5.8 Types of circuit breakers:

(i) Air-blast circuit breakers

(ii) Air-break circuit breakers

(ii) Oil circuit breakers

(iii) Sulphur hexafluoride circuit breaker

(iv) Miniature circuit breaker

(v) Moulded case circuit breaker

(iv) Vacuum circuit breakers

5.8.1. Air Blast Circuit Breaker

- 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.

Types of Air-Blast Circuit Breakers

(i) Axial-blast type

(ii) Cross-blast type

Axial-blast air circuit breaker

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

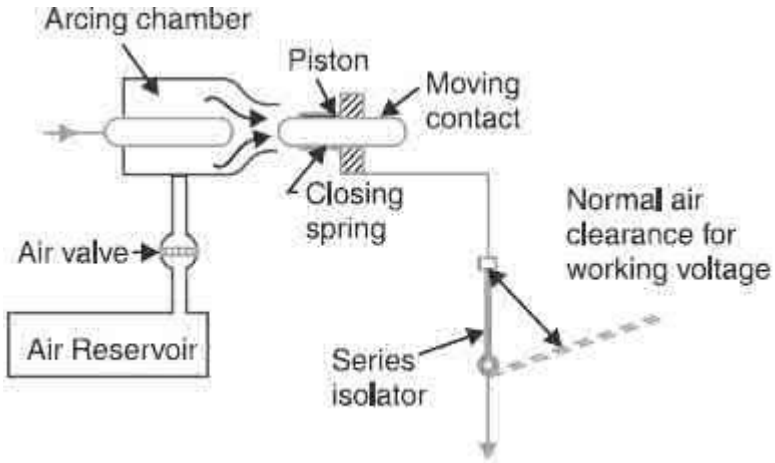

Figure 5.8.1 Axial - blast air circuit breaker

[Source: "Principles of Power System" by V.K Mehta, Page: 458]

- When a fault occurs, the tripping impulse causes opening of the air valve which connects the circuit breaker reservoir to the arcing chamber.
- The high pressure air entering the arcing chamber pushes away the moving contact against spring pressure. The moving contact is separated and an arc is struck.
- At the same time, high pressure air blast flows along the arc and takes away the ionized gases along with it. Consequently, the arc is extinguished and current flow is interrupted.
- It may be noted that in such circuit breakers, the contact separation required for interruption is generally small (1·75 cm or so).
- Such a small gap may constitute inadequate clearance for the normal service voltage. Therefore, an isolating switch is incorporated as a part of this type of circuit breaker.

Cross-blast air breaker

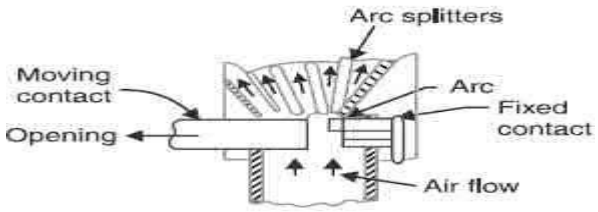

Figure 5.8.2 Cross- blast air circuit breaker

[Source: "Principles of Power System" by V.K Mehta, Page: 459]

- 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
- 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 give 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.

5.8.2. Air Break Circuit Breaker:

- 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.
- 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.

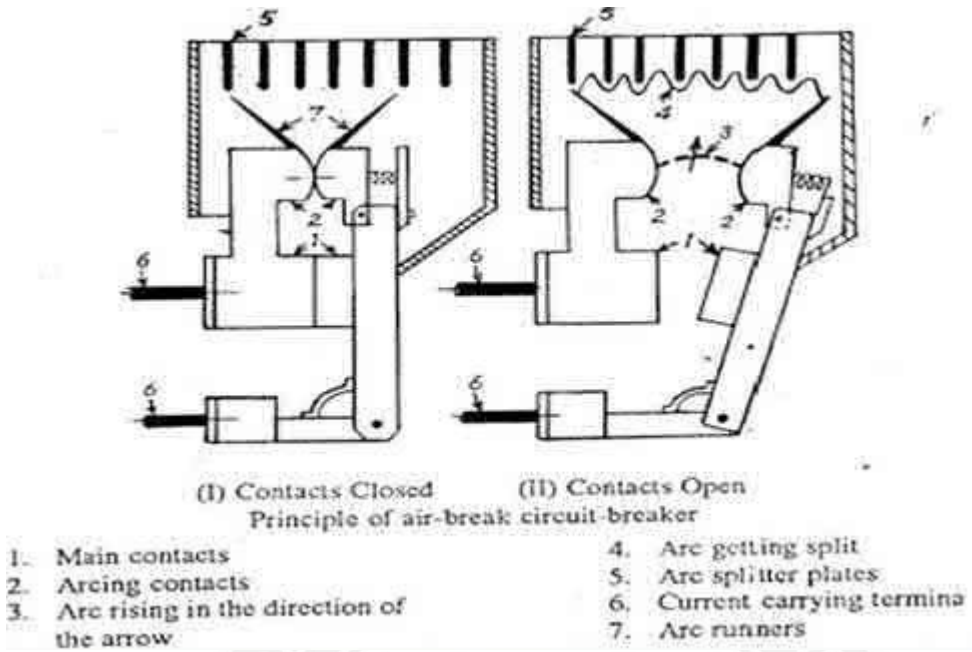

Figure 5.8.3 Air Break Circuit Breaker

[Source: "Switchgear and Protection'" by Sunil S.Rao, Page: 756]

- 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 of AC 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

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.

5.8.3 Oil circuit breakers:

- In such circuit breakers, some insulating oil (*e.g.*, transformer oil) is used as an arc quenching medium. The contacts are opened under oil and an arc is struck between them.
- The heat of the arc evaporates the surrounding oil and dissociates it into a substantial volume of gaseous hydrogen at high pressure. The hydrogen gas occupies a volume about one thousand times that of the oil decomposed.
- The oil is, therefore, pushed away from the arc and an expanding hydrogen gas bubble surrounds the arc region and adjacent portions of the contacts.

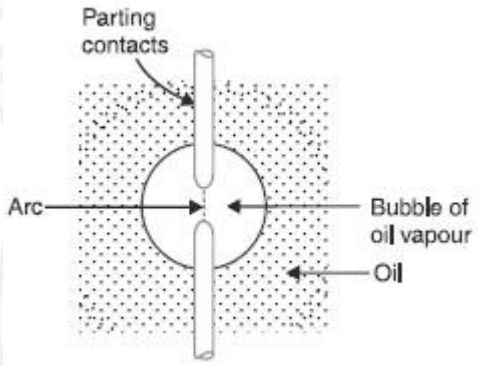

Figure 5.8.4 Oil circuit breaker

[Source: "Principles of Power System" by V.K Mehta, Page: 451]

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

Types of Oil Circuit Breakers

(i) Bulk oil circuit breakers

(ii) Low oil circuit breakers

Bulk oil circuit breakers

- 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.

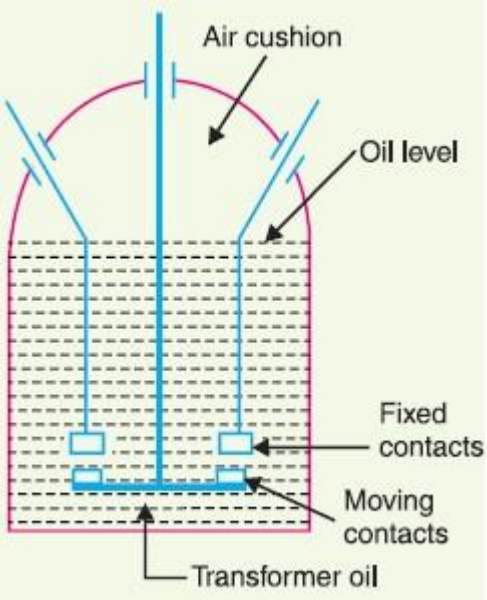

Figure 5.8.5 Plain oil circuit breaker

[Source: "Principles of Power System" by V.K Mehta, Page: 452]

- 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 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. 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 deionization 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.

Low Oil Circuit breakers

- In the bulk oil circuit breakers discussed so far, 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. For this reason, 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.
- The fact that only a small percentage of oil (about 10% of total) in the bulk oil circuit breaker is actually used for arc extinction leads to the question as to why the remainder of the oil, that is not immediately surrounding the device, should not be omitted with consequent saving in bulk, weight and fire risk.
- This led to the development of low-oil circuit breaker. A low oil circuit breaker employs solid materials for insulation purposes and uses a small quantity of oil which is just sufficient for arc extinction.
- As regards quenching the arc, the oil behaves identically in bulk as well as low oil circuit breaker. By using suitable arc control devices, the arc extinction can be further facilitated in a low oil circuit breaker.

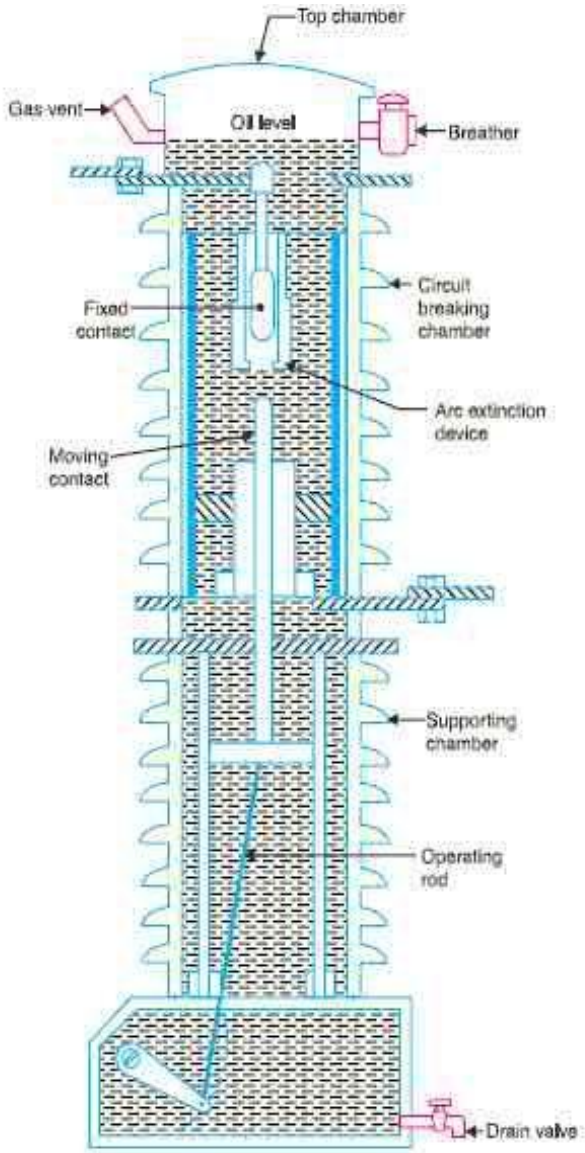

Figure 5.8.2 Low oil circuit breaker

[Source: "Principles of Power System" by V.K Mehta, Page: 456]

Construction

- There are two compartments separated from each other but both filled with oil. The upper chamber is the circuit breaking chamber while the lower one is the supporting chamber.
- The two chambers are separated 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 small volume of oil which is just enough for arc extinction. Secondly, the amount of oil to be replaced is reduced 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 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

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 ensures the interruption of low currents whereas radial venting helps in the interruption of heavy currents

(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.

5.8.4 SF6 circuit breakers:

- ✓ 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 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:

- ➢ 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.

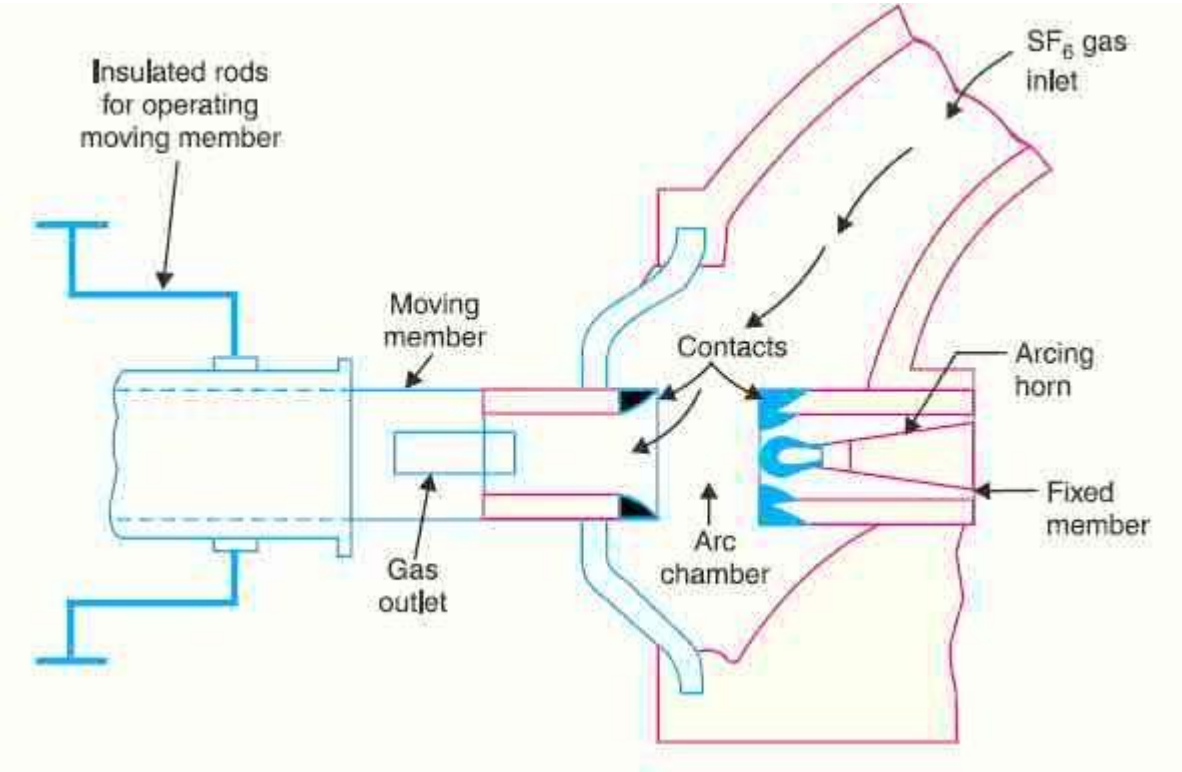

Figure 5.8.2 Low oil circuit breaker

[Source: "Principles of Power System" by V.K Mehta, Page: 460]

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.

5.8.5 Miniature Circuit breakers:

- There are two arrangement of operation of miniature circuit breaker. One due to thermal effect of over current and other due to electromagnetic effect of over current.
- The thermal operation of miniature circuit breaker is achieved with a bimetallic strip whenever continuous over current flows through MCB, the bimetallic strip is heated and deflects by bending.
- This deflection of bimetallic strip releases mechanical latch. As this mechanical latch is attached with operating mechanism, it causes to open the miniature circuit breaker contacts.
- But during short circuit condition, sudden rising of current, causes electromechanical displacement of plunger associated with tripping coil or solenoid of MCB.
- The plunger strikes the trip lever causing immediate release of latch mechanism consequently open the circuit breaker contacts.

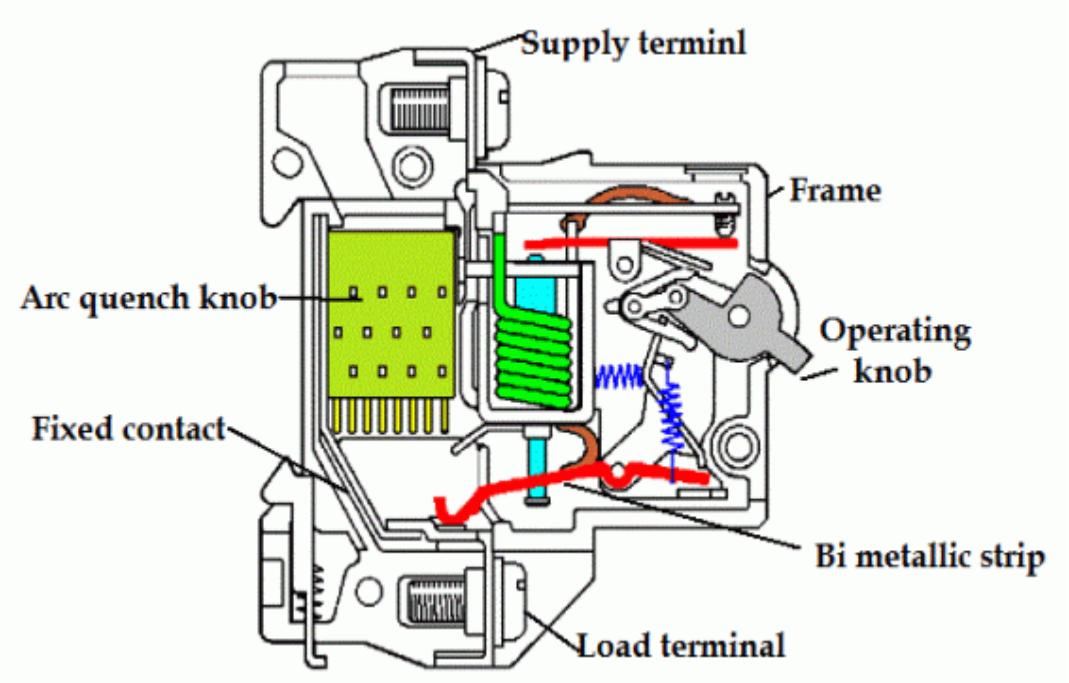

Figure 5.8.3 Air Break Circuit Breaker

[Source: "Switchgear and Protection'" by Sunil S.Rao, Page: 858]

- The operating mechanism of miniature circuit breaker provides the means of manual opening and closing operation of miniature circuit breaker. It has three-positions “ON,” “OFF,” and “TRIPPED”.
- The external switching latch can be in the “TRIPPED” position, if the MCB is tripped due to over-current. When manually switch off the MCB, the switching latch will be in “OFF” position.
- In close condition of MCB, the switch is positioned at “ON”. By observing the positions of the switching latch one can determine the condition of MCB whether it is closed, tripped or manually switched off.
- The trip unit is the main part, responsible for proper working of miniature circuit breaker. Two main types of trip mechanism are provided in MCB. A bimetal provides protection against over load current and an electromagnet provides protection against short- circuit current.
- Miniature circuit breaker construction is very simple, robust and maintenance free. Generally a MCB is not repaired or maintained, it just replaced by new one when required.

5.8.6 Moulded Case Circuit breakers (MCCB):

- Moulded Case Circuit Breaker is an electromechanical device which protects a circuit from over current and short circuit. It provides over current and short circuit protection for circuits ranging from 63 Amps up to 3000 Amps.
- The primary function of an MCCB is to provide a means to manually open a circuit and automatically open a circuit under overload or short circuit conditions. The over current, in an electrical circuit, may result from short circuit, overload or faulty design.
- Molded Case Circuit Breaker as devices designed to open or close a circuit by non automatic means and to open the circuit automatically on a predetermined over current without damage to itself when properly applied within its rating.
- The term “molded case” simply refers to the construction of the circuit breaker and refers to the fact that the circuit breaker is an assembled unit in a supporting housing of insulating material.

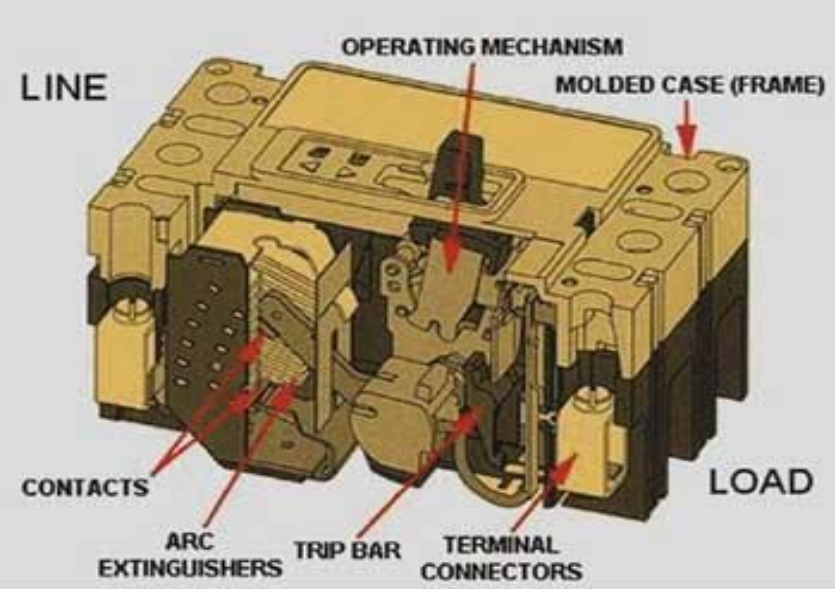

Figure 5.8.3 Air Break Circuit Breaker

[Source: "Switchgear and Protection'" by Sunil S.Rao, Page: 856]

- A thermal element for over current and a magnetic element for short circuit release which has to operate faster.
- MCCBs are manufactured such that end user will not have access to internal workings of the over-current protection device.
- Generally constructed of two pieces of heavy-duty electrically insulated plastic, these two halves are riveted together to form the whole. Inside the plastic shell is a series of thermal elements and a spring-loaded trigger.
- When the thermal element gets too warm, from an over current situation, the spring trips, which in turn will shut off the electrical circuit.

The major components of MCCB include

- A mechanism which makes and breaks a contact through a toggle link mechanism having a spring which can store tripping force,
- An over current trip device which reacts with over current and short circuit current and trips MCCB,
- An Arc extinguishing device which extinguishes the arc generated upon current interruption.
- Terminals for connecting wires and conductor, Contacts which open and close the circuit.

- A moulded case in which these components are integrated and compactly contained.

5.8.7 Vacuum Circuit breakers:

- 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.

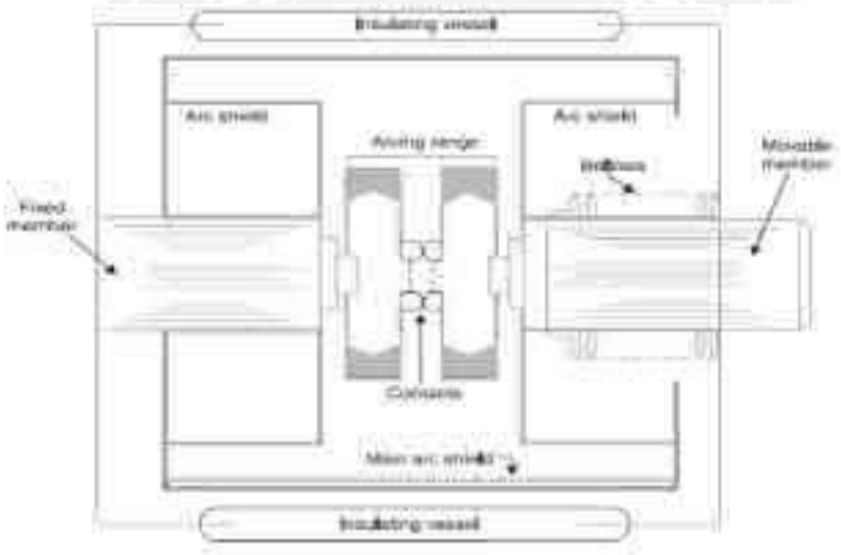

Figure 5.8.2 Vacuum circuit breaker

[Source: "Principles of Power System" by V.K Mehta, Page: 461]

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.

- 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 (say0·625 cm).

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