Lecture 02:

Circuit Breakers-I

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Why do we need circuit breakers?

With the advancements of power system, the operating voltage and current are very high. The conventional arrangements of switches along with fuses cannot serve the desired function of switchgear in such high capacity circuits.

So it necessitates to employ a more dependable means of control such as is obtained by the use of ***Circuit Breakers.***

Definition: *A circuit breaker can make or break a circuit either manually or automatically under all conditions viz., no-load, full-load and short-circuit conditions*

What can a circuit breaker do?

- *Make or break a circuit either manually or by remote control under n normal condition*
- *Break a circuit automatically under fault conditions*
- *Make a circuit either manually or by remote control under fault conditions*

Principle of Operation of Circuit Breaker

A circuit breaker consists of fixed and moving contacts, called electrodes. Under normal operating conditions, these contacts remain closed and will not open automatically until and unless the system becomes faulty. Of course, the contacts can be opened manually or by remote control whenever desired. When a fault occurs on any part of the system, the trip coils of the circuit breaker get energized and the moving contacts are pulled apart by some mechanism, thus opening the circuit.

When the contacts of a circuit breaker are separated under fault conditions, an arc is struck between contacts.

Why arc is produced in C.B.? What it does to C.B. and Power System?

Arc Phenomenon

- *Large current flow due to short circuit*
- *Rapid decrease in contact area of contacts at the time of separation*
- *Increases current density*
- *Rise in temperature*
- *Ionization of oil/ air due to excessive heat*
- *Conductive path due to ionization of oil/ air*
- *Current remains un-interrupted as long as arc is present*
- *Small potential difference at contacts enough to maintain arc*

What is arc resistance? How it can help to quench the arc? On what factors arc resistance depends?

Arc Resistance

It depends on following factors:

- *Degree of ionization*
- *Length of the arc*
- *Cross-section of arc*

How can we avoid arc? What is principle of arc-extinction?
What are the methods of arc-extinction?

Arc Extinction Methods

Factors responsible for maintaining arc between contacts are as follow:

- *Potential Difference between the contacts*
- *Ionized particles between contacts*

Methods of Arc Extinction:

- *High resistance method*
- *Low resistance method*

High Resistance Method

It is employed only in DC circuit breakers and low-capacity AC circuit breakers only due to enormous energy dissipation in arc.

However, following methods can be used to increase the arc resistance.

- *Lengthening the arc*
- *Cooling the arc*
- *Reducing X-section of the arc*
- *Splitting the arc*

Low Resistance/Current Zero Method

It is used only AC circuits only. All modern high power AC circuit breakers employ this method for arc extinction.

- *Resistance is kept low until current is zero*
- *Arc is extinguishes naturally at current zero*
- *Prevent the re-striking voltage*
- *Build dielectric strength of medium between contacts more rapidly than the voltage across the contacts (re-striking voltage), which can be achieved (a) Recombination of ions into neutral molecules (b) Swept ionized particles away and replace them with unionized particles.*

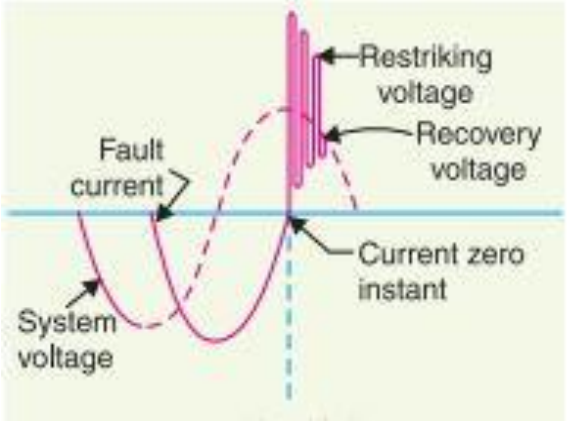
How can we achieve de-ionization of medium ?

(a) Lengthening of the gap (b) high pressure (c) Cooling (d) Blast effect

Important Terms in C.B. Analysis

- *Arc Voltage (Peak at current zero situation)*
- *Re-striking Voltage*
- *Recovery Voltage*

Recovery voltage is normal operating voltage of system that appears across the contacts after final extinction of arc.



Classification of Circuit Breaker

There are several ways of classifying the circuit breakers. However, the most general way of classification in on the basis of medium used for arc extinction.

- *Oil circuit breakers*
- *Air-blast circuit breakers*
- *Sulphur hexafluoride (SF6) circuit breakers*
- *Vacuum circuit breaker*

We shall briefly discuss these types of circuit breakers in next sections. The main emphasis will be on their applications, advantages and disadvantages as well as the method employed for arc extinction/quenching.

Oil Circuit Breakers

- *Decomposition of oil due to arc produces hydrogen gas*
- *Hydrogen occupies a volume thousand times that of the oil decomposed*
- *Hydrogen being a good heat conductor helps (de-ionization of arc path) quenching the arc*
- *Hydrogen bubble creates turbulence in the oil to force it to move between contact and consequently quenching the arc*

Advantages:

- *Oil absorbs arc energy to decomposes oil into gas which has excellent cooling properties*
- *Due to its insulating properties a smaller clearance is provided between Live conductors and earthed components*
- *The surrounding oil presents cooling surface in close proximity to the arc*

Oil Circuit Breakers

Disadvantages:

- *Oil can be inflammable*
- *When mixed with air can be explosive in nature*
- *Requires periodic monitoring and replacement due to arcing product (i.e. carbon) which deteriorates the properties of oil*

Types of Oil Circuit Breakers:

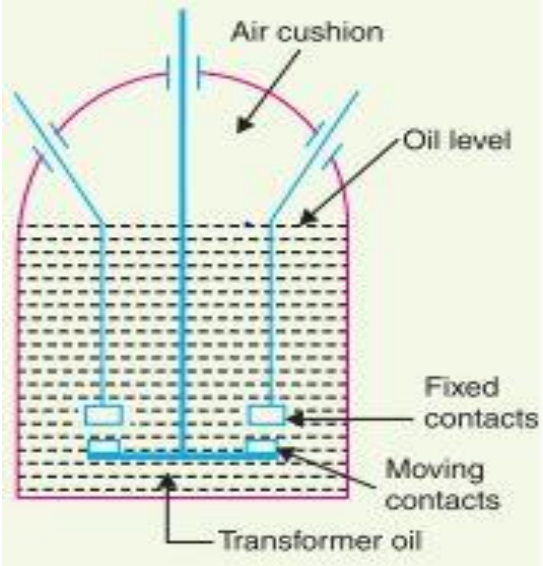
- *Bulk Oil Circuit Breaker*

  (a) Plain break oil circuit breaker *(b) Arc control circuit breaker*

- *Low Oil Circuit Breaker*

Bulk Oil C.B: Plain Break Oil C.Bs

- *Bulk Oil is used*
- *No special arrangement for arc control*
- *Air cushion for gases and oil movement*



Arc Extinction takes place as follow:

- *Lengthening of arc increases dielectric strength of the arc path*
- *Gas set up turbulence in oil which eliminates arcing products from arcing path*
- *De-ionization of arcing path is achieved by hydrogen bubbles' cooling properties*

It is the simplest form of C.B. It has certain disadvantages.

Bulk Oil C.B: Plain Break Oil C.Bs

Disadvantages:

- *No special control over the arc other than the increase in length by separating the moving contacts*
- *Long and inconsistent arcing times*
- *Very slow interruption*

Applications:

In view with the above mentioned disadvantages these circuit breakers are used only for low level voltage applications where high breaking-capacities are not required. These are used for voltage level not exceeding 11 kV.

Bulk Oil C.B: Arc Control Oil C.Bs

To address the shortcomings of the plain break oil C.Bs we use Arc Control Oil C.Bs.

There are three types as given below:

- *Self-Blast Oil Circuit Breaker*
- *Forced-Blast Oil Circuit Breaker*

Self-Blast Oil Circuit Breakers:

- *Also known as self-generated pressure oil circuit breaker*
- *Produced gases confinement in insulating rigid pressure chamber*
- *The pressure built in chamber depends upon the fault current to be interrupted*

The pressure chamber is relatively cheap to make and gives reduced final arc extinction gap length and arcing time as against plain-break oil C.B.

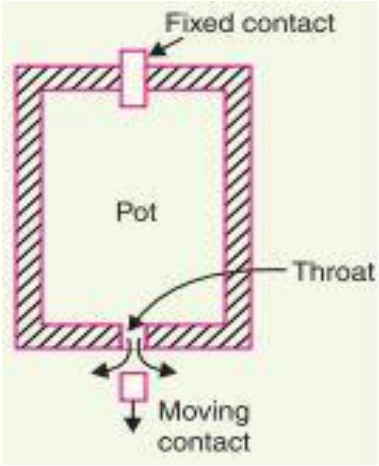
Arc Control Oil C.Bs: Self-Blasted Oil C.Bs

Based on the design of pressure chambers (explosion pot) the self-blast oil circuit breakers has following types:

- *Plain Explosion Pot*
- *Cross-Jet Explosion Pot*
- *Self-Compensated Explosion Pot*

Plain Explosion Pot:

- *Only used for medium capacity of voltage level applications*
- *Moving contact is of cylindrical nature*
- *Contact leaving the throat creates in-rush of oil and gas*



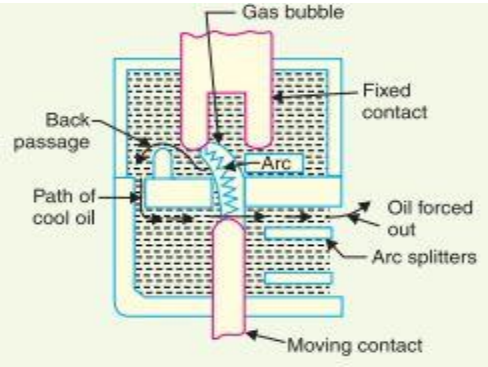
Self-Blasted Oil C.Bs

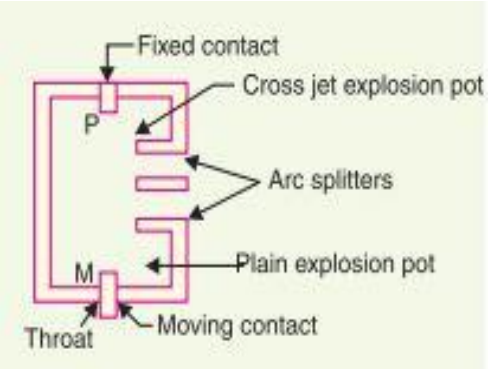
Cross-Jet Explosion Pot:

- *Just a modification of plain blast*
- *Arc splitters for increasing arc length*
- *Oil from back passage crosses arc at right angle*
- *Used for heavy/medium fault currents*

Self-Compensated Explosion Pot:

- *Combination of plain and cross-jet explosion pot*
- *Upper chamber is cross-jet with Arc splitters*
- *Lower chamber is plain blast with throat at end*
- *Used for l ow/medium as well as heavy fault current*





Forced-Blasted Oil C.Bs

- *Piston-cylinder arrangement for oil pressure*
- *Piston is connected with moving contact*
- *Piston forces a jet oil to quench arc*
- *The oil pressure not depends on fault current*

Advantages:

- *The performance is more consistent at low fault current, since oil pressure is independent of fault current*
- *Required amount of oil is considerably reduced*

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Low Oil Circuit Breakers

Bulk oil circuit breaker are mainly use oil for insulating live parts from earth, a very little amount of oil is used for arc-quenching.

For this reason:

- *Increase in expenses*
- *Large tank size*
- *More weight of breaker*
- *Increased risk of fire*
- *High maintenance*

Solid material is used for insulation and small amount of oil is used for arc quenching. Oil in supporting chamber is not contaminated due to arc, so reduced amount of oil to be replaced.

Low Oil Circuit Breakers

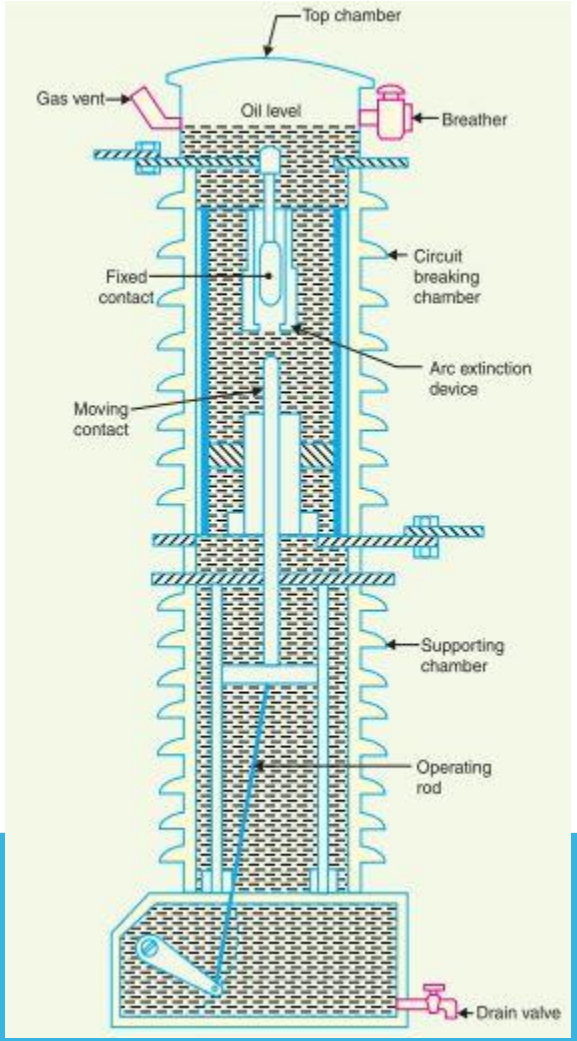
Construction: It contains three chambers.

- *Supporting chamber*
- *Circuit-breaking chamber*
- *Top chamber*

Circuit-breaking chamber: It is a porcelain enclosure mounted on supporting chamber. It has following parts:

- *Upper and lower fixed contacts*
- *Moving contact*
- *Turbulator*

Turbulator is an arc control device has both axial and radial vents. The axial and radial vents ensures interruption of low and heavy fault currents respectively.



Low Oil Circuit Breakers

Advantages:

- *Lesser quantity of oil*
- *Smaller space*
- *Reduced risk of fire*
- *Requires less maintenance*

Disadvantages:

- *Smaller quantity of oil increases degree of carbonization is increased*
- *Difficulty in removing gases from contact space in time*
- *Dielectric strength of the oil deteriorates rapidly due to high degree of carbonization*

Maintenance of Oil Circuit Breakers

The oil circuit breakers are inspected at regular intervals of 3 or 6 months. The maintenance of these breakers is mainly concerned with the checking of contacts and dielectric strength of oil. During inspection of breaker following points must be kept in view:

- *Check the current carrying contacts for burning*
- *Check the oil for dielectric strength. The oil in good condition must stand 30kV for one minute in a standard oil testing cup with 4mm gap between electrodes*
- *Check the insulation for possible damage. Clean the surface and remove carbon deposits with a strong and dry fabric*
- *Check oil level*
- *Check closing and tripping mechanism*

Thank you !

For any query you can contact me through class group on Whatsapp or can call on my cell number from 10:00 AM to 04:00 PM.