MODULE - 5

CIRCUITS BREAKERS

- **Air Circuit breakers** – Air break and Air blast Circuit breakers
- oil Circuit breakers – Single break, double break, minimum OCB
- SF6 breaker - Preparation of SF6 gas
- Puffer and non Puffer type of SF6 breakers
- Vacuum circuit breakers - principle of operation and constructional details
- Advantages and disadvantages of different types of Circuit breakers
- Testing of Circuit breakers, Unit testing
- Synthetic testing, substitution test
- Compensation test and capacitance test
- **Lightning arresters:** Causes of over voltages – internal and external lightning
- Working Principle of different types of lightning arresters. Shield wires

Types of circuit breakers

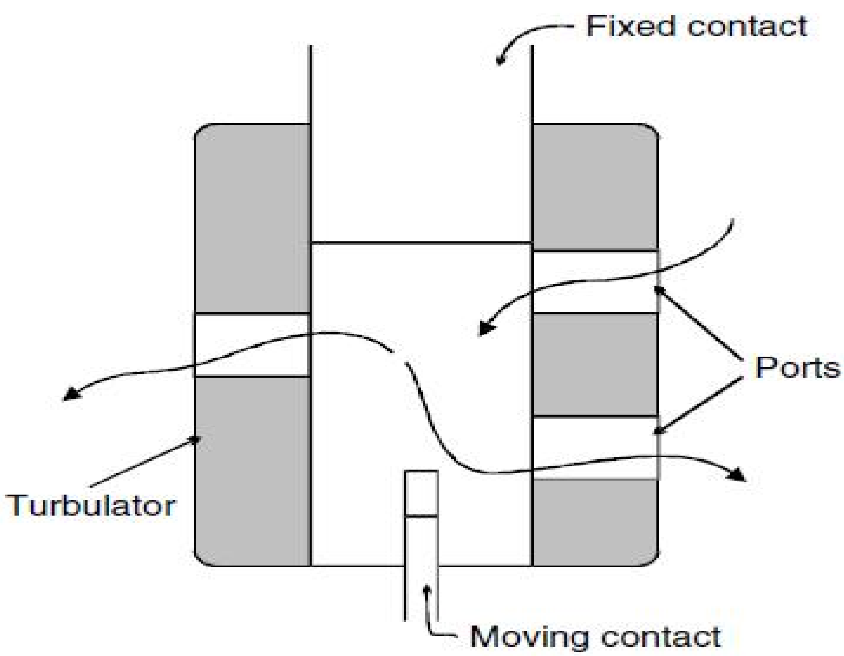
The types of breakers basically refer to the medium in which the breaker opens and closes. The medium could be oil, air, vacuum or SF6. The further classification is single break and double break. In a single break type only the busbar end is isolated but in a double break type, both busbar (source) and cable (load) ends are broken. However, the double break is the most common and accepted type in modern installations.

Arc control device: A breaker consists of moving and fixed contact, and during the breaker operation, the contacts are broken and the arc created during such separation needs to be controlled. The arc control devices, otherwise known as tabulator or explosion pot achieves this:

1. Turbulence caused by arc bubble.

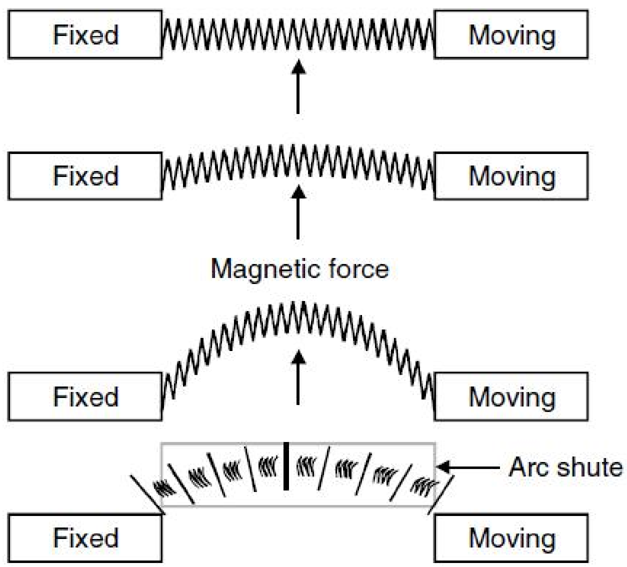
2. Magnetic forces tend to force main contacts apart and movement causes oil to be sucked in through ports and squirted past gap.

3. When arc extinguished (at current zero), ionized gases get swept away and prevents prestriking of the arc



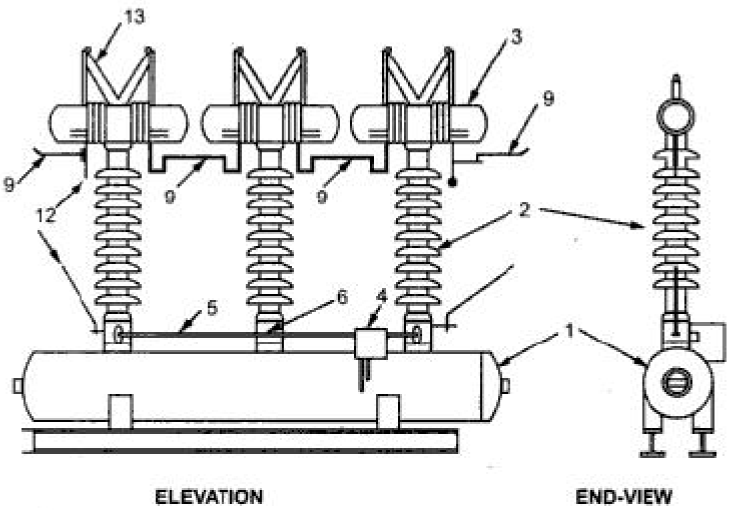
Air break switchgear

Interrupting contacts situated in air instead of any other artificial medium Arc is chopped into a number of small arcs by the Arc-Shute as it rises due to heat and magnetic forces. The air circuit breakers are normally employed for 380~480 V distribution.

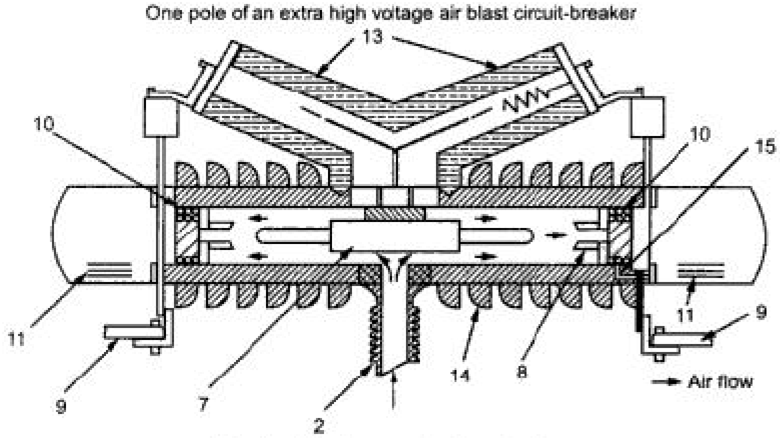


Air break switchgear

These types of circuit breakers are used in earlier days for the voltage ranges of 11kv to 1100kV. At the bottom there is a tank which is called air reservoir with the valves. On this reservoir there are three hollow insulator columns. On the top of each insulator column there is double arc extinguishing chamber. The current carrying parts are connected to the arc extinction chambers in series. The assembly of entire arc extinction chamber is mounted on insulators as there exists large voltage between the conductors and air reservoir. The double arc extinction chamber is shown separately in the Fig below. It can be seen that for each circuit breaker pole there are six break as there are three double arc extinction poles in series. Each arc extinction chamber consists of two fixed and two moving contacts. These contacts can move axially so as to open or close. The position depends on air pressure and spring pressure. The opening rod is operated by when it gets control signal (may be electrical or prtearnatic). This will lead to flow of high pressure air by opening the valve. The high pressure air enters the double arc extinction chamber rapidly. Due to the flow of air the pressure on moving contacts increases than spring pressure and contacts open The contacts travel through a small distance against the spring pressure. Due to the motion of moving contacts the port for outgoing air is closed and the whole arc extinction chamber is filled with high pressure air. But during the arcing period the air passes through the openings shown and takes away ionized air of arc. In case of making operation the valve is turned which connects hdlow column of insulator and the reservoir. The air is passed to the atmosphere due to which pressure of air in the chamber is dropped to atmospheric pressure and closing of moving contacts is achieved against spring pressure.



One pole of an extra high voltage air blast circuit-breaker



Details of double arc extinction chamber

1. Tank air reservior (receiver)
2. Hollow insulator assembly
3. Double arc extinction chamber
4. Pneumatic operating mechanism
5. Operating rod
6. Pneumatic value
7. Fixed contact (in 3)
8. Moving contact (in 3)
9. Connection for current
10. Compression springs
11. Openings for air outler
12. Arcing horns Optional
13. Resistance switching unit
14. Enclosure
15. Port

Working: An auxiliary compressed air system is required by this type of circuit breaker. This will supply air to the air reservior of the breaker. During the opening operation, the air is allowed to enter in the extinction chamber which push., away moving contacts. The contacts are separated and the blast of air will take ionized gases with it and helps in extinguishing the arc.

Advantages: The vanous advantages of air blast circuit breakers are, i) No fire hazards are possible with this type of circuit breaker. ii) The nigh speed operation is achieved. iii) The time for which arc persists is short. Thus the arc gets extinguished early. iv) As arc duration is short and consistent, the amount of heat released is less and the contdct points are burnt to a less extent. So life of circuit breaker is increased. v) The extinguishing medium in this type of circuit breaker is compressed air which is supplied fresh at each operation. The arc energy at each operation is less than that compared with oil circuit breaker. So air blast circuit breaker is most suitable where frequent operation is required. vi) This type of circuit breaker is almost maintenance free. vii) It provides facility of high speed reclosure. viii) The stability of the system can be well maintained.

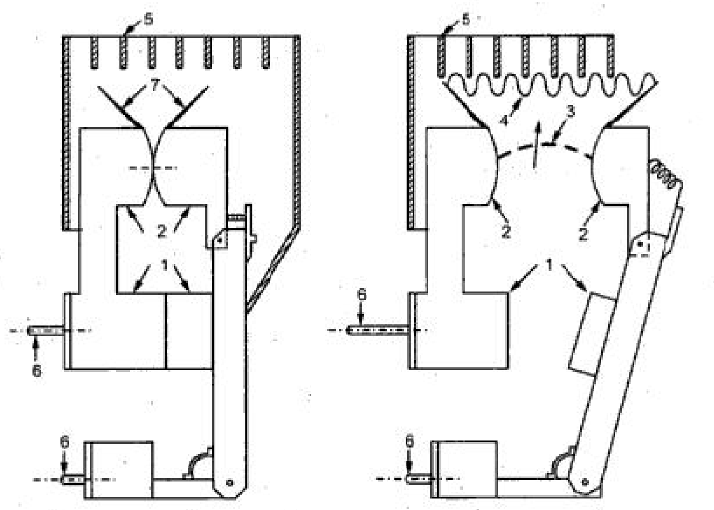
Disadvantages: The various disadvantages of air blast circuit breakers are, i) If air blast circuit breaker is to be used for frequent operation it is necessary to have a compressor with sufficient capacity of high prewure air. ii) The maintenance of compressor and other re!ated equipments is required. iii) There is possibility of air leakages at the pipe fittings. iv) It is very sensitive to restriking voltage. Thus current chopping may occur which may be avoided by employing resistance switching.

Applications :The air blast circuit breakers are preferred for arc furnace duty and traction system because they are suitable for repeated duty. These type of circuit breakers are finding their best application in systems operating in range of 132 kV to 400 kV with breaking capacities upto 700 MVA. This will require only one or two cycles. There are two major types - cross blast and aVial blast.

Air Break(circuit breaker)

In air circuit breakers the atmospheric pressure air s used as an arc extinguishing medium. the principle of high resistance interruption is employed for such type of breakers. The length of the arc is increased using arc runners which will increase its resistance in such a way that the voltage drop across the arc becomes mom than the supply voltage and the arc will he extinguished This type of circuit breaker is employed in both ac and d.c. type of circuits upto 12 kV. These are normally indoor type and installed on vertical panels. The lengthening of arc is done with the help of mangetic fields. Some typical ratings of this type of circuit breaker are 460V - 3.3 kV with current range 400 - 3503 A or 6.6 kV with current range 403-2400 A etc.

Construction The Fig. shows the constructional details of air break circuit breaker.



(I) Contact 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 terminals
7. Arc runners

It consists of two sets of contacts I) Main contacts 2) Arcing contacts

During the normal operation the main contacts are closed. They are having low resistance with silver plating. The arcing contact: are very hard, heat resistant. They are made up of copper alloy. Arc runners are provided at the one end of arcing contact. On the upper side arc splitter plates are provided.

Working As seen from the Fig the contacts remain in closed position during normal condition. Whenever fault occurs, the tripping signal makes the circuit Current breaker contacts to open. The arc is drawn in between the contacts When ever the arc is struck between the contacts, the surrounding air gets ionized. The arc i5 then cooled to reduce the diameter of arc core. While separating the main contacts are separated first. The current is then shifted to arcing contains. Later on the arcing contacts also start separating and arc between them is forced upwards by the electromagnetic forces and thermal action. The arc travels through the arc runners. Further it moves upwards and split by arc splitter plates. Due to all this finally the arc gets extinguished as the resistance of the arc is increased. Due to lengthening and cooling, arc resistance increases which will reduce the fault current and will not allow reaching at high value. The current zero points in the ac. wave will help the arc extinction with increase in arc resistance the drop across it will go on increasing. Whenever arc leaves the contacts it is passed through arc runners with the help of blow out coils which provide a magnetic field due to which it will experience a force as given by electromagnetic theory (F = 131/). This force wilts assist in moving the arc upwards. The magnetic field produced is insufficient to extinguish the arc. For systems having low inductances arc gets extinguished before reaching extremity of runners because lengthening of arc will increase the voltage drop which is insufficient to maintain the arc.

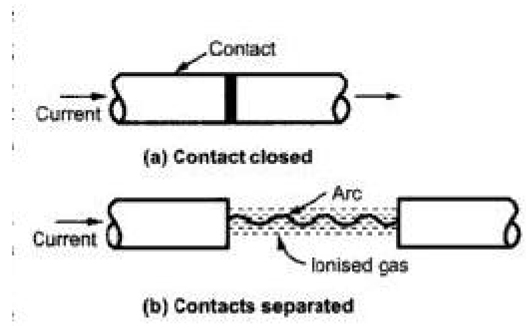


Fig working of air breaks circuit breaker

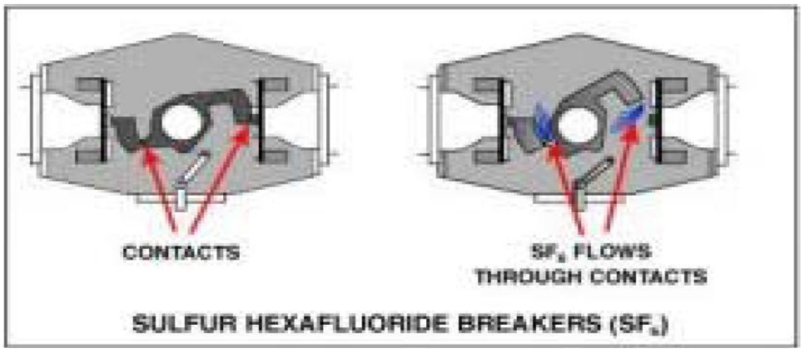
For high inductance circuits if it is not extinguished while travelling through arc runners then it is passed through arc splitters where it is cooled. This will make the effective deionized by removing the heat from arc.

Applications: this type of circuit breakers are commonly employed for industrial switchgear, auxiliary switch gear in generating stations.

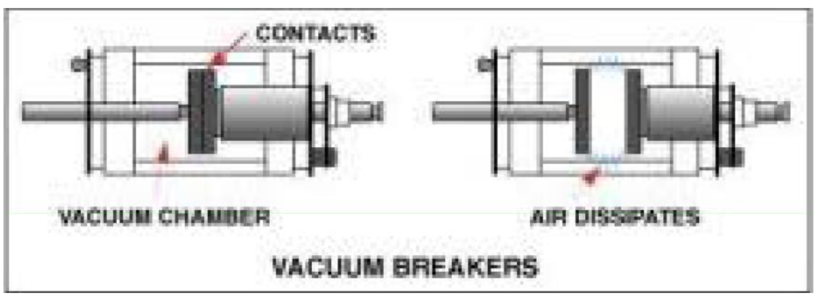
Sulphur Hexafluoride (SF6) Circuit Breaker Pure sulphur hexafluride gas is inert and thermally stable. It is having good dielectric and arc extinguishing properties. It is also an electronegative gas and has strong tendency to absorb free electrons. SF, gas remains in gaseous state up to a temperature of r C. Its density is about five times that of air and the free heat convection is 1.6 times as much as that of air. Also being inert it is non-in flammable, non-poisonous and odour less. The contacts of the breaker arc opened in a high pressure flow of SF6, gas and an arc is struck between them The conducting electrons front the arc are captured by the gas to form relatively immobile negative ions. The loss of this conducting electrons developes enough strength of insulation which will extinguish the arc. Thus SF, circuit breakers are found to be very effective for high power and high voltage service and widely used in electrical equipment. Only the care to be taken is that some by-products are produced due to breakdown of gas which are hazard to the health of the personnel it should be properly disposed. Several types of SF, circuit breakers are designed by various manufacturers in the world during the recent years which are rated for voltages from 3.6 to 760 kV. The property of this gas is that the gas liquifies at certain low temperatures. The liquification temperature can be increased with pressure this gas is commercially manufactured in many countries and now used extensively, in electrical industry. The gas is prepared by burning coarsely crushed roll sulphur in fluorine gas in a steel box. The box must be provided with staggered horizontal shelves each containing about 4 kg of sulphur. The steel box is gas tight. After the chemical reaction taking place in the box, the SF6 gas obtained contains impurities in the form of fluorides such as S21410, SF4 etc. Thus it must be purified before it is supplied. The manufacturing of this gas at large scale reduces its cost. The dielectric strength of SF6 gas at any pressure is more than that of air. When the gas comes in contact with the electric arc for long period, the decomposition effects are small and dielectric strength is not considerably reduced and the metallic fluorides that are formed are good insulators and are not harmful to the breaker.

Sulphur-hexa flouride (SF6) is an inert insulating gas, which is becoming increasingly popular in modern switchgear designs both as an insulating as well as an arc-quenching medium. Gas insulated switchgear (GIS) is a combination of breaker, isolator, CT, PT, etc., and are used to replace outdoor substations operating at the higher voltage levels, namely 66 kV and above. For medium- and low-voltage installations, the SF6 circuit breaker remains constructionally the same as that for oil and air circuit breakers mentioned above, except for the arc interrupting chamber which is of a special design, filled with SF6. To interrupt an arc drawn when contacts of the circuit breaker separate, a gas flow is required to cool the arcing zone at current interruption (i.e. current zero). This can be achieved by a gas flow generated with a piston (known as the 'puffer' principle), or by heating the gas of constant volume with the arc's energy. The resulting gas expansion is directed through nozzles to provide the required gas flow. The pressure of the SF6 gas is generally maintained above atmospheric; so good sealing of the gas chambers is vitally important. Leaks will cause loss of insulating medium and clearances are not designed for use in air. **Sulfur hexafluoride (SF6)**

Sulfur hexafluoride (SF6) is an insulating gas used in circuit breakers in two ways. In "puffer" designs, it's blown across contacts as they open to displace the arcing gas. In "blast" designs, it's used at high pressures to open contacts as it simultaneously extinguishes the arc.SF6 breakers are rated for the highest voltage of all breaker designs



Vacuum breakers enclose the contacts within a vacuum chamber, so when the arc of metallic vapor forms it is magnetically controlled and thereby extinguished at current zero. Vacuum breakers are rated up to 34.5 kV.



Salient features:

- Simple and compact design.
- Line to ground clearances as per customer specification.
- Self aligning contacts for easy re-assembly.
- Inspection / maintenance of pole unit possible without dismantling the breaker.
- Separate main and arcing contacts thus eliminating the possibility of erosion of the main contacts.
- Single break up to 245 kV level.
- Consistent operating characteristics as the closing spring is in relaxed condition.

- Stainless steel latches /catches for high reliability.
- Corrosion resistant materials for construction.
- Maintenance free operation of the pole unit for 15-20 years under normal conditions.
- Easy erection.
- No site adjustments.
- Easy access to all parts of operating mechanism through front/back opening panels.
- Low operating noise levels.
- Auto drain valve for unmanned substation operations.
- Pressure relief device.
- High seismic withstand capability - earthquake safety.

Construction & operation:

All our SF6 Circuit breakers have a similar interrupter design. The range of breakers from 72.5 kV to 245 kV is manufactured with single break interrupter design while 420 kV breakers are manufactured with double break interrupters. These breakers are of live tank design and employ puffer action for interruption ensuring higher operational reliability and safety of power transmission and distribution systems. The interrupting unit filled with SF6 gas is placed at the top of the pole and contains Stationary

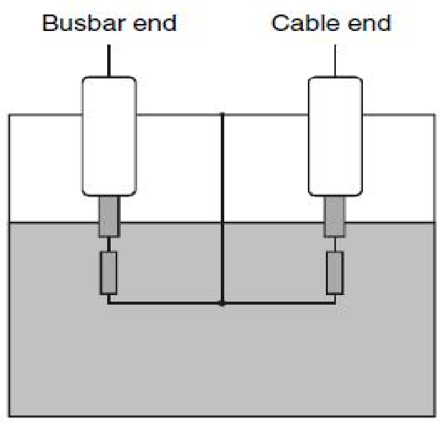
Contact, Nozzle, Moving Contact, Puffer Cylinder and Fixed Piston. During opening operation the Moving Contact along with the Puffer Cylinder is pulled down. The Puffer Cylinder, which moves along with the Moving Contact, compresses the SF6 gas against the Fixed Piston thus generating a powerful SF6 gas blast through the nozzle and over the arc. After travelling through some distance, the dielectric strength of the gap is sufficient to withstand the voltage and thus the arc extinguishes. The reliability of the system is further increased by the single pressure dual flow SF6 gas puffer interrupter which reduces the number of moving parts and auxiliary systems in the circuit breaker.

Oil circuit breakers

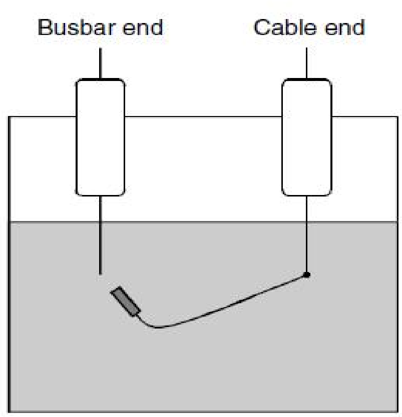
In modern installations, oil circuit breakers, which are becoming obsolete, are being replaced by vacuum and SF6 breakers. However there are many installations, which still employ these breakers where replacements are found to be a costly proposition. In this design, the main contacts are immersed in oil and the oil acts as the ionizing medium between the contacts. The oil is mineral type, with high dielectric strength to withstand the voltage across the contacts under normal conditions.

(a) Double break (used since 1890),.

(b) Single break (more popular in earlier days as more economical to produce –less copper, arc control devices, etc., Arc energy decomposes oil into 70% hydrogen, 22% acetylene, 5% methane and 3% ethylene. Arc is in a bubble of gas surrounded by oil.



Double break oil circuit breaker



Single break oil circuit breaker

Oil has the following advantages:

• Ability of cool oil to flow into the space after current zero and arc goes out

• Cooling surface presented by oil

• Absorption of energy by decomposition of oil

• Action of oil as an insulator lending to more compact design of switchgear.

Disadvantages:

• Inflammability (especially if there is any air near hydrogen)

• Maintenance (changing and purifying).

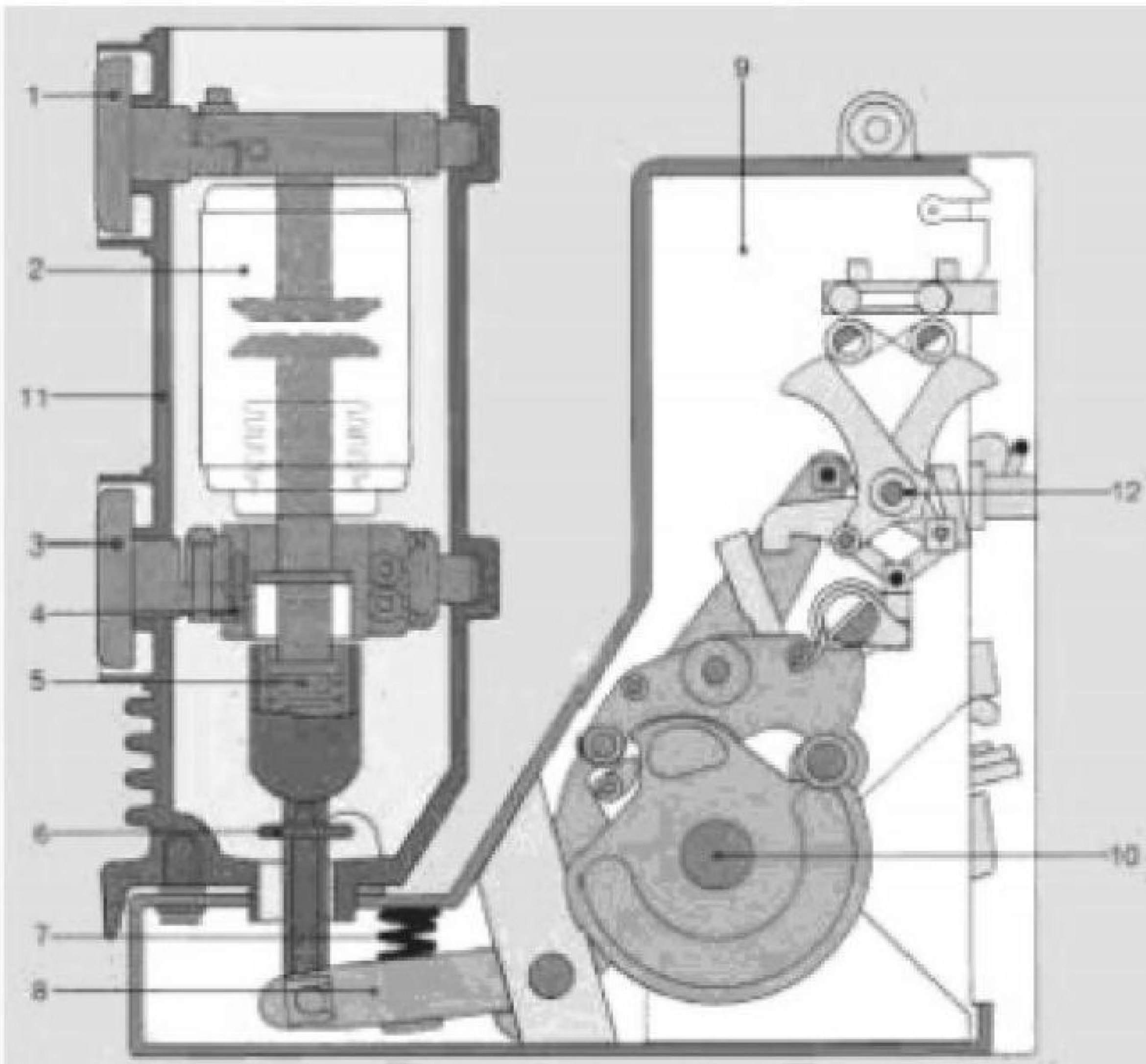
In the initial stages, the use of high-volume (bulk) oil circuit breakers was more common. In this type, the whole breaker unit is immersed in the oil. This type had the disadvantage of production of higher hydrogen quantities during arcing and higher maintenance requirements. Subsequently these were replaced with low oil (minimum oil) types, where the arc and the bubble are confined into a smaller chamber, minimizing the size of the unit.

Vacuum circuit breakers and contactors: Vacuum circuit breakers and contactors were introduced in the late 1960s. A circuit breaker is designed for high through-fault and interrupting capacity and as a result has a low mechanical life. On the other hand, a contactor is designed to provide large number of operations at typical rated loads of 200/400/600 A at voltages of 1500/3300/6600/11 000 V.

The following table illustrates the main differences between a contactor and a circuit breaker

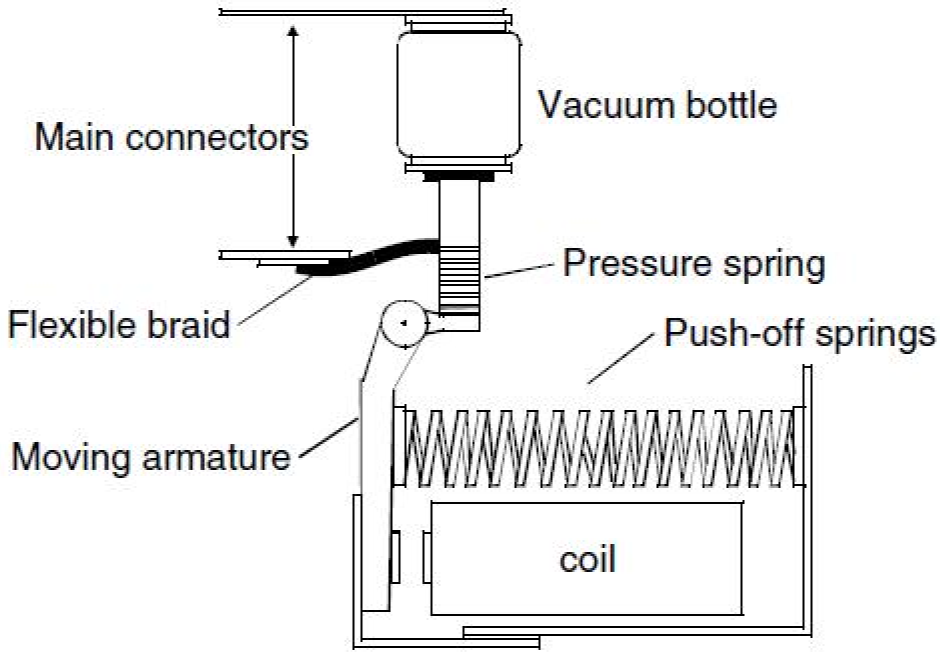
	Contactor	Circuit Breaker
Interrupting capacity	4.0 kA	40 kA
Current rating	400/630 A	630/3000 A
Contact gap at 11 kV	6.0 mm	16.0 mm
Contact force	10 kg	80 kg
Mechanical life	1–2.5 million	10 000

Hence, it is necessary to use back-up fuses when contactors are employed to take care of the high fault conditions. Vacuum breakers are also similar in construction like the other types of breakers, except that the breaking medium is vacuum and the medium sealed to ensure vacuum. Figures below give the components of a vacuum circuit breaker.



1 Upper connection	7 Opening spring
2 Vacuum interrupter	8 Shift lever
3 Lower connection	9 Mechanism housing with spring operating mechanism
4 Roller contact (swivel contact for 630 A)	10 Drive shaft
5 Contact pressure spring	11 Pole tube
6 Insulated coupling rod	12 Release mechanism

General construction of a vacuum circuit breaker



The modern vacuum bottle, which is used in both breakers and contactors, is normally made from ceramic material. It has pure oxygen-free copper main connections; stainless steel bellows and has composite weld-resistant main contact materials. A typical contact material comprises a tungsten matrix impregnated with a copper and antimony alloy to provide a low melting point material to ensure continuation of the arc until nearly current zero.

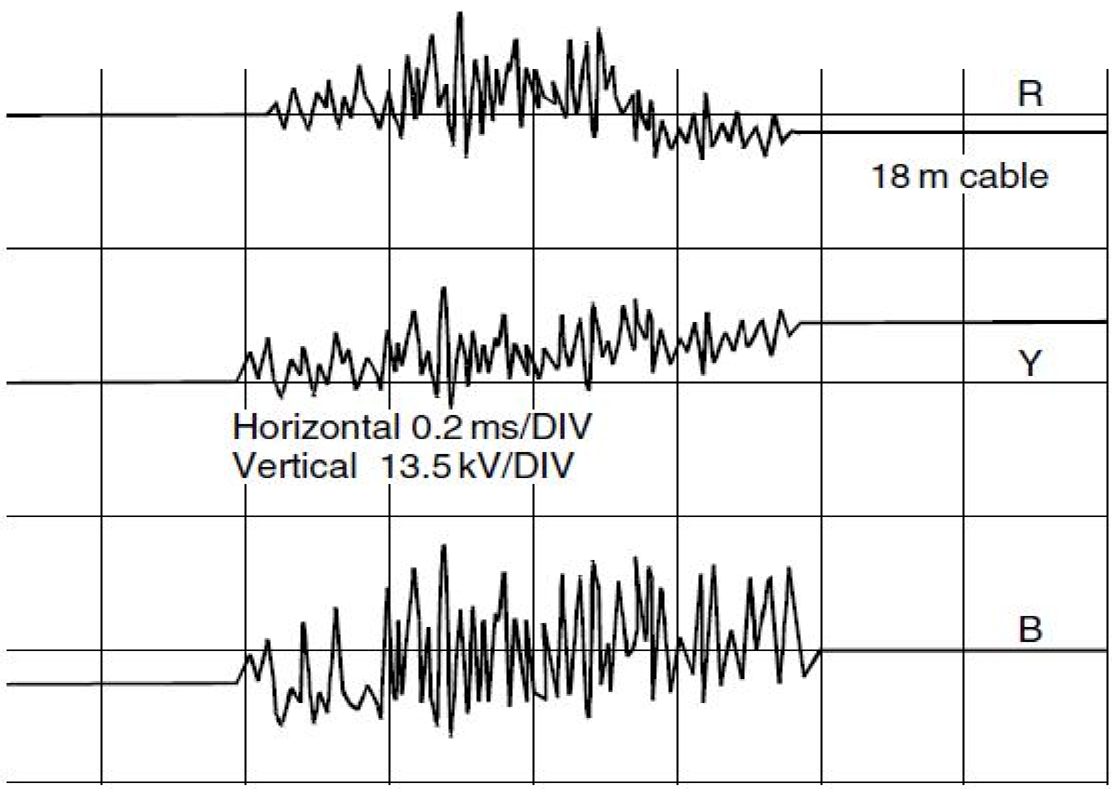
Because it is virtually impossible for electricity to flow in a vacuum, the early designs displayed the ability of current chopping i.e. switching off the current at a point on the cycle other than current zero. This sudden instantaneous collapse of the current generated extremely high-voltage spikes and surges into the system, causing failure of equipment.

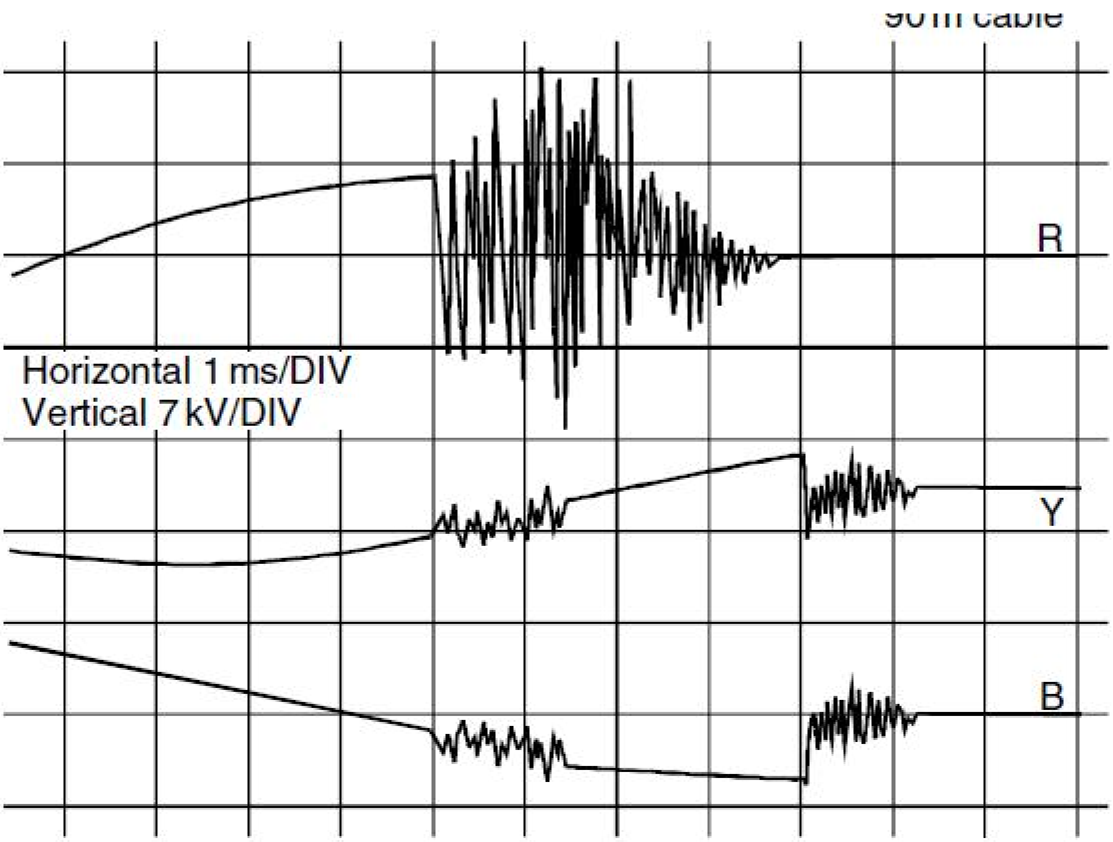
Another phenomenon was pre-strike at switch on. Due to their superior rate of dielectric recovery, a characteristic of all vacuum switches was the production of a train of pulses during the closing operation. Although of modest magnitude, the high rate of rise of voltage in pre-strike transients can, under certain conditions produce high-insulation stresses in motor line end coils. Subsequent developments attempted to alleviate these shortcomings by the use of 'softer' contact materials, in order to maintain metal vapor in the arc plasma so that it did not go out during switching. Unfortunately, this led to many instances of contacts welding on closing.

Restrike transients produced under conditions of stalled motor switch off was also a problem. When switching off a stalled induction motor, or one rotating at only a fraction of synchronous speed, there is little or no machine back emf, and a high voltage appears across the gap of the contactor immediately after extinction. If at this point of time the gap is very small, there is the change that the gap will break down and initiate a restrike transient, puncturing the motor's insulation.

Modern designs have all but overcome these problems. In vacuum contactors, higher operating speeds coupled with switch contact material are chosen to ensure high gap breakdown strength, produce significantly shorter trains of pulses. In vacuum circuit breakers, operating speeds are also much higher which, together with contact materials that ensure high dielectric strength at a small gap, have ensured that prestrike transients have ceased to become a significant phenomenon. These have led to the use of vacuum breakers more common in modern installations.

Practical Power Systems Protection





Switch off of stalled 6.6 kV 200 kW motor-escalating restrike on R phase

Dashpots

In oil circuit breakers, when the breaker is closed, if the operation is not damped then contact bounce may occur and the breaker may kick open. Dashpots prevent this. They may also prevent unnecessary physical damage to the contacts on impact. Their use of course depends on the design.

Contacts

Fixed contacts normally have an extended finger for arc control purposes. Moving contacts normally have a special tip (Elkonite) to prevent burning from arcing.

Comparison of insulating methods for CBs

Property	Air	Oil	SF6	Vacuum
Number of operations	Medium	Low	Medium	High
'Soft' break ability	Good	Good	Good	Fair
Monitoring of medium	N/A	Manual test	Automatic	Not possible
Fire hazard risk	None	High	None	None
Health hazard risk	None	Low	Low	None
Economical voltage range	Up to 1 kV	3.3–22 kV	3.3–800 kV	3.3–36 kV

Comparison of breaker types

Following curve gives the requirement of electrode gaps for circuit breakers with different insulating mediums

Practical Power Systems Protection

The following table highlights the features for different types of circuit breakers.

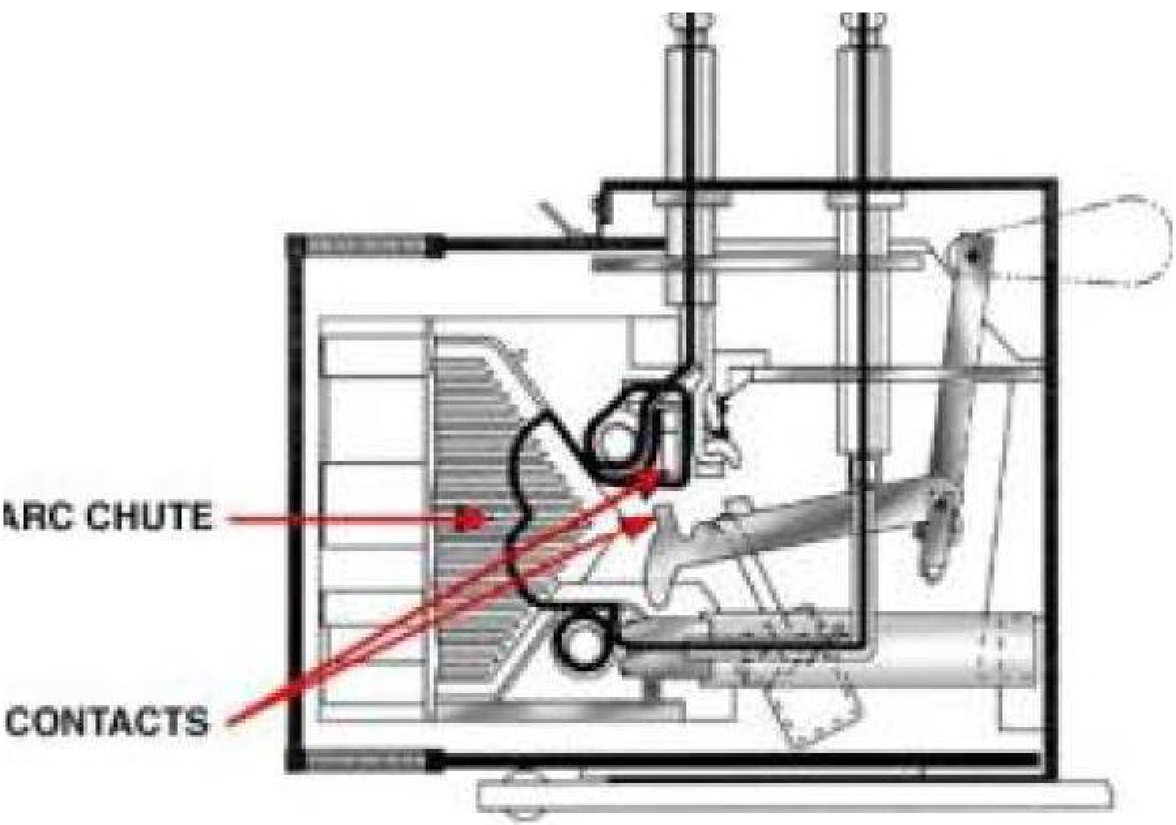
Factor	Oil Breakers	Air Breakers	Vacuum/SF6
Safety	Risk of explosion and fire due to increase in pressure during multiple operations	Emission of hot air and ionized gas to the surroundings	No risk of explosion
Size	Quite large	Medium	Smaller
Maintenance	Regular oil replacement	Replacement of arcing contacts	Minimum lubrication for control devices
Environmental factors	Humidity and dust in the atmosphere can change the internal properties and affect the dielectric		Since sealed, no effect due to environment
Endurance	Below average	Average	Excellent

Circuit Breaker Operation

In addition to the events that cause a trip, a circuit breaker for switchgear applications must also be selected for the method by which it opens when tripped. This is important, because when contacts are opened quickly at high voltage levels, a conductive metallic vapor can form that allows current to continue to travel between the open contacts. This phenomenon, known as arcing, creates the greatest obstacle to circuit interruption.

As a result, medium- and high-voltage circuit breakers employ one of four different arc interrupting technologies. All take advantage of the fact that even the most powerful AC overcurrent cycles pass the zero current level twice in one cycle. By reducing the amount of conductive gas between the contacts, the arc cannot be sustained when it passes through a current zero. Since the current in DC circuits does not follow a sine-wave pattern, circuit interruption is very difficult. This makes the DC interrupting rating for most breakers much lower than the interrupting rating for AC circuits.

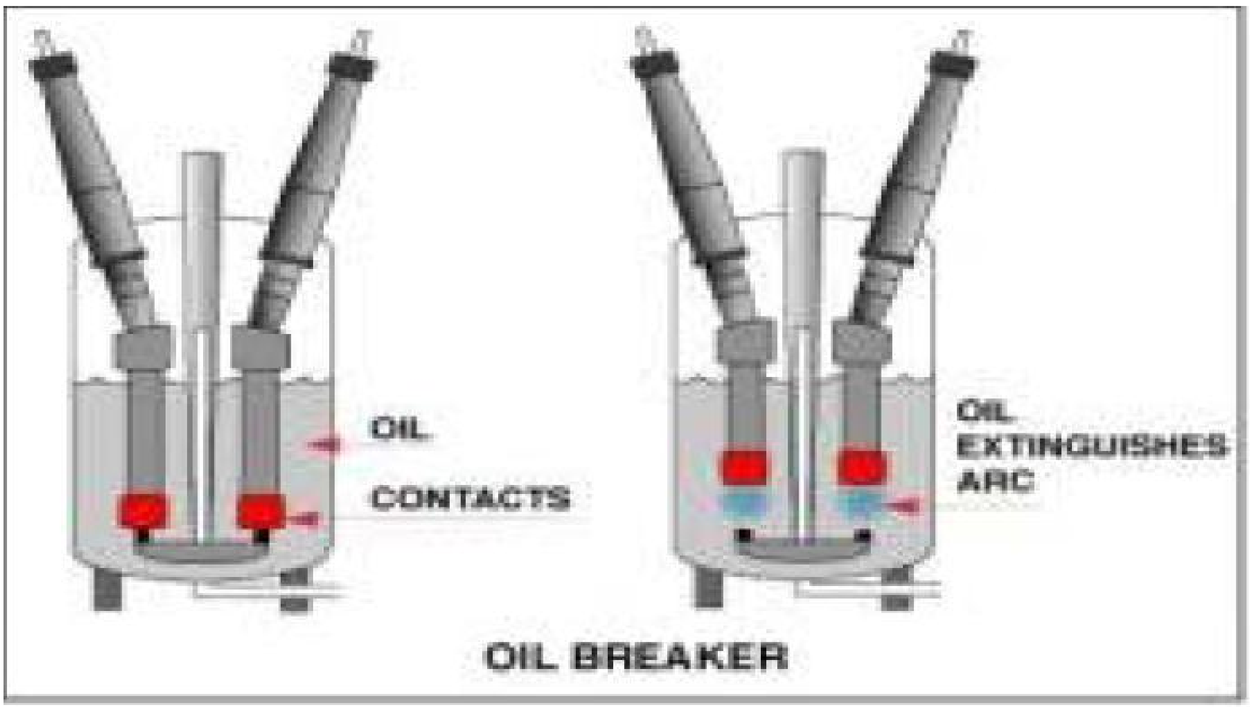
Air magnetic breakers



Air magnetic breakers use the arc to generate a magnetic field that forces the arc into arc chutes, which lengthen and cool the arc, allowing it to be extinguished at a current zero.

Oil breakers

Oil breakers are of several types, including bulk oil, but they all work in a relatively similar way. Here, the contacts are immersed in a container of non-conductive oil. When an overcurrent occurs, the arc heats the surrounding oil forcing it to flow violently. The rapidly flowing oil displaces the arcing gases and breaks the arc path.



Oil breakers always carry the hazards of handling and disposing of spent oil, and the potential for oil fire. Different oil breakers are designed for different power levels, with the highest rated for 345 kV to 500 kV.

Testing of Circuit breakers

Type Tests As mentioned earlier these tests are carried out on first few circuit breakers to prove the rated characteristics of the breakers. The necessary information which includes assigned ratings, drawings, reference standards, rated operating pressure and voltage, support structure etc must he supplied to the testing authorities More conducting these test.. These details are included in the type tests report. After certifying the breaker by carrying out these tests, there should not be any change in design. Type tests are classified as follows,

a) Mechanical tests

b) Tests of temperature rise, milli volt drop test

c) High voltage test

d) Basic short circuit test i) Making test ii) Breaking test iii) Operating sequence tests at 10%, 30%, 60%, 100% of rated breaking current with specified TRV conditions.

e) Critical current tests

f) Single phase short circuit test

g) Short time current test In addition to above tests some more tests are recommended breakers to be used in specific applications, which are, a) Short line fault tests b) Out of phase switching tests c) Cable charging current switching test d) Capacitive current switching tests e) Small inductive current breaking tests of Reactor current switching tests

Routine Tests

Before dispatch of circuit breakers, these tests are performed. Routine test is defined as a test of every circuit breaker made to the same specifications. They include the following tests. a) Mechanical operation tests b) Millivolt drop test, Measurement of resistance c) Power frequency voltage tests d) Voltage tests on auxiliary circuits, control circuits the quality of the circuit breaker can be very well checked by these tests. Also any defect in the materials and construction is detected.

Development Tests These tests, are very much essential to observe the effect of different parameters on the circuit breakers performance. Variety of tests is performed on individual items as well as on complete assemblies. If a circuit breaker is tested frequently with change in its contact speed, then we can see the effect of contact speed on breaking capacity the different parameters and their effects are theoretically predicted. Full scale prototypes are manufactured after testing and measurement. The data available in the company is used by the designers for name for the design of contacts; the configuration can be derived from available designs of contact assemblies. Each subassembly has certain functional requirement e.g. the contacts should give low resistance in closed position. Therefore to verify the capability of contact configurations, development tests are conducted, depending on functional requirements. The modifications are done on the basis of these test results.

Reliability Tests The newly manufactured circuit breakers are tested by type tests and routine tests. But the conditions during these tests are not the conditions that exist at the field. At site the circuit breaker is subjected to various stresses due to,

a) Variation in ambient temperatures

b) Extremely low and high temperatures

c) Rain moisture

d) Vibrations on account of earthquakes

e) Dust and chemical fumes, Overloads and over voltages

Unit Testing The modern FEW circuit breakers contains two or more similar interrupters per pole. These interrupters operate simultaneously and share the voltage across the pole equally. The breaking capacity is also equally shared. The results obtained on one unit can be extended further for total capacity of breaker. This is known as unit testing or element testing. It is internationally accepted method. During the application of unit test, the voltage must be reduced by a factor b so the corresponding impedances are also reduced by b to get test voltage across the unit following expression. a = where m = number of units per pole and one unit is tested

are in opposition. The stress ei produced in the synthetic test and those in actual network must be same but it is not the actual case because of several factors like high current, high voltage, instant of applying voltage etc.

Brown Boveri's Synthetic Testing Circuit This circuit is shown in the Fig. 10.35. The short circuit current is supplied from low voltage circuit. The restriking and recovery voltage is supplied by different high voltage circuit.

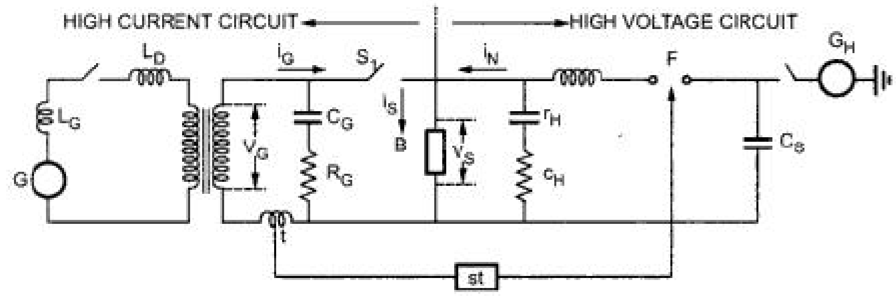


Fig. shows Brown-Boveri's synthetic testing circuit The high current circuit on left side consists of short circuit generator G, short circuit transformer with resistor Rc and capacitor Cc which controls natural frequency of current. The short circuit power is supplied at voltages Vs which corresponds to about 30 kV which is smaller than recovery voltage required for testing. The recovery voltage is supplied by high voltage circuit on right side. The test breaker and auxiliary breaker S, are opened together. Before the current interruption takes place in breaker B, the spark gap is triggered by control St and voltage V is applied to breaker B. During final current zero only current if, Lows through breaker B. which is interrupted by S, and breaker B. But now breaker B has to interrupt only. Hence restriking voltage across breaker B is given by NV circuit.

Lightning arresters

Introduction: The voltage wave having magnitude more than its normal value and which remains for a very short duration are called overvoltage surges or transmit over voltages. For any electrical equipment, its insulation requirements are decided by these transient over voltages. The over voltages in the system occur due to various reasons such as lightning surges, switching surges, faults and travelling waves. There is high rate of rise and high peak value in transient over voltages which are dangerous for the Insulation and hence protection is rewired against these over voltages.

Lightning Phenomenon: A lightning stroke on any overhead line or on outdoor equipment causes lightning surges. Before studying the protection against these lightning surges, let us study the mechanism of lightning. An electrical discharge in the air between clouds, between the separate charge centers in the same cloud or between cloud and the earth is nothing but lightning. It produces the large spark accompanied by the light. This discharge of electricity through the air from the clouds under turbulent conditions is always abrupt and discontinuous. The serious hazards may take place sometimes if this discharge terminates on the earth. There are various theories which explain the potentials required for lightning strokes, are built up. However we will assume that because of some process taking place. In the atmosphere under the turbulent conditions there is accumulation of charges in the clouds. With the dielectric medium as the air the cloud and the ground form plates of a capacitor. If the lower part of the cloud la negatively charged, the earth is positively charged by induction. For lightning discharge to take place, it requires breakdown of air between the cloud and the earth. With increase in the charge, the potential between the cloud and the earth increases. As a result of this the potential in the air increases. The potential gradient required for the breakdown of air is 30 kV/cm peaks. But there is large moisture content in the air and because of lower pressure at high altitude; the breakdown of air takes place at 10 kV/ar. The process of lightning discharge is shown in the Fig.

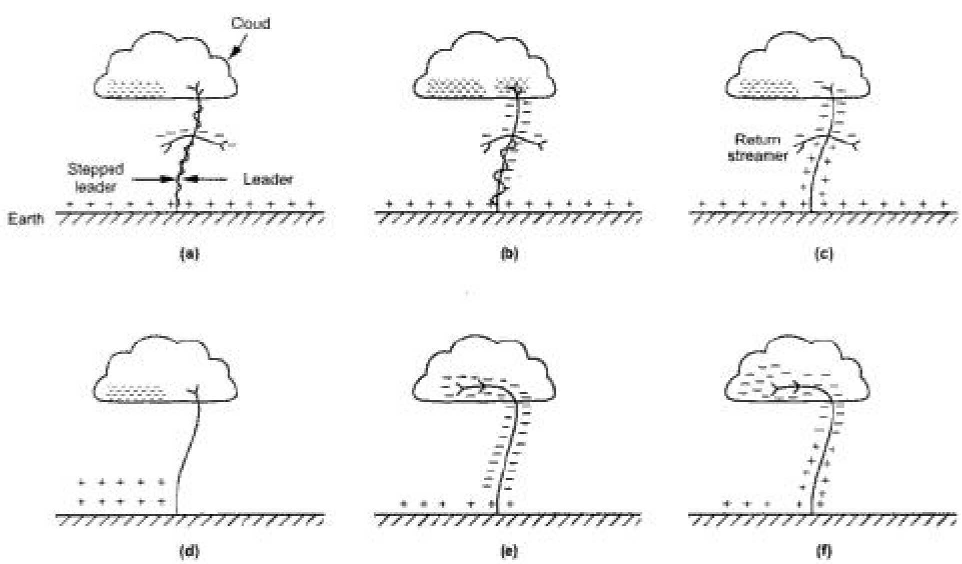


Fig. When charge increases there is difference in potential between cloud and earth which also increases resulting in increase of potential gradient of air which is non uniformly distributed. The potential gradient is more at the center of charge in the cloud. This gradient appears across some part of the air and when it is more than breakdown strength of air, this air breaks down A streamer called pilot streamer or leader streamer starts from cloud towards the earth and carries the charge with it as shown in the Fig. (Till the time the cloud through which this stream is initiated supplies enough charge to maintain the potential gradient at the tip of the leader streamer above the breakdown strength of air, the leader streamer continues to travel towards the earth. With the loss of this gradient, the streamer stops without reaching to the earth. The charge dissipated without forming the complete stroke. The lightning stroke may start with the potentials of the order of 5* 106 Vie 20x 106 V between cloud and earth while the current of the leader streamer is low, typically less than 100 A and its propagation velocity is 0.03 % of that of velocity of light.

Many times the streamer travels towards the earth until it is reached to the earth or some abject on earth. As the initial moves towards earth, it is accompanied by points of luminescence which travel in jumps giving rise to stepped leaders In step the distance travelled is about 50 in while the velocity of stepped leader exceeds one sixth of that of light. The stepped leaders results in first visual phenomenon of discharge. The electrostatic field and potential gradient at earth's surface is high as this streamer reaches to the earth. When sufficiently large then a short upward streamer called return streamer rises form the earth as shown in the Fig. When the contact of leader b made with the earth then a sudden spark may be appeared. This contact is similar to closing of a switch between two opposite charges, the downward leader with negative change and upward streamer with positive charge. Due to this sudden sparks appearing which causes the most neutralization of negative charges on the cloud? This is called lightning. Any further discharge from the cloud must be originated form other portion of it. When lightning occurs then it is associated with high current followed by lower current for significant duration as the charge in the cloud is neutralized. The upward streamer carries high current with a speed of propagation of about 30 m/ iL sec which is faster than the speed of the leader streamer. The current rises sharply within microseconds and then decays slowly compared to its rise. this is similar to discharge of a capacitor through a circuit but it is not periodic. The experiments conducted in the laboratories show that when the charge in the channel is near exhaustion, there is smooth transition in current into its low value which is associated with the remaining charge in the cloud. When the streamer reaches the earth and much of charge in the cloud from which it was originated, is neutralized then potential pertaining to point of charge center reduces. But there may exist high potential between this original charge center and other charge centers. Due to this, there may be discharge from other charge centers into the region where the leader streamer was originated. Thus a subsequent discharge takes place along with the original stroke to the earth. Many strokes can be observed which contains more than one current peak which are called multiple or repetitive. Separate peaks are termed as components. In summary we can say that lightning is a phenomenon of breakdown of air and discharge which can he seen by eve as a sing 'e flash but contains number of separate strokes that travels with same path practically. The variation of time interval between them is from 0.5 m sec< to 300 msec. 87 % of the lightning strokes originate from negatively charged clouds while remaining 13 % originate from positively charged clouds. Lightning discharge current magnitude lies in the range of 10 kA to 90 kA.