Oscillating Lightning Impulse

Tests with lightning impulse voltages are especially effective for detection of sharp protrusions; However, due to risk of flashover, the amplitude of the wave form must be choosen in consultation with the manufacturer. Based on the recommendations of the manufacturers, oscillating impulse voltages with front time upto about 10 μs are suitable.

DC voltages

DC voltages affect the insulator dielectric strength; However, manufacturer have recommended DC voltage tests only in case where cone insulators also come under the testing zone during the testing of adjacent cables. Not more than one core insulator is included.

Based on the recommendations made by experts, following observations are to be noted.

— For lower voltages upto 400 kV, AC voltage may be preferred for field testing; In addition, in case complete bays have been transported and assembled on site, a partial discharge measurement may also be pursued. The second choice may be to use oscillating switching impulse voltage. For this, no partial discharge measurement has been suggested.

— For extra high voltage (EHV), an additional impulse testing may be considered as back up to a.c. testing. For EHV, Oscillating lightning impulse testing (10 μs) is generally preferable to PD measurement as it provides clear evidence of whether any minor defect is potentially dangerous or not.

— For voltages upto 420 kV, AC voltage test (80% of rated voltage peak for one minute) followed by PD-measurement has been largely recommended. Another method is to use 80 percent of rated switching impulse level with a peak of 150 μs.

No partial discharge measurement is required in such case.

For voltage of 800 kV, the preferable procedure is to use AC voltage testing and oscillating lightning impulse voltage.

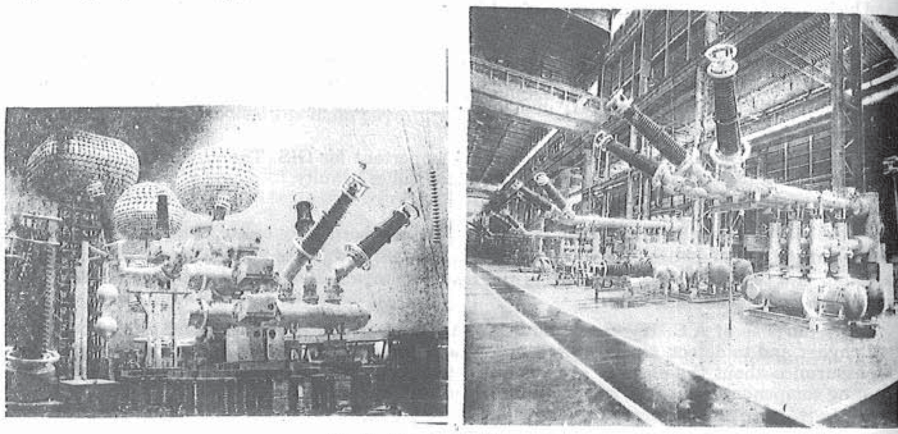


Fig. 7A.2. Factory testing process.

QUESTIONS

1. The function of SF_6 in GIS is

   (*a*) to act as dielectric medium (*b*) to act as arc quenching medium (*c*) to act as cooling medium (*d*) to act as Dielectric medium as well as arc quenching medium. (**Ans.** *d*)
2. What are the main difference between High speed and slow moving earthing switches in GIS ?
3. Name common type of interfuse required in GIS.
4. What is the function of partial Discharge monitoring (PDM) system in GIS ?
5. Name five field Acceptance Tests of GIS.

8

Minimum Oil Circuit-Breaker and Bulk Oil Circuit-Breaker

Bulk Oil or Tank type OCB—MOCB—Arc quenching in oil—Internal Source of Extinguishing Energy —Pre-arcing—Description of a 145 kV, MOCB—Modular Construction—Summary

8.1. INTRODUCTION

In minimum oil circuit-breakers, dielectric oil is used as an arc quenching medium and dielectric medium.

For voltages upto 12 kV, minimum oil circuit-breakers are generally enclosed in draw-out type metal-clad switchgear (Refer Ch. 15—Fig. 15.1 b).

For 36 kV, 72 kV and 145 kV ratings MOCB's are outdoor type, with one interrupter per pole and single opening mechanism for three poles (Refer Sec. 2.7).

For 245 kV and above, modular construction is necessary. In such a construction, the twin interrupter units are connected in series in T or Y formation.

Bulk oil circuit-breakers (tank type circuit-breakers) have become obsolete and have been described here in brief.

Minimum oil circuit-breakers have the following demerits:

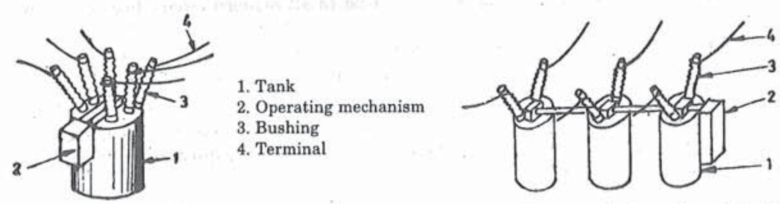
(1) Short Contact Life, (2) Frequent Maintenance (3) Possibility of Explosion. (4) Larger arcing time for small currents (5) Prone to restrikes.

They are being superseded by SF_6 circuit-breakers in all ranges.

8.2. TANK TYPE BULK OIL CIRCUIT-BREAKER (NOW OBSOLETE)

Oil circuit-breakers were widely used for rated upto 72.5 kV before 1960.

However the popularity of this breaker is decreasing and it is no more favoured in modern installation. The tank type circuit-breakers have 3 separate tanks for 72.5 kV and above. For 36 kV and below single tank construction is popular. In single tank construction phase barriers are provided between phases. This type of circuit-breaker is used for indoor metal-clad draw out type switchgear upto 12 kV (Fig. 15.1a). Above 12 kV, it is usually of outdoor type. Dielectric oil is used in circuit-breakers as an arc extinction medium as well as insulating medium. It is also called transformer oil.



(*a*) Appearance of a single tank three-phase bulk oil circuit breaker

(*b*) Appearance of a three phase bulk oil circuit breaker with three tanks.

Fig. 8.1. Bulk oil circuit-breaker.

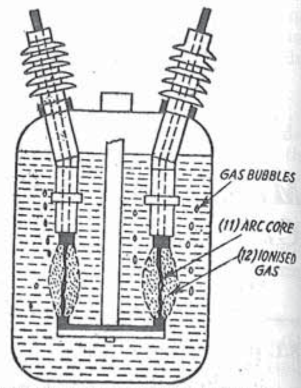
The contact separation takes place in steel tanks filled with oil. The gases formed due to the heat of the arc expand and set the turbulent flow in the oil.

To assist of arc extinction process, arc control devices are fitted to the contact assembly. These are semi-enclosed chamber of dielectric materials. The performance of oil circuit-breaker depends on the effectiveness of arc control devices.

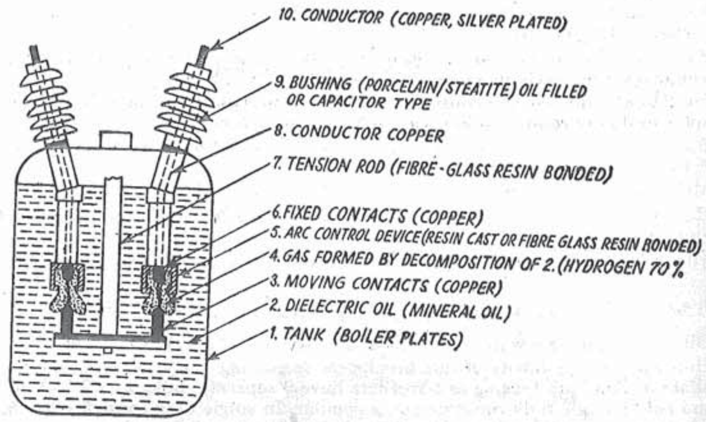
Fig. 8.2 illustrates the tank type will circuit-breaker, in open positions with the arc not yet extinguished.

The tension rod (7) is raised by operating mechanism (not shown in the figure) while closing the circuit-breaker. The opening and closing is obtained by lowering and raising the tension rod. As the contacts separate, and arc is drawn. This arc is extinguished by the oil and by the gases formed by the decomposition of oil.

The arc control devices (5) are normally connected to the fixed contact assembly, such that contact separation takes place inside this semi-enclosed devices. The gas produced in the device (4) produces high pressures in it. Thereby the arc extinction is quick. As the moving contacts leave the arc control



(a) Plain break bulk oil circuit-breaker.



(b) Bulk oil circuit-breaker with arc control device.

Fig. 8.2. Explaining BOCB.

devices, the trapped gas gets released from the arc control device, while doing so, the arc is extinguished by blast effect. Arc control devices are fitted to all modern circuit-breakers rated 3.6 kV and above.

The construction and venting or arc-control devices is such that the gases flow *axially or radially* with respect to arc. The major disadvantages of tank type-circuit-breaker are :

1. Large quantity of oil is necessary in oil circuit-breakers through only a small quantity is necessary for arc extinction. The large quantity is necessary to provide insulation between the live parts and earthed steel tank. If the container is made of ceramic material, the size of container could be made small.

2. The entire oil in the tank is likely to get deteriorated duo to sludge formation in the proximity of arc. Then the entire oil needs replacement.

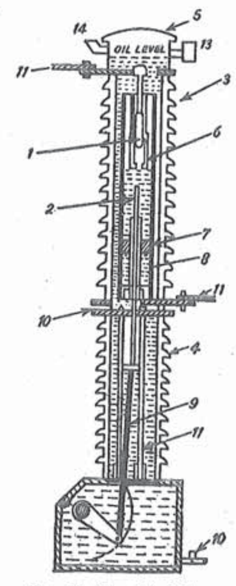
3. The tanks are too big, at 36 kV and above the tank type oil circuit-breaker loses its simplicity.

These causes led to the development of *Minimum oil circuit-breaker*. As the name itself signifies the minimum oil circuit-breaker requires less oil. The arc extinction medium is dielectric oil, the same as that used in tank type circuit-breaker. There is no steel tank but the arc extinction takes place in porcelain containers.

8.3. MINIMUM OIL CIRCUIT-BREAKER

This type is also known as poor oil or small oil circuit-breaker. In minimum oil circuit-breakers the current interruption takes place inside 'interrupter'. The enclosure of the interrupter is made of insulating material like procelain. Hence the clearance between the live parts and the enclosure can be reduced and lesser quantity of oil require for internal insulation. One pole of a 3 pole outdoor minimum oil circuit-breaker is illustrated in Fig. 8.3.

There are two chambers (3) and (4) separated from each other, but both filled with oil. The upper chamber (3) is arc extinction chamber. The oil from this chamber does not mix with that in the lower chamber. Lower chamber acts like a dielectric support.



1. Fixed Contact
2. Moving Contact
3. Current Interruption Chamber
4. Supporting Chamber
5. Top Chamber
6. Arc Extinction Device
7. Lower Fixed Contact
8. Glass-Fibre Enclosure
9. Operating Rod
10. Drain valve
11. Terminals
12. Relief valve
13. Gas vent
14. Operating mechanism (not shown)

Fig. 8.3. Simplified diagram of an outdoor minimum oil circuit-breaker pole with one interrupter pole.

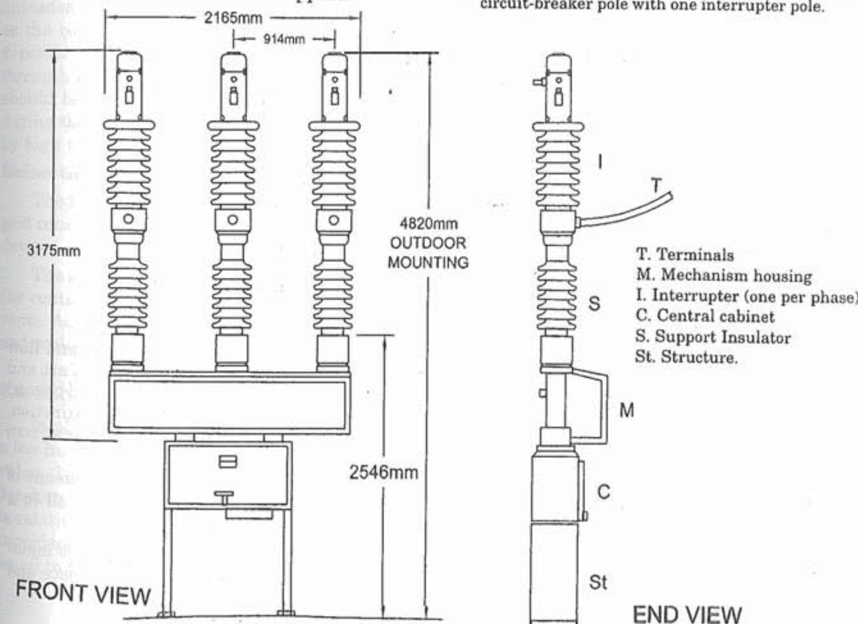


Fig. 8.4. A typical 145 kV out-door minimum oil circuit-breaker.

Arc extinction device (6) is fitted to the upper fixed contact. The lower fixed contact (7) is ring shaped. The moving contact (2) makes a sliding contact with the lower fixed contacts. A resin bounded glass-fibre cylinder (8) encloses the contact assembly. This cylinder (8) is also filled with oil. Porcelain cylinder (3) encloses the fibre-glass cylinder (8). Other provisions are similar to the bulk oil circuit-breaker.

The operating rod is operated by operating mechanism. The three poles operate simultaneously.

8.4. PRINCIPLE OF ARC-EXTINCTION ON OIL BREAKERS

As the current carrying contacts are separated under oil, the heat of the arc causes decomposition of the oil. The gases formed due to the decomposition expand, causing increase in pressure. The pressure built-up and the flow of gases is influenced by the design of arc-control device speed of contact travel, the energy liberated by the arc, etc. The gas flowing near the contact zone causing cooling and splitting of the arc. The contact space is filled with fresh dielectric oil after the final arc interruption at a current zero.

Arc control devices are fitted to the fixed contact of minimum oil circuit-breaker.

Arc control devices modify the behaviour of circuit-breakers. These are enclosures of dielectric material fitted to contacts of the circuit-breaker such that the actual contacts are separated inside the cavity of the device. At current zero of the wave, the arc diameter is very small and the gas

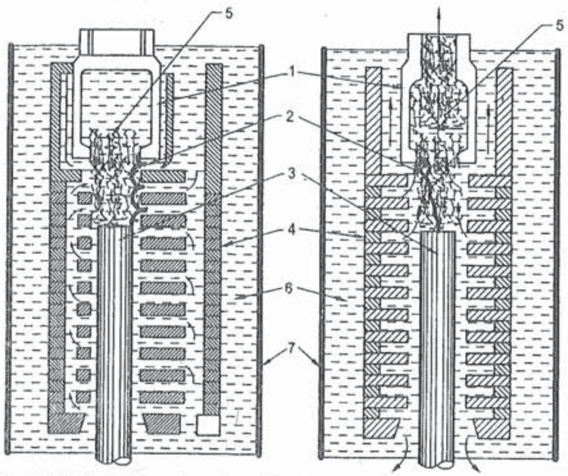
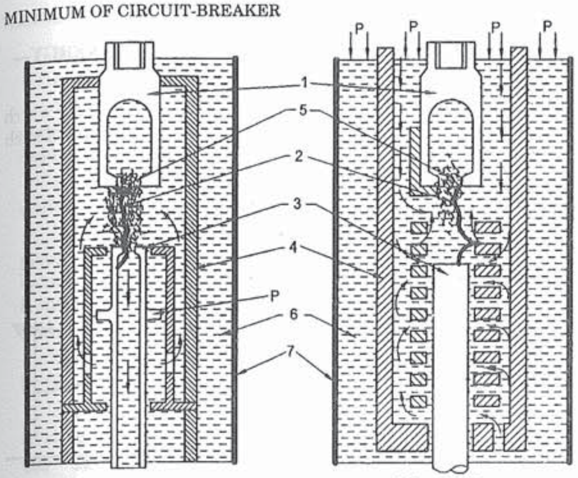


Fig. 8.5. (*a*) Techniques of arc Quenching in minimum oil circuit-breakers.

flow is able to interrupt the arc. The interruption of the arc stops the generation of gas and flow of oil. The contact space contains hot gases during the brief period after the interruption of arc and high rate of rise of TRV can cause a restrike. To avoid this the contact travel is extended well beyond the arc control devices so the fresh dielectric oil filled the contact space after the arc extinction. The techniques adopted to increase the rate of gain of dielectric strength after final current zero are :

— Flushing the contact space by fresh dielectric oil forced into the contact space by means of piston-action. A piston attached to the moving contact compresses the dielectric oil in a cylinder. The oil at a high pressure in the cylinder flows into the contact space.

— Maintaining the pressure on the oil in the interrupter. If the oil in the interrupter is maintained at higher pressure by means of an inert gas, the oil flow into the contact space and the hot gases travel upwards. Pressure reduces the size of gas bubbles.



1. Fixed constactor assembly.
2. Arc
3. Moving contact with Tungsten-Copper Tip
4. Fibre Reinforced Tube
5. Gases envolved by decomposition of oil
6. Dielectric oil
7. Outer Enclosure (Porecelain or Fibre reinforced Epoxy)
   P — Piston
   P — Pressure

Fig. 8.5. (*b*).

These techniques are used in minimum oil circuit-breakers to avoid restrikes during switching (Sec. 3.14.1).

8.5. PRE-ARCING PHENOMENON

The pre-arcing phenomenon is of significance in high voltage circuit-breakers used for closing unloaded transmission lines and capacitors. While closing a circuit-breaker, the arc is established as the contacts come near each other, before the final contact touch. The duration of pre-arcing depends upon the voltage across the interrupter, speed of travel while closing and the dielectric strength of the medium. The pre-arcing causes generation of heat and gases. The circuit-breakers should be capable of withstanding the temperature stresses and the internal pressures arising during the pre-arcing. While closing on the capacitor banks, the prearcing current is characterised by high frequency and the energy converted into heat during the pre-arcing is significant.

Deion Grid

The further development adopted for bulk oil circuit-breakers was that of deion grid. The deion grid consists of insulated iron discs of various shapes placed one above the other in the arc control device.

The shapes are such that narrow space is available for tear and there are side vents too. During the contact separation the magnetic material of discs gets magnetized and pulls the arc into the vents. Additional magnetic field is also provided separately. The arc is thus lengthened, constrained and cooled. Magnetic type Deion grids interrupter fault currents rapidly and efficiently.

8.6. SENSITIVITY TO TRV

In plain break circuit-breaker the posts zero resistance is generally fairly low (of the order of a few hundreds of ohm) so that the rate of rise of restriking voltage is damped down to a fairly low value. The inherent rate of rise of restriking voltage has little effect on behaviour of oil circuit-breakers. In oil circuit-breakers with arc control devices the post zero resistance of contact space is relatively high so that there is less damping effect. At low currents, the performance may be considerably improved by adopting *Resistance Switching*. The value of resistance is approximately equal to 0.5 $\sqrt{LC}$ ohms which is of the order of few hundred ohms.

8.7. CIRCUIT-BREAKERS WITH INTERNAL SOURCES OF EXTINGUISHING ENERGY—CRITICAL CURRENT (Refer Sec. 6.4)

In oil current-breaker the energy for arc extinction is provided by the short circuit itself, which decomposes oil and thereby pressure inside the tank is increased. The characteristic feature of such breakers is that the amount of extinguishing energy depend on the magnitude of current to be interrupted. For larger currents (upto a certain limit) the breaking time is less. For too small currents, the arc extinction is rapid because the arc simply breaks on its own; in oil. Between these limits, there is a range of small currents called "Critical Range" in which the breaking of currents is difficult and arc duration time is high. In this critical range of current the current is not in a position to build up enough pressure so as to cause rapid arc extinction. The characteristic of breaking current *vs.* arc duration in Fig. 8.6 explains the phenomenon. The range of critical current varies with the design of oil circuit-breaker (Refer Sec. 6.4)

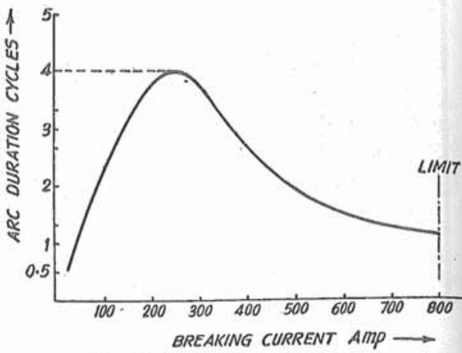


Fig. 8.6. Arc duration characteristic, an example (Refer Fig. 6.4).

The typical ranges of critical current are between 10 to 20% of rated short circuit-breaker current. Higher arcing time for smaller breaking current is a particular disadvantage of oil circuit-breaker.

8.8. CONTACT ASSEMBLY (Refer Sec. 2.18)

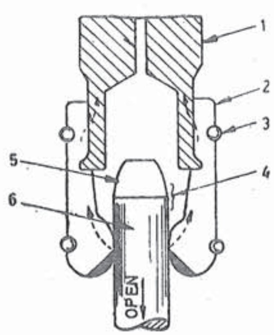
As this stage, we will discuss some aspects of contact design. The contact, design is influenced by the type of arc control device.

1. The main contacts should have low contact resistance.

2. Resistance being inversely proportional to the pressure. The contact pressure should be appropriate.

3. The contacts should be self-cleaning type, *i.e.* the layer of copper oxide should be cleaned by rubbing of contacts.

4. Contact area (true) should be well defined.



1. Contact support
2. Main contacts (Electrolytic-copper with tungsten copper tips)
3. Coiled spring (Phosphor-bronze)
4. Moving contact
5. Arcing tip of (4) brazed to (6) (Tungsten-copper)
6. Moving contact stem (Electrolytic copper)

Arrow indicates current path.

Fig. 8.7. Typical finger contact assembly in oil circuit-breakers.

5. Springs used for contacts should have gradually rising characteristic *i.e.* they should be soft.

6. The contact tips should be replaceable without the need to replace the entire contact.

7. The contact should not provide what is called "Contact-Grip". In some contacts the electromagnetic forces grip the contacts and oppose the opening process. Hence the opening speed is reduced.

8. It is desirable to have separate main contacts and arcing contacts. The resistance of main contacts is low because of silver plating, the arcing contacts have longer life.

The moving contact is invariably a copper rod of cylindrical shape with specially tipped contact pieces. The fixed contacts fitted with arc control device, are normally in four or six pieces with spring behind them. These pieces are arranged symmetrically to form a central cavity. The moving contact is inserted in this cavity (Refer Fig. 8.7).

Summary

Oil circuit breakers were used for voltage upto 145 kV. This type of breaker has been replaced by SF_6 breakers.

Oil circuit-breakers use Dielectric oil (Transformer oil) for the purpose of arc extinction. In bulk-oil circuit breakers the arc-extinction takes place in a tank; whereas in minimum oil circuit-breakers the arc-extinction takes place in insulating housing enclosed in ceramic enclosures.

For MOCB, rated upto 145 kV single break designs prevail, for higher voltages multibreak designs were common.

Modular construction was adopted for minimum oil circuit-breakers of 245 kV and above. However SF_6 Circuit Breakers are now preferred for entire range of breakers.