Solution: Given: $I_1 = 400 + j0$ A, $I_2 = 150 + j0$, and CT ratios = 500/5 A

Therefore, CT secondary currents will be:

$$I_{1s} = \frac{(400 + j0) \times 5}{500} \text{ A} = (4 + j0) \text{ A}$$

$$I_{2s} = \frac{(150 + j0) \times 5}{500} \text{ A} = (1.5 + j0) \text{ A}$$

Differential operating current $(I_d) = (I_{1s} - I_{2s}) = (4 - 1.5)$ A = 2.5 A

(i.e., current in the operating coil)

$$\text{Restraining current } (I_r) = \frac{(I_{1s} + I_{2s})}{2} = \frac{(4 + 1.5)}{2} \text{ A} = 2.75 \text{ A}$$

(i.e. current in the restraining coil)

Slope of the characteristic, $K = 10\% = 0.1$

The differential operating current required for the operation of the relay corresponding to restraining current of 2.75 A = $KI_r = 0.1 \times 2.75 = 0.275$ A.

Since, the actual current in the operating coil is 2.5 A, the relay will operate to trip the circuit breaker.

Q 16. Explain Construction, operating principle and characteristics of an electromagnetic impedance relay.

There is one type of relay which functions depending upon the distance of fault in the line. More specifically, the relay operates depending upon the impedance between the point of fault and the point where relay is installed. These relays are known as **distance relay** or **impedance relay**.

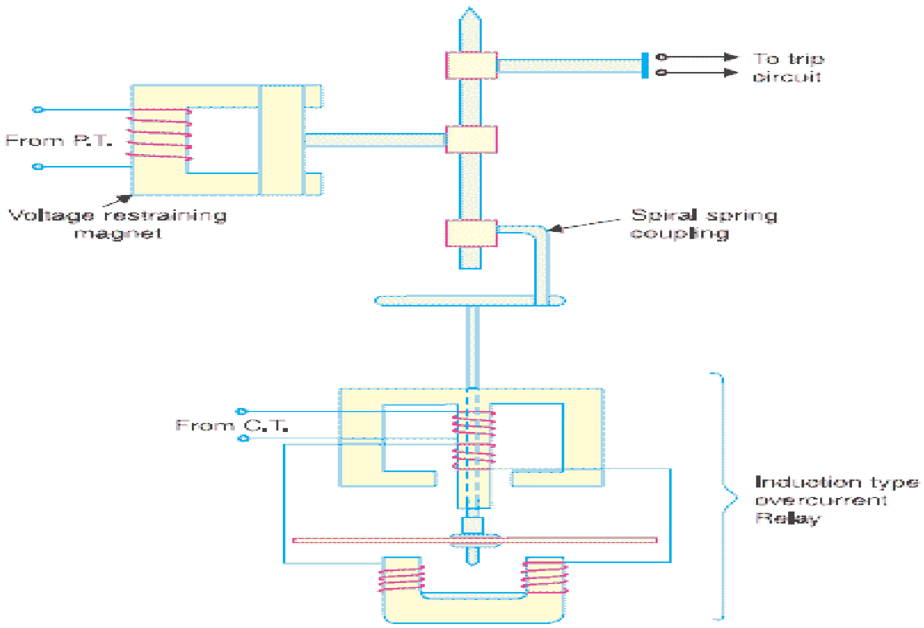
Working Principle of Distance or Impedance Relay

The **working principle of distance relay** or **impedance relay** is very simple. There is one voltage element from potential transformer and a current element fed from current transformer of the system. The deflecting torque is produced by secondary current of CT and restoring torque is produced by voltage of potential transformer. In normal operating condition, restoring torque is more than deflecting torque. Hence relay will not operate. But in faulty condition, the current becomes quite large whereas voltage becomes less. Consequently, deflecting torque becomes more than restoring torque and dynamic parts of the relay starts moving which ultimately close the No contact of relay. Hence clearly **operation or working principle of distance relay** depends upon the ratio of system voltage and current. As the ratio of voltage to current is nothing but impedance so a distance relay is also known as impedance relay. The operation of such relay depends upon the predetermined value of voltage to current ratio. This ratio is nothing but impedance. The relay will only operate when this voltage to current ratio becomes less than its predetermined value. Hence, it can be said that the relay will only operate when the impedance of the line becomes less than predetermined impedance (voltage / current). As the impedance of a transmission line is directly proportional to its length, it can easily be concluded that a distance relay can only operate if fault is occurred within a predetermined distance or length of line. There are mainly two types of distance relay-

1. Definite distance relay.

This is simply a variety of balance beam relay. Here one beam is placed horizontally and supported by hinge on the middle. One end of the beam is pulled downward by the magnetic force of voltage coil, fed from potential transformer attached to the line. Other end of the beam is pulled downward by the magnetic force of current coil fed from current transformer connected in series with line. Due to torque produced by these two downward forces, the beam stays at an equilibrium position. The torque due to voltage coil, serves as restraining torque and torque due to current coil, serves as deflecting torque. Under normal operating condition restraining torque is greater than deflecting torque. Hence contacts of this distance relay remain open. When any fault occurs in the feeder, under protected zone, voltage of feeder decreases and at the same time current increases. The ratio of voltage to current i.e. impedance falls below the pre-determined value. In this situation, current coil pulls the beam more strongly than voltage coil, hence beam tilts to close the relay contacts and consequently the circuit breaker associated with this impedance relay will trip. This delay automatically adjusts its operating time according to the distance of the relay from the fault point. The time distance impedance relay will not only be operated depending upon voltage to current ratio, its operating time also depends upon the value of this ratio. That means

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



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

Operating Principle of Time Distance Impedance Relay

During normal operating condition the attraction force of armature fed from PT is more than force generated by induction element, hence relay contacts remain in open position when a short circuit fault occurs in the transmission line, the current in the induction element increases. Then the induction in the induction element increases. Then the induction element starts rotating. The speed of rotation of induction elements depends upon the level of fault i.e. quantity of current in the induction element. As the rotation of the disc proceeds, the spiral spring coupling is wound up till the tension of the spring is sufficient to pull the armature away from the pole face of the voltage excited magnet. The angle through which the disc travels the disc travel before relay operate depends upon the pull of the voltage excited magnet. The greater the pull, the greater will be the travel of the disc. The pull of this magnet depends upon the line voltage. The greater the line voltage the greater the pull hence longer will be the travel of the disc i.e. operating time is proportional to V. Again, speed of rotation of induction element approximately proportional to current in this element. Hence, time of operation is inversely proportional to current. $Hence,\ operating\ time\ \propto\ \frac{1}{I}$ Therefore time of operation of relay, $T\ \propto\ \frac{V}{I}\ or\ T\ \propto\ Z$

Q 17. Explain in detail about induction cup type reactance relay.

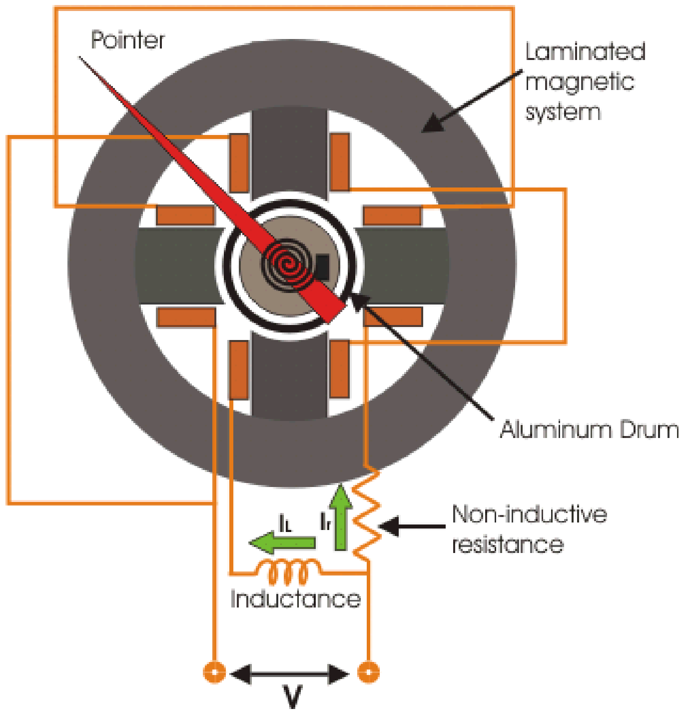
Sol. This relay in nothing but one version of induction disc relay. **Induction cup relay** work in same principle of induction disc relay. The basis construction of this relay is just like four poles or eight pole induction motor. The number of poles in the protective relay depends upon the number of winding to be accommodated. The figure shows a four pole induction cup relay.
Actually when any one replaces disc of induction relay by a aluminum cup, the inertia of rotating system of relay is significantly reduced. Due to low mechanical inertia, the operating speed of induction cup relay is much higher than that of induction disc relay. Moreover, projected pole system is designed to give maximum torque per VA input. In four pole unit, shown in our example, the eddy current produced in the cup due to one pair of poles, directly appears under other pair of poles. This makes, torque per VA of this relay is about three times more than that of induction disc type relay with a C-shaped electromagnet. If magnetic saturation of the poles can be avoided by designing, the operating characteristics of the relay can be made linear and accurate for a wide range of operation.

Working Principle of Induction Cup Relay

As we said earlier, the working principle of induction cup relay, is same as the induction motor. A rotating magnetic field is produced by different pairs of field poles. In four poles design both pair of poles are supplied from same current transformer's secondary, but phase difference between the currents of two pole pairs is 90 deg; This is done by inserting an inductor in series with coil of one pole pair, and by inserting a resistor in series with coil of another pole pair. The rotating magnetic field induces current in the aluminum brum or cup. As per working principle of induction motor, the cup starts rotating in the direction of rotating magnetic field, with a speed slightly less than the speed of rotating magnetic field. The aluminum cup is attached with a hair spring : In normal condition the restoring torque of the spring is higher than deflecting torque of the cup. So there is no movement of the cup. But during faulty condition of system, the current through the coil is quite high, hence, deflecting torque produced in the cup is much higher than restoring torque of spring, hence the cup start rotating as rotor of induction motor. The contacts attached to the moving of the cup to specific angle of rotation.

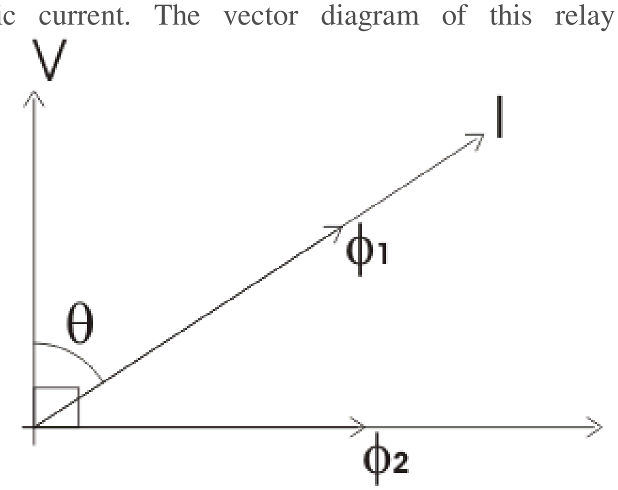
Construction of Induction Cup Relay

The magnetic system of the relay is constructed by attaching numbers of circular cut steel sheets. The magnetic pole are projected in the inner periphery of these laminated sheets. The field coils are wound on these laminated poles. The field coil of two opposite facing poles are connected in series. The aluminum cup or drum, fitted on a laminated iron core is carried by a spindle whose ends fit in jeweled cups or bearings. The laminated magnetic field is provided on inside the cup or drum to strengthen the magnetic field cutting the cup.



Induction Cup Directional or Power Relay

Induction cup relay is very suitable for directional or phase comparison units. This is because, besides the sensitivity, induction cup relay have steady non vibrating torque and parasitic torques due to current or voltage alone are small. In induction cup directional or power relay, coils of one pair of poles are connected across voltage source, and coils of another pair of poles are connected with current source of the system. Hence, flux produced by one pair of poles is proportional to voltage and flux produced by another pair of poles is proportional to electric current. The vector diagram of this relay can be represented as follows,



Here, in the vector diagram, the angle between system voltage V and current I is θ The flux produced due to current I is φ_1 which is in phase with I. The flux produced due to voltage V, is φ_2 which is in quadrature with V. Hence, angle between φ_1 and φ_2 is (90^o - θ). Therefore, if torque produced by these two fluxes is T_d. $T \propto \phi_1\phi_2\sin(90 - \theta) = K\phi_1\phi_2\sin(90 - \theta)$

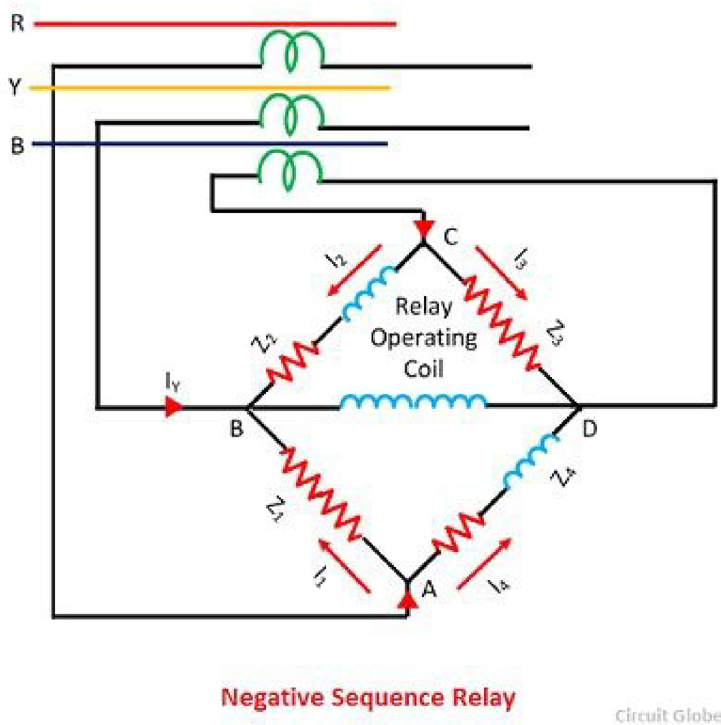
Where, K is constant of proportionality. Here in this equation we have assumed that, flux produced by voltage coil lags 90^o behind its voltage. By designing this angle can be made to approach any value and a torque equation T = KVIcos (θ – φ) obtained where θ is angle between V and I. Accordingly, induction cup relays can be designed to produce maximum torque when the angle θ = 0 or 30^o, 45^o or 60^o. The relays which are such designed, that, they produce maximum torque at θ = 0, is P induction cup power relay. The relays produce maximum torque when θ = 45^o or 60^o, are used as directional protection relay.

Q 19. Explain the working principle of earth fault relay.

Sol. Earth-fault relay is used to protect feeder against faults involving ground. Typically, earth faults are single line to ground and double line to ground faults. For the purpose of setting and coordination, only single line to ground faults are considered. Consider a radial system as shown in fig 17.1. For a fault near the source, the maximum fault current for a-g fault is given by . If we model the utility system with identical values for all the sequence impedances then, . This value is identical to the bolted three phase fault current. If however, ZS0 < ZS1 then the bolted single line to ground fault current can be higher than the three phase fault current. As we move away from the source, for a bolted fault, fault current reduces due to larger feeder impedance contribution to the denominator. Since, for a feeder, zero sequence impedance can be much higher than the positive or negative sequence impedance, it is apparent that fault current for bolted fault reduces significantly as we go away from source. Thus, as we go away from the source, the bolted three phase fault current will be higher than corresponding ground fault current as it does not depend upon zero sequence impedance of the feeder. In addition, if the single line to ground fault has an impedance ZF, then the fault current can fall even below the bolted a-g fault value, . In contrast, for a balanced system, three phase fault current is independent of the value of ZF**.** Thus, we conclude that there can be significant variation in the earth fault current values. They can be even below the load current due to large impedance to ground. Hence, to provide sensitive protection, earth fault relays use zero sequence current rather than phase current for fault detection. Note that the zero sequence component is absent in normal load current or phase faults. Hence, pickup with zero sequence current can be much below the load current value, thereby providing sensitive earth fault protection. In what follows, we will discuss the setting and coordination of earth fault relays. In practice, distribution systems are inherently unbalanced. Thus, load current would also have a small percentage of zero sequence due to unbalance. Hence, it is mandatory to keep the pick up current above the maximum unbalance expected under normal conditions. A rule of thumb is to assume maximum unbalance factor to be between 5 to 10%. It should be also observed that earth fault relays will not respond to the three phase or line to line faults. One earth fault relay is adequate to provide protection for all types of earth fault (a-g, b-g, c-g, a-b-g etc). Three phase relays are required to provide protection against phase faults (three phase, a-b, b-c, c-a). Thus with four relays as shown in fig 17.2 complete overcurrent protection can be provided.

Q 20. **Explain in short negative sequence relay.**

A relay which protects the electrical system from negative sequence component is called a negative sequence relay or unbalance phase relay. The negative sequence relay protects the generator and motor from the unbalanced load which mainly occurs because of the phase-to-phase faults. The negative sequence relay has a filter circuit which operates only for the negative sequence components. The relay always has a low current setting because the small magnitude overcurrent can cause dangerous situations. The negative sequence relay has earthing which protects them from phase to earth fault but not from phase to phase fault. The phase to phase fault mainly occurs because of the negative sequence components. The construction of the negative sequence relay is shown in the figure below. The Z_1, Z_2, Z_3, and Z_4 are the four impedance of the circuit which is connected in the form of the bridge. The impedance is energized by the current transformers. The relay operating coil is connected to the midpoint of the circuit as shown in the figure below.



Negative Sequence Relay

The Z_1 and Z_3 are purely resistive and the Z_2 and Z_4 are both resistive and inductive in nature. The impedance Z_2 and Z_4 are adjusted in such a manner that the current flowing through them is always lagging by an angle of 60º than those current which is flowing through Z_1 and Z_3. The current flowing through the junction A is split into two parts i.e. I_1 and I_4. The I_4 lagging by an angle of 60º regards I_1.

$$I_1 = I_4 = \frac{I_R}{\sqrt{3}} \quad I_R^2 = I_1^2 + I_4^2 + 2I_1I_4cos60°$$

Similarly, current from phase B split at junction C into two equal components I_3 and I_2, I_2 lagging behind I_3 by 60º.

$$I_2 = I_3 = \frac{I_B}{\sqrt{3}}$$

The current I_4 lags by an angle of 30º to the I_1. Similarly, I_2 lags by an angle of 30º concerning I_B and I_3 leads I_B by 30º. The current passing through the junction B is equal to the sum of I_1, I_2, and I_Y.

$$I_{relay} = I_1 + I_2 + I_Y \quad \frac{I_R}{\sqrt{3}} = leading\ I_R\ by\ 30° + \frac{I_B}{\sqrt{3}} lagging\ I_B\ by\ 30° + \ I_Y$$

The flow of Positive Sequence Current – The phasor diagram of positive sequence components is shown in the figure below. When the load is in balanced conditions, then there is no negative sequence current. The current flows through the relay is given by the equation

$$I_1 + I_2 + I_Y = 0$$

$$I_1 + I_2 = -I_Y$$

So the relay remains operative for a balanced system.

The flow of Negative Sequence Current – The figure above shows that the current I_1 and I_2 are equal. Thus, they cancel each other. The current I_Y flows through the operating coils of the relay. The current setting value of the relay is kept less than the normal full load rating current because the small overload current can cause the serious conditions.