5.1.Types of circuit breakers

(i) Air-blast circuit breakers

(ii) Oil circuit breakers

(iii) Sulphur hexafluoride circuit breaker

(iv) Vacuum circuit breakers

5.8.1Air blast CB

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

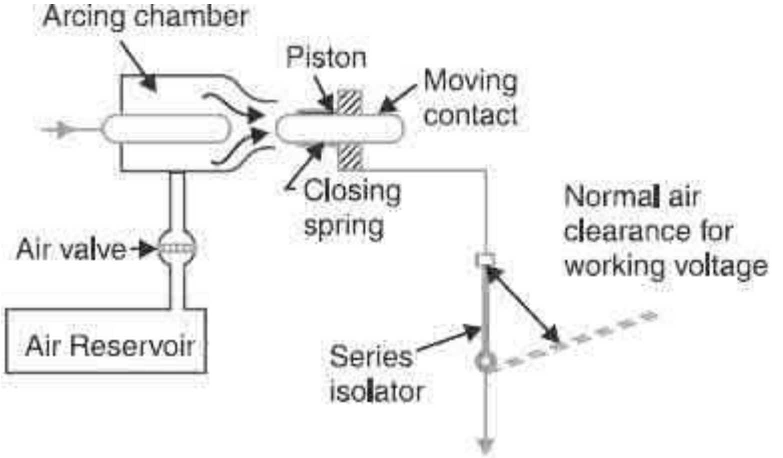
Types of Air-Blast Circuit Breakers

(i) Axial-blast type

(ii) Cross-blast type

(iii) Radial-blast type

Axial-blast air circuit breaker



The fixed and moving contacts are held in the closed position byspring pressure under normal conditions. The air reservoir is connected to the arcing chamberthrough an air valve. This valve remains closed under normal conditions but opensautomatically by the tripping impulse when a fault occurs on the system.

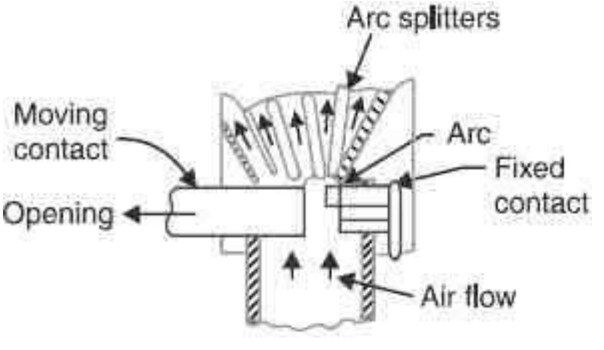
When a fault occurs, the tripping impulse causes opening of the air valve which connects thecircuit breaker reservoir to the arcing chamber. The high pressure air entering the arcing chamberpushes away the moving contact against spring pressure. The moving contact is separated and an arcis struck. At the same time, high pressure air blast flows along the arc and takes away the ionisedgases along with it. Consequently, the arc is extinguished and current flow is interrupted.

It may be noted that in such circuit breakers, the contact separation required for interruption isgenerally small (1·75 cm or so). Such a small gap may constitute inadequate clearance for the normalservice voltage. Therefore, an isolating switch is incorporated as a part of this type of circuit breaker.

Cross-blast air breaker.

In this type of circuit breaker, an air-blast is directed at rightangles to the arc. The cross-blast lengthens and forces the arc into a suitable chute for arcextinction

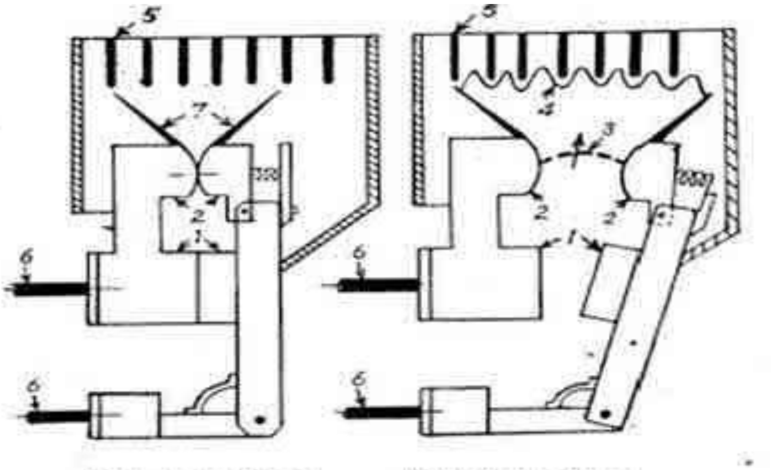
Whenthe moving contact is withdrawn, an arc is struckbetween the fixed and moving contacts. The highpressure cross-blast forces the arc into a chute consistingof arc splitters and baffles. The splittersserve to increase the length of the arc and bafflesgive improved cooling. The result is that arc isextinguished and flow of current is interrupted.Since blast pressure is same for all currents, theinefficiency at low currents is eliminated. The final gap for interruption is great enough togive normal insulation clearance so that a series isolating switch is not necessary.



5.8.2 Air break CB

In air break circuit breaker the arc is initiated and extinguish in substantially static air in which the arc moves. Such breakers are used for low voltages, generally up to 15KV and rupturing capacities of 500MVA. Air circuit breaker has several advantages over the oil, as an arc quenching medium. These are

- Elimination of risk and maintenance associated with the use of oil.
- The absence of mechanical stress that is set up by gas pressure and oil movement.
- Elimination of the cost of regular oil replacement that arises due to deterioration of oil with the successive breaking operation.



(I) Contacts Closed (II) Contacts Open

Principle of air-break circuit breaker

1. Main contacts
2. Arcing contacts
3. Arc rising in the direction of the arrow
4. Arc getting split
5. Arc splitter plates
6. Current carrying termina
7. Arc runners

In the air break, circuit breaker the contact separation and arc extinction take place in air at atmospheric pressure. In air break circuit breaker high resistance principle is employed. In this circuit breaker arc is expanded by the mean of arc runners, arc chutes, and arc resistance is increased by splitting, cooling and lengthening.

The arc resistance is increased to such an extent that the voltage drop across the arc becomes more than the system voltage, and the arc gets extinguished at the current zero ofAC wave.

Air break circuit breakers are employed in DC circuits and Ac circuits up to 12,000 voltages. Such breakers are usually of indoor type and installed on vertical panels or indoor draw out switch gear. AC circuit breakers are widely employed indoor medium voltage and low voltage switchgear.

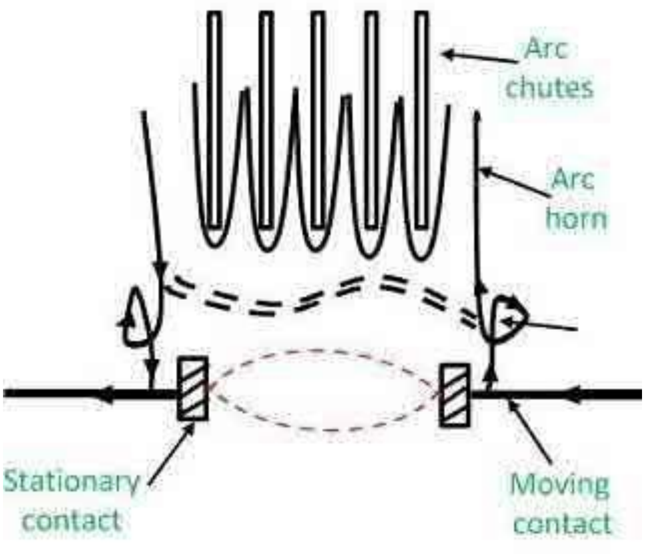
<u>Plain Break Type Air Break Circuit Breaker</u>

It is the simplest one in which contacts are made in the shape of two horns. The air initially strikes across the shortest distance between the horns and is driven steadily upwards by the convection currents caused by heating of air during arcing and the interaction of the magnetic and the electric fields. The arc extends from one tip to the other when the horns are fully separated resulting in lengthening and cooling arc.The relative slowness of the process and the possibility of arc spreading of adjacent metal works limits the application of about 500V and too low power circuits.

<u>Magnetic Blow-Out Type Air Break Circuit Breaker</u>

Some air circuit breakers are used in the circuits having voltage up to 11 KV, the arc extinction is accomplished using magnetic field provided by the current in blowout coils connected in series with the circuit being interrupted. Such coils are called blow out the coil.

The magnetic field itself does not extinguish the arc. It simply moves the arc into chutes where the arc is lengthened, cooled and extinguished. The arc shields prevent arc spreading to an adjacent network.



It is important to connect the coils at correct polarity so that the arc is directed upwards. As the breaking action becomes more effective with large currents, this principle has resulted in increasing the rupturing capacities of such breakers to higher values.

Arc chute is an efficient device for arc extinction in air and performs the following three interrelated functions

- 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 ensures arc extinction by deionization.

Air Chute Air Break Circuit Breaker

The normal arrangement of air-chute air break circuit breaker employed for low and medium voltage circuits is shown in the figure below. There are two sets of contacts called the main contacts and arcing or auxiliary contacts. Main contacts are usually of copper and conduct the current in the closed position of the breakers. They have low contact resistance and are silver plated.

The arcing contacts are hard, heat resistant and usually of copper alloy. Arcing contacts are used to relieve the main contacts from damage due to arcing. The arcing contactsare easily renewable when required. The auxiliary and arcing contacts close before and open after the main contacts during the operation.

Here the blowouts consist of a steel insert in the arcing chutes. These are so arranged that the magnetic field induced in them by the current in the arc moves it upwards still faster. The steel plates divide the arc into a number of arcs in the series.

The distribution of voltage along the arc length is not linear, but it is accompanied by a rather large anode and cathode drops. In case the total sum of anode and drops of all the short arcs in series exceeds the system voltage, conditions for the quick extinction of the arc are automatically established.

When the contact has come in contact with the relatively cool surfaces of the steel plants gets rapidly and effectively cooled. The movement of the arc may be naturally or aidedby a magnetic blowout. Thus, the arc is extinguished by lightening and increasing the power loss of the arc.

Working Principle Air Break Circuit Breaker

When the fault occurs, the main contacts are separate first, and the current is shifted to the arcing contacts. Now the arcing contacts are separate, and the arc is drawn between them. This arc is forced upwards by the electromagnetic forces and thermal action. The arc ends travel along the arc runner. The arc moves upward and is split by the arc splitter plates. The arc is extinguished by lengthening, cooling, splitting, etc.

Applications of Air Break Circuit Breaker

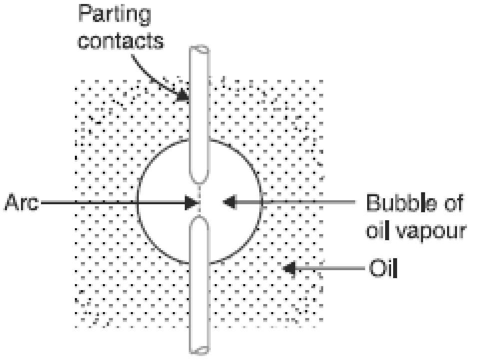
Air break circuit breaker is suitable for the control of power station auxiliaries and industrial plants. They do not require any additional equipment such as compressors, etc. They are mainly used in a place where there are possibilities of fire or explosion hazards. Air break principle of lengthening of the arc, arc runners magnetic blow-up is employed for DC circuit breakers up to 15 KV.

Drawback of Air Break Circuit Breaker

A drawback of arc chute principle is its inefficiency at low currents where the electromagnetic fields are weak. The chute itself is not necessarily less efficient in its lengthening and deionizing action than at high currents, but the arc movement into the chute tends to become slower, and high-speed interruption is not necessarily obtained

5.8.3.Oil CB

In such circuit breakers, some insulating oil (*e.g.*, transformeroil) is used as an arc quenching medium. The contactsare opened under oil and an arc is struck betweenthem. The heat of the arc evaporates the surrounding oiland dissociates it into a substantial volume of gaseous hydrogenat high pressure. The hydrogen gas occupies avolume about one thousand times that of the oil decomposed.The oil is, therefore, pushed away from the arc andan expanding hydrogen gas bubble surrounds the arc regionand adjacent portions of the contacts.



The arc extinction is facilitated mainly by two processes.Firstly, the hydrogen gas has high heat conductivity andcools the arc, thus aiding the de-ionisation of the medium between the contacts. Secondly, the gassets up turbulence in the oil and forces it into the space between contacts, thus eliminating the arcingproducts from the arc path. The result is that arc is extinguished and circuit current †interrupted.

Advantages.

The advantages of oil as an arc quenching medium are :

(i) It absorbs the arc energy to decompose the oil into gases which have excellent cooling properties.

(ii) It acts as an insulator and permits smaller clearance between live conductors and earthed components.

(iii) The surrounding oil presents cooling surface in close proximity to the arc.

Disadvantages.

The disadvantages of oil as an arc quenching medium are:

(i) It is inflammable and there is a risk of a fire.

(ii) It may form an explosive mixture with air

(iii) The arcing products (*e.g.*, carbon) remain in the oil and its quality deteriorates with successive operations. This necessitates periodic checking and replacement of oil.

Types of Oil Circuit Breakers

The oil circuit breakers find extensive use in the power system. These can be classified into thefollowing types:

(i) *Bulk oil circuit breakers*which use a large quantity of oil. The oil has to serve two purposes.

Firstly, it extinguishes the arc during opening of contacts and secondly, it insulates the currentconducting parts from one another and from the earthed tank. Such circuit breakersmay be classified into :

(a) Plain break oil circuit breakers

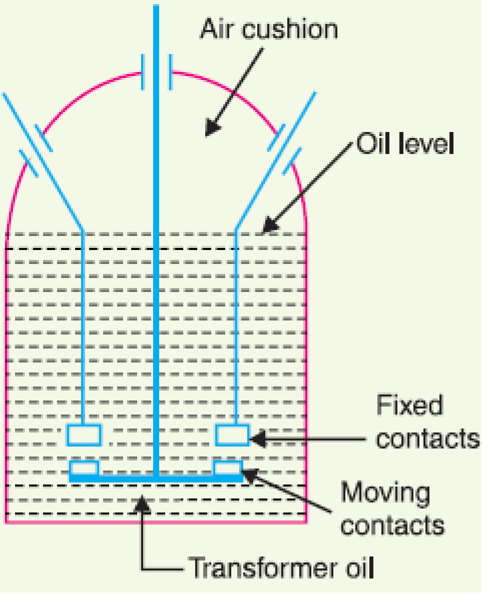
(b) Arc control oil circuit breakers.

In the former type, no special means is available for controlling the arc and the contacts aredirectly exposed to the whole of the oil in the tank. However, in the latter type, special arc controldevices are employed to get the beneficial action of the arc as efficiently as possible.

(ii) *Low oil circuit breakers*which use minimum amount of oil. In such circuit breakers, oil isused *only* for arc extinction; the current conducting parts are insulated by air or porcelain or organic insulating material.

Plain Break Oil Circuit Breakers

A plain-break oil circuit breaker involves the simple process of separating the contacts under thewhole of the oil in the tank. There is no special system for arc control other than the increase in lengthcaused by the separation of contacts. The arc extinction occurs when a certain critical gap betweenthe contacts is reached.The plain-break oil circuit breaker is the earliest type fromwhich all other circuit breakers have developed. It has a verysimple construction.



It consists of fixed and moving contactsenclosed in a strong weather-tight earthed tank containing oil uptoa certain level and an air cushion above the oil level. The aircushion provides sufficient room to allow for the reception of thearc gases without the generation of unsafe pressure in the domeof the circuit breaker. It also absorbs the mechanical shock ofthe upward oil movement. It is called a double break because it providestwo breaks in series.Under normal operating conditions, the fixed and movingcontacts remain closed and the breaker carries the normal circuitcurrent. When a fault occurs, the moving contacts are pulleddown by the protective system and an arc is struck whichvaporises the oil mainly into hydrogen gas. The arc extinctionis facilitated by the following processes:

(i) The hydrogen gas bubble generated around the arc cools the arc column and aids the deionisationof the medium between the contacts.

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

(iii) As the arc lengthens due to the separating contacts, the dielectric strength of the medium isincreased.The result of these actions is that at some critical gap length, the arc is extinguished and thecircuit current is interrupted.

<u>Disadvantages</u>

(i) There is no special control over the arc other than the increase in length by separating themoving 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 applicationswhere high breaking-capacities are not important. It is a usual practice to use such breakersfor low capacity installations for voltages not exceeding †11 kV.

<u>Arc Control Oil Circuit Breakers</u>

In case of plain-break oil circuit breaker discussed above, there is very little artificial control over thearc. Therefore, comparatively long arc length is essential in order that turbulence in the oil caused bythe gas may assist in quenching it. However, it is necessary and desirable that final arc extinctionshould occur while the contact gap is still short. For this purpose, some arc control is incorporatedand the breakers are then called arc control circuit breakers. There are two types of such breakers,namely :

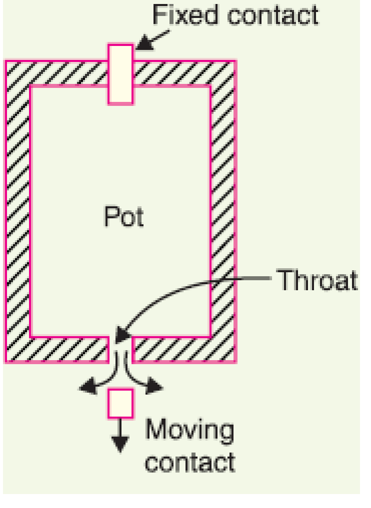
(i) *Self-blast oil circuit breakers*— in which arc control is provided by internal means *i.e.* the arc itself is employed for its own extinction efficiently.

(ii) *Forced-blast oil circuit breakers*— in which arc control is provided by mechanical meansexternal to the circuit breaker.

<u>(i) Self-blast oil circuit breakers.</u>

In this type of circuit breaker, the gases produced duringarcing are confined to a small volume by the use of an insulating rigid pressure chamber or potsurrounding the contacts. Since the space available for the arc gases is restricted by the chamber, avery high pressure is developed to force the oil and gas through or around the arc to extinguish it. Themagnitude of pressure developed depends upon the value of fault current to be interrupted. As thepressure is generated by the arc itself, therefore, such breakers are sometimescalled self-generated pressure oil circuit breakers.The pressure chamber is relatively cheap to make and gives reducedfinal arc extinction gap length and arcing time as against the plain-breakoil circuit breaker. Several designs of pressure chambers (sometimes calledexplosion pots) have been developed and a few of them are describedbelow :

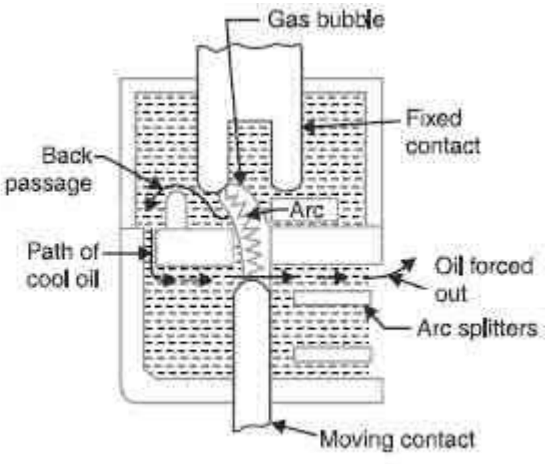
(a) Plain explosion pot.It is a rigid cylinder of insulating materialand encloses the fixed and moving contacts. The movingcontact is a cylindrical rod passing through a restricted opening (calledthroat) at the bottom.



When a fault occurs, the contacts get separated andan arc is struck between them. The heat of the arc decomposes oil into agas at very high pressure in the pot. This high pressure forces the oil andgas through and round the arc to extinguish it. If the final arc extinction does not take place while themoving contact is still within the pot, it occurs immediately after the moving contact leaves the pot. Itis because emergence of the moving contact from the pot is followed by a violent rush of gas and oilthrough the throat producing rapid extinction.The principal limitation of this type of pot is that it cannot be used for very low or for very highfault currents. With low fault currents, the pressure developed is small, thereby increasing the arcingtime. On the other hand, with high fault currents, the gas is produced so rapidly that explosion pot isliable to burst due to high pressure. For this reason, plain explosion pot operates well on moderateshort-circuit currents only where the rate of gas evolution is moderate.

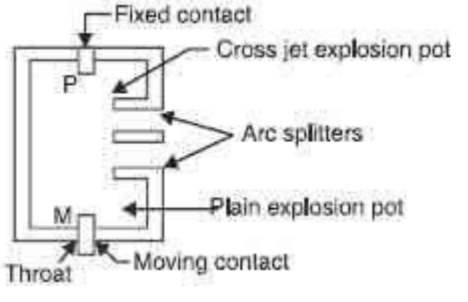
Cross jet explosion pot.

This type of pot is just a modification of plain explosion pot andis illustrated in Fig.



It is made of insulating material and has channels on one side which act asarc splitters. The arc splitters help in increasing the arc length, thus facilitating arc extinction. Whena fault occurs, the moving contact of the circuit breaker begins to separate. As the moving contact iswithdrawn, the arc is initially struck in the top of the pot. The gas generatedby the arc exerts pressureon the oil in the back passage. When the moving contact uncovers the arc splitter ducts, fresh oil isforced *across* the arc path. The arc is, therefore, driven sideways into the –arc splitters‖ whichincrease the arc length, causing arc extinction.Thecross-jet explosion pot is quite efficient for interrupting heavy fault currents. However, forlow fault currents, the gas pressure is †small and consequently the pot does not give a satisfactoryoperation.

(*c*) Self-compensated explosion pot. This type of pot is essentially a combination of plainexplosion pot and cross jet explosion pot. Therefore, it can interrupt low as well as heavy shortcircuit currents with reasonable accuracy.



It consists of two chambers; the upper chamber is the cross-jet explosion pot with two arc splitter ducts while the lowerone is the plain explosion pot. When the short-circuit current is heavy, the rate of generation of gas isvery high and the device behaves as a cross-jet explosion pot. The arc extinction takes place when themoving contact uncovers the first or second arc splitter duct. However, on low short-circuit currents,the rate of gas generation is small and the tip of the moving contact has the time to reach the lowerchamber. During this time, the gas builds up sufficient pressure as there is very little leakage througharc splitter ducts due to the obstruction offered by the arc path and right angle bends. When themoving contact comes out of the throat, the arc is extinguished by plain pot action.It may be noted that as the severity of the short-circuit current increases, the device operates lessand less as a plain explosion pot and more and more as a cross-jet explosion pot. Thus the tendencyis to make the control self-compensating over the full range of fault currents to be interrupted.

(ii) Forced-blast oil circuit breakers.

In the self-blast oil circuit breakers discussed above, thearc itself generates the necessary pressure to force the oil across the arc path. The major limitation ofsuch breakers is that arcing times tend to be long and inconsistent when operating against currentsconsiderably less than the rated currents. It is because the gas generated is much reduced at lowvalues of fault currents. This difficulty is overcome in forced-blast oil circuit breakers in which thenecessary pressure is generated by external mechanical means independent of the fault currents to bebroken.In a forced -blast oil circuit breaker, oil pressure is created by the piston-cylinder arrangement.The movement of the piston is mechanically coupled to the moving contact. When a fault occurs, thecontacts get separated by the protective system and an arc is struck between the contacts. The pistonforces a jet of oil towards the contact gap to extinguish the arc. It may be noted that necessary oilpressure produced does not in any way depend upon the fault current to be broken.

Advantages

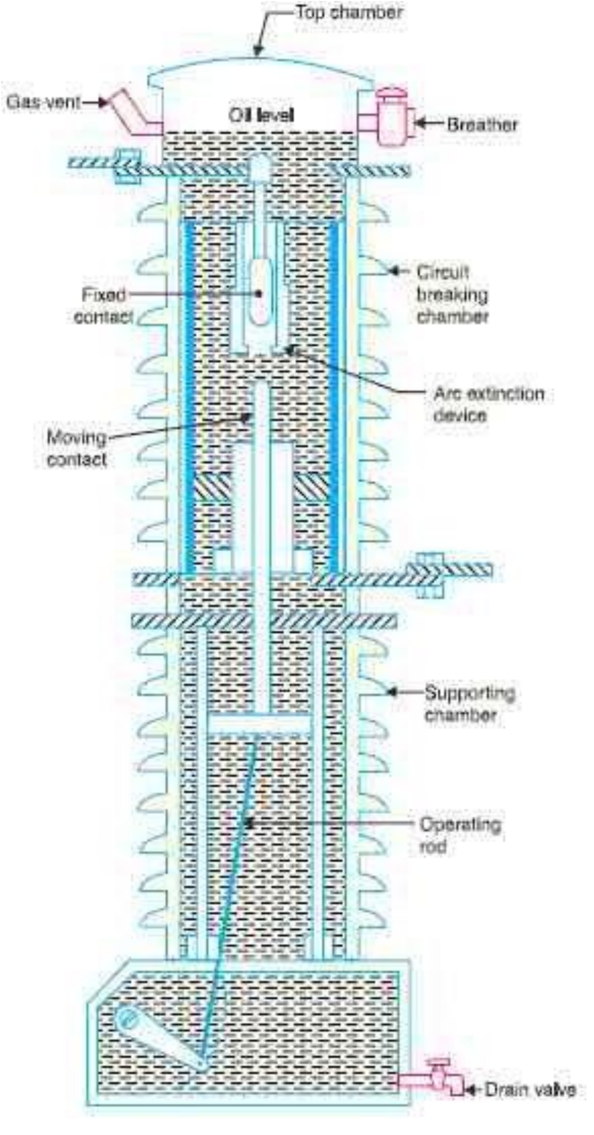
(a) Since oil pressure developed is independent of the fault current to be interrupted, the performanceat low currents is more consistent than with self-blast oil circuit breakers.

(b) The quantity of oil required is reduced considerably.

Low Oil Circuit Breakers

In the bulk oil circuit breakers discussed so far, the oil has to perform two functions. Firstly, it acts asan arc quenching medium and secondly, it insulates the live parts from earth. It has been found thatonly a small percentage of oil is actually used for arc extinction while the major part is utilised forinsulation purposes. For this reason, the quantity of oil in bulk oil circuit breakers reaches a very highfigure as the system voltage increases. This not only increases the expenses, tank size and weight ofthe breaker but it also increases the fire risk and maintenance problems.

The fact that only a small percentage of oil (about 10% of total) in the bulk oil circuit breaker isactually used for arc extinction leads to the question as to why the remainder of the oil, that is notimmediately surrounding the device, should not be omitted with consequent saving in bulk, weightand fire risk. This led to the development of low-oil circuit breaker. A low oil circuit breakeremploys solid materials for insulation purposes and uses a small quantity of oil which is just sufficientfor arc extinction. As regards quenching the arc, the oil behaves identically in bulk as well as low oilcircuit breaker. By using suitable arc control devices, the arc extinction can be further facilitated in alow oil circuit breaker.



Construction.

Thereare two compartments separated from each other but both filled with oil. The upper chamber is thecircuit breaking chamber while the lower one is the supporting chamber. The two chambers areseparated by a partition and oil from one chamber is prevented from mixing with the other chamber.This arrangement permits two advantages. Firstly, the circuit breaking chamber requires a smallvolume of oil which is just enough for arc extinction. Secondly, the amount of oil to be replaced isreduced as the oil in the supporting chamber does not get contaminated by the arc.

(i) *Supporting chamber.*

It is a porcelain chamber mounted on a metal chamber. It is filled withoil which is physically separated from the oil in the circuit breaking compartment. The oilinside the supporting chamber and the annular space formed between the porcelain insulationand bakelised paper is employed for insulation purposes only.

(ii) *Circuit-breaking chamber.*

It is a porcelain enclosure mounted on the top of the supportingcompartment. It is filled with oil and has the following parts :

(a) upper and lower fixed contacts

(b) moving contact

(c) turbulator

The moving contact is hollow and includes a cylinder which moves down over a fixed piston.The turbulator is an arc control device and has both axial and radial vents. The axial venting ensuresthe interruption of low currents whereas radial venting helps in the interruption of heavy currents

(iii) *Top chamber.*

It is a metal chamber and is mouted on the circuit-breaking chamber. Itprovides expansion space for the oil in the circuit breaking compartment. The top chamberis also provided with a separator which prevents any loss of oil by centrifugal action causedby circuit breaker operation during fault conditions.

Operation.

Under normal operating conditions, the moving contact remains engaged with theupper fixed contact. When a fault occurs, the moving contact is pulled down by the tripping springsand an arc is struck. The arc energy vaporises the oil and produces gases under high pressure. Thisaction constrains the oil to pass through a central hole in the movingcontact and results in forcingseries of oil through the respective passages of the turbulator. The process of turbulation is orderlyone, in which the sections of the arc are successively quenched by the effect of separate streams of oilmoving across each section in turn and bearing away its gases.

Advantages.

A low oil circuit breaker has the following advantages over a bulk oil circuit breaker:

(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.

A low oil circuit breaker has the following disadvantages as compared to a bulkoil circuit breaker:

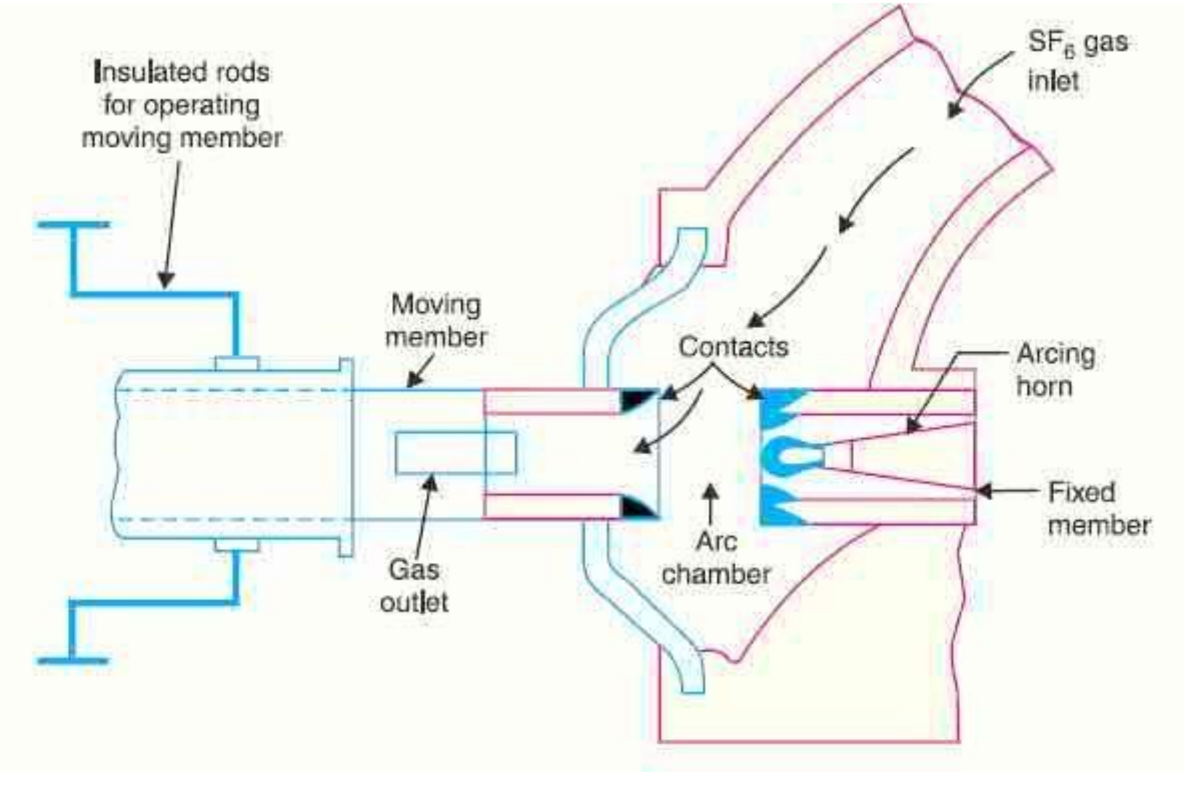
(i) Due to smaller quantity of oil, the degree of carbonisation is increased.

(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.

5.8.4 SF6 CB

In such circuit breakers, sulphur hexaflouride (SF6) gas is used as the arc quenching medium. TheSF6 is an electro-negative gas and has a strong tendency to absorb free electrons. The contacts of thebreaker are opened in a high pressure flow of SF6 gas and an arc is struck between them. Theconducting free electrons in the arc are rapidly captured by the gas to form relatively immobilenegative ions. This loss of conducting electrons in the arc quickly builds up enough insulation strengthto extinguish the arc. The SF6 circuit breakers have been found to be very effective for high powerand high voltage service.



Construction

It consists of fixedand 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 valvemechanism permits a high pressure SF6 gas from the reservoir to flow towards the arc interruptionchamber. 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 gasto let out through these holes after flowing along and across the arc. The tips of fixed contact, movingcontact and arcing horn are coated with copper-tungsten arc resistant material. Since SF6 gas iscostly, 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 apressure of about 2·8 kg/cm2. When the breaker operates, the moving contact is pulled apart and anarc is struck between the contacts. The movement of the moving contact is synchronised with theopening of a valve which permits SF6 gas at 14 kg/cm2 pressure from the reservoir to the arc interruptionchamber. The high pressure flow of SF6 rapidly absorbs the free electrons in the arc path to formimmobile negative ions which are ineffective as charge carriers. The result is that the medium betweenthe 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 ofsprings.

Advantages.

Due to the superior arc quenching properties of SF6 gas, the SF6 circuit breakershave many advantages over oil or air circuit breakers. Some of them are listed below :

(i) Due to the superior arc quenching property of SF6, such circuit breakers have very shortarcing time.

(ii) Since the dielectric strength of SF6 gas is 2 to 3 times that of air, such breakers can interruptmuch larger currents.

(iii) The SF6 circuit breaker gives noiselss 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 minimumauxiliary equipment.

(viii) Since SF6 breakers are totally enclosed and sealed from atmosphere, they are particularlysuitable 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 equipmentis required for this purpose.

Applications.

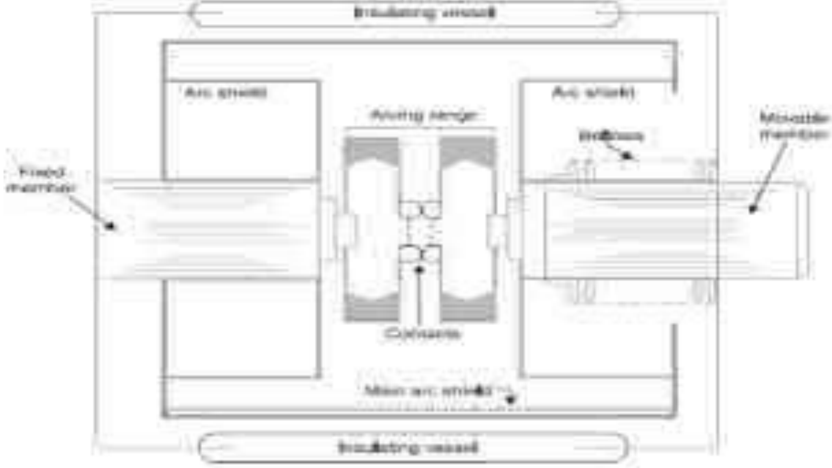
A typical SF6 circuit breaker consists of interrupter units each capable of dealingwith currents upto 60 kA and voltages in the range of 50—80 kV. A number of units are connectedinseries according to the system voltage. SF6 circuit breakers have been developed for voltages 115 kVto 230 kV, power ratings 10 MVA to 20 MVA and interrupting time less than 3 cycles.

5.8.5 Vaccum CB

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. 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 explainedas 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 isquickly extinguished because the metallic vapours, electrons and ions produced during arc rapidlycondense on the surfaces of the circuit breaker contacts, resulting in quick recovery of dielectricstrength. The reader may note the salient feature of vacuum as an arc quenching medium. As soon asthe arc is produced in vacuum, it is quickly extinguished due to the fast rate of recovery of dielectricstrength in vacuum.



Construction.

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 andan arc is struck between the contacts. The production of arc is due to the ionisation of metal ions anddepends very much upon the material of contacts. The arc is quickly extinguished because the metallicvapours, electrons and ions produced during arc are diffused in a short time and seized by thesurfaces of moving and fixed members and shields. Since vacuum has very fast rate of recovery ofdielectric strength, the arc extinction in a vacuum breaker occurs with a short contact separation (say0·625 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.

(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 toremote areas difficult, the installation of such outdoor, maintenance free circuit breakers should provea definite advantage. Vacuum circuit breakers are being employed for outdoor applications rangingfrom 22 kV to 66 kV. Even with limited rating of say 60 to 100 MVA, they are suitable for a majorityof applications in rural areas.

5.8.6 Comparision

	SF6 Circuit Breakers		Vacuum Circuit Breakers
Criteria	Puffer Circuit Breaker	Self-pressuring circuit-breaker	Contact material-Chrome-Copper

Operating energy requirements	Operating Energy requirements are high, because the mechanism must supply the energy needed to compress the gas.	Operating Energy requirements are low, because the mechanism must move only relatively small masses at moderate speed, over short distances. The mechanism does not have to provide the energy to create the gas flow	Operating energy requirements are low, because the mechanism must move only relatively small masses at moderate speed, over very short distances.
Arc Energy	Because of the high conductivity of the arc in the SF6 gas, the arc energy is low. (arc voltage is between 150 and 200V.)		Because of the very low voltage across the metal vapour arc, energy is very low. (Arc voltage is between 50 and 100V.)
Contact Erosion	Due to the low energy the contact erosion is small.		Due to the very low arc energy, the rapid movement of the arc root over the contact and to the fact that most of the metal vapour re-condenses on the contact, contact erosion is extremely small.
Arc extinguishing media	The gaseous medium SF6 possesses excellent dielectric and arc quenching properties. After arc extinction, the dissociated gas molecules recombine almost completely to reform SF6. This means that practically no loss/consumption of the quenching medium occurs. The gas pressure can be very simply and permanently supervised. This function is not needed where the interrupters are sealed for life.		No additional extinguishing medium is required. A vacuum at a pressure of 10-7 bar or less is an almost ideal extinguishing medium. The interrupters are _sealed for life‘ so that supervision of the vacuum is not required.
Switching behavior in relation to current chopping	The pressure build-up and therefore the flow of gas is independent of the value of the current. Large or small currents are cooled with the same intensity. Only small values of high frequency, transient currents, if any, will be interrupted. The de-ionization of the contact gap proceeds very rapidly, due to the electro-negative characteristic of the SF6 gas and the arc products.	The pressure build-up and therefore the flow of gas is dependent upon the value of the current to be interrupted. Large currents are cooled intensely, small currents gently. High frequency transient currents will not, in general, be interrupted. The de-ionization of the contact gap proceeds very rapidly due to the electro-negative characteristic of the SF6 gas and the products.	No flow of an _extinguishing‘ medium needed to extinguish the vacuum arc. An extremely rapid de-ionization of the contact gap, ensures the interruption of all currents whether large or small. High frequency transient currents can be interrupted. The value of the chopped current is determined by the type of contact material used. The presence of chrome in the contact alloy with vacuum also.

No. of short-circuit operation	10—50	10—50	30—100
No. full load operation	5000—10000	5000—10000	10000—20000
No. of mechanical operation	5000—20000	5000—20000	10000—30000

5.8.7 Rating and selection of Circuit breakers

The rating of circuit breaker is given according to the duties that are performed by it. For complete specifications, standard rating and various tests of switches and circuit breakers IS 375/1951 may be consulted. A circuit breaker is required to perform the following three major duties.

1. It must be capable of opening the faulty circuit and breaking the fault current. This is described as breaking capacity of a circuit breaker
2. It must be capable of being closed on to a fault. This refers to making capacity of a circuit breaker
3. It must be capable of carrying fault current for a short time while another circuit breaker is clearing the fault. This refers to short time capacity of the circuit breaker.

In addition to the above ratings, a circuit breaker should be specified in terms of

- *Rated voltage:* the rated maximum voltage of a circuit breaker is the highest rms voltage, above nominal system voltage ,for which circuit breaker is designed and is the upper limit for operation. The rated voltage is expressed in kVrms and refer phase to phase voltage for three phase circuit.
- *Rated current:* the rated normal current of a circuit breaker is the rms value of the current which the circuit breaker shall be able to carry at rated frequency and at the rated voltage continuously, under specified condition.
- *Rated frequency:* the rated frequency of a circuit breaker is the frequency at which it is designed to operate.
- *Operating Duty*: the operating duty of a circuit breaker consist of the prescribed number of unit operations at stated intervals.

Breaking capacity:

Breaking current is the RMS value of current that a circuit breaker is required to break at the instant of contact separation. The symmetrical breaking current is the RMS value of its symmetrical component. If however, at the instant of contact separation, the wave is still asymmetrical it is known as the asymmetrical breaking current.

Breaking capacity (MVA) = Rated symmetrical breaking current (kA) × Rated service voltage (kV) × √3

Making capacity:

A circuit breaker may complete a full short circuit on being closed. This is known as making capacity.

Making capacity = 1.8 × √2 × Symmetrical breaking capacity.

Short time rating:

Circuit breaker should be capable of carrying high currents safely and without showing undue stress for a specified short period in a closed position. This is known as short time rating. This happens in case of momentary fault like bird age on the transmission lines and the fault is automatically cleared and persists only for 1 or 2 seconds. For this reason the circuit breakers are short time rated and they trip only when the fault persists for a duration longer than the specified time limit.