Various Types of Circuit Breakers used in Power System for Smooth Working of the Transmission Line

Saurabh Saxena  
Assistant Professor  
Moradabad Institute of Technology  
Moradabad, UP, INDIA  
Email: ss_saurabh912@rediffmail.com

Alok Singh  
Assistant Professor,  
Moradabad Institute of Technology  
Moradabad, UP, INDIA  
Email: asingh0619521003@gmail.com

Maroof Ali  
Assistant Professor  
Moradabad Institute of Technology  
Moradabad, UP, INDIA  
Email: maroofali.ali@yahoo.com

Kapil Gandhi  
Assistant Professor  
Moradabad Institute of Technology  
Moradabad, UP, INDIA  
Email: kapilkiet@gmail.com

ABSTRACT

Once a power system is established it is necessary to protect it from faults (whether internal or external). So we use some protecting and sensing device like circuit breakers, Relays, Fuses etc. Circuit breaker is a mechanical device capable of making, carrying and breaking currents under normal circuit conditions and also making, carrying for a specified time. This paper represents information about the basic types and electrical characteristics of circuit breaker based on medium used for arc quenching, that how it automatically breaks currents under specified abnormal circuit conditions such as those of faults. The insulating medium in which circuit interruption is performed is designated by suitable prefix, such as oil circuit breaker, air-break circuit breaker, air blast circuit breaker, sulphur hexafluoride (SF6) circuit breaker, vacuum circuit breaker.

Keywords: circuit breaker, fault time, restriking voltage.

I. INTRODUCTION

As name indicates that circuit breaker means device which breaks (Open) the circuit under abnormal condition and protect the system from hazards. The function of a circuit breaker is to isolate the faulty point of the power system in case of abnormal conditions such as faults. Another important device which is protective relay detects abnormal conditions and sends a tripping signal to the circuit breaker after receiving tripping command from the relay, the circuit breaker isolates the faulty part from the power system. For opening and closing the circuit the contacts are presents. These contacts are placed in the closed chamber containing a fluid containing medium (either liquid or gas) which quenches the arc formed between the contacts.

Under normal conditions these are at closed position but when the circuit breaker requires to isolate the faulty part, the moving contacts moves to interrupt the circuit on separation arc is formed and until this arc is quenched the current continues to flow the circuit is isolated when the arc is quenched. These contacts are shown in the Figure 2.

Figure 1: Circuit breaker for control for opening operation

Figure 2: Separation of the contacts of circuit breaker.
II. FAULT CLEARING TIME OF A CIRCUIT BREAKER

A circuit breaker is required in the power system to give rapid fault clearance, in order to avoid over current damages to the equipment and loss of system stability. The fault tripping signal is derived from the relay via the trip circuit. After the fault inception, relay senses the fault and closes its contact to complete the trip circuit and relay takes some time to complete its operation then the trip coil of the circuit breaker is energized and the operating mechanism comes into operation. The contacts of the circuit breaker start separating to clear the fault. On the separation arcing takes place but current continues to flow till the arc is completely quenched.

The whole process takes some time and the time taken to follow these steps is known as fault clearing time of a circuit breaker and this is shown by the Figure 3.

The fault clearing time is sum of relaying time and breaker interrupting time, where relaying time is time from fault inception to closure of trip circuit of CB and breaker interrupting time is sum of breaker operating time and arcing time.

The wave shape of the arc voltage is shown below. The voltage drop across the arc is called arc voltage. As, arc path is purely resistive, the arc voltage is in phase with the arc current. The magnitude of the arc voltage is very low, amounting to only few percent of the rated voltage. Arc may be interrupted by two methods, one is high resistance interruption and another is current zero interruption (Based on slepian’s theory and cassie’s theory).

III. RESTRIKING VOLTAGE AND RECOVERY VOLTAGE

When the arc persists between contacts of CB, the voltage across the contacts of the circuit breaker is arc voltage. This voltage becomes the system voltage when the arc is extinguished. The arc is extinguished at the instant of current zero. After the arc is extinguished, the voltage across the terminals does not normalize instantaneously but it oscillates and there is a transient condition.

The transient voltage which appears across the breaker contacts at the instant of arc being quenched is called as restriking voltage. The power frequency rms voltage, which appears across the breaker contacts after the arc is finally extinguished and transient oscillations die out is called recovery voltage. A figure given below explains it. It is very important for better operation CB the rate of rise of restriking voltage (RRRV) should be low.

IV. RESISTANCE SWITCHING

The low value of RRRV reduces the transient period time and makes the system stable, to reduce the restriking voltage, RRV and severity of the transient oscillations, a resistance is connected across the contacts of the circuit breaker. This is known as resistance switching. The resistance is in parallel with the arc.

A part of arc current flows through this resistance resulting a decrease in the arc current and decrease in the deionization of the arc path and resistance of the path. This process continues and the current through the parallel resistance increases and arc current decreases, Therefore restriking voltage and RRRV decreases. The resistance switching is of greater help in switching out the capacitive current and low inductive current.
V. CLASSIFICATION OF CIRCUIT BREAKERS

Circuit breakers can be classified using the different criteria such as, different voltage application, location of installation, their external design characteristics, insulating medium used for arc quenching etc.

A. Classification Based on Voltage Range:
1. Low voltage CB (less than 1kv)
2. Medium voltage CB (1-52kv)
3. High voltage CB (66-220kv)]
4. Extra high voltage CB (300-765kv)
5. Ultra high voltage CB (above 765kv)

B. Classification Based on Location:
1. Indoor type
2. Outdoor type

Low and medium switchgears and high voltage gas insulated switchgears are categorized as indoor switchgears, whereas which have air as an external insulating medium, i.e they are classified as outdoor switchgears.

C. Classification Based on External Design (Only for Outdoor Type CB):
1. dead tank
2. live tank type

D. Classification Based on Medium used for ARC Quenching:
1. air-break circuit breakers
2. oil circuit breakers
3. air blast circuit breakers
4. sulphur hexa fluoride (sf₆) circuit breakers
5. vacuum circuit breakers

The development of circuit breakers outlined above has taken place chronologically in order to meet two important requirements of the power system which has progressively grown in size. For larger faults, the breaker should have larger breaking capacity and smaller interruption time.

D(1) Air-Break Circuit Breakers

These circuit breakers are suitable for high current interruption at low voltage, this type of circuit breaker uses air at atmospheric pressure as an quenching medium. It employs two pairs of contact main contact and the arcing contacts. They have low contact resistance. The main contact carries the current when breaker is at the closed position. When contacts are opened, the main contacts separate first, the arcing contacts remain in closed position. Therefore the current is shifted from main contacts to the arcing contacts. The arcing contacts separate later on the arc is drawn between them. The principle of high resistance is employed for arc interruption, the arc resistance is increased by lengthening, splitting and cooling the arc. The arc interruption is assisted by current zero in case of air break circuit breakers, high resistance is obtained near current zero.

These circuit breakers are available in the voltage 400 to 12kv. They are widely used in the low and medium voltage system. The Figure (6) of air break circuit breaker is given below.

\[ Figure 6: \text{Air break circuit breaker.} \]

D(2) Oil Circuit Breaker

Mineral oil is the best insulator than air and it has good cooling properties. So, This is employed in many electrical equipments as, well as circuit breakers. But these type of circuit breakers are not suitable for heavy current interruption at low voltages due to carbonization of oil. some of the types of oil circuit breakers are given below.

(a) Plain–Break Oil Circuit Breakers

In these circuit breakers the moving as well as fixed contacts are immersed in oil, the metal tank is strong, weather tight and earthed When the contacts are separated there is a severe arc which decomposes the gas into oil. Mainly hydrogen is obtained from the oil. Hence, the oil is pushed away from the arc and gaseous medium surrounds the arc, creating a large gaseous pressure, to withstand this pressure tank is made strong. Plain break oil CB is shown by Figure 7.

\[ Figure 7: \text{Plain-break oil circuit breaker} \]
(b) **Self Generated Pressure Oil Circuit Breaker**

In these type of C.B. the arc energy is utilized to generate a high pressure in a chamber known as pot. The contacts are enclosed within the pot and it is made up of insulating material. It is placed inside the tank. They are of several types, some of them are given below.

(i) **Plain Explosion Jet**

This is the simplest form of explosion pot, when the moving contact separates a sever arc is formed. The oil is decomposed and gas is produced. It generates a high pressure within the pot because there is a close fitting throat at the lower end pot. So, the high pressure developed causes turbulent flow of streams of the gas into the arc resulting in arc-extinction. If the arc extinction does not occur within the pot, it occurs immediately after the moving contact leaves the pot, due to high velocity axial blast of the gas which is released through the throat. Plain explosion jet is shown by Figure 8.

(ii) **Cross-Jet Explosion Jet**

It is suitable for high current interruptions. Arc splitters are used to obtain an increased arc length for a given amount of contact travel. When moving contact is separated from the fixed contact, an arc is formed.

(iii) **Double Break Oil Circuit Breaker**

To obtain high arc interruption, particularly at low currents is provided by the double break oil circuit, it employs an intermediate contact between the fixed and moving contact. When the moving contact separates, the intermediate contact also follows it. The arc first appears between the fixed contact and the intermediate contact. soon after, the intermediate contact stops and second arc is extinguished quickly by employing gas pressure and oil momentum developed by first arc. Figure 10 given below shows the double break oil circuit breaker.

![Figure 8: Plain explosion jet.](image)

![Figure 9: Cross-jet explosion pot.](image)

D(3) **Air Blast Circuit Breakers**

In the air blast circuit breakers, compressed air at pressure of 20-30kg/cm² is employed as, an arc quenching medium. Air blast circuit breakers are suitable for operating voltage of 132kv and above. The main advantage of using them is their cheapness and free availability of the interrupting medium, chemical stability and inertness of air, high speed operation.

![Figure 10: Double break oil circuit breaker](image)

They are further classified into:

(i) **Cross-blast circuit breaker**

(ii) **Axial-blast circuit breaker**

Figure 11 Shows air blast circuit breaker.

(i) **Cross-Blast Circuit Breaker**

In this type, a high pressure blast of air is directed perpendicularly to the arc for it’s interruption. The arc is forced into a suitable chute. Sufficient lengthening of the arc is obtained, resulting in the introduction of appreciable resistance in the arc itself. Therefore, resistance switching is not common in this type.

(ii) **Axial Blast Circuit Breaker**

In this type of circuit breaker, a high pressure of air is directed longitudinally, i.e in the line with the arc. These are suitable for EHV and super high application. This is because interrupting channels can be fully enclosed in porcelain tubes. The number...
of breaks depend upon the system voltage, for Example 4 at 220 kv and 8 at 750kv. They have also been commissioned to 1100 kv system. Figures of both the types are given below:

![Airblast Circuit breaker](image1)

**D(4) SF₆ Circuit Breaker**

These type of circuit breakers have good dielectric strength and excellent arc quenching property. It is an inert, non-toxic, non-flammable and heavy gas. As circuit breakers are totally enclosed and sealed from atmosphere so it is very careful where explosion hazards exist. At atmospheric pressure, it’s dielectric strength is about 2.35 times that of air. At normal conditions it is chemically inert, these properties of sf₆ has made it possible to design circuit breakers with smaller overall dimensions, shorter contact gaps, which help in the constructions of outdoor breakers with fewer interrupts and evolution of metalclad. It is particularly suitable for metaclad switch-gear. It is suitable for the range 3.3kv to 765kv. They are preferred for voltages 132kv and above. Electrical Since, these are of two types. They are as, follows:

(i) **Double Pressure Type SF₆ Circuit Breaker**

In double pressure type circuit breaker, the system employed is double pressure system in which the gas from a high pressure compartment is released into low pressure compartment through a nozzle during the arc extinction process. This type of circuit breaker has become obsolete.

(ii) **Single Pressure Type SF₆ Circuit Breaker**

In this type the gas is compressed by the moving cylinder system and is released through the nozzle during arc extinction. This is most popular type of design of sf₆ circuit breaker.

**Properties of SF₆ Circuit Breaker**

1. Physical properties:
   - Colorless, odorless, non-toxic and non-inflammable gas.
   - Pure gas is not harmful to health.
   - It has excellent heat transfer property.

2. Chemical properties:
   - It’s chemically stable at atmospheric pressure and temperature.
   - It is chemically inert.
   - It’s non-corrosive on all metals at ambient temperatures.

**Vacuum Circuit Breaker**

The dielectric strength and interrupting ability of high vacuum is superior to those of porcelain, oil, air and SF₆ at atmospheric pressure. It’s construction is very simple as, compared to other circuit breakers. When contacts are separated in high vacuum, an arc is drawn between them. The arc does not take place on the entire surface of the contacts but only a few spots. The contact surface is not perfectly smooth. It has certain micro-projections. At the time of contact separation, these projections form the last point of separation. The current flows through these points of separation resulting in the formation of a few hot spots, these spots emit electrons and act as cathode spots. It’s enclosure is made up of insulating material such as, glass, porcelain or glass fibre reinforced plastic. The vapour condensing shield is made up of synthetic resin. The schematic diagram of vacuum circuit breaker is given below by Figure 12. Vacuum CB is now very popular for voltage rating up to 36kv. The main advantage of vacuum CB is it’s suitability for repeated operations, least maintenance silent operation, long life etc.

![Vacuum Circuit Breaker](image2)

VI. CONCLUSION

As in growth of electrical engineering the power generation
is important, also power transmission, distribution and utilization makes the power system complete. Once the power system is completely designed, it is necessary to protect it from faults (abnormal conditions). If power system is not secure and stable, then economic cost for power delivery also increases. So we use some protecting and sensing devices which protects the circuit under abnormal conditions. Circuit breaker is one of the important protecting device which protects the circuit from abnormal conditions by opening the contacts and take very less time for fault clearing. The function of a circuit breaker is to isolate the faulty part of the power system in case of abnormal conditions. When the fault occurs in the protected circuit, the relay connected to the CT and PT detects the fault and sends the tripping signal to the circuit breaker. After receiving the trip command from the relay, the circuit breaker isolates the faulty part of the power system. Therefore we can say that circuit breakers is considered as, the major component of the power system.

REFERENCES