

## UNIT – II

### CIRCUIT BREAKERS – II

#### INTRODUCTION

- ❖ *Circuit breakers are mechanical devices designed to close or open contact members, thus closing or opening of an electrical circuit under normal or abnormal conditions.*
- ❖ Automatic circuit breakers, which are usually employed for protection of electrical circuits, are equipped with a trip coil connected to a relay or other means, designed to open the breaker automatically under abnormal conditions, such as over-current.
- ❖ *The automatic circuit breakers perform the following duties:-*
- ❖ It carries the full-load current continuously without overheating or damage.
- ❖ It opens and closes the circuit on no load.
- ❖ It makes and breaks the normal operating current.
- ❖ It makes and breaks the short-circuit currents magnitude up to which it designed for.
- ❖ The circuit breaker performs the first three duties satisfactorily but in performing fourth duty i.e., when it is to make or break short-circuit currents, it is subjected to mechanical and thermal stresses.
- ❖ The interrupting or rupturing capacity of a circuit breaker is the maximum value of current which can be interrupted by it without any damage.
- ❖ The circuit breakers are also rated in MVA which is the product of interrupting current, rated voltage and  $10^{-6}$ .

#### OPERATING PRINCIPLE OF CIRCUIT BREAKER

- ❖ A circuit breaker is a switching and current interrupting device.
- ❖ It consists, of fixed and moving contacts which are touching each other and carry the current under normal conditions i.e., when circuit breaker is closed.
- ❖ When the circuit breaker is closed, the current carrying contacts called the electrodes engage each other under the pressure of a spring.
- ❖ During the normal operating condition the circuit breaker can be opened or closed manually for switching and maintenance purpose.
- ❖ To open the circuit breaker, only a small pressure is required to be applied on a trigger.

## SWITCHGEAR AND PROTECTION

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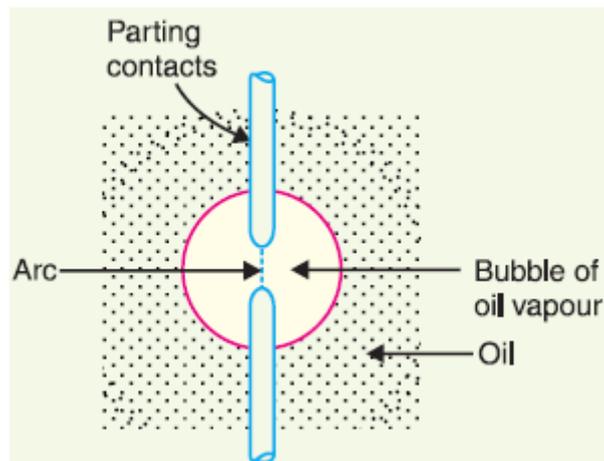
- ❖ Whenever a fault occurs on any part of the power system, trip coils of the breaker gets energized and moving contact are pulled apart by some mechanism, thus opening the circuit.
- ❖ The separation of current carrying contacts produces an arc.
- ❖ The current is thus able to continue until the discharge ceases.
- ❖ The production of arc not only delays the current interruption process but also generates enormous heat which may cause damage to the system or to the breaker itself.
- ❖ Therefore the main problem in the circuit breaker is to extinguish the arc with in the short period of time so that heat generated by it may not reach a dangerous value.
- ❖ The basic construction of a circuit breaker requires the separation of contacts in an insulating fluid which serves two functions:-
  - ❖ Extinguishes the arc drawn between the contacts when the circuit breaker is open.
  - ❖ Provides insulation between the contacts and from each contact to earth.

### **CLASSIFICATION OF CIRCUIT BREAKERS**

- ❖ There are several ways of classifying the circuit breakers but the most general way of classification is on the basis of medium used for arc extinction.
- ❖ The medium used for arc extinction is usually *oil, air, sulphur hexafluoride or vacuum.*
- ❖ *Depending upon the above the circuit breakers are classified as :-*
  - ❖ Oil circuit breakers
  - ❖ Air-blast circuit breakers
  - ❖ Sulphur hexafluoride circuit breakers
  - ❖ Vacuum circuit breakers

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## OIL CIRCUIT BREAKERS



- ❖ *In these types of circuit breakers, some insulating oil (transformer oil) is used as an arc quenching medium.*
- ❖ The contacts of the circuit breaker 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 as shown in the figure.
- ❖ *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-ionization of the medium between the contacts.
- ❖ Secondly, the gas sets up turbulence in the oil and forces it into space between the contacts, thus eliminating the arcing products from the arc path.
- ❖ Thus the arc is extinguished and circuit current is interrupted.

## **ADAVANTAGES**

- ❖ It absorbs the arc energy to decompose the oil into gases which have excellent cooling properties.
- ❖ It acts as an insulator and permits smaller clearance between live conductors and earthed components.
- ❖ The surrounding oil presents cooling surface in close proximity to the arc.

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### DISADVANTAGES

- ❖ It is inflammable and there is a risk of a fire.
- ❖ It may form an explosive mixture with air.
- ❖ The arcing products (carbon) remain in the oil and its quality decreases with successive operations, this needs periodic checking and replacement of oil.

### TYPES OF OIL CIRCUIT BREAKERS

- ❖ *There are mainly two types of oil circuit breakers*

#### ❖ **BULK OIL CIRCUIT BREAKERS**

- ❖ These types of circuit breakers use large quantity of oil.
- ❖ These are further classified into two types
  - Plain oil circuit breakers
  - Arc control oil circuit breakers
- ❖ In plain oil circuit breakers there is no special means is available for controlling the arc and the contacts are directly exposed to the whole of the oil in the tank.
- ❖ In arc control oil circuit breakers, special arc control devices are employed to get the beneficial action of the arc as efficiently as possible.

#### ❖ **LOW OIL CIRCUIT BREAKERS**

- ❖ In these types of circuit breakers small amount of oil will be used.
- ❖ In such breakers, oil is used only for arc extinction.
- ❖ The current conducting parts are insulated by air or porcelain or organic insulating material.

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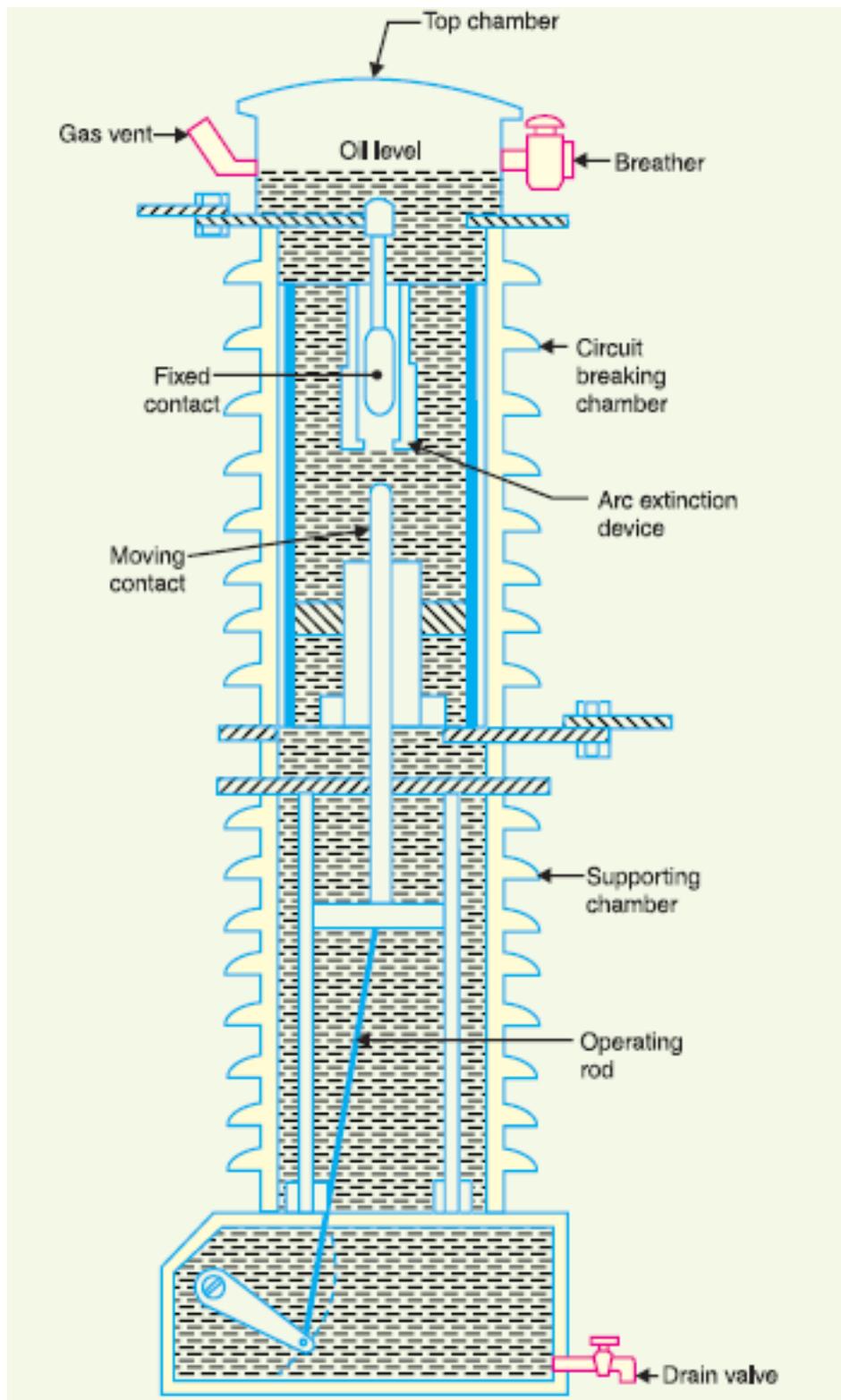
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### LOW OIL CIRCUIT BREAKERS

- ❖ In bulk oil circuit breakers, the oil should perform two functions.
- ❖ It should act as arc quenching medium and also it insulates the live parts from earth.
- ❖ It has been found that only small percentage of oil is used for arc extinction where the majority of the oil will be used for insulation purpose.
- ❖ Due to this the quantity of oil in bulk oil circuit breakers reaches a very high as the system voltage increases.
- ❖ This will increase the expenses, tank size and weight of the breaker but it also increases the fire risk and maintenance problem.
- ❖ The fact that only a small percentage of oil 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 leads to the development of low oil circuit breakers.
- ❖ *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.*

# SWITCHGEAR AND PROTECTION

## CONSTRUCTION



## SWITCHGEAR AND PROTECTION

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- ❖ The above figure shows the cross section of a single phase low oil circuit breaker.
- ❖ 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.

### ❖ **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.

### ❖ **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:-
  - fixed contacts
  - moving contact
  - 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.

### ❖ **TOP CHAMBER**

- ❖ It is a metal chamber and is mounted on the circuit-breaking chamber.

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- ❖ 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 contacts.
- ❖ When a fault occurs, the moving contact is pulled down by the tripping springs and an arc is struck.
- ❖ The arc energy vaporizes 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 passage of the turbulator.
- ❖ The process of turbulation is orderly one, in which the sections of the arc are successively quenched by the effect of separate streams of oil moving across each section in turn and bearing away its gases.
  
- ❖ **ADVANTAGES:-**
- ❖ It requires lesser quantity of oil.
- ❖ It requires smaller space.
- ❖ There is reduced risk of fire.
- ❖ Maintenance problems are reduced.
  
- ❖ **DISADVANTAGES:-**
- ❖ Due to smaller quantity of oil, the degree of carbonization is increased.
- ❖ There is a difficulty of removing the gases from the contacts space in time.
- ❖ The dielectric strength of the oil deteriorates rapidly due to high degree of carbonization.

### AIR-BLAST CIRCUIT BREAKERS

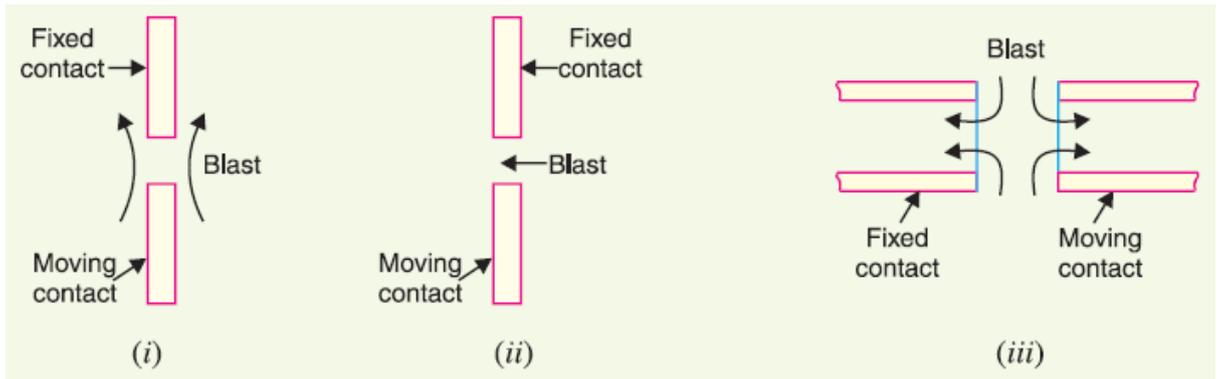
- ❖ *These breakers employ a high pressure air-blast as an arc quenching medium.*
- ❖ The contacts are opened in a flow of air-blast established by the opening of blast valve.
- ❖ The air-blast cools the arc and sweeps away the arcing products to the atmosphere.

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- ❖ This rapidly increases the dielectric strength of the medium between contacts and prevents from re-establishing the arc.
- ❖ Thus the arc is extinguished and flow of current is interrupted.

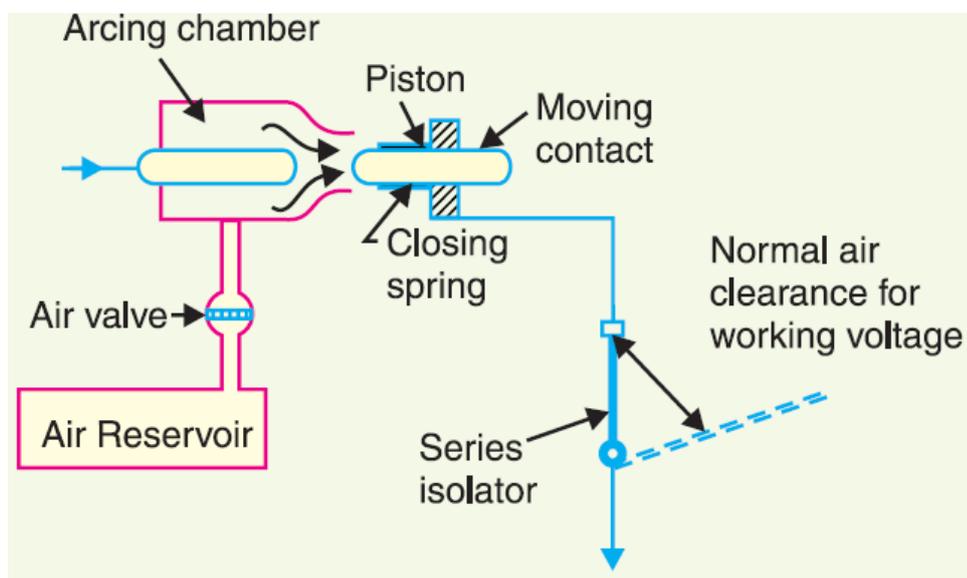
### TYPES OF AIR-BLAST CIRCUIT BREAKERS

- ❖ *Depending up on the direction of air-blast in relation to arc, they are classified into following types shown in figure:-*



- ❖ **Axial blast type** :- in which the air-blast is directed along the arc path as shown in figure (i)
- ❖ **Cross blast type**:- in which the air-blast is directed at right angles to the arc path as shown in figure (ii)
- ❖ **Radial blast type**:- in which the air-blast is directed radially as shown in figure (iii)

### AXIAL-BLAST AIR CIRCUIT BREAKER

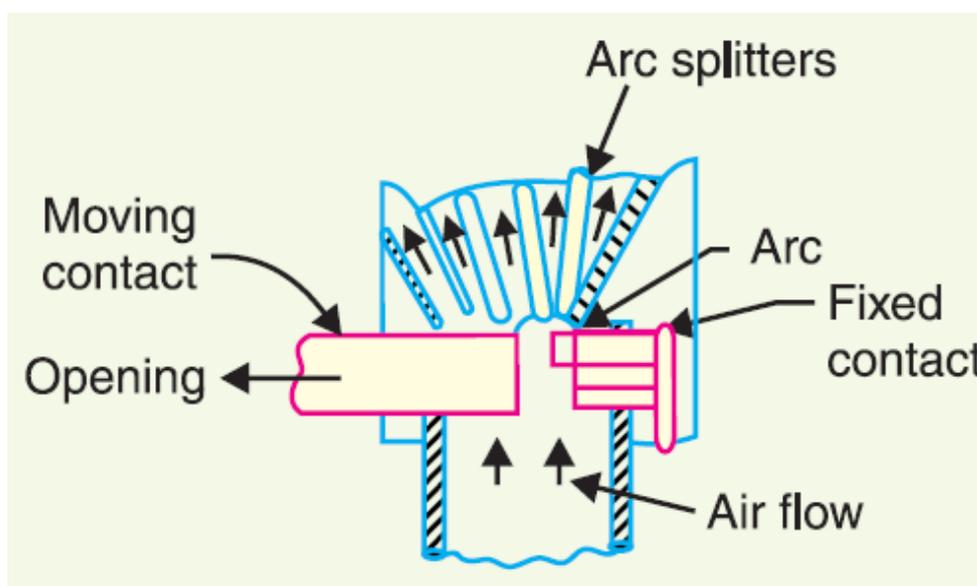


## SWITCHGEAR AND PROTECTION

- ❖ The above figure shows the essential components of axial blast air circuit breaker.
- ❖ The fixed and moving contacts are held in closed position by spring pressure under normal operating conditions.
- ❖ The air reservoir is connected to the arcing chamber through an air valve.
- ❖ The valve remains closed under normal conditions but opens automatically 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 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, the pressure air blast flows along the arc and takes away the ionized gases along with it.
- ❖ Thus the arc is extinguished and current flow is interrupted.
- ❖ In such breakers, the contact separation required for interruption is generally small (**1.7 cm**).
- ❖ Such a small gap may constitute inadequate clearance for insulation.
- ❖ This switch opens immediately after fault interruption to provide the necessary clearance for insulation.

### CROSS-BLAST AIR CIRCUIT BREAKER

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



## SWITCHGEAR AND PROTECTION

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- ❖ The above figure shows the essential parts of cross-blast circuit breaker.
- ❖ When the moving contact is withdrawn, an arc is struck between the fixed and moving contacts.
- ❖ The high pressure cross-blast forces the arc into chutes consisting of arc splitters and baffles.
- ❖ The splitters serve to increase the length of the arc and baffles gives improved cooling.
- ❖ The result is that arc is extinguished and flow of current is interrupted.
- ❖ Since blast pressure is same for all currents, the inefficiency at low currents is eliminated.
- ❖ The final gap for interruption is great enough to give normal insulation clearance so that a series isolating switch is not necessary.

### ADVANTAGES

- ❖ The risk of fire is eliminated.
- ❖ The arc products are completely eliminated by the blast whereas the oil deteriorates with successive operations.
- ❖ The growth of dielectric strength is so rapid that final contact gap needed for arc extinction is very small.
- ❖ The arcing time is very small due to rapid buildup of dielectric strength between contacts.
- ❖ Due to less arc energy air blast circuit breakers are very suitable for conditions where frequent operation is required.

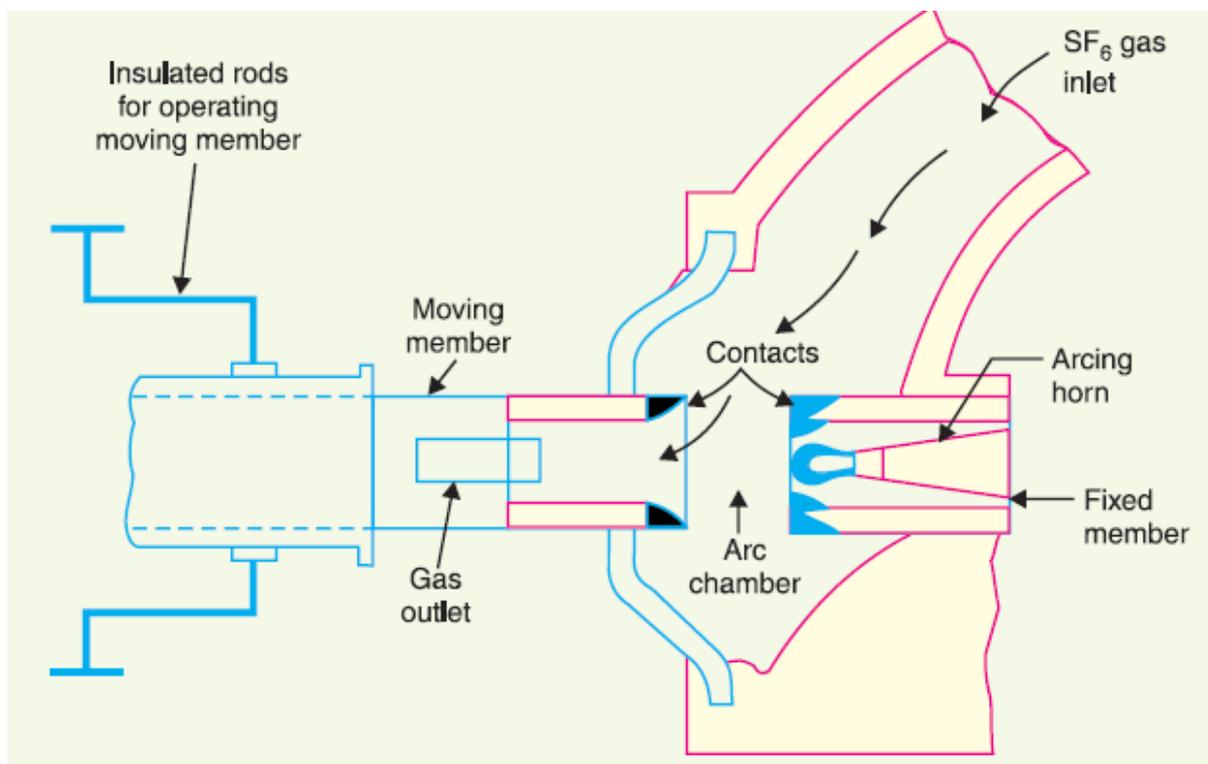
### DISADVANTAGES

- ❖ The air has relatively inferior arc extinction properties.
- ❖ The air blast circuit breakers are very sensitive to the variation in the RRRV.
- ❖ Considerable maintenance is required for the compressor plant which supplies the air blast.

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### SULPHUR HEXAFLUORIDE CIRCUIT BREAKER (SF<sub>6</sub>)

- ❖ *In this type of circuit breakers SF<sub>6</sub> gas is used as the arc quenching medium.*
- ❖ The SF<sub>6</sub> is an electro-negative gas has a strong tendency to absorb free electrons.
- ❖ The contacts of the breaker are opened in a high pressure flow of SF<sub>6</sub> gas and an arc is struck between them.
- ❖ The conducting free electrons in the arc 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 SF<sub>6</sub> circuit breakers have been found to be very effective for high power and high voltage services.



- ❖ The figure shows the parts of SF<sub>6</sub> circuit breaker.
- ❖ It consists of fixed and moving contacts enclosed in a chamber contains SF<sub>6</sub> gas.
- ❖ This chamber is connected to SF<sub>6</sub> gas reservoir.
- ❖ When the contacts of breaker are opened, the valve mechanism permits a high pressure SF<sub>6</sub> gas from the reservoir to flow towards the arc interruption chamber.
- ❖ The fixed contact is a hollow cylindrical current carrying contacts fitted with an arc horn.

## SWITCHGEAR AND PROTECTION

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- ❖ The moving contact is also hollow cylinder with rectangular holes in side to permit the SF<sub>6</sub> gas to let out through these holes after flowing along and across the arc.
- ❖ The tips of fixed contact, moving contact and arching horn are coated with copper-tungsten arc resistance material.
- ❖ Since SF<sub>6</sub> gas is costly it is reconditioned and reclaimed by suitable auxiliary system after each operation of the breaker.

### WORKING

- ❖ In the closed position of the breaker, the contacts remain surrounded by SF<sub>6</sub> gas at a pressure of about **2.8 kg/cm<sup>2</sup>**.
- ❖ 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 SF<sub>6</sub> gas at **14 kg/cm<sup>2</sup>** pressure from the reservoir to the arc interruption chamber.
- ❖ The pressure flow of SF<sub>6</sub> 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, the valve is closed by the action of a set of springs.

### ADVANTAGES

- ❖ Due to the superior arc quenching property of SF<sub>6</sub>, such circuit breakers have very short arcing time.
- ❖ Since the dielectric strength of SF<sub>6</sub> gas is 2 to 3 times that of air, such breakers can interrupt much larger currents.
- ❖ The SF<sub>6</sub> circuit breakers give noiseless operation due to its closed gas circuit.
- ❖ The closed gas enclosure keeps the interior dry so that there is no moisture problem.
- ❖ There is no fire risk in such breakers because SF<sub>6</sub> gas is non-inflammable.
- ❖ As there are totally enclosed and sealed from atmosphere they are suitable for explosive hazards.

## SWITCHGEAR AND PROTECTION

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### DIADVANTAGES

- ❖ SF<sub>6</sub> breakers are costly due to high cost of SF<sub>6</sub>.
- ❖ Since SF<sub>6</sub> gas has to be reconditioned after every operation of the breaker, additional equipment is required for the purpose.

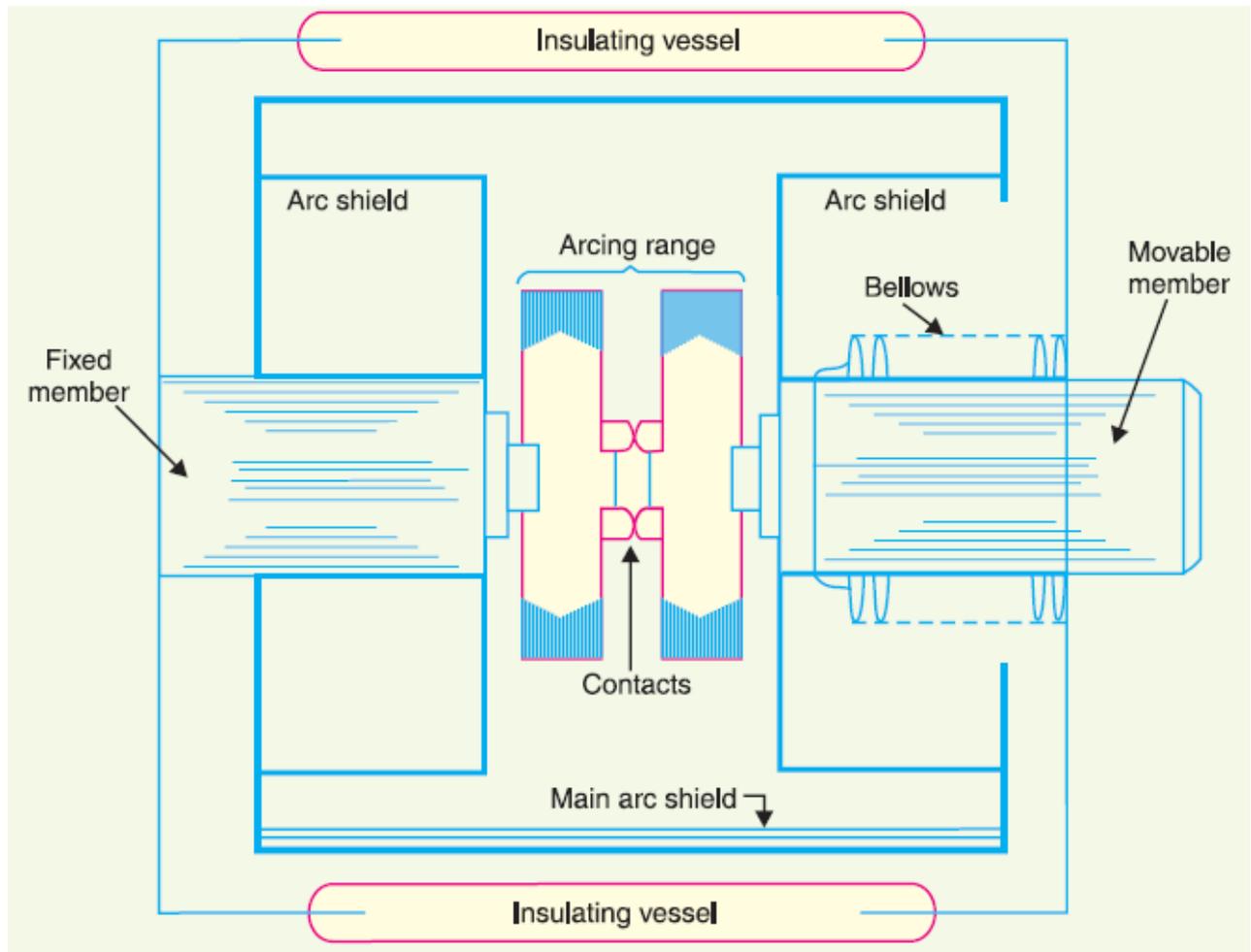
### VACUUM CIRCUIT BREAKERS

- ❖ In such breakers, vacuum 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.
- ❖ When the contacts of the breaker are opened in vacuum, the interruption occurs at the first current zero with the 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, an arc is produced between the contacts by the ionization of metal vapours of contacts.
- ❖ However, the arc is quickly extinguished because the metallic vapours, electrons and ions produced during the arc rapidly condense on the surface of the circuit breaker contacts, resulting in quick recovery of dielectric strength.
- ❖ As soon as the arc produced in vacuum, it is quickly extinguished due to the fast rate of recovery of dielectric strength in vacuum.

## CONSTRUCTION



- ❖ The above figure shows the essential parts of vacuum circuit breaker.
- ❖ It consists of fixed contact, moving contact and arc shield mounted inside a vacuum chamber.
- ❖ The movable member is connected to 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 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.

## SWITCHGEAR AND PROTECTION

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### WORKING

- ❖ When the breaker operates, the moving contact separates from the fixed one and arc is struck between the contacts.
- ❖ The production of arc is due to the ionization 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 surface of moving and fixed members and shield.
- ❖ Since vacuum has very fast rate of recovery of dielectric strength, the arc extinction in a vacuum breaker occurs with a short contact separation (**0.625 cm**).

### ADVANTAGES

- ❖ They are compact, reliable and having longer life.
- ❖ There are no fire hazards.
- ❖ There is no generation of gas during and after operation.
- ❖ They can interrupt any fault current. The main features of these types of breakers are that it can break any heavy fault current perfectly just before the contacts reach definite opening position.
- ❖ They require less maintenance.
- ❖ They can successfully withstand lightening surges.
- ❖ They have low arc energy.