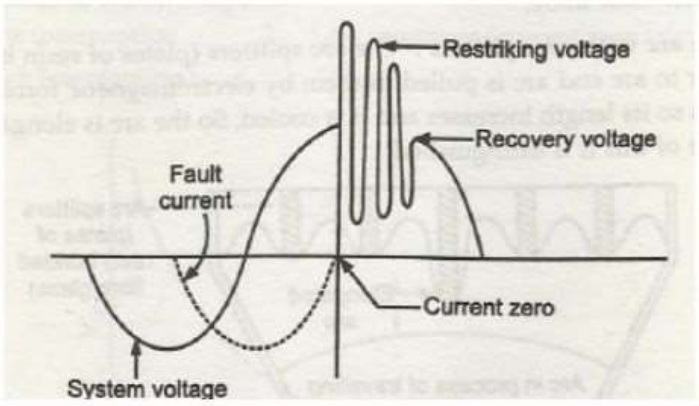
SHORT QUESTION AND ANSWER-2MARK EACH

1. **Define recovery voltage and restriking voltage.**

Ans: **restriking Voltage**: It is the transient voltage that appears across the contacts at or near current zero during arcing period. If dielectric strength rise is greater than the rise of restriking voltage then the arc will not restrike.

Recovery Voltage:

It is the rms voltage after final arc extinction. (Normal frequency 50 or 60 Hz). Both voltages appear between circuit breaker poles.



2. **What are the advantages of air break circuit breaker**?
Ans: the advantages of air break circuit breaker are listed below
It confines the arc within a restricted space.
It provides magnetic control over the arc movement so as to make arc extinction within the devices.
It provides for the rapid cooling of arc gasses to ensure arc extinction by deionization.

3. Why AC circuit is more easily interrupted than DC circuit?

Ans: Circuit breaking is easier in AC because an AC sine wave changes its amplitude every time.(0 ,+ve max,0,-ve max ,0).When it reaches zero the voltage is

zero therefore the disconnecting arc can be successfully quenched using a simple arc quenching mechanism.

But DC is constant and its peak value is at maximum the tendency to form and sustain arc causes fire and may explosion therefore dc arc quenching mechanism is more complex . DC breakers use magnetic arc chutes to quench dc arcs.

4. Define short time rating of circuit breaker.

Ans: The short circuit current of a circuit breaker is the RMS value of current that a breaker can carry in a fully closed condition without damage, for the specified time interval under prescribed condition. It is normally expressed regarding terms of KA for 1 second or 4 seconds. These ratings are based on thermal limitation.

5. **What is use of oil in M.O.C.B?**

Ans: oil performs mainly two functions. Firstly, it acts as an arc extinguishing medium and secondly, it insulates the live parts of the breaker from earth.

6. What is current chopping and where does it occour?

Ans: Current Chopping in circuit breaker is defined as a phenomenon in which current is forcibly interrupted before the natural current zero. Current Chopping is mainly observed in Vacuum Circuit Breaker and Air Blast Circuit Breaker. There is no such phenomenon in Oil Circuit Breaker. Current chopping is predominant while switching Shunt Reactor or unloaded Transformer.

7**. What is restriking voltage transient?**

When the current across the contact of the circuit breaker is zero, a high-frequency transient voltage develops in the whole breaker contact and is produced by the sudden distribution of energy between the electric and magnetic field. This transient voltage is called restriking voltage. The voltage appears across the breaker contacts at the moment of final current has a serious influence on the arc extinction process. Under the influence of this voltage, the arc tries to restrike and hence it is named as the restriking voltage. After the zero current, the arc gets extinguished, if the rate of rising of restriking voltage between the contact is less than the rate at which the dielectric strength of the medium between the contact gains. Immediately after the final current interruption, the voltage that appears

across the breaker contacts (transient voltage) superimposed on the power frequency system voltage (recovery voltage).

8. What are the various method of increasing arc resistance?

Ans: Methods of increasing arc resistance.

1. Lengthening of arc.
2. Cooling of arc.
3. Reducing cross section area of arc.
4. Splitting the arc.

9. What is auto recloser and what is its function?

Ans: The extra high voltage transmission lines transmit huge amount of electric power. Hence, it is always desirable that the continuation of power flow through the lines should not be interrupted for a long time. There may be a temporary or permanent fault in the lines. Temporary faults get automatically cleared, and these do not require any attempt for fault rectification. It is normal practice by the operators that after each initial faulty tripping of the line, they close the line. If the fault is transient, the line holds after the second attempt of closing the circuit breaker, but if the fault persists, the protection system again trips the line and then it is declared as permanent fault.

10. Define making and breaking capacity of circuit breaker

Ans: Breaking capacity: 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). It is a common practice to express the breaking capacity in MVA by taking into account the rated breaking current and rated service voltage. Thus, if I is the rated breaking current in amperes and V is the rated service line voltage in volts, then for a 3-phase circuit

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

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.

11.what is RRRV .find out its expression and where it is maximum?

Ans: It is the rate of rise of re-striking voltage and is expressed in kV/μs. It may be defined as the slope of the steepest tangent to the re-striking voltage curve. For a re-striking voltage having a single frequency transient component the RRRV is obtained by dividing the maximum amplitude of the oscillation by the duration of the first half wave

$$v = V_{max}\left(1 - \cos\frac{t}{\sqrt{LC}}\right)$$

$$\text{and RRRV} = \frac{dv}{dt} = \frac{V_{max}}{\sqrt{LC}}\sin\frac{t}{\sqrt{LC}}$$

RRRV will be maximum when $\sin\frac{t}{\sqrt{LC}} = 1$ or $t = \frac{\pi}{2}\sqrt{LC}$

Hence maximum value of RRRV, $RRRV_{max} = V_{max}/\sqrt{LC}$

Further, the peak restriking voltage occurs when v is maximum *i.e.*, when

$$\frac{dv}{dt} = 0 \quad \text{or} \quad \sin\frac{t}{\sqrt{LC}} = 0 \text{ or } t = \pi\sqrt{LC}$$

12. Write any two properties of contact material used in vaccum circuit breaker

Ans: 1. High electrical conductivity so as to pass normal load currents without overheating.
2. Low contact resistance.
3. High thermal conductivity so as to dissipate rapidly the large heat generated during arcing.
4. High cold and hot hardness to prevent wear and tear during normal opening and closing operations.

FOCUSED SHORT ANSWER TYPE-6MARK EACH

1. **Draw the schematic diagram of minimum oil circuit breaker**

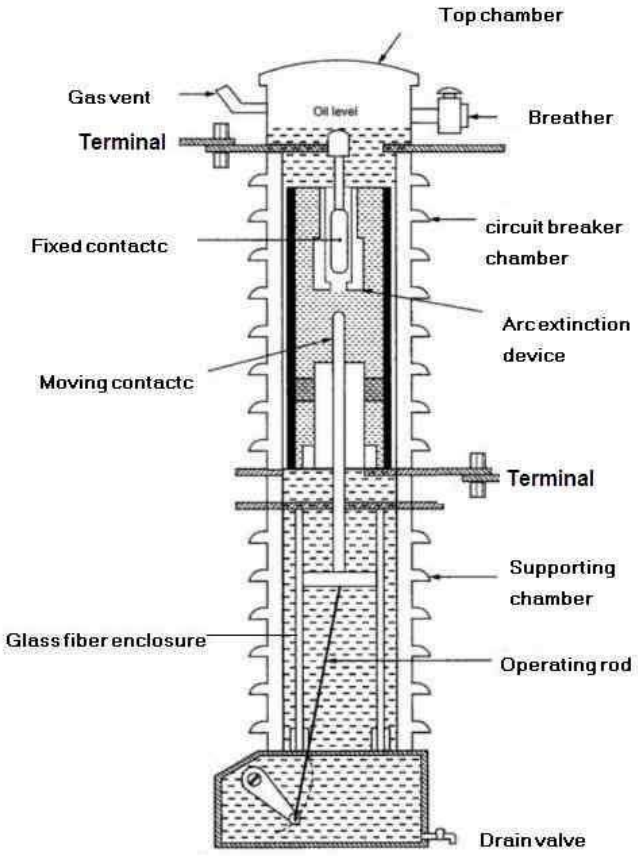
Ans: In this type of circuit breaker minimum oil is used as an arc quenching medium and it is mounted on a porcelain insulator to insulate it from the earth. The arc chamber of such type of circuit breaker is enclosed in a bakelised paper. The lower portion of this breaker is supported by the porcelain and the upper porcelain enclosed the contacts.

This circuit breaker is of the single breaker type in which a moving contact tube moves in a vertical line to make or break contact with the upper fixed contacts mounted within the arc control devices.

A lower ring of fixed contacts is in permanent contact with the moving arm to provide the other terminal of the phase unit. Within the moving contact, the tube is a fixed piston. When the moving contact moves downwards, it forces the insulating oil to enter into the arc control devices. Thus, the arc gets extinguished.

Minimum oil circuit breaker requires less space as compared to bulk oil circuit breaker which is an important feature in large installations. But it is less suitable in places where the frequent operation is required because the degree of carbonization produced in the small volume of oil is far more dangerous than in the conventional bulk oil circuit breakers and this also decreases the dielectric strength of the material.

The low oil circuit breakers have the advantages of a requirement of the lesser quantity of oil, smaller space requirement, smaller tank size, smaller weight, low cost, reduced risk of fire and reduced maintenance problems. Minimum oil circuit breaker suffers from the following drawbacks when compared with the bulk oil circuit breakers



2. Write short notes on DC circuit breaker.

Ans: The HVDC circuit breaker is a switching device that interrupts the flow of abnormal direct current in the circuit. When the fault occurs in the system, the mechanical contacts of the circuit breaker are pulled apart and thus their circuit is open. In HVDC circuit breaker, circuit breaking is difficult because the current flow through it is unidirectional and there is no zero current.

The main application of the HVDC circuit breaker is to interrupt the high voltage direct current flows in the network. AC circuit breaker easily interrupts the arc at natural current zero in the AC wave. At zero current, the energy to be interrupted is also zero. The contact gap has to recover the dielectric strength to withstand natural transient recovery voltage.

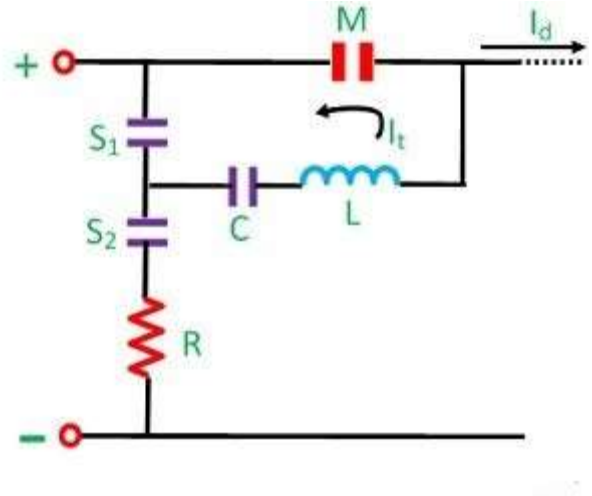
With DC circuit breakers, the problem is more complex as the DC waveform does not have natural current zeros. Forced arc interruption would produce high transient recovery voltage and restrike without arc interruption and ultimate

destruction of the breaker contacts. In designing of HVDC circuit breakers, there are three main problems to be overcome. These problems are

- Creation of artificial current zero.
- Prevention of restrikes arc.
- Dissipation of stored energy.

The artificial current zero principles are used in HVDC circuit breakers for arc extinction. By introducing a parallel L-C circuit, the arc current is subjected to oscillations. These oscillations are severe and have several artificial current zeros. The breaker extinguishes the arc at one of the artificial current zeros. The crest current of the oscillation must be greater than the direct current to be interrupted.

A series resonant circuit with L and C is connected across the main contact M of a conventional DC circuit breaker through an auxiliary contact S_1, and resistor R is connected through contact S_2. Under normal operating conditions, main contact M and charging contact S_2 remain closed, and the capacitor C is charged to line voltage through the high resistance R. Contact $S_1$is open and has line voltage across it.



For interrupting main circuit current I_d, the operating mechanism open contact S_2 and closes contact S_1. This indicates discharge of capacitor C through inductance L, main contact M and auxiliary contact S_1 setting up an oscillatory current shown in the figure below. Thus, artificial current zeros are created, and the circuit breaker main contact M is opened at a current zero. After that, contact S_1 is opened, and contact S_2 is closed.

3. Briefly explain various circuit breakers testing method.

Ans: **Testing of Circuit Breaker**

Testing of circuit breakers is more difficult as compared to other electrical equipment like transformer or machine because the short circuit current is very large. Testing of the transformer is mainly divided into two groups, type tests, and routine tests.

Type Tests of Circuit Breaker

Type tests are conducted for the purpose of proving the capabilities and confirming the rated characteristic of the circuit breaker. Such tests are conducted in the specially built testing laboratory. Type tests can be broadly classified as the mechanical performance test, thermal test, dielectric or insulating test, short circuit test for checking the making capacity, breaking capacity, short time rating current and operating duty.

Mechanical Test – It is mechanical ability type test involving the repeated opening and closing of the breaker. A circuit breaker must open and close at the correct speed and perform its designated duty and operation without mechanical failure.

Thermal Test – Thermal tests are carried out to check the thermal behavior of the circuit breakers. The breaker under test deal with the steady-state temperature rises due to the flow of its rated current through its pole in a rated condition. The temperature rise for rated current should not exceed 40° for current less than 800A normal current and 50° for normal value of current 800A and above.

Dielectric Test – These tests are performed to check power frequency and impulse voltage withstand capacity. Power frequency tests are kept on a new circuit breaker; the test voltage changes with a circuit breaker rated voltage.
The test voltage with a frequency between 15-100Hz is applied as follows. (1) between poles with circuit breaker closed (2) between pole and earth with circuit breaker open, and (3) across terminals with circuit breaker open.
In impulse tests impulse voltage of specified magnitude is applied to the breaker. For outdoor circuit dry and wet tests are conducted.

Short -Circuit Test – Circuit breakers are subjected to sudden short-circuits in short-circuit test laboratories, and oscillograms are taken to know the behavior of the circuit breakers at the time of switching in, during contact breaking and after the arc extinction.

The oscillograms are studied with particular reference to the making and breaking currents, both symmetrical and asymmetrical restriking voltages, and switchgear is sometimes tested at rated conditions.

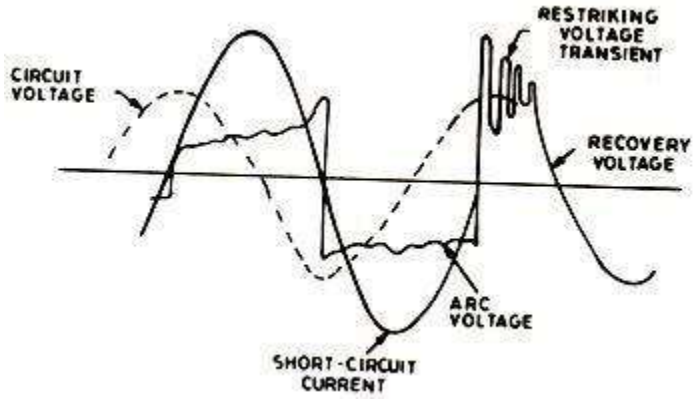
Routine Tests of a Circuit Breaker

Routine tests are also performed as per recommendations of the standards of Indian Engineering Service and Indian Standards. These tests are performed on the manufacturers' premises. Routine tests confirm the proper functioning of the circuit breaker. The routine tests confirm the proper functioning of the circuit breaker.

Power frequency voltage test being the same as mentioned under the heading of type tests, the mill volt drop test is performed to determine the voltage drop within the current path of the breaker mechanism. Operational test is performed on the breaker by simulating its tripping by artificially closing the contacts of the relays.

5. Explain the phenomena of current chopping.

Ans: While interrupting highly inductive current, like no-load current of transformer, the rapid deionization of contact space and blast effect may cause current interruption before its natural zero. Such an'interruption of current before its natural zero is termed as "**current chopping**".This phenomenon is more pronounced in case of air-blast circuit breakers which exerts the same deionizing force for all currents within its short-circuit capacity. Even though, the instantaneous value of current being interrupted may be less than the normal current rating of the breaker, it is quite dangerous from the point of view of overvoltages which may result in the system.



Let,
L = Inductance of the system
C = Capacitance of the system
i =Instantaneous value of arc current
V = Instantaneous value of capacitor voltage (which appears across the breaker when it opens)
The electromagnetic energy stored in the system at the instant before interruption is 1/2(Li²) As soon as the current is interrupted the value of i becomes zero. But, the electromagnetic energy stored in the system [1/2(Li²)] cannot become zero instantaneously and so it is converted into electrostatic energy [1/2(CV²)] as the system has some capacitance.
According to the principle of energy conversion we have,

$\frac{1}{2}\mathrm{L}i^2=\frac{1}{2}CV^2$

$\mathrm{V}=\mathrm{i}\sqrt{\frac{L}{C}}$

This theoretical value of V is called as "**prospective Voltage or Arc Voltage**". If this voltage is very high when compared with the gap withstanding voltage, then the gap breakdowns and so "the arc restrikes. Again the current is chopped (interrupted) because of high quenching force and so, restriking occurs. This process repeats until the current is suppressed finally without any restrike and this occurs near current zero

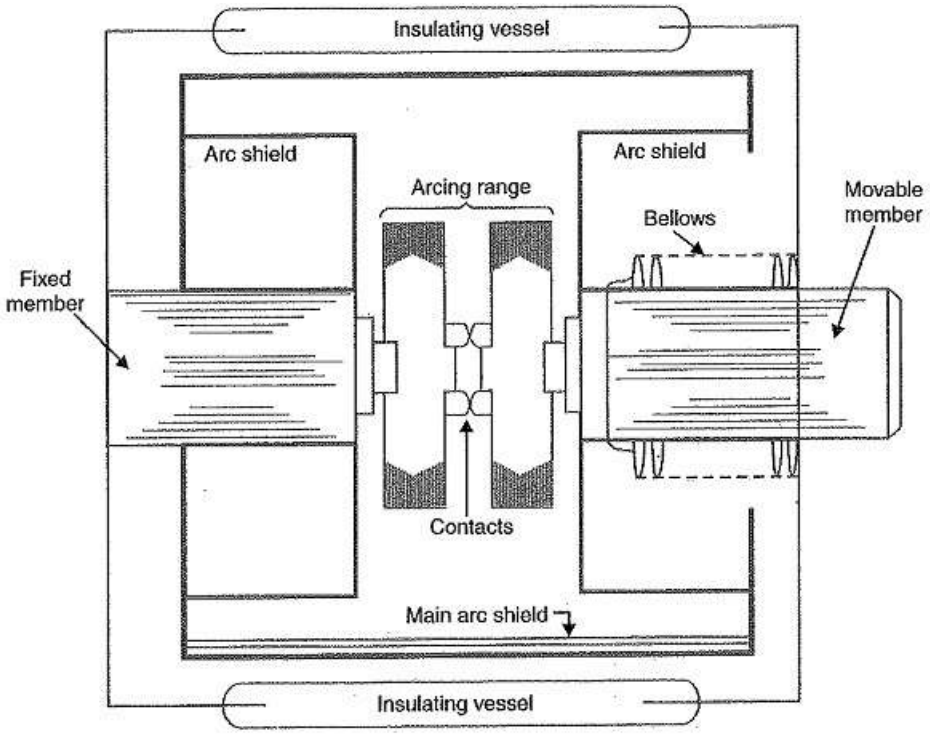
LONG QUESTION AND ANSWER-16 MARK EACH

1.Describe construction, operating principle and application of vacuum circuit breaker and for what voltage level it is used?

Ans: in Vacuum Circuit 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. For example, when contacts of a breaker are opened in vacuum, the interruption occurs at first current zero with dielectric strength between the contacts building up at a rate thousands of times higher than that obtained with other circuit breakers.

Principle: The production of arc in a vacuum circuit breaker and its extinction can be explained as follows: 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. The reader may note the salient feature of vacuum as an arc quenching medium. 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. **Construction**: Fig. below 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 metallic 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: They are compact, reliable and have longer life. There are no fire hazards. There is no generation of gas during and after operation. 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. They require little maintenance and are quiet in operation

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

2. With neat sketch describe working of air blast circuit breaker

Ans: Air blast circuit breaker used compressed air or gas as the arc interrupting medium. In the air blast, circuit breaker compressed air is stored in a tank and released through a nozzle to produce a high-velocity jet; this is used to extinguish the arc. Air blast circuit breakers are used for indoor services in the medium high voltage field and medium rupturing capacity. Generally up to voltages of 15 KV and rupturing capacities of 2500 MVA. The air blast circuit breaker is now employed in high voltage circuits in the outdoors switch yard for 220 KV lines.

Though gasses such as carbon dioxide, nitrogen, Freon or hydrogen are used as the arc interrupting medium, compressed air is the accepted circuit breaking medium for gas blast circuit breakers. The reasons are given below.

The circuit breaking capacities of nitrogen are similar to compressed air and hence no advantage of using it. Carbon dioxide has the drawback of its being difficult to control owing to freezing at valves and other restricted passages. Freon has high dielectric strength and good arc extinguishing properties, but it is expensive, and it is disintegrated by the arc into acid-forming elements. The desirable features to be found in air blast circuit breaker are

High-Speed Operation – It is very necessary on large interconnected networks so that the system stability can be maintained. This is achieved in circuit breaker because the time interval between the discharge of triggering impulse and contacts separation are very short.

Suitability for frequent operation – Repeated switching by an air blast circuit is possible simply because of the absence of oil, which rapidly carbonizes with the frequent operation and because there is an insignificant amount of wear and tear at the current-carrying contact surfaces. But it must be remembered that if frequent switching is anticipated, then the maintenance of a sufficient air supply is essential.

Negligible Maintenance – The ability of the air blast circuit breaker to deal with repeated switching also mean that negligible maintenance is required.

Elimination of Fire Hazard – Because of the absence of oil the risk of fire is eliminated.

Reduced Size – The growth of dielectric strength is so rapid in air blast circuit breakers that final gap required for arc extinction is very small. This reduces the sizes of the devices.

Principle of Arc Extinction in Circuit Breaker

The air blast needs an additional compressed air system which supplies air to the air receiver. When opening air is required, compressed air is admitted to the arc extinction chamber. It pushes away the moving contacts. In doing so, the contacts are pulled apart, and the air blast moves away the ionized gas along with it and assists arc extinction.

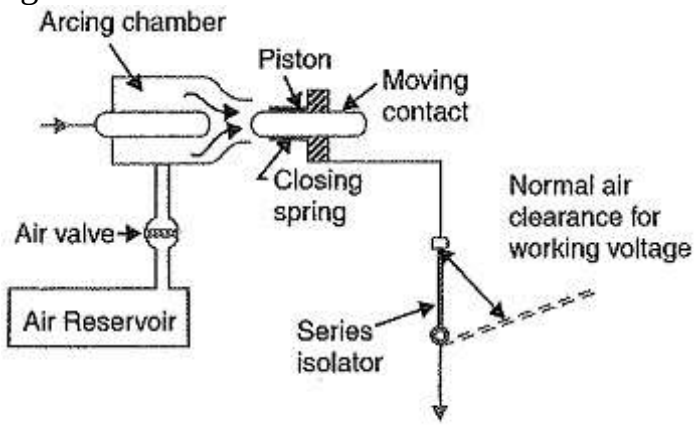
Air blast extinguishes the arc within one or more cycles, and the arc chamber is filled with high-pressure air, which prevents restrikes. The air blast circuit breakers fall under the category of external extinguishing energy type. The energy supplied for arc quenching is achieved from the high-pressure air, and it is free from the current to be interrupted

Types of Air Blast Circuit Breaker

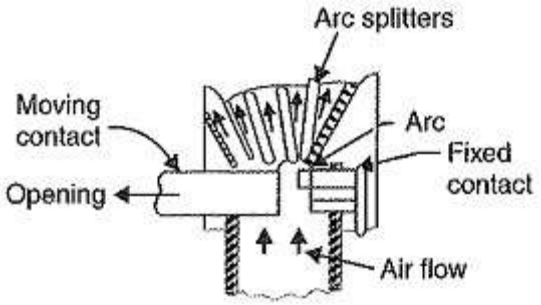
All air blast circuit breakers follow the principle of separating their contacts in a flow of arc established by the opening of a blast valve. The arc which is drawn is usually rapidly positioned centrally through a nozzle where it is kept to a fixed length and is subjected to the maximum range by the air flow. The air blast circuit breakers according to the type of flow of blast of compressed around the contacts are of three types namely axial, radial and cross blast.

Axial blast Air Circuit Breaker – In the air blast circuit breaker, the flow of air is longitudinal along the arc. Air blast circuit breaker may be a single blast or double blast. Breakings employing double blast arrangement are sometimes called radial

blast circuit breakers as the air blast flows radially into the nozzle or space between the contacts. The essential feature of air blast circuit breaker is shown above. The fixed and moving contacts are kept in a closed position by spring pressure under normal operating conditions. The air reservoir tank is connected to the arc chamber through an air valve, which is opened by a triple impulse. When the fault occurs, the tripling impulse causes opening of the air valve connecting the reservoir to the arcing chamber. The air entering the arc chamber exerts pressure on the moving contacts which moves when the air pressure exceeds the spring force.
The contacts are separated, and an arc is developed between them. The air flowing at a great speed axially along the arc cause removal of heat from the edge of the arc and the diameter of the arc reduced to a very small value at current zero. Thus, the arc is interrupted, and the space between the contacts is flushed with fresh air flowing through the nozzle. The flow of fresh air removes the hot gasses between the contacts is flushed with fresh air flowing through the nozzle. The flow of fresh air removes the hot gasses between the



<u>Cross Blast Air Circuit Breaker</u> – In such breaker, an arc blast is directed at right angles to the arc. The schematic representation of the cross principle of cross blast air circuit breaker is given in the figure below. A moving contact arm is operated in close spaces to draw an arc which is forced by a transverse blast of air into the splitter plates, thereby lightening it to the point when it cannot restrike after zero current.
Resistance switching is not normally required as the lightening of arc automatically introduces some resistance to control the restriking voltage transient but if extra resistance is thought desirable. It is possible to introduce it by connecting it in the section across the arc splitter.



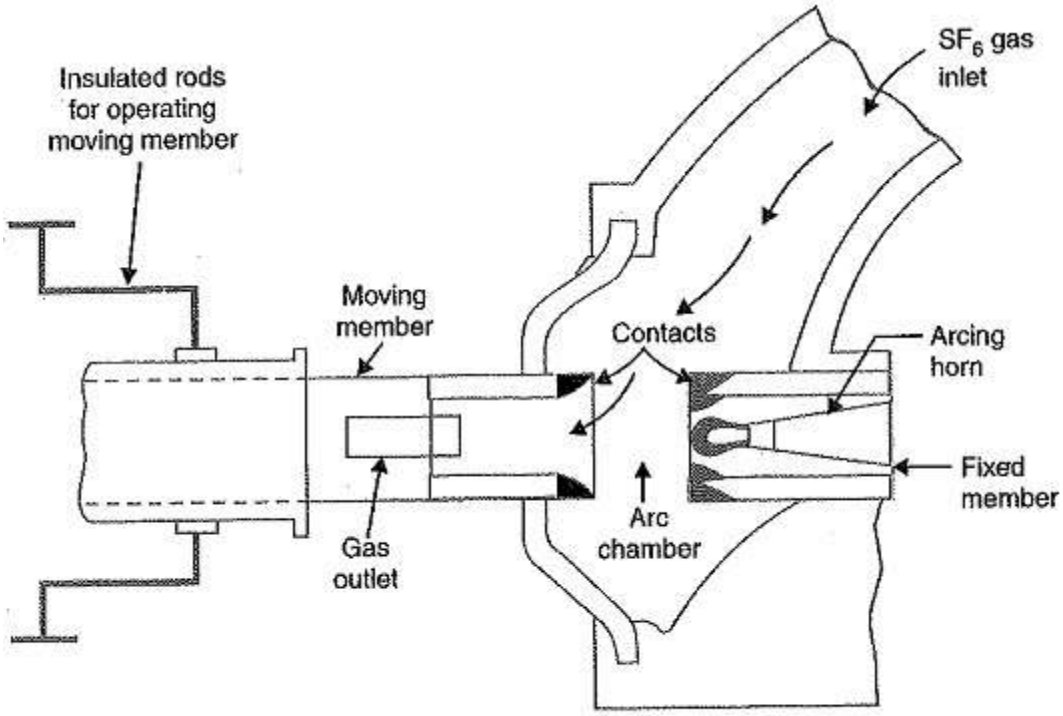
3. With neat sketch explain sf6 circuit breaker .mention its advantage .point the problem associated with sf6 circuit breaker.

ANS: Sulphur Hexafluoride Circuit Breaker: In Sulphur Hexafluoride Circuit Breaker (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 SF6gas 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 synchronized with the opening of a valve which permits SF6 gas at 14kg/cm2 pressure from the reservoir to the arc interruption chamber. The high pressure flow of Sulphur Hexafluoride Circuit Breaker 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: Due to the superior arc quenching properties of SF6 gas, the SF6 circuit breakers have many advantages over oil or air circuit breakers. Some of them are listed below : Due to the superior arc quenching property of SF6, such circuit breakers have very short arcing time. Since the dielectric strength of SF6 gas is 2 to 3 times that of air, such breakers can interrupt much larger currents. The SF6 circuit breaker gives noiseless operation due to its closed gas circuit and no exhaust to atmosphere unlike the air blast circuit breaker. The closed gas enclosure keeps the interior dry so that there is no moisture problem. There is no risk of fire in such breakers because SF6 gas is non-inflammable. There are no carbon deposits so that tracking and insulation problems are eliminated. The SF6 breakers have low maintenance cost, light foundation requirements and minimum auxiliary equipment. Since SF6 breakers are totally enclosed and sealed from atmosphere, they are particularly suitable where explosion hazard exists e.g., coal mines. Disadvantages: Sulphur Hexafluoride Circuit Breaker are costly due to the high cost of SF6. Since Sulphur Hexafluoride Circuit Breaker gas has to be reconditioned after every operation of the breaker, additional equipment is required for this purpose. Applications: A typical Sulphur Hexafluoride Circuit Breaker of interrupter units each capable of dealing with currents up to 60 kA and voltages in the range of 50-80 kV. A number of units are connected in series according to the system voltage. SF6 circuit breakers have been developed for voltages 115 kV to 230 kV, power ratings 10 MVA to 20 MVA and interrupting time less than 3 cycles.

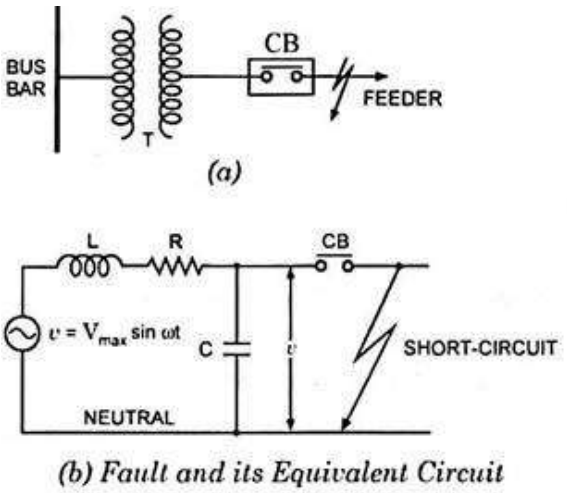


4. **What is restriking voltage transient and deduce its expression. What is the characteristic of restriking voltage transient? Derive the expression of RRRV.**

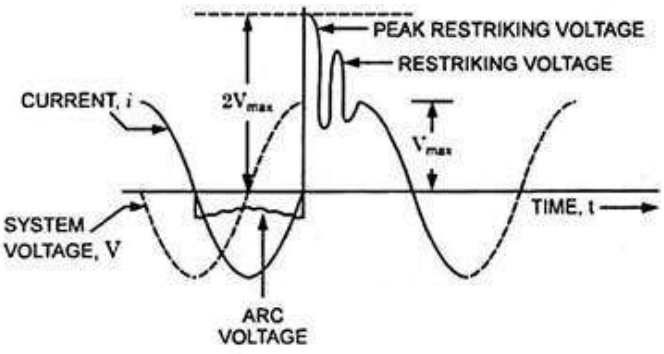
Ans: When the current across the contact of the circuit breaker is zero, a high-frequency transient voltage develops in the whole breaker contact and is produced by the sudden distribution of energy between the electric and magnetic field. This transient voltage is called restriking voltage. The voltage appears across the breaker contacts at the moment of final current has a serious influence on the arc extinction process. Under the influence of this voltage, the arc tries to restrike and hence it is named as the restriking voltage.

After the zero current, the arc gets extinguished, if the rate of rising of restriking voltage between the contact is less than the rate at which the dielectric strength of the medium between the contact gains. Immediately after the final current interruption, the voltage that appears across the breaker contacts (transient voltage) superimposed on the power frequency system voltage (recovery voltage).

Considered a simple circuit, having a circuit breaker CB, as shown in the figure below



(b) Fault and its Equivalent Circuit



(c) Operating of a Circuit Breaker

. Let L be the inductance per phase of the system up to the fault point; R be the resistance per phase of the system up to the fault point, and C be the capacitance of the circuit.

When the fault occurs in the system under fault condition the contacts of the breaker are open, and the capacitance C is short-circuited by the fault, and the short circuit current is limited by the resistance and the inductance.

When the breaker contacts are opened, and the arc certainly quenches at some current zero, a voltage v is suddenly applied across the capacitor and therefore across the circuit breaker contacts. The current i which would flow to the fault is not injected in the capacitor and inductor. Thus

$$i = i_L + i_C$$

$$i = \frac{1}{L}\int v dt + C\frac{dv}{dt}$$

$$\frac{di}{dt} = \frac{v}{L} + C\frac{d^2s}{dt^2} \ldots\ldots\ldots\ldots\ldots equ(1)$$

Assuming Zero time at zero currents when t = 0 and the value of current and voltage before opening of circuit breaker is expressed as

$$\frac{di}{dt} = \frac{V_{max}}{wl} \times w \times coswt$$

$$t = 0; \quad \left|\frac{di}{dt}\right| = \frac{V_{max}}{L}$$

On substituting the above values in equation (1), we get

$$\frac{V_{max}}{L} = \frac{v}{L} + C\frac{d^2v}{dt^2}$$

$$v = V_{max}\left[1 - cos\frac{1}{\sqrt{LC}}\right] = V_{max}(1 - 2\pi f_n t) \ldots\ldots\ldots equ(3)$$

Characteristic of Restriking Voltage

The important characteristic of restriking voltage which affects the performance of the circuit breaker is as follows –

Amplitude Factor – It is defined as the ratio of the peak of transient voltage to the peak system frequency voltage.

The rate of Rising of Restriking Voltage – It is defined as the slope of the steepness tangent of the restriking voltage curve. It is expressed in kV/μs. RRRV is directly proportional to the natural frequency. The expression for the restriking voltage is expressed as

$$RRRV_{max} = \frac{V_{max}}{\sqrt{LC}}$$

The transient voltage vanishes rapidly due to the damping effect of system resistance, and the normal frequency system voltage is established. This voltage across the breakers contact is called recovery voltage.

Expression for RRRV: It is given as –

$$v = V_{max}\left(1 - \cos\frac{t}{\sqrt{LC}}\right)$$

$$\text{and RRRV} = \frac{dv}{dt} = \frac{V_{max}}{\sqrt{LC}}\sin\frac{t}{\sqrt{LC}}$$

RRRV will be maximum when $\sin\frac{t}{\sqrt{LC}} = 1$ or $t = \frac{\pi}{2}\sqrt{LC}$

Hence maximum value of RRRV, $RRRV_{max} = V_{max}/\sqrt{LC}$

Further, the peak restriking voltage occurs when v is maximum *i.e.*, when

$$\frac{dv}{dt} = 0 \quad \text{or} \quad \sin\frac{t}{\sqrt{LC}} = 0 \text{ or } t = \pi\sqrt{LC}$$