BALASORE SCHOOL OF ENGINEERING

SUB – SWITCH GEAR & PROTECTING DEVICE
CODE – EET - 601

SEM – 6TH

BRANCH – ELECTRICAL ENGG.

Submitted by

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CHAPTER-01

INTRODUCTION TO SWITCH GEAR

SHORT TYPE QUESTION

1. **State any two causes of fault. .[2014 (w) 4(a)]**

   Ans:-The two causes of fault are

   1) Breakdown of equipment in the transmission line
   2) Deterioration of insulation in the generator and transformer.

2. **Why discrimination is a essential features of switchgear? [2017 (s) 5(a)]**

   Ans:-This feature identifies the section in which fault has been occurred. After knowing the section it will be easy to clear out the fault.

3. **At what voltage outdoor type switchgear equipment is installed? [2017 (s) 6(a)]**

   Ans:-Voltage beyond 66Kv outdoor type switchgear equipment is installed.

LONG TYPE QUESTION

1. **Briefly describe the essential features of switchgear? [2016(s)- 6(b)]**

   Ans:- The essential features of switchgear are :

   (i) Complete reliability:- Reliability when fault occurs on any part of the power system, the switchgear must operate to isolate the faulty section from the remainder circuit. The need for a reliable switchgear has become of paramount importance.

   (ii) Absolutely certain discrimination:- When fault occurs on any section of the power system, the switchgear must be able to discriminate between the faulty section and the healthy section. It should isolate the faulty section from the healthy section. This will ensure continuity of supply.

   (iii) Quick operation:- When fault occurs on any part of the power system, the switchgear must operate quickly so that no damage is done to generators, transformers and other equipment by the short-circuit currents.

   (iv) Provision for manual control:- A switchgear must have provision for manual control. In case the electrical (or electronics) control fails, the necessary operation can be carried out through manual control.

   i) Provision for instruments:- There must be provision for instruments which may be required. These may be in the form of ammeter or voltmeter on the unit itself or the necessary current and voltage transformers for connecting to the main switchboard or a separate instrument

CHAPTER -02

FAULT CALCULATION

SHORT TYPE QUESTION

1. **Define short circuit KVA? [2014 (s)- 6(a)], [2017 (w)- 4(a)]**

The product of normal system voltage and short-circuit current at the point of fault expressed in kVA is known as short-circuit kVA.

Short-circuit kVA for 3-phase circuit=Base kVA × 100/ %X

2. Define percentage of reactance. [2019 (s)- 1(a)]

It is the percentage of the total phase-voltage dropped in the circuit when full-load current is flowing

i.e., $\%X = IX/V \times 100$

where I = full-load current

V = phase voltage

X = reactance in ohms per phase

3. Write short circuit KVA in terms of base KVA and % of reactance. [2015 (s)- 6(a)]

Ans:-Short-circuit kVA = Base kVA × 100 /%X

4. What is short circuit KVA and base KVA? [2018(s)-3(a)]

Ans:-short circuit KVA

The product of normal system voltage and short-circuit current at the point of fault expressed in kVA is known as short-circuit kVA.

Short-circuit kVA for 3-phase circuit=Base kVA × 100/ %X

base KVA

Generally, the various equipments used in the power system have different kVA ratings. Therefore, it is necessary to find the percentage reactances of all the elements on a common kVA rating. This common kVA rating is known as base kVA. The value of this base kVA is quite unimportant and may be : (i) equal to that of the largest plant (ii) equal to the total plant capacity (iii) any arbitrary value.

LONG TYPE QUESTION

1. State functions of reactor and types of reactor. [2014 (w)- 4(b)], [2017 (s)- 1(b)]

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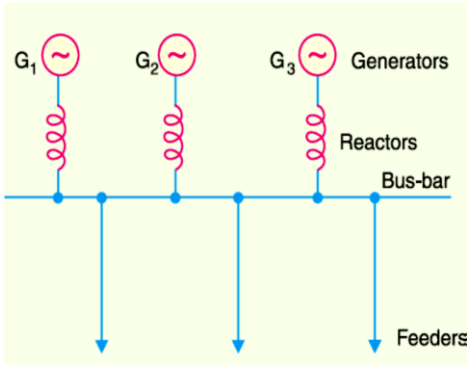
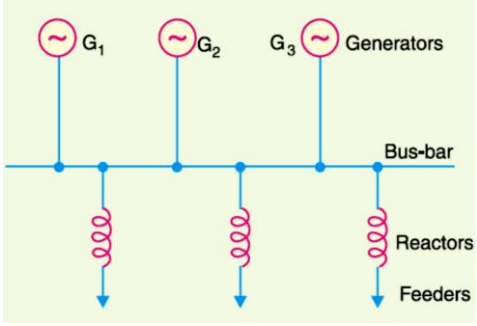
What do we use reactors in the power system?Explain the various methods of connecting short circuit current limiting reactors in the power system? [2019 (s)- 1(b)]



Ans:-Reactor is a coil having number of turns which has high reactance as compared to its ohmic resistance.

It is connected in series with the circuit to be protected. It is used to limit the short circuit current.

The reactors used in the power system are of three types. a)Generator reactor b)Feeder reactor c)Bus Bar reactor



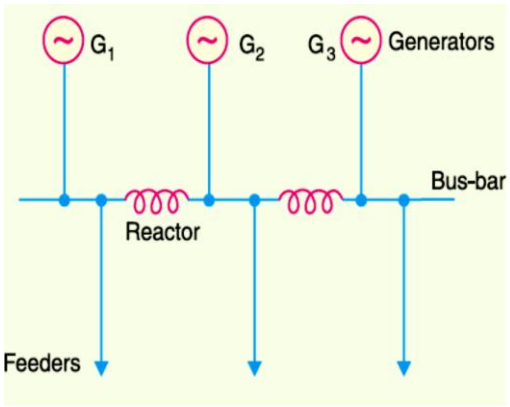
(1) Generator reactors. When the reactors are connected in series with each generator, they are known as generator reactors. In this case, the reactor may be considered as a part of leakage reactance of the generator. Hence its effect is to protect the generator in the case of any short-circuit beyond the reactors.

Disadvantages (i) There is a constant voltage drop and power loss occurs in the reactors even during normal operation .ii) If a fault occurs on any feeder, the continuity of supply to other is likely to be affected.

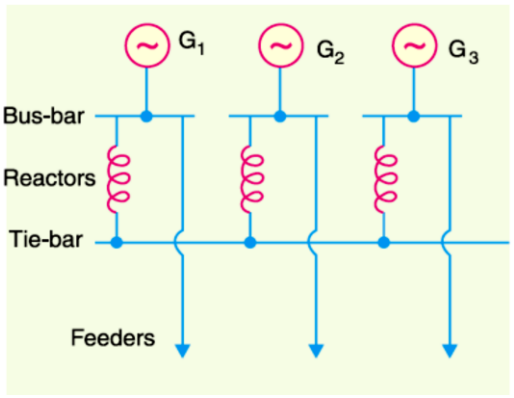
(2) **Feeder reactors.** When the reactors are connected in series with each feeder, they are known as feeder reactors .Since most of the short-circuits occur on feeders, a large number of reactors are used for such circuits. Advantages are Firstly, if a fault occurs on any feeder, the voltage drop in its reactor will not affect the bus-bars voltage so that there is a little tendency for the generator to lose synchronism. Secondly, the fault on a feeder will not affect other feeders.

Disadvantage:- (i) There is a constant power loss and voltage drop in the reactors even during normal operation. (iii) If the number of generators is increased, the size of feeder reactors will have to be increased to keep the short-circuit currents within the ratings of the feeder circuit breakers.

(3) **Bus-bar reactors**. The above two methods of locating reactors suffer from the disadvantage that there is considerable voltage drop and power loss in the reactors even during normal operation. This disadvantage can be overcome by locating the reactors in the bus-bars. There are two methods for this purpose, namely ; Ring system and Tie-Bar system.



(i) **Ring system**. In this system, bus-bar is divided into sections and these sections are connected through reactors as shown in Fig, the principal advantage of the system is that if a fault occurs on any feeder, only one generator mainly feeds the fault current while the current fed from other generators is small due to the presence of reactors. Therefore, only that section of bus-bar is affected to which the feeder is connected, the other sections being able to continue in normal operation.



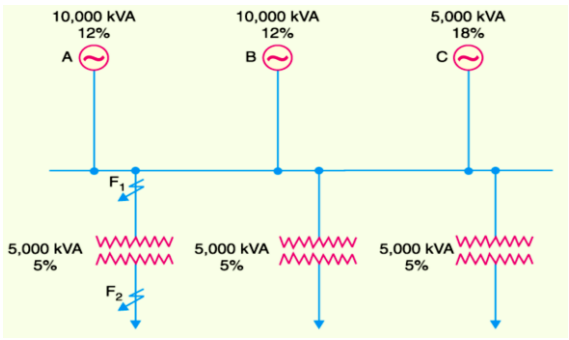
(ii) **Tie-Bar system**. The figure shows the tie-bar system . In tie-bar system, it is clear that , there are effectively two reactors in series between sections so that reactors must have approximately half the reactance of those used in a comparable ring system. Another advantage of tie bar system is that additional generators may be connected to the system without requiring changes in the existing reactors.

2. The plant capacity of a 3-phase generating station consists of two 10000 KVA generators of reactance 12% each and one 5000 KVA generator of reactance 18%.The generators are connected to the station bus bar from which load is taken through three 5000 KVA step up transformer each having a reactance of 5%.Determine the max. Fault MVA which the circuit breakers on

(i)Low voltage side and

(ii) high voltage side may have to deal with. [2019(s)-2(c)]

Solution:- Let 10,000 kVA be the base kVA.



The percentage reactance of generators A, B and C and that of each transformer on the selected base kVA is

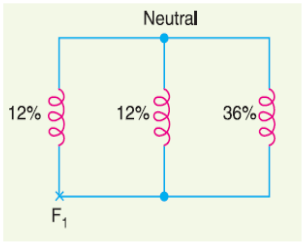
$$\% X_A = 12 \times 10{,}000/10{,}000 = 12\%$$

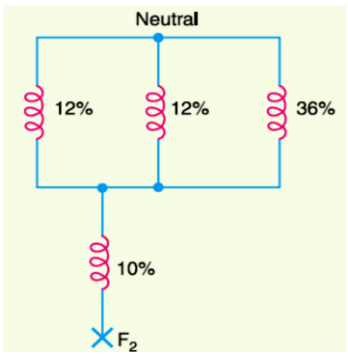
$$\% X_B = 12 \times 10{,}000/10{,}000 = 12\%$$

$$\% X_C = 18 \times 10{,}000/5{,}000 = 36\%$$

$$\% X_T = 5 \times 10{,}000/5{,}000 = 10\%$$

(i) When the fault occurs on the low voltage side of the transformer i.e. point F_1 in Fig., the reactance diagram at the selected base kVA will be as shown in Fig. Given below. The total reactance up to the point of fault F_1 is the parallel combination of the reactances of the three alternators i.e.





Total % reactance form generator neutral up to fault point F_1

$$= \%X_A \,||\, \%X_B \,||\, \%X_C$$

$$= 12\% \,||\, 12\% \,||\, 36\%$$

$$= 6 \times 36 / 6 + 36 = 5{\cdot}14\%$$

Hence Fault MVA = 10,000 × 100/ 5 .14 X 1/ 1000 = 194·5

(ii) When the fault occurs on the high voltage side of the transformer (point F2 in Fig,)the reactance diagram will be as shown in Fig. 2

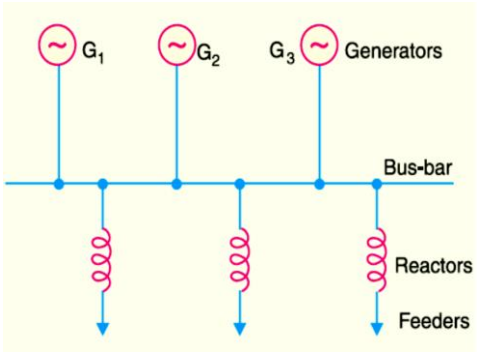
Total % reactance from generator neutral up to fault point F2

$$= 5{\cdot}14 + 10 = 15{\cdot}14\%$$

$$\therefore \text{Fault MVA} = 10{,}000 \times 100 / 15 .14 \times 1/ 1000 = 66$$

It may be noted that circuit breakers of lower ratings will be required on the high voltage side of the transformer

3. With neat sketch explain about feeder reactor.[2015(s)-7(c)]



Ans:- (2) **<u>Feeder reactors.</u>** When the reactors are connected in series with each feeder, they are known as feeder reactors .Since most of the short-circuits occur on feeders, a large number of reactors are used for such circuits.

Advantages :- (1), if a fault occurs on any feeder, the voltage drop in its reactor will not affect the bus-bars voltage so that there is a little tendency for the generator to lose synchronism. (2) the fault on a feeder will not affect other feeders.

Disadvantage:- (i) There is a constant power loss and voltage drop in the reactors even during normal operation.(ii) If a short-circuit occurs at the bus-bars, no protection is provided to the generators. (iii) If the number of generators is increased, the size of feeder reactors will have to be increased to keep the short-circuit currents within the ratings of the feeder circuit breakers.

4. Write down the various steps for symmetrical fault calculation.

Ans:- The steps for symmetrical fault calculation:

(i) Draw a single line diagram of the complete network indicating the rating, voltage and percentage reactance of each element of the network.

(ii) Choose a numerically convenient value of base kVA and convert all percentage reactances to this base value.

(iii) Corresponding to the single line diagram of the network, draw the reactance diagram showing one phase of the system and the neutral. Indicate the % reactances on the base kVA in the reactance diagram. The transformer in the system should be represented by a reactance in series.

(iv) Find the total % reactance of the network up to the point of fault. Let it be X%.

(v) Find the full-load current corresponding to the selected base kVA and the normal system voltage at the fault point. Let it be I.

(vi) Then various short-circuit calculations are :

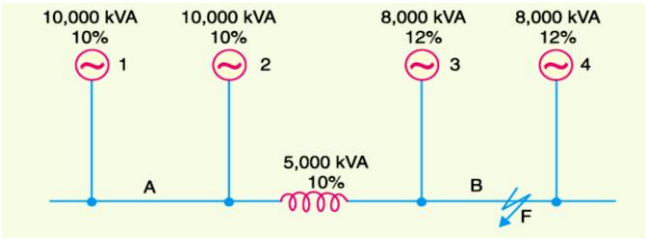
Short-circuit current, ISC = I ×100 /%X

Short-circuit kVA = Base kVA × 100/ %X

5. The section bus bar A and B are linked by a bus bar reactor rated at 5000 KVA with 10% reactance on bus bar A there are two generators each of 10000 KVA with 10% reactance and on B two generators each of 8000 KVA with 12% reactance. Find the steady state MVA fed into a dead short ckt between all phases on B with bus bar reactor in the ckt. .[2013(w)-2(c)]

Ans:-

Let 10,000 kVA be the base kVA.



% Reactance of generator 1 or 2 on the base kVA= 10 * 10,000/10,000 = 10%

% Reactance of generator 3 or 4 on the base kVA= 12 * 10,000/8000 = 15%

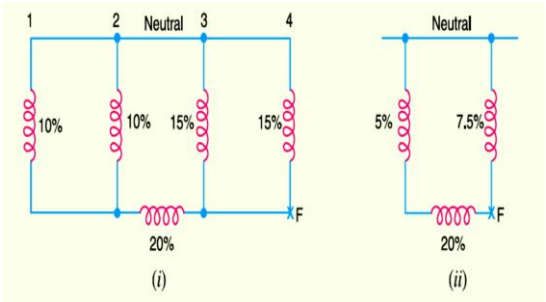
% Reactance of bus-bar reactor on the base kVA = 10 * 10,000/5000 = 20%

When fault occurs on section *B* (point *F* in Fig.), the reactance diagram at the selected base kVA will be as shown in Fig given bellow,

This series parallel circuit is further reduced to Fig.(*ii*).

From the figure, it is clear that reactance from generator neutral up to the fault point *F* is

=(5% + 20%) II 7·5% *i.e.*



Total % reactance from generator neutral up to fault point *F*

= (5 % + 20%) || 7·5%

=25 x 7. 5/ 25 +7.5 = 5·77%

Fault kVA = 10,000 x100/5·77 = 1,73,310

or Fault MVA = 173

6

CHAPTER-03

FUSES

SHORT TYPE QUESTION

1. **What is fuse ? write one of its major advantage? [2015(s)-1(a)]**

   Ans:-A fuse is a short piece of metal, inserted in the circuit in series with the phase, which melts when excessive current flows through it and thus breaks the circuit

   Advantage:-(i) It is the cheapest form of protection available.

   (ii) It requires no maintenance.

2. **What are the materials used for fuse element? .[2014(s)-1(a)]**

   The materials used for fuse element are copper , silver ,aluminium , lead , tin , zinc etc.

3. **Write the difference between fuse and C.B.? .[2014(s)-2(a)] [2018 (w)- 2(a)]**

Fuse	Circuit breaker
1. It performs both detection and interruption functions. 2. Inherently completely automatic. 3. Requires replacement after every operation.	1. It performs interruption function only. The detection of fault is made by relay system. 2. Requires elaborate equipment (i.e. relays) for automatic action. Very large 3. No replacement after operation.

4. **Write the advantage of HRC fuse? .[2014(s)-3(a)]**

   Advantages (i) They are capable of clearing high as well as low fault currents.

   (ii) They do not deteriorate with age.

   (iii) They have high speed of operation. (iv) They require no maintenance.

5. **Define fusing factor? .[2014(s)-5(a)], .[2013(w)-1(a)], [2017 (w)- 1(a)], [2017 (s)- 2(a)]**

   Fusing factor:-It is the ratio of minimum fusing current to the current rating of the fuse element

   i.e. Fusing factor =Minimum fusing current/ Current rating of fuse.

6. **What is fusing current & breaking capacity?[2019 (s)- 2(a)]**

Ans:- **Fusing current.** It is the minimum current at which the fuse element melts and thus disconnects the circuit protected by it. its value will be more than the current rating of the fuse element.

Breaking capacity:-it is the RMS value of maximum prospective current that a fuse can deal with at rated service voltage.

6. **What is cut off current and prospective current ? [2018 (w)- 1(a)]**

Ans:- Prospective Current. The fault current would normally have a very large first loop, but it actually generates sufficient energy to melt the fuseable element well before the peak of this first loop is reached. The *r.m.s.* value of the first loop of fault current is known as prospective current. Therefore, prospective current can be defined as under:

It is the r.m.s. value of the first loop of the fault current obtained if the fuse is replaced by an ordinary conductor of negligible resistance.

Cut-off current. It is the maximum value of fault current actually reached before the fuse melts. On the occurrence of a fault, the fault current has a very large first loop due to a fair degree of asymmetry. The heat generated is sufficient to melt the fuse element well before the peak of first loop is reached.

LONG TYPE QUESTION

1. **Explain semi enclosed rewirable fuse and state its advantage and disadvantage. .[2014(w)-2(b)]**

Ans:- Semi-enclosed rewireable fuse.

- Rewireable fuse (also known as kit-kat type) is used where low values of fault current are to be interrupted.
- It consists of (i) a base and (ii) a fuse carrier.
- The base is of porcelain and carries the fixed contacts to which the incoming and outgoing phase wires are connected.
- The fuse carrier is also of porcelain and holds the fuse element (tinned copper wire) between its terminals. The fuse carrier can be inserted in or taken out of the base when desired.
- When a fault occurs, the fuse element is blown out and the circuit is interrupted.
- The fuse carrier is taken out and the blown out fuse element is replaced by the new one. The fuse carrier is then reinserted in the base to restore the supply.

Advantages:-i) The detachable fuse carrier permits the replacement of fuse element without any danger of coming in contact with live parts.

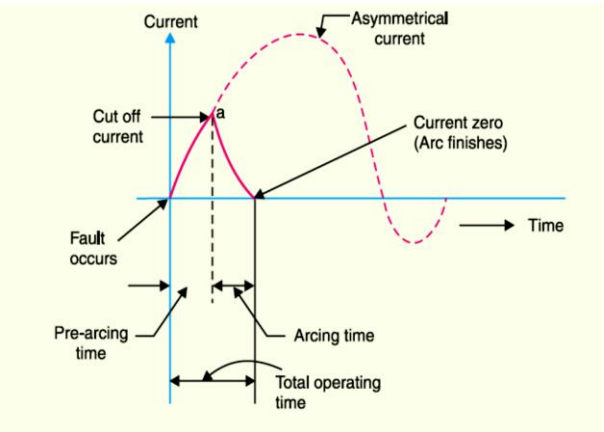
ii) The cost of replacement is negligible.

Disadvantages:- (i) There is a possibility of renewal by the fuse wire of wrong size or by improper material. (ii) This type of fuse has a low-breaking capacity and hence cannot be used in circuits of high fault level. (iii) Due to deterioration due to oxidation through the continuous heating up of the element the current rating of the fuse decreases (iv) The protective capacity of such a fuse is uncertain as it is affected by the ambient conditions. (v) Accurate calibration of the fuse wire is not possible.

- Semi-enclosed rewireable fuses are made up to 500 A rated current, but their breaking capacity is low e.g., on 400 V service, the breaking capacity is about 4000 A. Therefore, the use of this type of fuses is limited to domestic and lighting loads.

2. **Draw the wave diagram of current and explain briefly about cut off current , pre arcing time, arcing time and total operating time. .[2015(s)-1(b)]**

Ans:-fig.



Cut-off current. It is the maximum value of fault current actually reached before the fuse melts. On the occurrence of a fault, the fault current has a very large first loop due to a fair degree of asymmetry. The heat generated is sufficient to melt the fuse element well before the peak of first loop is reached .The current corresponding to point 'a' is the cut off current. The cut off value depends upon : (a) current rating of fuse (b) value of prospective current (c) asymmetry of short-circuit current

Pre-arcing time:- When a fault occurs, the fault current rises rapidly and generates heat in the fuse element due to which cut off occurs. So pre arcing time is the time between the commencement of fault

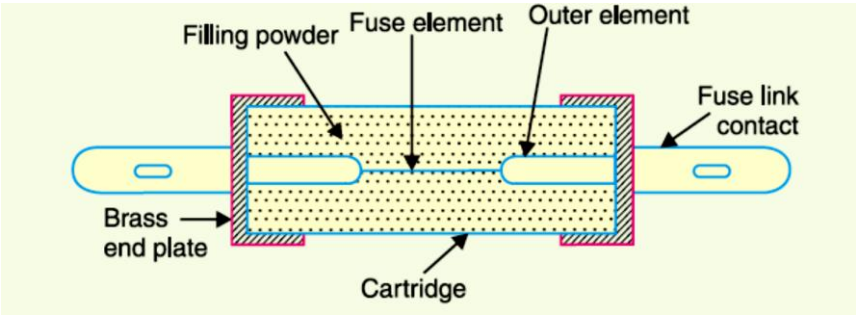
and the instant when cut off occurs. The pre-arcing time is generally small: a typical value being 0·001second .

Arcing time:- This is the time between the end of pre-arcing time and the instant when the arc is extinguished .It is the time between point B and C in the graph.

Total operating time:- It is the sum of pre-arcing and arcing times. It may be noted that operating time of a fuse is generally quite low (say 0·002 sec.) as compared to a circuit breaker (say 0·2 sec or so). In the graph it is the time between point A and B

3. With neat sketch explain about HRC type fuse. [2019 (s)- 1(c)]

Ans:- High-Rupturing capacity (H.R.C.) cartridge fuse. The primary objection of low and uncertain breaking capacity of semi-enclosed rewireable fuses is overcome in H.R.C. cartridge fuse. Fig shows the essential parts of a typical H.R.C. cartridge fuse.



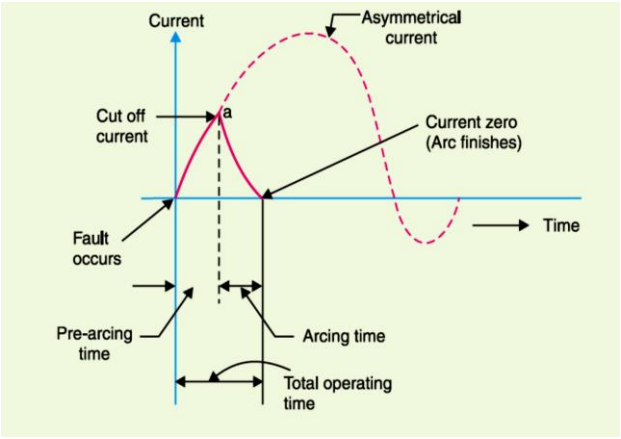
- It consists of a heat resisting ceramic body having metal end-caps to which a silver current-carrying element is welded.
- The space within the body surrounding the element is completely packed with a filling powder. The filling material may be chalk, plaster of paris, quartz or marble dust and acts as an arc quenching and cooling medium.
- Under normal load conditions, the fuse element is at a temperature below its melting point .Therefore, it carries the normal current without overheating.
- When a fault occurs, the current increases and the fuse element melts before the fault current reaches its first peak.
- The heat produced in the process vapourises the melted silver element.
- The chemical reaction between the silver vapour and the filling powder results in the formation of a high resistance substance which helps in quenching the arc.
- **Advantages** (i) They are capable of clearing high as well as low fault currents.
  ii)They do not deteriorate with age.
  (iii)They have high speed of operation.
  (iv) They provide reliable discrimination.
  (v) They require no maintenance.
  (vi) They are cheaper than other circuit interrupting devices of equal breaking capacity.
  (vii) They permit consistent performance.
- **Disadvantages** (i) They have to be replaced after each operation.
  (ii) Heat produced by the arc may affect the associated switches.

4. What are the differences between fuse and C.B.? [2017 (s)- 2(b)], [2019(s)-3(b)]

fuse	Circuit breaker
➢ It performs both detection and interruption functions. ➢ Its Operation is Inherently completely automatic. ➢ Breaking capacity Small ➢ Operating time Very small (0·002 sec or so) ➢ Requires replacement after every operation.	➢ It performs interruption function only. The detection of fault is made by relay system. ➢ Requires elaborate equipment (i.e. relays) for automatic action. ➢ Breaking capacity is Very large ➢ Operating time is Comparatively large (0·1 to 0·2 sec) ➢ No replacement after operation

5. Define prospective current and cut off current. [2017 (w)- 1(b)]

Ans:- Prospective Current. Fig. 20.2 shows how a.c. current is cut off by a fuse. The fault current would normally have a very large first loop, but it actually generates sufficient energy to melt the fuseable element well before the peak of this first loop is reached. The *r.m.s.* value of the first loop of fault current is known as prospective current. Therefore, prospective current can be defined as under:



It is the r.m.s. value of the first loop of the fault current obtained if the fuse is replaced by an ordinary conductor of negligible resistance.

Cut-off current. It is the maximum value of fault current actually reached before the fuse melts.

On the occurrence of a fault, the fault current has a very large first loop due to a fair degree of asymmetry. The heat generated is sufficient to melt the fuse element well before the peak of first loop is reached. The current corresponding to point '*a*' is the cut off current. The cut off value depends upon :

(*a*) current rating of fuse

(*b*) value of prospective current

(*c*) asymmetry of short-circuit current

It may be mentioned here that outstanding feature of fuse action is the breaking of circuit *before* the fault current reaches its first peak. This gives the fuse a great advantage over a circuit breaker since the most severe thermal and electro-magnetic effects of short-circuit currents (which occur at the peak value of prospective current) are not experienced with fuses. Therefore, the circuits protected by fuses can be designed to withstand maximum current equal to the cut-off value. This consideration together with the relative cheapness of fuses allows much saving in cost.

CHAPTER-04

CIRCUIT BREAKERS

SHORT TYPE QUESTION

1. **Define arc voltage? [2017 (s)- 3(a)], [2019(s)-3(a)]**
   Ans:-When fault occurs the C.B. contacts separates. But at current zero, the voltage between the C.B. contacts rises rapidly to peak value and this peak voltage tends to maintain the current flow in the form of arc. The voltage that appears across the contacts of the circuit breaker during the arcing period is known as arc voltage.

2. **Define R.R.R.V.? .[2014(w)-2(a)]**
   Ans:-R.R.R.V. stands for rate of rise of restriking voltage. it means the rise in the dielectric strength between the two contacts of C.B. according to the rise in the restriking voltage between them.This R.R.R.V. determines whether arc will form or not. it's unit is KV/μ sec.
3. **What is breaking capacity of a circuit breaker. .[2014(w)-3(a)]**
   Ans:- It is current (r.m.s.) that a circuit breaker is capable of breaking at given recovery voltage and under specified conditions (e.g., power factor, rate of rise of restriking voltage).
   Breaking capacity = $3\times V \times I \times 10{-}6$ MVA
   Where I=rated breaking current
   V=supply voltage
4. **What is restriking voltage? [2019(s)-3(a)]**
   Ans:- In an a.c. system, current drops to zero after every half-cycle. At every current zero, the arc extinguishes for a brief moment. But at that time the medium between the contacts contains sufficient ions and electrons so that it has small dielectric strength and can be easily broken down by the rising contact voltage. The voltage at which current flows again between the contacts is known as restriking voltage.
5. **Name the quenching medium used in C.B.? .[2015(s)-2(a)], [2017(w)- 2(a)]**
   Ans:-The different quenching medium used in circuit breaker are insulating oil , air , sulphur hexafluoride(SF6)gas , vacuum.
6. **Why a.c. ckt is more easily interrupted then d.c. ckt? .[2015(s)-7(a)]**
   Ans:-In a.c. ckt current value reaches zero in every half cycle. so when current value is zero it is easy to interrupt the current. But that does not occurs in d.c. ckt.
7. **Define recovery voltage. [2019(s)-3(a)]**
   Ans:-it is the normal system voltage that appears across the contacts of circuit breaker with normal frequence after the final arc extinction.
8. **What rating of C.B.? [2019(s)-4(a)]**

Ans:- A circuit breaker may be called upon to operate under all conditions. However, major duties are imposed on the circuit breaker when there is a fault on the system in which it is connected. Under fault conditions, a circuit breaker is required to perform the following three duties :

(i) It must be capable of opening the faulty circuit and breaking the fault current.

(ii) It must be capable of being closed on to a fault.

(iii) It must be capable of carrying fault current for a short time while another circuit breaker (in

series) is clearing the fault.

Corresponding to the above mentioned duties, the circuit breakers have three ratings i.e.

(i)breaking capacity **(ii)** making capacity and **(iii)** short-time capacity

LONG TYPE QUESTIONS

9. A circuit breaker is rated as 2000 A, 1500 MVA, 33kV, 3 second ,3 phase oil circuit breaker. Find
i) Rated normal current , ii) Breaking capacity , iii) Rated symmetrical breaking current
iv) Rated making current , v) Short time rating

Ans:- (*i*) Rated normal current = 2000 A

(*ii*) Breaking capacity = 1500 MVA

(*iii*) Rated symmetrical breaking current = $1500 \times 10^6/\sqrt{3} \times 33 \times 10^3$ = 26243 A (r.m.s.)

(*iv*) Rated making current = 2·55 x 17496 = 66920 A (peak)

(*v*) Short-time rating = 26243A for 3 seconds

(*vi*) Rated service voltage = 33 kV (r.m.s.)

10. State the maintenance procedure of oil C.B.

Ans:- The maintenance of oil circuit breaker is generally concerned with the checking of contacts and dielectric strength of oil. After a circuit breaker has interrupted fault currents a few times or load currents several times, its contacts may get burnt by arcing and the oil may lose some of its dielectric strength due to carbonisation. Therefore, it is a good practice to inspect the circuit breaker at regular intervals of 3 or 6 months. During inspection of the breaker, the following points should be kept in view :

(*i*) Check the current carrying parts and arcing contacts. If the burning is severe, the contacts should be replaced.

(*ii*) Check the dielectric strength of the oil. If the oil is badly discoloured, it should be changed or reconditioned.

(*iii*) Check the insulation for possible damage. Clean the surface and remove carbon deposits with a strong and dry fabric.

(*iv*) Check the oil level.

(*v*) Check closing and tripping mechanism.

11. Write down the methods of arc extinction?

Ans:- There are two methods of extinguishing the arc in circuit breakers.

1. High resistance method. **2.** Low resistance or current zero method

1. High resistance method. In this method, arc resistance is made to increase with time so that current is reduced to a value insufficient to maintain the arc. Consequently, the current is interrupted or the arc is extinguished. The principal disadvantage of this method is that enormous energy is dissipated in the arc. Therefore, it is employed only in d.c. circuit breakers and low-capacity a.c. circuit breakers.

The resistance of the arc may be increased by :

(i) Lengthening the arc.

(ii) Cooling the arc.

(iii) Reducing X-section of the arc.

(iv) Splitting the arc.

2. Low resistance or Current zero method. This method is employed for arc extinction in a.c. circuits only. In this method, arc resistance is kept low until current is zero where the arc extinguishes naturally and is prevented from restriking inspite of the rising voltage across the contacts. All modern high power a.c. circuit breakers employ this method for arc extinction. In an a.c. system, current drops to zero after every half-cycle. At every current zero, the arc extinguishes for a brief moment. Now the medium between the contacts contains ions and electrons so that it have small dielectric strength and can be easily broken down by the rising contact voltage known as restriking voltage. If such a breakdown does occur, the arc will persist for another half cycle.If immediately after current zero, the dielectric strength of the medium between contacts is built up more rapidly than the voltage across the contacts, the arc fails to restrike and the current will be interrupted. The rapid increase of dielectric strength of the medium near current zero can be achieved by :

(*a*) causing the ionised particles in the space between contacts to recombine into neutral molecules.

(*b*) sweeping the ionised particles away and replacing them by un-ionised particles

Therefore, the real problem in a.c. arc interruption is to rapidly deionise the medium between contacts as soon as the current becomes zero so that the rising contact voltage or restriking voltage cannot breakdown the space between contacts. The de-ionisation of the medium can be achieved by:

(i) Lengthening the arc gap.

(ii) By increasing the pressure of the contact place.

(iii) By cooling the contact.

(iii) By blast effect.

12. Explain high resistance method of arc extinction? .[2015(s)-2(b)]

High resistance method. In this method, arc resistance is made to increase with time so that current is reduced to a value insufficient to maintain the arc. Consequently, the current is interrupted or the arc is extinguished. The principal disadvantage of this method is that enormous energy is dissipated in the arc. Therefore, it is employed only in d.c. circuit breakers and low-capacity a.c. circuit breakers.

The resistance of the arc may be increased by :

(*i*) Lengthening the arc. The resistance of the arc is directly proportional to its length. The length of the arc can be increased by increasing the gap between contacts.

(*ii*) Cooling the arc. Cooling helps in the deionisation of the medium between the contacts. This increases the arc resistance. Efficient cooling may be obtained by a gas blast directed along the arc.

(*iii*) Reducing X-section of the arc. If the area of X-section of the arc is reduced, the voltage necessary to maintain the arc is increased. In other words, the resistance of the arc path is increased. The cross-section of the arc can be reduced by letting the arc pass through a narrow opening or by having smaller area of contacts.

(*iv*) Splitting the arc. The resistance of the arc can be increased by splitting the arc into a number of smaller arcs in series. Each one of these arcs experiences the effect of lengthening and cooling. The arc may be split by introducing some conducting plates between the contacts.

13. Explain rating of C.B.? .[2014(s)-1(b)]

Ans:- A circuit breaker may be called upon to operate under all conditions. However, major duties are imposed on the circuit breaker when there is a fault on the system in which it is connected. Under fault conditions, a circuit breaker is required to perform the following three duties :

(i) It must be capable of opening the faulty circuit and breaking the fault current.

(ii) It must be capable of being closed on to a fault.

(iii) It must be capable of carrying fault current for a short time while another circuit breaker (in series) is clearing the fault.

Corresponding to the above mentioned duties, the circuit breakers have three ratings i.e.

(i)breaking capacity **(ii)** making capacity and **(iii)** short-time capacity

(i) Breaking capacity. It is the current (in r.m.s.) that a circuit breaker is capable of breaking at given recovery voltage and under specified conditions (e.g., power factor, rate of rise of restriking voltage).

Breaking capacity=$\sqrt{3}$ x V x I x 10^{-6} MVA

(ii) Making capacity. There is always a possibility of closing or making the circuit under short circuit conditions. The capacity of a breaker to "make" current depends upon its ability to withstand and close successfully against the effects of electromagnetic forces. These forces are proportional to the square of maximum instantaneous current on closing. Therefore, making capacity is stated in terms of a peak value of current instead of r.m.s. value.

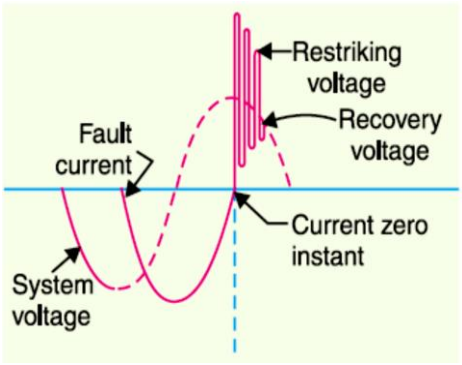
The peak value of current (including d.c. component) during the first cycle of current wave after the closure of circuit breaker is known as making capacity.

Making capacity =2·55 x Symmetrical breaking capacity

(iii) Short-time rating. It is the period for which the circuit breaker is able to carry fault current while remaining closed. The short-time rating of a circuit breaker depends upon its ability to withstand **(a)** the electromagnetic force effects and (b) the temperature rise.

14. With neat sketch explain about restriking and recovery voltage. .[2014(s)-5(b)], [2017 (s)- 5(b)]

Ans:- (ii) Restriking voltage. It is the transient voltage that appears across the contacts at or near current zero during arcing period. At current zero, a high-frequency transient voltage appears across the contacts and is caused by the rapid distribution of energy between the magnetic and electric fields associated with the plant and transmission lines of the system. This transient voltage is known as restriking voltage.

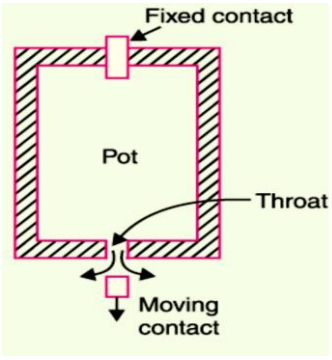


The current interruption in the circuit depends upon this voltage. If the restriking voltage rises more rapidly than the dielectric strength of the medium between the contacts, the arc

will persist for another half-cycle. On the other hand, if the dielectric strength of the medium builds up more rapidly than the restriking voltage, the arc fails to restrike and the current will be interrupted.

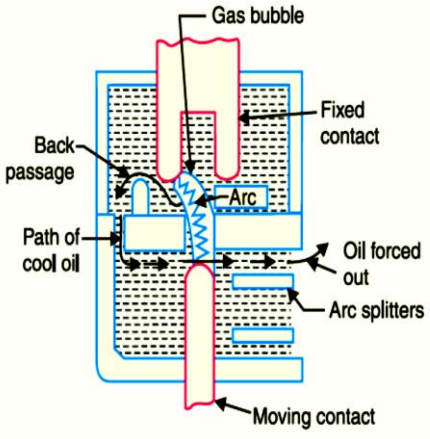
(iii) Recovery voltage. It is the normal frequency (50 Hz) r.m.s. voltage that appears across the contacts of the circuit breaker after final arc extinction. It is approximately equal to the system voltage. When contacts of circuit breaker are opened, current drops to zero after every half cycle. At some current zero, the contacts are separated sufficiently apart and dielectric strength of the medium between the contacts attains a high value due to the removal of ionised particles. At such an instant, the medium between the contacts is strong enough to prevent the breakdown by the restriking voltage .Consequently, the final arc extinction takes place and circuit current is interrupted. Immediately after final current interruption, the voltage that appears across the contacts has a transient part . However, these transient oscillations subside rapidly due to the damping effect of system resistance and normal circuit voltage appears across the contacts. The voltage across the contacts is of normal frequency and is known as recovery voltage.

15. Explain briefly plain explosion pot and cross jet explosion pot? .[2013(w)-3(b)]



Ans:- (*a*) Plain explosion pot. It is a rigid cylinder of insulating material and encloses the fixed and moving contacts as shown in figure. The moving contact is a cylindrical rod passing through a restricted opening (called throat) at the bottom. When a fault occurs, the contacts get separated and an arc is struck between them. The heat of the arc decomposes oil into a gas at very high pressure in the pot. This high pressure forces the oil and gas through and round the arc to extinguish it. If the final arc extinction does not take place while the moving contact is still within the pot, it occurs immediately after the moving contact leaves the pot. It is because when the moving contact comes out from the pot a violent rush of gas and oil occurs through the throat producing rapid extinction.

(b) Cross jet explosion pot. This type of pot is just a modification of plain explosion pot and is illustrated in Fig. Given bellow. It is made of insulating material and has channels on one side which act as arc splitters. The arc splitters help in increasing the arc length, thus facilitating arc extinction.



When a fault occurs, the moving contact of the circuit breaker begins to separate. As the moving contact is withdrawn, the arc is initially struck in the top of the pot. The gas generated by the arc exerts pressure on the oil in the back passage. When the moving contact uncovers the arc splitter ducts, fresh oil is forced across the arc path. The arc is therefore driven sideways into the "arc splitters" which increase the arc length, causing arc extinction.

16. Explain low oil circuit breaker?[2017 (w)- 1(c)], [2019(s)-3(c)]

Ans:- In the bulk oil circuit breakers, the oil has to perform two functions. Firstly, it acts as an arc quenching medium and secondly, it insulates the live parts from earth. It has been found that only a small percentage of oil is actually used for arc extinction while the major part is utilised for insulation purposes. So the quantity of oil in bulk oil circuit breakers reaches a very high figure as the system voltage increases. This not only increases the expenses, tank size and weight of the breaker but it also increases the fire risk and maintenance problems. This can be avoided by low oil C.B.

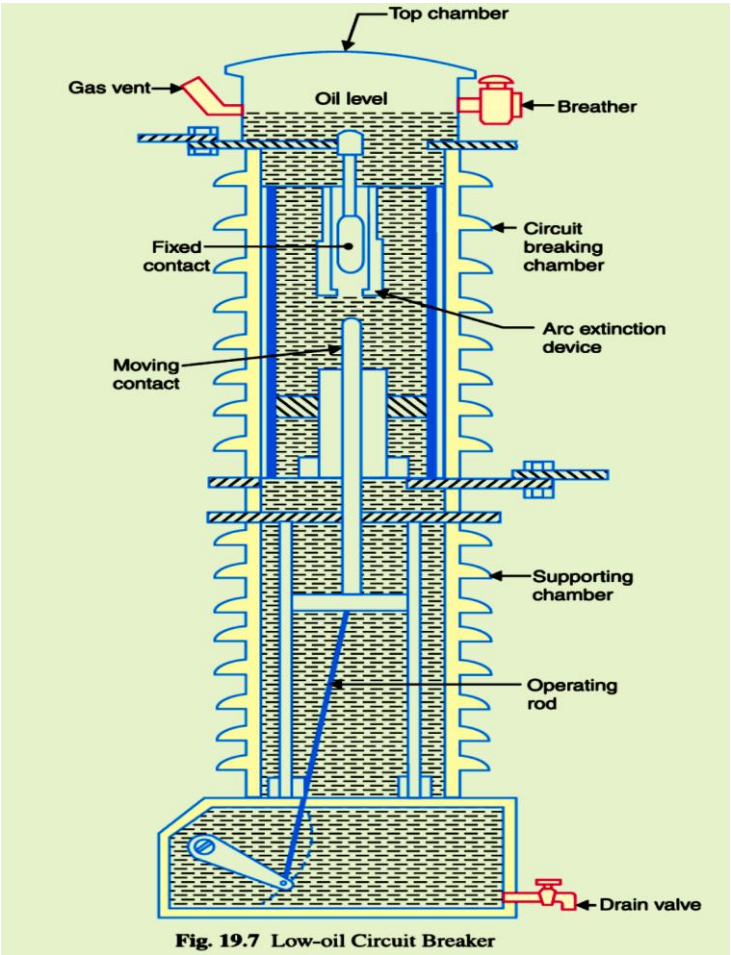


Fig. 19.7 Low-oil Circuit Breaker

Construction

As shown in figure it consists of three chambers.i.e. **(i)** Supporting chamber **(ii)** Circuit-breaking chamber**(iii)** Top chamber

(i) Supporting chamber. It is a porcelain chamber mounted on a metal chamber. It is filled with oil

which is physically separated from the oil in the circuit breaking compartment. The oil inside the supporting chamber and the annular space formed between the porcelain insulation and bakelised paper is employed for insulation purposes only.

(ii) Circuit-breaking chamber. It is a porcelain enclosure mounted on the top of the supporting compartment. It is filled with oil and has the following parts :

(a) upper and lower fixed contacts

(b) moving contact

(c) turbulator

(iii) Top chamber. It is a metal chamber and is mounted on the circuit-breaking chamber. It provides expansion space for the oil in the circuit breaking compartment. The top chamber is also provided with a separator which prevents any loss of oil by centrifugal action caused by circuit breaker operation during fault conditions.

Operation. Under normal operating conditions, the moving contact remains 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 energy vaporises the 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 the arc are successively quenched by the effect of separate streams of oil moving across each section in turn and bearing away its gases.

Advantages.

(i) It requires lesser quantity of oil.

(ii) It requires smaller space.

(iii) There is reduced risk of fire.

(iv) Maintenance problems are reduced.

Disadvantages.

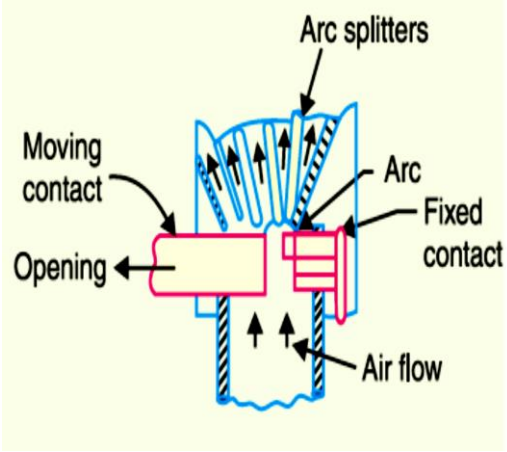
(i) Due to smaller quantity of oil, the degree of carbonisation is increased.

(ii) There is a difficulty of removing the gases from the contact space in time.

(iii) The dielectric strength of the oil deteriorates rapidly due to high degree of carbonisation.

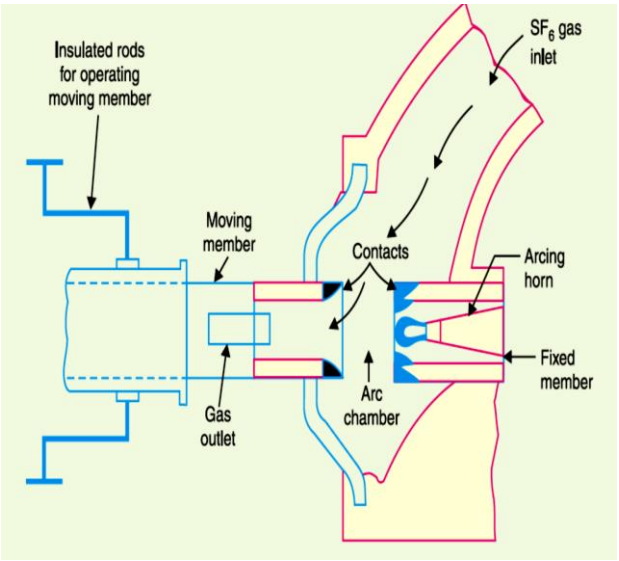
17. Explain cross blast air circuit breaker? .[2014(w)-3(b)]

Cross-blast air 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.



The given Fig. shows the essential 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 the arc into a chute consisting of arc splitters and baffles. The splitters serve to increase the length of the arc and baffles gives improved cooling. The result is that arc is extinguished and flow of current is interrupted. Since 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 a series isolating switch is not necessary.

18. Explain SF-6 circuit breaker? .[2018(w)-1(c)], [2017 (s)- 3(c)]



Ans:- In such circuit breakers, sulphur hexafluoride (SF6) gas is used as the arc quenching medium. The SF6 is an electro-negative gas and has a strong tendency to absorb free electrons. The contacts of the breaker are opened in a high pressure flow of SF6 gas and an arc is struck between them. The conducting free electrons in the arc are rapidly captured by the gas to form relatively immobile negative ions. This loss of conducting electrons in the arc quickly builds up enough insulation strength to extinguish the arc. The SF6 circuit breakers have been found to be very effective for high power and high voltage service.

Construction.

Fig. shows the parts of a typical SF6 circuit breaker. It consists of fixed and moving contacts enclosed in a chamber (called arc interruption chamber) containing SF6 gas. This chamber is connected to SF6 gas reservoir. When the contacts of breaker are opened, the valve mechanism permits a high pressure SF6 gas from the reservoir to flow towards the arc interruption chamber. The fixed contact is a hollow cylindrical current carrying contact fitted with an arc horn. The moving contact is also a hollow cylinder with rectangular holes in the sides to permit the SF6 gas to let out through these holes after flowing along and across the arc. The tips of fixed contact, moving contact and arcing horn are coated with copper-tungsten arc resistant material. Since SF6 gas is costly, it is reconditioned and reclaimed by suitable auxiliary system after each operation of the breaker.

Working. In the closed position of the breaker, the contacts remain surrounded by SF6 gas at a pressure of about 2·8 kg/cm2. 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 synchronised with the opening of a valve which permits SF6 gas at 14 kg/cm2 pressure from the reservoir to the arc interruption chamber. The high pressure flow of SF6 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.

(i) Due to the superior arc quenching property of SF6, such circuit breakers have very short arcing time.
(ii) Since the dielectric strength of SF6 gas is 2 to 3 times that of air, such breakers can interrupt much larger currents.
(iii) The SF6 circuit breaker gives noiseless operation due to its closed gas circuit and no exhaust to atmosphere unlike the air blast circuit breaker.

(iv) The closed gas enclosure keeps the interior dry so that there is no moisture problem.
(v) There is no risk of fire in such breakers because SF6 gas is non-inflammable.
(vi) There are no carbon deposits so that tracking and insulation problems are eliminated.
(vii) The SF6 breakers have low maintenance cost, light foundation requirements and minimum auxiliary equipment.

(viii) Since SF6 breakers are totally enclosed and sealed from atmosphere, they are particularly suitable where explosion hazard exists e.g., coal mines.

Disadvantages

(i) SF6 breakers are costly due to the high cost of SF6.

(ii) Since SF6 gas has to be reconditioned after every operation of the breaker, additional equipment is required for this purpose.

19. Write advantages of Air Blast Circuit Breaker? [2019(s)- 6(b)] [2018(S)- 3(b)]

Ans:- These breakers employ a high pressure air-blast as an arc quenching medium.The contacts are opened in a flow of air-blast established by the opening of blast valve. The air-blast cools the arc and sweeps away the arcing products to the atmosphere .This rapidly increases the dielectric strength of the medium between contacts and prevents from re-establishing the arc. Consequently, the arc is extinguished and flow of current is interrupted.

Advantages. An air-blast circuit breaker has the following advantages over an oil circuit breaker:

(*i*) The risk of fire is eliminated.

(*ii*) The arcing products are completely removed by the blast whereas the oil deteriorates with successive operations; the expense of regular oil replacement is avoided.

(*iii*) The growth of dielectric strength is so rapid that final contact gap needed for arc extinction is very small. This reduces the size of the device.

(*iv*) The arcing time is very small due to the rapid build up of dielectric strength between contacts. Therefore, the arc energy is only a fraction of that in oil circuit breakers, thus resulting in less burning of contacts.

(*v*) Due to lesser arc energy, air-blast circuit breakers are very suitable for conditions where frequent operation is required.

(*vi*) The energy supplied for arc extinction is obtained from high pressure air and is independent of the current to be interrupted.

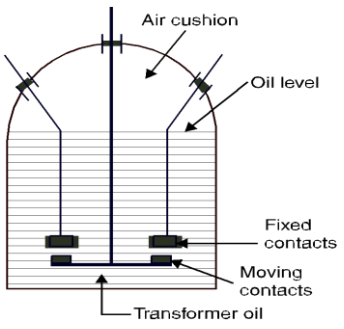
Disadvantages. The use of air as the arc quenching medium offers the following disadvantages

(*i*) The air has relatively inferior arc extinguishing properties.

(*ii*) The air-blast circuit breakers are very sensitive to the variations in the rate of rise of restriking voltage.

(*iii*) Considerable maintenance is required for the compressor plant which supplies the air-blast. The air blast circuit breakers are finding wide applications in high voltage installations. Majority of the circuit breakers for voltages beyond 110 kV are of this type.

20. Explain plain break oil circuit breaker. [2017 (s)- 3(b)]



Ans:- A plain-break oil circuit breaker involves the simple process of separating the contacts under the whole of the oil in the tank. There is no special system for arc control other than the increase in length caused by the separation of contacts. The arc extinction occurs when a certain critical gap between the contacts is reached.

The plain-break oil circuit breaker is the earliest type from which all other circuit breakers have developed. It has a very simple construction. It consists of fixed and moving contacts enclosed in a strong weather-tight earthed tank containing oil upto a certain level and an air cushion above the oil level. The air cushion provides sufficient room to allow for the reception of the arc gases without the generation of unsafe pressure in the dome of the circuit breaker. It also absorbs the mechanical shock of the upward oil movement. Fig shows a *double break plain oil circuit breaker. It is called a double break because it provides two breaks in series. Under normal operating conditions, the fixed and moving contacts remain closed and the breaker carries the normal circuit current. When a fault occurs, the moving contacts are pulled down by the

protective system and an arc is struck which vaporises the oil mainly into hydrogen gas. The arc extinction is facilitated by the following processes:

(*i*) The hydrogen gas bubble generated around the arc cools the arc column and aids the de-ionisation of the medium between the contacts.

(*ii*) The gas sets up turbulence in the oil and helps in eliminating the arcing products from the arc path.

(*iii*) As the arc lengthens due to the separating contacts, the dielectric strength of the medium is increased.

The result of these actions is that at some critical gap length, the arc is extinguished and the circuit current is interrupted.

Disadvantages

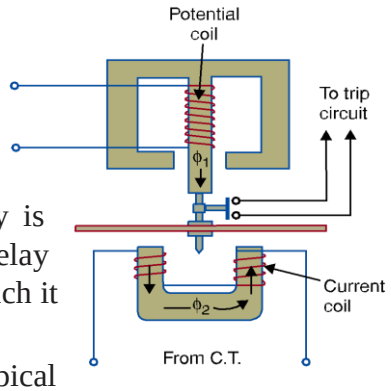
(*i*) There is no special control over the arc other than the increase in length by separating the moving contacts. Therefore, for successful interruption, long arc length is necessary.

(*ii*) These breakers have long and inconsistent arcing times.

(*iii*) These breakers do not permit high speed interruption.

Due to these disadvantages, plain-break oil circuit breakers are used only for low-voltage applications where high breaking-capacities are not important. It is a usual practice to use such breakers for low capacity installations for voltages not exceeding †11 kV.

21. Explain Induction Type Directional Power Relay. [2017 (s)- 4(c)]



This type of relay operates when power in the circuit flows in a specific direction. Unlike a *non- directional over current relay, a directional power relay is so designed that it obtains its operating torque by the interaction of magnetic fields derived from both voltage and current source of the circuit it protects. Thus this type of relay is essentially a wattmeter and the direction of the torque set up in the relay depends upon the direction of the current relative to the voltage with which it is associated.

Constructional details. Fig. 21.18 shows the essential parts of a typical induction type direc- tional power relay. It consists of an aluminum disc which is free to rotate in between the poles of two electromagnets. The upper electromagnet carries a winding (called *potential coil*) on the central limb which is connected through a potential transformer (P.T.) to the circuit voltage source. The lower electromagnet has a separate winding (called *current coil*) connected to the secondary of C.T. in the line to be protected. The current coil is provided with a number of tappings connected to the plug- setting bridge (not shown for clarity). This permits to have any desired current setting. The restrain- ing torque is provided by a spiral spring.

The spindle of the disc carries a moving contact which bridges two fixed contacts when the disc has rotated through a pre-set angle. By adjusting this angle, the travel of the moving disc can be adjusted and hence any desired time-setting can be given to the relay.

Operation. The flux ϕ_1 due to current in the potential coil will be nearly 90° lagging behind the applied voltage V. The flux ϕ_2 due to current coil will be nearly in phase with the operating current I [See vector diagram in Fig. 21.18 (*ii*)]. The interaction of fluxes ϕ_1 and ϕ_2 with the eddy currents induced in the disc produces a driving torque given by :

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

Since $\phi_1 \propto V$, $\phi_2 \propto I$ and

$\alpha = 90 - \theta$

$$\therefore \quad T \propto V I \sin (90 - \theta)$$

$$\propto V I \cos \theta$$

$\propto$ power in the circuit

It is clear that the direction of driving torque on the disc depends upon the direction of power flow in the circuit to which the relay is associated. When the power in the circuit flows in the normal direction, the driving torque and the restraining torque (due to spring) help each other to turn away the moving contact from the fixed contacts. Consequently, the relay remains inoperative. However, the reversal of current in the circuit reverses the direction of driving torque on the disc. When the reversed driving torque is large enough, the disc rotates in the reverse direction and the moving contact closes the trip circuit. This causes the operation of the circuit breaker which disconnects the faulty section.

22. Write short note on arc phenomena. .[2017(w)-2(b)]

Ans:- When a short-circuit occurs, a heavy current flows through the contacts of the circuit breaker before they are opened by the protective system. At the instant when the contacts begin to separate, the contact area decreases rapidly and large fault current causes increased current density and hence rise in temperature. The heat produced in the medium between contacts (usually the medium is oil or air) is sufficient to ionise the air or vapourise and ionise the oil. The ionised air or vapour acts as conductor and an arc is struck between the contacts. The p.d. between the contacts is quite small and is just sufficient to maintain the arc. The arc provides a low resistance path and consequently the current in the circuit remains uninterrupted so long as the arc persists.

During the arcing period, the current flowing between the contacts depends upon the arc resistance. The greater the arc resistance , the smaller the current that flows between the contacts. The arc resistance depends upon the following factors :

(i) Degree of ionisation— the arc resistance increases with the decrease in the number of ionised particles between the contacts.

(ii) Length of the arc— the arc resistance increases with the length of the arc i.e., separation of contacts.

(iii) Cross-section of arc— the arc resistance increases with the decrease in area of X-section of the arc.

23. Explain low resistance method of arc extinction?
[2019(S)-2(b)]

ANS:- **. Low resistance or Current zero method.** This method is employed for arc extinction in a.c. circuits only. In this method, arc resistance is kept low until current is zero where the arc extinguishes naturally and is prevented from restriking inspite of the rising voltage across the contacts. All modern high power a.c. circuit breakers employ this method for arc extinction. In an a.c. system, current drops to zero after every half-cycle. At every current zero, the arc extinguishes for a brief moment. Now the medium between the contacts contains ions and electrons so that it have small dielectric strength and can be easily broken down by the rising contact voltage known as restriking voltage. If such a breakdown does occur, the arc will persist for another half cycle.If immediately after current zero, the dielectric strength of the medium between contacts is built up more rapidly than the voltage across the contacts, the arc fails to restrike and the current will be interrupted. The rapid increase of dielectric strength of the medium near current zero can be achieved by :

(*a*) causing the ionised particles in the space between contacts to recombine into neutral molecules.

(*b*) sweeping the ionised particles away and replacing them by un-ionised particles

Therefore, the real problem in a.c. arc interruption is to rapidly deionise the medium between contacts as soon as the current becomes zero so that the rising contact voltage or restriking voltage cannot breakdown the space between contacts. The de-ionisation of the medium can be achieved by:

(i) Lengthening the arc gap.

(ii) By increasing the pressure of the contact place.

(iii) By cooling the contact.

(iv) By blast effect.

24. With neat sketch explain constructional and operating details of vaccum circuit breaker? [2019(S)-4(c)] ANS:- In such breakers, vacuum (degree of vacuum being in the range from 10^{-7} to 10^{-5} torr) is used as the arc quenching medium. Since vacuum offers the highest insulating strength, it has far superior arc quenching properties than any other medium.

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 ionisation of metal vapours of contacts. However, the arc is quickly extinguished because the metallic vapours, electrons and ions produced during arc rapidly condense 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 quickly extinguished due to the fast rate of recovery of dielectric strength in vacuum.

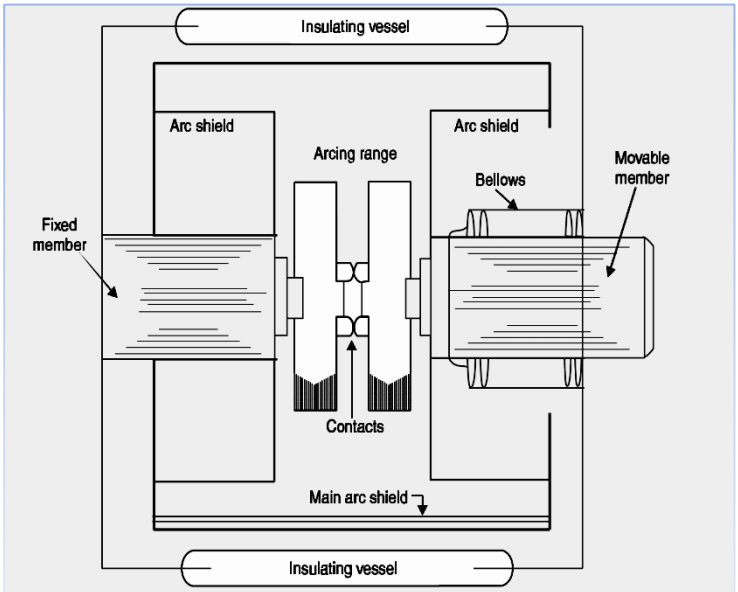


Fig. 19.12

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 contact separates from the fixed contact and an arc is struck between the contacts. The production of arc is due to the ionisation of metal ions and depends very much upon the material of contacts. The arc is quickly extinguished because the metal- lic vapours, electrons and ions produced during arc are diffused in a 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 (say 0·625 cm).

Advantages. Vacuum circuit breakers have the following advantages :

(*i*) They are compact, reliable and have longer life.

(*ii*) There are no fire hazards.

(*iii*) There is no generation of gas during and after operation.

(*iv*) 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.

(*v*) They require little maintenance and are quiet in operation.

(*vi*) They can successfully withstand lightning surges.

(*vii*) They have low arc energy.

(*viii*) They have low inertia and hence require smaller power for control mechanism.

Applications. For a country like India, where distances are quite large and accessibility to remote areas difficult, the installation of such outdoor, maintenance free circuit breakers should prove a definite advantage. Vacuum circuit breakers are being employed for outdoor applications ranging from 22 kV to 66 kV. Even with limited rating of say 60 to 100 MVA, they are suitable for a majority of applications in rural areas.

CHAPTER-05

PROTECTIVE RELAYS

SHORT TYPE QUESTION

1. **What is back up relaying ? .[2014(w)-5(a)]**

   Ans:-It is the second line of defence for a system .it works when the primary protection fails .it is provided by taking 3 to4 or more small parts having primary protection .it's operating time is greater than primary protection.

2. **What is P.S.M.? . [2017 (w)- 3(a)], [2019(s)-6(a)]**

Ans:- (P.S.M.) Plug-setting multiplier . It is the ratio of fault current in relay coil to the pick-up current

i.e. P.S.M. =Fault current in relay coil/Pick - up current

=Fault current in relay coil/(Rated secondary current of *CT x* Current setting)

3. **What is pick up current? [2017(w)- 6(a)], [2017 (s)- 4(a)], [2019(s)-5(a)]**

Ans:- It is the minimum current in the relay coil at which the relay starts to operate. So long as the current in the relay is less than the pick-up value, the relay does not operate and the breaker controlled by it remains in the closed position. However, when the relay coil current is equal to or greater than the pickup value, the relay operates to energise the trip coil which opens the circuit breaker.

4. **What is T.S.M.? [2018(w)-5(a)]**

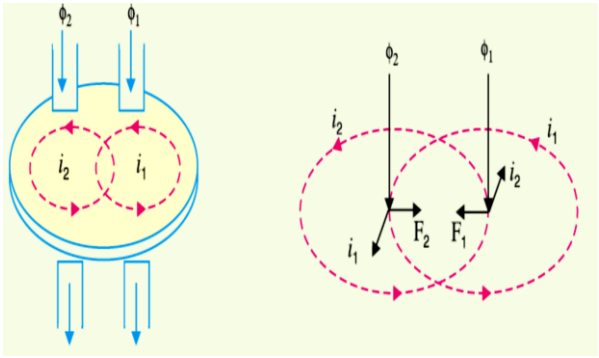
Ans:-

Time-setting multiplier.(T.S.M) A relay is generally provided with control to adjust the time of operation. This adjustment is known as time-setting multiplier. The time-setting dial is calibrated from 0 to 1 in steps of 0.05 sec .

LONG TYPE QUESTION

1. Explain basic relay operation of induction relay.[2013(w)-4(b)], .[2014(w)-5(c)]

Ans:- Electromagnetic induction relays operate on the principle of induction motor and are widely used for protective relaying purposes involving a.c. quantities. They are not used with d.c. quantities owing to the principle of operation. An induction relay essentially consists of a pivoted aluminium disc placed in two alternating magnetic fields of the same frequency but displaced in time and space. The torque is produced in the disc by the interaction of one of the magnetic fields with the currents induced in the disc by the other .To understand the production of torque in an induction relay, refer to the elementary arrangement shown in Fig.The two a.c. fluxes ϕ2 and ϕ1 differing in phase by an angle α induce e.m.f. in the disc and cause the circulation of eddy currents *i*2 and *i*1 respectively. These currents lag behind their respective fluxes by 90 degree. Referring to Fig. where the two a.c. fluxes and induced currents are shown separately for clarity, let



$$\phi 1 = \phi 1_{max} \sin(wt)$$

$$\phi 2 = \phi 1_{max} \sin(wt + \alpha)$$

where ϕ1 and ϕ2 are the instantaneous values of fluxes and ϕ2 leads ϕ1 by an angle α.

Assuming that the paths in which the rotor currents flow have negligible self-inductance, the rotor currents will be in phase with their voltages.

$$\therefore \quad i1 \propto \frac{d\phi 1}{dt}$$

$$i1 \propto \frac{d\varphi 1 max \sin(wt)}{dt}$$

$$\propto \phi 1_{max} \cos(wt)$$

and

$$i2 \propto \frac{d\phi 2}{dt}$$

$$\propto \phi 1_{max} \cos(wt + \alpha)$$

Now, $F_1 \propto \phi_1 i_2$ and $F_2 \propto \phi_2 i_1$

Fig. shows that the two forces are in opposition.

$\therefore$ Net force F at the instant considered is

$$F \propto F_2 - F_1$$

$$\propto \phi_2 i_1 - \phi_1 i_2$$

$$\propto \phi_{2max} \sin(\omega t + \alpha)\, \phi_{1max} \cos \omega t - \phi_{1max} \sin \omega t\, \phi_{2max} \cos(\omega t + \alpha)$$

$$\propto \phi_{1max}\, \phi_{2max} [\sin(\omega t + \alpha) \cos \omega t - \sin \omega t \cos(\omega t + \alpha)]$$

$$\propto \phi_{1max}\, \phi_{2max} \sin \alpha$$

$$\propto \phi_1\, \phi_2 \sin \alpha$$

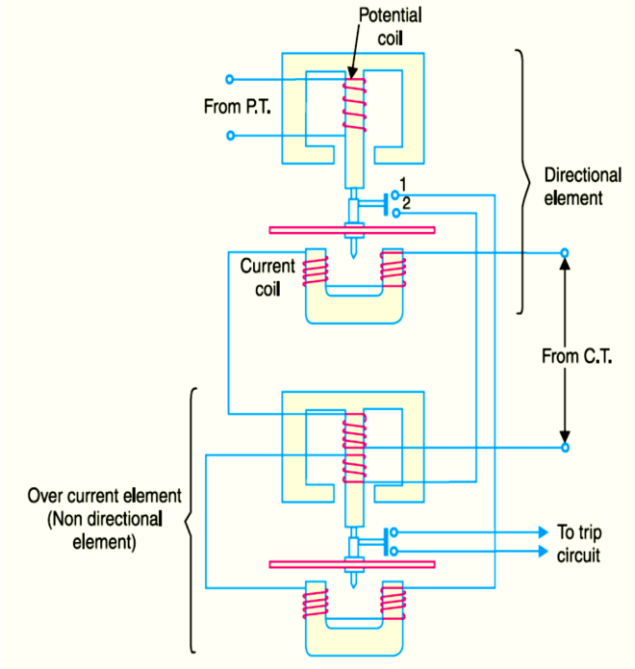
The following points may be noted from exp.

(*a*) The greater the phase angle α between the fluxes, the greater is the net force applied to the disc.

(*b*) The net force is the same at every instant.

(*c*) The direction of net force and hence the direction of motion of the disc depends upon which

flux is leading.



2. Describe the construction and principle induction type directional over current relay? .[2019(s)-5(b)]

Ans:- The directional power relay discussed above is unsuitable for use as a directional protective relay under short-circuit conditions. When a short-circuit occurs, the system voltage falls to a low value and there may be insufficient torque developed in the relay to cause its operation. This difficulty is overcome in the directional over current relay which is designed to be almost independent of system voltage and power factor.

Constructional details. Fig. shows the constructional details of a typical induction type directional over current relay. It consists of two relay elements mounted on a common case. (i) directional element and (ii) non-directional element.

(i) Directional element. It is essentially a directional power relay which operates when power flows in a specific direction. The potential coil of this element is connected through a potential transformer (P.T.) to the system voltage. The current coil of the element is energised through a C.T. by the circuit current.

(ii) Non-directional element. It is an over current element similar in all respects to a non-directional over current relay. The spindle of the disc of this element carries a moving contact which closes the fixed contacts (trip circuit contacts) after the operation of directional element.

Operation. Under normal operating conditions, power flows in the normal direction in the circuit protected by the relay. Therefore, directional power relay (upper element) does not operate, thereby keeping the over current element (lower element) unenergised . However, when a short-circuit occurs, there is a tendency for the current or power to flow in the reverse direction. Should this happen, the disc of the upper element rotates to bridge the fixed contacts 1 and 2. This completes the circuit for over current element. The disc of this element rotates and the moving contact attached to it closes the trip circuit. This operates the circuit breaker which isolates the faulty section. The two relay elements are so arranged that final tripping of the current controlled by them is not made till the following conditions are satisfied :

(*i*) current flows in a direction such as to operate the directional element.

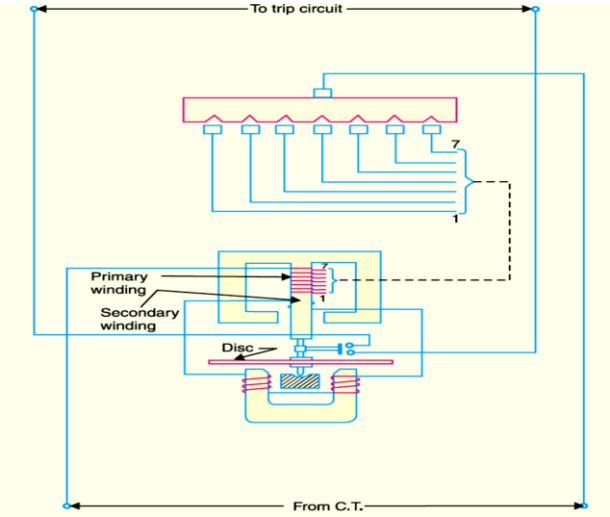
(*ii*) current in the reverse direction exceeds the pre-set value.

(*iii*) excessive current persists for a period corresponding to the time setting of over current element.

3. Explain induction type over current relay. .[2014(w)-6(b)]

Ans:- This type of relay works on the induction principle and initiates corrective measures when current in the circuit exceeds the predetermined value. The actuating source is a current in the circuit supplied to the relay from a current transformer. These relays are used on a.c. circuits only and can operate for fault current flow in either direction.

Constructional details. Fig. shows the important constructional details of a typical non directional induction type over current relay. It consists of a metallic (aluminium) disc which is free to rotate in between the poles of two electromagnets. The upper electromagnet has a primary and a secondary winding. The primary is connected to the secondary of a C.T. in the line to be protected and is tapped at intervals. The secondary winding is energised by induction from primary and is connected in series with the winding on the lower magnet. The controlling torque is provided by a spiral spring. The spindle of the disc carries a moving contact which bridges two fixed contacts (connected to trip circuit) when the disc rotates through a pre-set angle. This angle can be adjusted to any value between 0^0 and 360^0 . By adjusting this angle, the travel of the moving contact can be adjusted and hence the relay can be given any desired time setting.



Operation. The driving torque on the aluminium disc is set up due to the induction principle. This torque is opposed by the restraining torque provided by the spring. Under normal operating conditions, restraining torque is greater than the driving torque produced by the relay coil current. Therefore, the aluminium disc remains stationary. However, if the current in the protected circuit exceeds the pre-set value, the driving torque becomes greater than the restraining torque. Consequently, the disc rotates and the moving contact bridges the fixed contacts when the disc has rotated through a pre-set angle. The trip circuit operates the circuit breaker which isolates the faulty section.

4. State essential qualities of good protective system. .[2014(w)-5(b)], [2017 (w)- 6(b)]

Ans:-The essential qualities of a good protective relay are:-

(*i*) selectivity (*ii*) speed (*iii*) sensitivity

(*iv*) reliability (*v*) simplicity (*vi*) economy

(i) Selectivity. It is the ability of the protective system to select correctly that part of the system in trouble and disconnect the faulty part without disturbing the rest of the system.

(ii) Speed. The relay system should disconnect the faulty section as fast as possible otherwise it will also affect the healthy parts.

(i) **Sensitivity.** It is the ability of the relay system to operate with low value of actuating quantity. Sensitivity of a relay is a function of the volt-amperes input to the coil of the relay necessary to cause its operation.

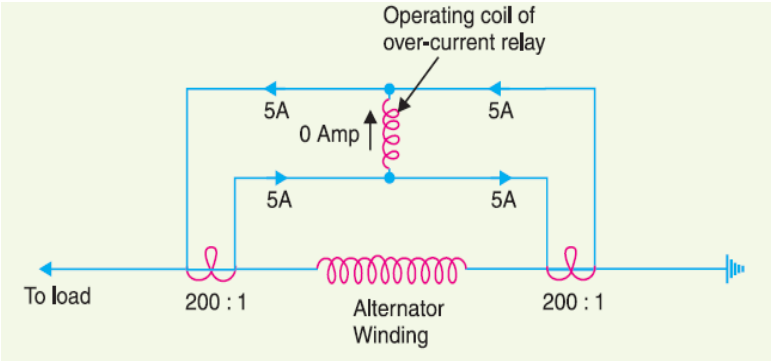
(ii) **Reliability.** It is the ability of the relay system to operate under the pre-determined conditions. Without reliability, the protection would be rendered largely ineffective and could even become a liability.

(vi) Simplicity. The relaying system should be simple so that it can be easily maintained. Reliability is closely related to simplicity. The simpler the protection scheme, the greater will be its reliability.

(vii) Economy. The most important factor in the choice of a particular protection scheme is the economic aspect. Sometimes it is economically unjustified to use an ideal scheme of protection and a compromise method has to be adopted. As a rule, the protective gear should not cost more than 5% of total cost.

5. Explain current differencial relay? .[2016(s)-3(b)]

Ans:- Fig. shows an arrangement of an over current relay connected to operate as a differential relay.



A pair of identical current transformers are fitted on either end of the section to be protected (alternator winding in this case). The secondaries of CT's are connected in series in such a way that they carry the induced currents in the same direction. The operating coil of the over current relay is connected across the CT secondary circuit . This differential relay compares the current at the two ends of the alternator winding.

Under normal operating condition the current in the two secondary of the C.T. are equal. These current will circulate between the two C.T.s and no current will flow through the differential relay. Therefore the relay remains in operative. If any fault occurs on the alternator than the two secondary currents will not be equal and the difference in the current will flow through the operating coil of the relay and the relay starts operating and gives a command to the circuit breaker to operate which isolates the alternator from the system.

6. Define and explain P.S.M and T.S.M. [2017(s)-4(b)]

Plug-setting multiplier (P.S.M.) . It is the ratio of fault current in relay coil to the pick-up current *i.e.*

$$\text{P.S.M.} = \frac{\text{Fault current in relay coil}}{\text{Pick up current}}$$

$$= \frac{\text{Fault current in relay coil}}{\text{Rated secondary current of C.T} \times \text{current setting}}$$

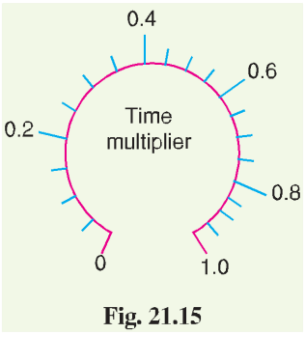


Fig. 21.15

Time-setting multiplier.(T.S.M) A relay is generally provided with control to adjust the time of operation. This adjustment is known as time-setting multiplier. The time-setting dial is calibrated from 0 to 1 in steps of 0.05 sec (see Fig. 21.15). These figures are multipliers to be used to convert the time derived from time/P.S.M. curve into the actual operating time. Thus if the time setting is 0·1 and the time obtained from the time/P.S.M. curve is 3 seconds, then actual relay operating time = 3 × 0·1 = 0·3 second. For instance, in an induction relay, the time of operation is controlled by adjusting the amount of travel of the disc from its reset position to its pickup position. This is achieved by the adjustment of the position of a movable backstop which controls the travel of the disc and thereby varies the time in which the relay will close its contacts for given values of fault current. A so-called "time dial" with an evenly divided scale provides this adjustment. The actual time of operation is calculated by multiplying the time setting multiplier with the time obtained from time/P.S.M. curve of the relay.

7. Describe various steps for calculating the actual relay operating time. [2019(S)-4(b)]

Ans:-step:-1

Calculate pick up current=rated secondary current * current setting

Step:-2

Calculate fault current in relay coil from actual fault current in the system.

Step:-3

Calculate plug setting multiplier=fault current in relay coil / pick up current

Step:-4

Calculate the operating time from from the p.s.m and time graph.

Step:-5

Actual operating time =operating time from graph * time setting

CHAPTER-06

PROTECTION OF ELECTRICAL POWER EQUIPMENT AND LINES

SHORT TYPE QUESTION

1. **What is arcing ground. [2015(s)-5(a)], [2017(w)- 5(a)]**

Ans:- The phenomenon of intermittent arc taking place in line-to-ground fault of a 3ϕ system with consequent production of transients is known as **arcing ground.** The transients produced due to arcing ground are cumulative and may cause serious damage to the equipment in the power system by causing breakdown of insulation. Arcing ground can be prevented by earthing the neutral.

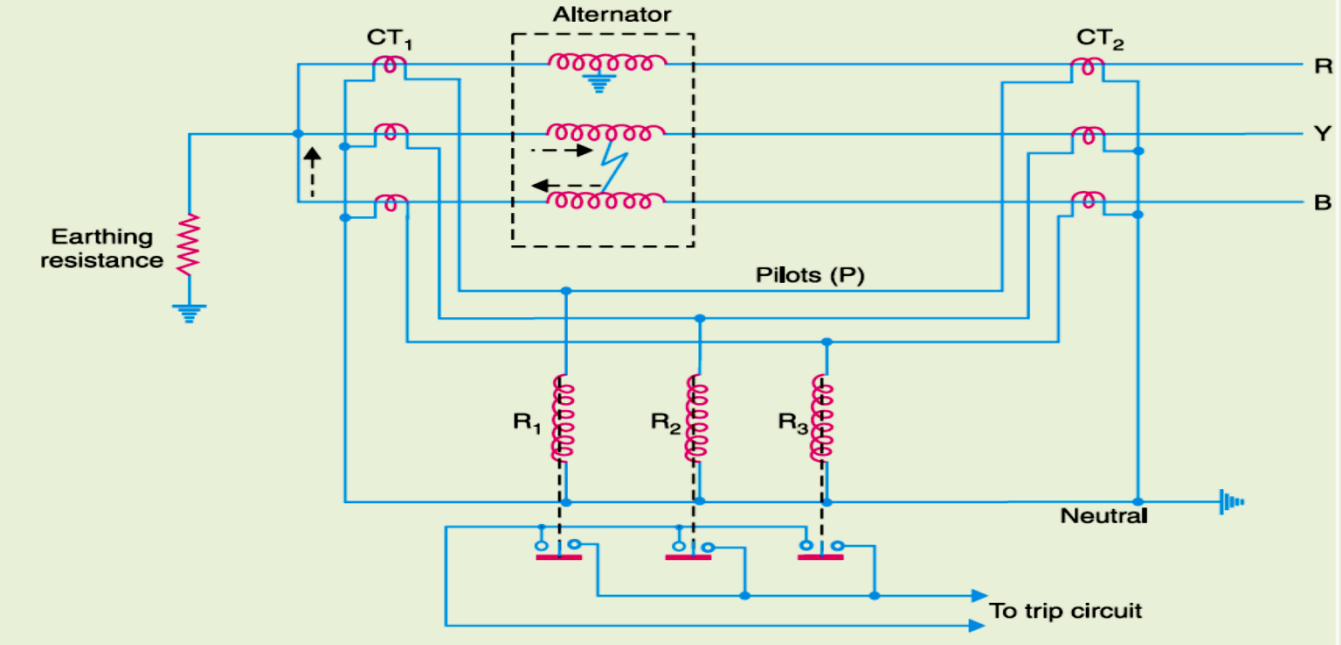
LONG TYPE QUESTION

1. **Explain with neat diagram of Mertz price circulating current principle for the protection of alternator. [2017 (s)- 5(c)], [2019 (s)- 7(b)],**

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

Schematic arrangement . Fig. shows the schematic arrangement of current differential protection for a 3-phase alternator. Identical current transformer pairs *CT*1 and *CT*2 are placed on either side of each phase of the stator windings. The secondary of each set of current transformers are connected in star ; the two neutral points and the corresponding terminals of the two star groups being connected together by

means of a four-core pilot cable. Thus there is an independent path for the currents circulating in each pair of current transformers and the corresponding pilot *P*.



The relay coils are connected in star, the neutral point being connected to the current-transformer common neutral and the outer ends one to each of the other three pilots. In order that burden on each current transformer is the same, the relays are connected across equipotential points of the three pilot wires and these equipotential points would naturally be located at the middle of the pilot wires. The relays are generally of electromagnetic type and are arranged for instantaneous action since fault should be cleared as quickly as possible.

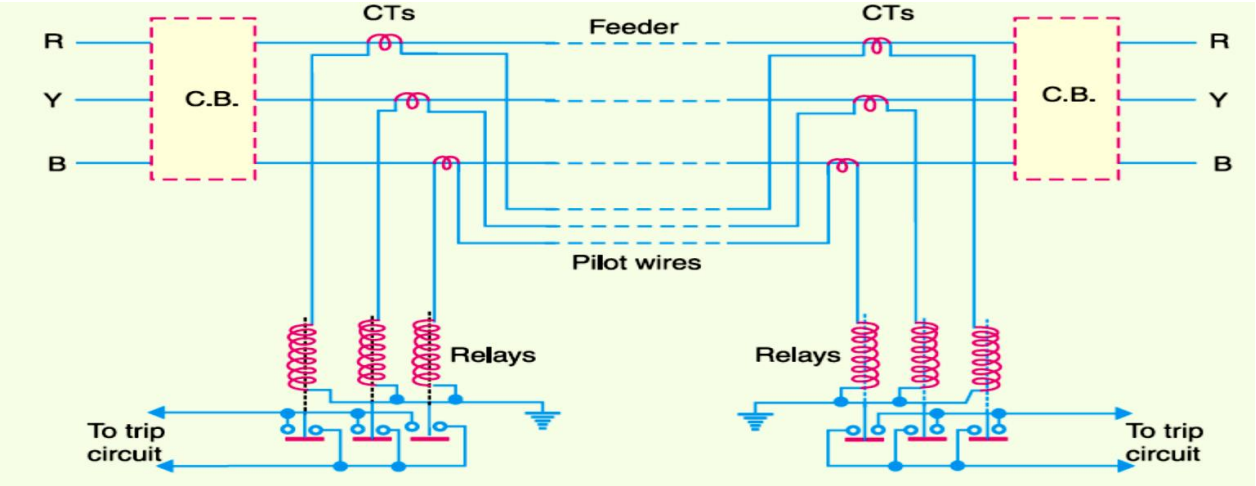
Operation. Referring to Fig., it is clear that the relays are connected in shunt across each circulating path. Therefore, the circuit of Fig. can be shown in a simpler form in Fig.. Under normal operating conditions, the current at both ends of each winding will be equal and hence the currents in the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

2. Explain mertz-price voltage balance system of protection of three phase line. [2013(w)-5(b)]

Or

Explain mertz-price protection for feeders. [2015(s)-4(b)]

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



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

Advantages

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

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

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

Disadvantages

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

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

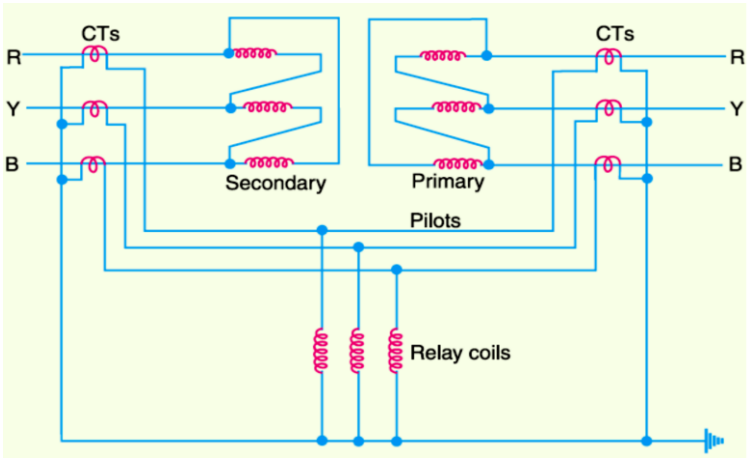
(*iii*) This system is very expensive owing to the greater length of pilot wires required.

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

3. Explain mertz-price protection for transformer. [2014(w)-6(c)],

Or)

Explain about current differential relay with neat sketch for protection of transformer?[2017 (w)- 4(b)]

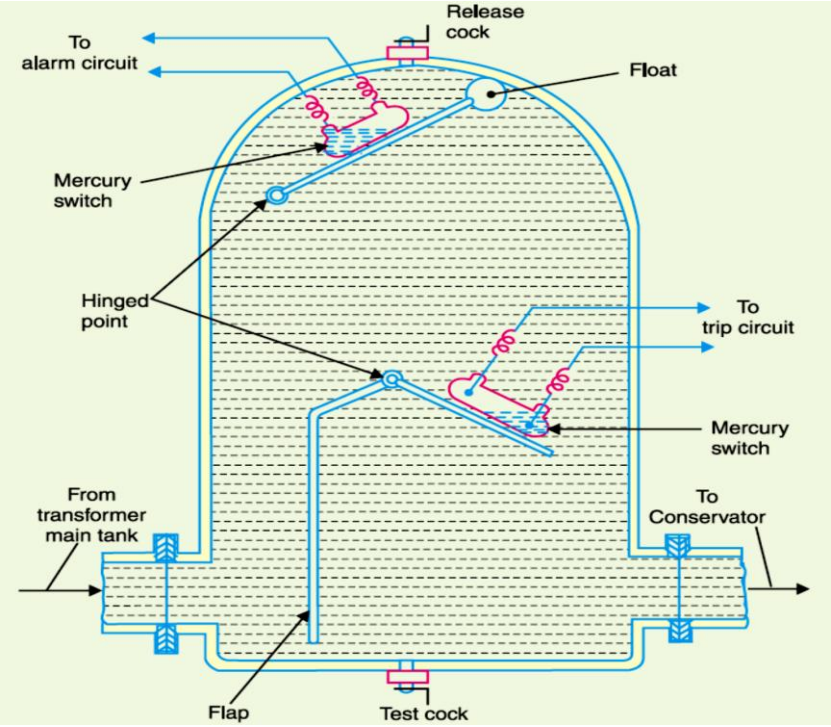


Ans:- Fig. shows Mertz-Price circulating-current scheme for the protection of a 3-phase delta/delta power transformer against phase-to ground and phase-to-phase faults. Note that *CT*s on the two sides of the transformer are connected in star. This compensates for the phase difference between the power transformer primary and secondary. The *CT*s

on the two sides are connected by pilot wires and one relay is used for each pair of *CT*s. During normal operating conditions, the secondary of *CT*s carry identical currents. Therefore, the currents entering and leaving the pilot wires at both ends are the same and no current flows through the relays. If a ground or phase-to-phase fault occurs, the currents in the secondary of *CT*s will no longer be the same and the differential current flowing through the relay circuit will clear the breaker on both sides of the transformer. The-protected zone is limited to the region between *CT*s on the high-voltage side and the *CT*s on the low-voltage side of the power transformer. It is worthwhile to note that this scheme also provides protection for short-circuits between turns on the same phase winding. When a short circuit occurs between the turns, the turn-ratio of the power transformer is altered and causes unbalance between current transformer pairs. If turn-ratio of power transformer is altered sufficiently, enough differential current may flow through the relay to cause its operation. However, such short-circuits are better taken care of by Buchholz relays.

4. Describe the construction and working of Buchholz relay.[2017 (w)- 3(b)], [2019(s)-5(c)]

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



Operation. The operation of Buchholz relay is as follows :

(*i*) In case of incipient faults within the transformer, the heat due to fault causes the decomposition of some transformer oil in the main tank. The products of decomposition contain more than 70% of hydrogen gas. The hydrogen gas being light tries to go into the conservator and in the process gets entrapped in the upper part of relay chamber. When a predetermined amount of gas gets accumulated, it exerts sufficient pressure on the float to cause it to tilt and close the contacts of mercury switch attached to it. This completes the alarm circuit to sound an alarm.

(*ii*) If a serious fault occurs in the transformer, an enormous amount of gas is generated in the main tank. The oil in the main tank rushes towards the conservator *via* the Buchholz relay and in doing so tilts the flap to close the contacts of mercury switch. This completes the trip circuit to open the circuit breaker controlling the transformer.

Advantages

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

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

Disadvantages

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

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

5. Explain earth fault protection of transformer. [2015(s)-4(c)], [2017 (w)- 4(c)] [2018(W)- 4(b)]

Ans:- An earth-fault usually involves a partial breakdown of winding insulation to earth. The resulting leakage current is considerably less than the short-circuit current. The earth-fault may continue for a long time and cause considerable damage before it ultimately develops into a short-circuit and removed from the system. Under these circumstances, it is profitable to employ earth-fault relays in order to ensure the disconnection of earth-fault or leak in the early stage. An earth-fault relay is essentially an overcurrent relay of low setting and operates as soon as an earth-fault or leak develops. One method of protection against earth-faults in a transformer is the *core-balance leakage protection shown inFig.

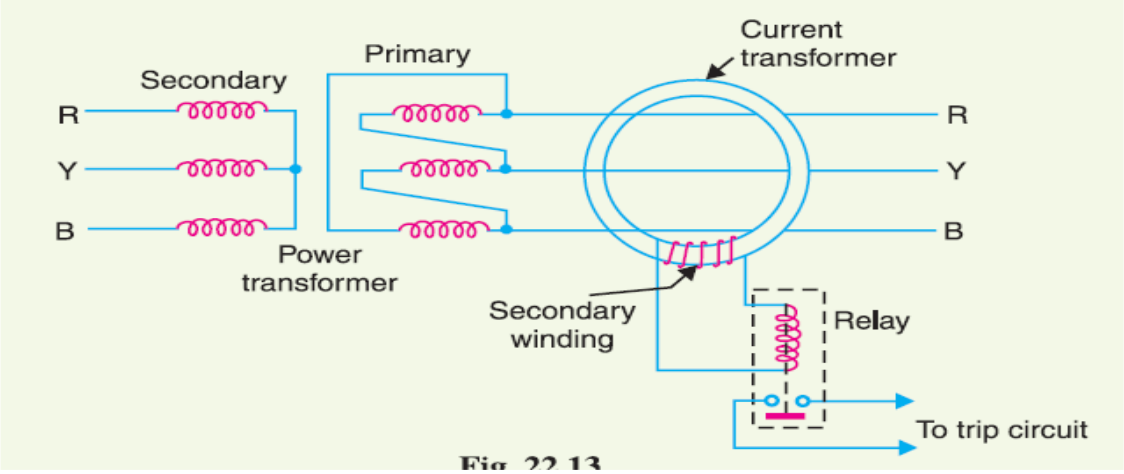


Fig. 22.13

The three leads of the primary winding of power transformer are taken through the core of a current transformer which carries a single secondary winding. The operating coil of a relay is connected to this secondary. Under normal conditions (*i.e.* no fault to earth), the vector sum of the three phase currents is zero and there is no resultant flux in the core of current transformer no matter how much the load is out of balance. Consequently, no current flows through the relay and it remains inoperative. However, on the occurrence of an earth-fault, the vector sum of three phase currents is no longer zero. The resultant current sets up flux in the core of the C.T. which induces e.m.f. in the secondary winding. This energises the relay to trip the circuit breaker and disconnect the faulty transformer from the system.

CHAPTER 07

PROTECTION AGAINST OVER VOLTAGE AND LIGHTING

SHORT TYPE QUESTION

1. What is voltage surge? [2014(w)-7(a)]

Ans:- A sudden rise in voltage for a very short duration on the power system is known as a voltage surge or transient voltage. Transients or surges are of temporary nature and exist for a very short duration (a few hundred μ*s*) but they cause overvoltages on the power system.

2. State harmful effect of lightning. [2016(s)-4(a)]

Ans:- (*i*) The travelling waves produced due to lightning surges will shatter the insulators and may even wreck poles.
(*ii*) If the travelling waves produced due to lightning hit the windings of a transformer or generator, it may cause considerable damage.
(*iii*) If the arc is initiated in any part of the power system by the lightning stroke, this arc will set up very disturbing oscillations in the line. This may damage other equipment connected to the line.

3. What are the causes of over voltages? [2016(s)-5(a)]

Ans:- The over voltages on a power system may be broadly divided into two main categories *viz*.
1. Internal causes
   (*i*) Switching surges (*ii*) Insulation failure
   (*iii*) Arcing ground (*iv*) Resonance
2. External causes:- lightning

LONG TYPE QUESTION

1. What are the protection against lightning taken in electrical power system. [2015(s)-5(b)], [2017 (w)- 5(b)]

Ans:-The different protections taken against lightning are (I) Earthing screen,(ii)Overhead ground wire,(iii)Lightning arrester or surge diverters

The Earthing Screen:-The power stations and sub-stations generally house expensive equipment. These stations can be protected against direct lightning strikes by providing earthing screen. It consists of a network of copper conductors (generally called shield or screen) mounted all over the electrical equipment in the sub-station or power station. The shield is properly connected to earth on at least two points through a low impedance. On the occurrence of direct stroke on the station, screen provides a low resistance path by which lightning surges are conducted to ground. In this way, station equipment is protected against damage. The limitation of this method is that it does not provide protection against the travelling waves which may reach the equipment in the station.

Overhead Ground Wires:- The most effective method of providing protection to transmission lines against direct lightning strokes is by the use of overhead ground wires .There is one ground wire and one

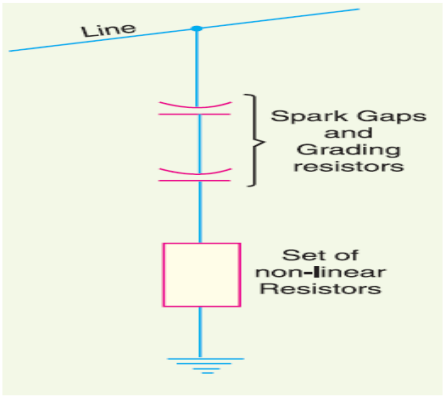
line conductor .The ground wires are placed *above* the line conductors at such positions that practically all lightning strokes are intercepted by them (*i.e*. ground wires). The ground wires are grounded at each tower or pole through as low resistance as possible. Due to their proper location, the ground wires will take up all the lightning strokes instead of allowing them to line conductors

Lightning Arresters:- The earthing screen and ground wires can well protect the electrical system against direct lightning strokes but they fail to provide protection against travelling waves which may reach the terminal apparatus. The lightning arresters or surge diverters provide protection against such surges. A lightning arrester or a surge diverter is a protective device which conducts the high voltage surges on the power system to the ground.

2. Discuss the construction and working principle of valve type lightning arrester. [2019(s)- 7(c)]

Ans:- Valve type arrester. Valve type arresters incorporate non-linear resistors and are extensively used on systems operating at high voltages. Fig. shows the various parts of a valve type arrester. It consists of two assemblies (*i*) series spark gaps and (*ii*) non-linear resistor discs (made of material such as thyrite or metrosil) in series. The non-linear elements are connected in series with the spark gaps. Both the assemblies are accommodated in tight porcelain container.

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



Advantages

(*i*) They provide very effective protection (especially for transformers and cables) against surges.

(*ii*) They operate very rapidly taking less than a second.

(*iii*) The impulse ratio is practically unity.

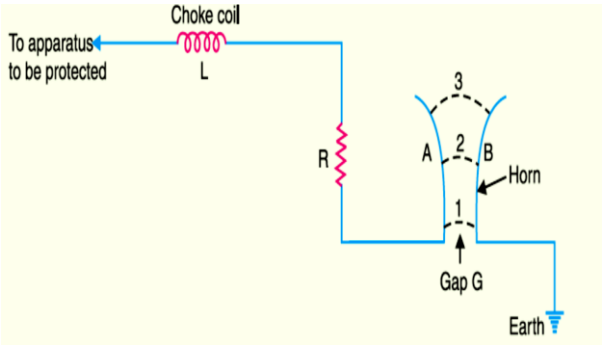
Limitations

(*i*) They may fail to check the surges of very steep wave front from reaching the terminal apparatus. This calls for additional steps to check steep-fronted waves.

(*ii*) Their performance is adversely affected by the entry of moisture into the enclosure. This necessitates effective sealing of the enclosure at all times.

3. Explain horn gap arrester. [2014(w)-7(b)], [2017 (s)-6(b)] [2018(s)- 4(C)]

Ans:- Horn Gap Arrester. It consists of two horn shaped metal rods *A* and *B* separated by a small air gap. The horns are so constructed that distance



between them gradually increases towards the top as shown. The horns are mounted on porcelain insulators .One end of horn is connected to the line through a resistance *R* and choke coil *L* while the other end is effectively grounded. The resistance *R* helps in limiting the follow current to a small value. The choke coil is so designed that it offers small reactance at normal power frequency but a very high reactance at transient frequency. Thus the choke does not allow the transients to enter the apparatus to be protected. The gap between the horns is so adjusted that normal supply voltage is not enough to cause an arc across the gap. Under normal conditions, the gap is non-conducting *i.e*. normal supply voltage is insufficient to initiate the arc between the gap. On the occurrence of an overvoltage, spark-over takes place across the small gap *G*. The heated air around the arc and the magnetic effect of the arc cause the arc to travel up the gap. The arc moves progressively into positions 1, 2 and 3. At some position of the arc (perhaps position 3), the distance may be too great for the voltage to maintain the arc. Consequently, the arc is extinguished. The excess charge on the line is thus conducted through the arrester to the ground.

Advantages

(*i*) The arc is self-clearing. Therefore, this type of arrester does not cause short-circuiting of the system after the surge is over as in the case of rod gap.

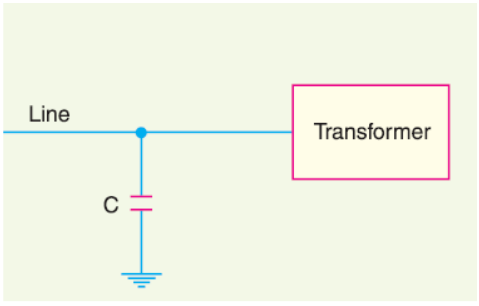
(*ii*) Series resistance helps in limiting the follow current to a small value.

Limitations

(*i*) The bridging of gap by some external agency (*e.g*. birds) can render the device useless.

(*ii*) The setting of horn gap is likely to change due to corrosion or pitting. This adversely affects the performance of the arrester.

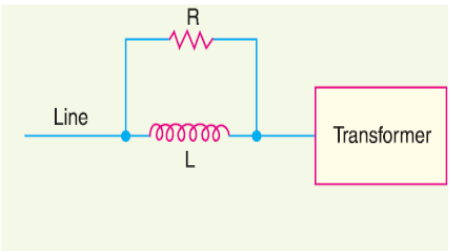
4. Explain surge absorber. [2013(w)-6(b)], [2016(s)-4(b)]



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

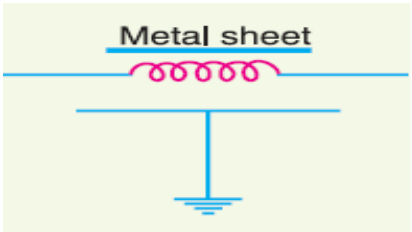
A few cases of surge absorption are discussed below:

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



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

(*iii*) Fig. shows the another type of surge absorber. It is called Ferranti surge absorber. It consists of an air cored inductor connected in series with the line. The inductor is surrounded by but insulated from an earthed metallic sheet called dissipater. This arrangement is



equivalent to a transformer with short-circuited secondary .The inductor forms the primary whereas the dissipater forms the short circuited secondary. The energy of the surge is used up in the form of heat generated in the dissipator due to transformer action. This type of surge absorber is mainly used for the protection of transformers.

5. What is lightning ? describe the mechanism of lightning dicgarge ? [2019(s)-6(c)]

Ans:- An electric discharge between cloud and earth, between clouds or between the charge centres of the same cloud is known as **lightning.**

Mechanism of Lightning Discharge

When a charged cloud passes over the earth, it induces equal and opposite charge on the earth below. Fig. 24.4 shows a negatively charged cloud inducing a positive charge on the earth below it. As the charge acquired by the cloud increases, the potential between cloud and earth increases and, therefore, gradient in the air increases. When the potential gradient is sufficient (5 kV*/cm to 10 kV/cm) to break down the surrounding air, the lightning stroke starts. The stroke mechanism is as under :

(i) As soon as the air near the cloud breaks down, a streamer called leader streamer or pilot streamer starts from the cloud towards the earth and carries charge with it as shown in Fig.24.4 (i). The leader streamer will continue its journey towards earth as long as the cloud, from which it originates feeds enough charge to it to maintain gradient at the tip of leader streamer above the strength of air. If this gradient is not maintained, the leader streamer stops and the charge is dissipated without the formation of a complete stroke. In other words, the leader streamer will not reach the earth. Fig. 24.4 (i) shows the leader streamer being unable to reach the earth as gradient at its end cloud not be maintained above the strength of air. It may be noted that current in the leader streamer is low (<100 A) and its velocity of propagation is about 0·05% that of velocity of light. Moreover, the luminosity of leader is also very low.

(ii) In many cases, the leader streamer continues its journey towards earth [See Fig. 24.4 (ii)] until it makes contact with earth or some object on the earth. As the leader streamer moves towards earth, it is accompanied by points of luminescence which travel in jumps giving rise to stepped leaders. The velocity of stepped leader exceeds one-sixth of that of light and distance travelled in one step is about 50 m. It may be noted that stepped leaders have sufficient luminosity and give rise to first visual phenomenon of discharge.

(iii) The path of leader streamer is a path of ionisation and, therefore, of complete breakdown of insulation. As the leader streamer reaches near the earth, a return streamer shoots up from the earth [See Fig. 24.4 (iii)] to the cloud, following the same path as the main channel of the downward leader. The action can be compared with the closing of a switch between the positive and negative terminals; the downward leader having negative charge and re- turn streamer the positive charge. This phenomenon causes a sudden spark which we call lightning. With the resulting neutralisation of much of the negative charge on the cloud, any further discharge from the cloud may have to originate from some other portion of it.

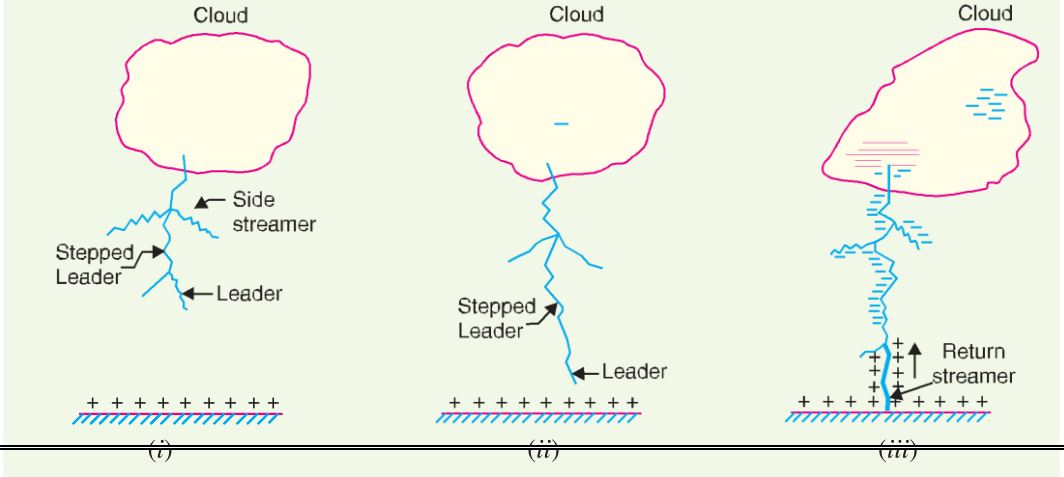


Fig. 24.4

CHAPTER -08

STATIC RELAY

LONG TYPE QUESTION

1. What is static relay,explain its advantages [2019(s)-7(a)]

Ans:- (i) As there is no moving part so unwanted tripping does not occur.

(i) The C.T. and P.T. are employed are lesser V-I rating because static relay required very small voltage and current for its operation.

(ii) It is more accurate than electromagnetic type relay.

(iii) Quick response and longer life.

(iv) Compact in size.

(v) There is no effect of gravity on its operation.

(vi) Static relay can be designed for repeated operation.