6.9. COMPRESSED AIR SYSTEM FOR ABCB

The EHV-ABCB's are outdoor equipment. The air pressure in the receivers of the circuit breaker is of the order of 20–30 kgf/cm^2. The local receivers are of such a size that the air pressure is maintained for some 4 to 12 repeated operations. When the pressure in the receiver of the breaker reduces below a certain value [say 20 kg/cm^2] the pneumatic valves automatically open and air is let into the receivers from compressed air system of a higher pressure [30 kgf/cm^2 to 40 kgf/cm^2], and the pressure in the air receiver is maintained a desired value.

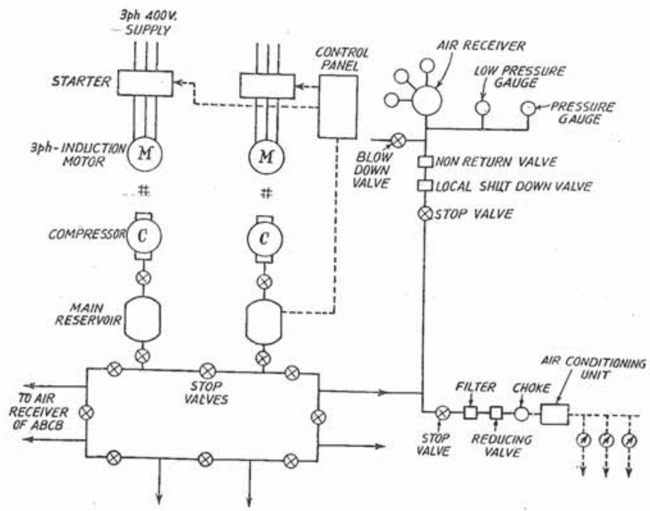


Fig. 6.9 Schematic diagram of compressed air system.

7

Sulphur Hexafluoride (SF_6) Circuit-Breaker and SF_6 Insulated Metalclad Switchgear (GIS)

Part I—Properties of SF_6 Gas—Physical properties—Chemical properties—Dielectric properties—Arc extinguishing properties of SF_6 gas.
Part II—Outdoor High Voltage SF_6 Circuit-Breakers—Type of designs—Single pressure puffer type SF_6 Circuit-breakers—Double pressure dead tank type SF_6 Circuit-breaker—Merits of SF_6 Circuit-breakers—Some demerits—SF_6 filled load-break switches—Auxiliaries and accessories.
Part III—SF_6 Insulated Metalclad Switchgear—Introduction—Advantage—Demerits—design aspects—Busbars—Isolators—Earthing switch—Circuit-breakers Components—Gas systems—Typical Ratings—Summary.

7.1. INTRODUCTION

Sulphur hexafluoride (SF_6) is an inert, heavy gas having good dielectric and arc extinguishing properties. The dielectric strength of the gas increases with pressure and is more than that of dielectric of oil a pressure of 3 kgf/cm^2. SF_6 is now being very widely used in electrical equipment like high voltage metal enclosed cables; high voltage metalclad switchgear, bushings, circuit-breakers, current transformers, etc. This gas liquefies at certain low temperatures, the liquefaction temperature increases with pressure. This gas is commercially manufactured in many countries and is now being extensively used by electrical industry in Europe, U.S.A. and Japan.

Several types of SF_6 circuit-breakers have been developed by various manufactures in the world during last fifteen years, for rated voltages from 3.6 to 760 kV.

SF_6 gas insulated-metalclad switchgear comprises factory assembled metal clad, sub-station equipment like circuit-breaker, isolators earthing switches bus-bars etc. These are filled with SF_6 gas. Such sub-stations are compact and are being favoured in densely populated urban areas.

Sulphur hexafluoride gas is prepared by burning coarsely crushed roll sulphur in fluorine gas, in a steel box, provided with staggered horizontal shelves, each bearing about 4 kg of sulphur. The steel box is made gas-tight. The gas thus obtained contains other fluorides such as S_2F_{10}, SF_4 and must be purified further SF_6 gas is generally supplied by chemical firms. The cost of gas is low if manufactured on a large scale.

The gas is transported in liquid form in cylinders. Before filling the gas, the circuit-breaker is evacuated to the pressure of about 4 mm of mercury so as to remove the moisture and air. The gas is then filled in the circuit-breaker. The gas can be reclaimed by the gas-handling unit.

Part I—Properties of SF_6 gas

7.2. PHYSICAL PROPERTIES OF SF_6 GAS

— Colourless.
— Odourless.
— Nontoxic, Pure SF_6 gas is not harmful to health.

— Non-inflammable. However impure SF_6 gas contains toxic impurities.

— State-Gas at normal temperature Pressure.

— Density-Heavy gas density 5 time that of air at 20°C and Atmospheric pressure.

Liquefaction of SF_6 Gas

The gas starts liquefying at certain low temperatures. The temperature of liquefaction depends on pressure. At 15 kg/c m² the gas starts liquefying at 10°C Hence this gas is not suitable for pressures above 15 kgf/c m². Ref. the notes at end of ch. 7 for units of pressure.

The temperature at which the SF_6 gas changes to liquid state depends on pressure. With higher pressure, this temperature increases. To avoid the liquefaction of SF_6 gas the temperature of SF_6 should be maintained above certain value. For 15 atm. pressure, SF_6 gas starts liquefying at a temperature of about 10°C. Hence thermostatically controlled heaters are provided, which maintain the gas temperature above about 16°C in case of high pressure system. Fig. 7.1 illustrates the characteristics of SF_6 medium. The curve shows transition condition, the left side represents liquid state and right side represents gaseous state. The inclined lines (L/kg) represent constant specific volume. (litres per kg).

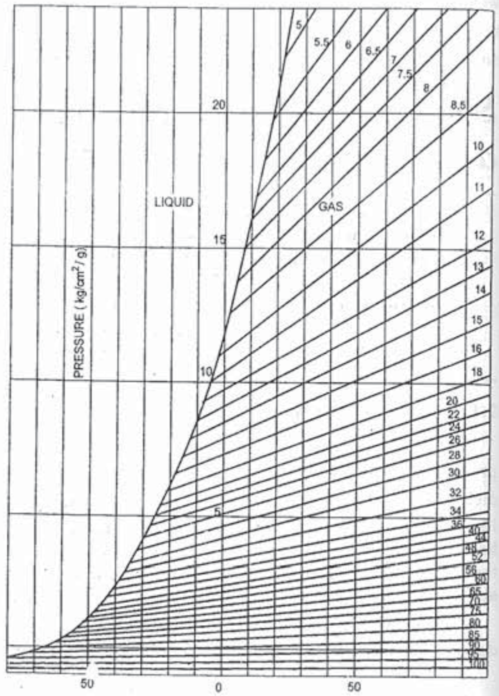


Fig. 7.1. Temperature-Pressure variation characteristics of SF_6 gas at constant specific volumes (litre/kg).

Heat transferability. The heat transferability of SF_6 gas is 2 to 2.5 times that of air at same pressure. Hence for the equal conductor size, the current carrying capacity is relatively more.

Enthalpy. Heat content property at temperatures below 6000°K is much higher than nitrogen. This assists cooling of arc space after current zero, due to continuous removal of heat from the contact space by the surrounding gas.

Low arc-time constant. The time constant of the medium is defined as "the time between current zero and the instant the conductance of contact space reaches zero value."

Due to the electronegativity of SF_6 gas the arc time constant of SF_6 gas is very low and the rate of rise of dielectric strength is high. Hence SF_6 circuit-breakers are suitable for switching condition involving high rate of rise of TRV.

7.3. CHEMICAL PROPERTIES OF SF_6 GAS

(*i*) Stable upto 500°C.

(*ii*) *Inert.* The chemical inertness of this gas is advantageous in switchgear. The life of metallic part, contacts is longer in SF_6 gas. The components do not get oxidised or deteriorated. Hence the maintenance requirements are reduced. Moisture is very harmful to the properties of the gas. In the presence of moisture, hydrogen fluoride is formed during arcing which can attack the metallic and insulating parts in the circuit-breaker.

(*iii*) Electronegative-gas.

(*iv*) Does not react with structural material—upto 500°C.

(*v*) *Products of Decomposition.* During arc extinction process SF_6 is broken down to some extent into SF_4, SF_2. The products of decomposition recombine upon cooling to form the original gas. The remainder is removed by filters containing activated alumina (Al_2OI_3). Loss factor is small. The products of decomposition arc toxic attack certain structural materials.

(*iv*) The metallic fluorides are good dielectric materials hence are safe for electrical equipment. However, they must be removed during periodic maintenance, as they absorb moisture and loose their dielectric property. This happens if the breaker is dismantled during rainy-season.

7.4. DIELECTRIC PROPERTIES OF SF_6 GAS

(*I*) *Dielectric Properties.* Dielectric strength of SF_6 at atmospheric pressure is 2.35 times that of air, it is 30% less than that of dielectric oil used in oil circuit breakers.

(*ii*) At higher pressure the dielectric strength of the gas increases. At pressure about 3 kgf/cm² the dielectric strength of SF_6 gas is more than that of dielectric oil. This property permits smaller clearances and small size of equipments for the same kV.

(*iii*) *Effect of Pressure on Breakdown Voltage.* The breakdown voltage in SF_6 gas depends on several aspects such as electrode configuration, roughness of electrodes distribution of electric field, vicinity of insulating supports, moisture, waveshapes etc. other parameters remaining constant the breakdown voltage in SF_6 gas increases with pressure. The gas follows Paschen's law which states that "In uniformly distributed electric field. The breakdown voltage (V_b) in a gas is directly proportional to the product of gas pressure (p) and electrode-gap (d)"—$V_b \alpha pd$.

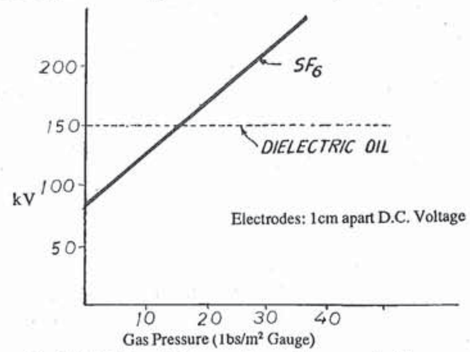


Fig. 7.2. D.C. break-down voltage of 1 cm gap in SF_6 gas.

(*ii*) *Critical Pressure Zone.* With the non-uniform field, the breakdown voltage versus pressure, curve does not follow the Paschen's law strictly. The probable curve is indicated in Fig. 7.3. The breakdown voltages increases with pressure. However after about 2.5 kgf/cm² it starts reducing and then rises again. The pressure at which the breakdown voltage starts reducing is called 'critical Pressure'. The dielectric strength at pressure between 2-3 kgf/c m² is high. Hence this pressure range is preferred in SF_6 insulated metal enclosed switchgear. However in circuit-breaker compartment, the pressure of the order of 5 kgf/cm² is preferred for arc quenching purposes.

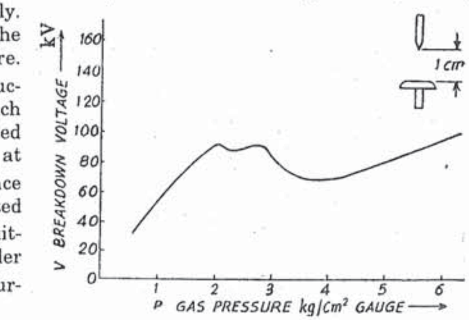


Fig. 7.3. Variation in Breakdown voltage in SF_6 gas with non-uniform fields.

(*v*) *Effect of Electrode Surface.* Rough electrode surface reduces the breakdown voltage with rough surface the ionisation starts earlier near the sharp points on conductors. Hence, conductor surfaces should be smooth.

(vi) Effect of Insulating Support on Breakdown Voltage. The conductors in SF_6 insulating equipment are supported on epoxy or porcelain insulators. The flashover invariably takes place along the surface of the support insulators.

The breakdown can occur at extremely low values if the insulator supports are covered by moisture and conducting dust. Hence the insulators should be extremely clean and should have anti-tracking properties.

(vii) Sharp Contours. The breakdown is initiated at sharp edges of conducting parts and parts having maximum stress concentration. The limiting value of breakdown stress is of the order of $24 \times P$ kV/cm for pure SF_6 gas, P is pressure of gas in kgf/cm^2. Good dielectric stress distribution is very important is SF_6 insulated equipment.

(viii) Effect of Wave-shape and Polarity. The breakdown value depends on the wave-shape characterised by peak value, wave front, wave-tail, polarity in case of impulse wave. Voltage withstand value reduces with increase in steepness and increase in duration of the wave. Negative polarity is generally more severe than positive.

Effect of Dilution of SF_6 Gas by Air on Dielectric Strength

SF_6 gas maintains high dielectric strength even when diluted by air (Nitrogen). 30% SF_6 + 70% Air by volume has a dielectric strength twice that of air at same pressure). Below. 30% by volume, the dielectric strength reduces quickly.

(ix) The gas is Electronegative. The ability of an atom to attract and hold electrons has been designed as its 'Electronegativity'. Such gases have high dielectric strengths.

The molecules of electronegative gases have an ability to attract, hold free electrons and form negative ions. The negative ions being heavy and practically immobile they do not flow easily. Hence the dielectric strength of electronegative gases is more than that of air.

Electronegativity of the gas gives lower arc-time constant. The time required for the medium to regain its dielectric strength after final current zero is called arc-time constant. The arc-time constant of SF_6 gas is of the order of a few Microseconds.

7.5. ARC EXTINCTION IN SF_6 CIRCUIT-BREAKERS (Ref. Sec. 11.20)

The arc extinction process in SF_6 circuit breakers is different from that in Air Blast Circuit Breakers.

During the arcing period, SF_6 gas is blown axially along the arc. The gas removes the heat from the arc by axial convection and radial dissipation. As a result, the arc diameter reduces during the decreasing node of the current wave. The diameter becomes small during current zero. Turbulent flow is introduced around current zero to extinguish the arc.

Due to its electronegativity and low arc-time constant, the SF_6 gas regains its dielectric strength rapidly after the final current zero, the rate of rise of dielectric strength is very high and the time constant is very small.

The arc extinguishing properties of SF_6 gas was pointed out in 1953*.

The paper points out that SF_6 is a remarkable medium for arc extinction. The arc extinguishing properties are improved by moderate rates of forced gas flow through the arc space.

Plain break contacts drawn apart, (AC Arcs), in SF_6 can interrupt about 100 times more current than in air at given voltage.

* An Investigation of the Arc Quenching Behaviour of SF_6 by H.J. Lingal, A.R. Strom T.E. Browne, Westinghouse Electric Corpn.—AIEE PAS April 1953, p. 242.

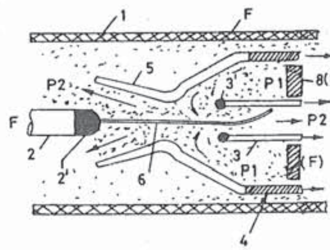
The basic requirements in arc extinction is not primarily the dielectric strength, but high rate of recovery of dielectric strength. In SF_6 gas, the electrons get attached with molecules to become ions. Thereby the dielectric strength is quickly regained. Problems connected with current chopping are, therefore minimum.

In SF_6 circuit-breakers, the gas is made to flow from a high pressure zone to a low pressure zone through a convergent-divergent nozzle. The mass flow is a function of nozzle-throat diameter the pressure ratio and the time of blow. The nozzle is located such that the gas flows axially over the arc-length. The gas flow attains almost supersonic speed in the divergent portion of the nozzle, thereby the gas takes away the heat from the periphery of the arc, causing reduction in the diameter of the arc. Finally the arc diameter becomes almost zero at current zero and the arc is extinguished. The arc space is filled with fresh SF_6 gas and the dielectric strengths of the contact space is rapidly recovered due to the electronegativity of the gas and turbulent flow of fresh gas in the contact space.

(SF_6 gas flows from P_1 to P_2 through the Convergent Divergent Insulating Nozzle over the arc lengthened during opening stroke.) P_1/P_2 is achieved by relative movement of Puffer Cylinder 4 against Fixed Piston.

7.5.1. Single Pressure Puffer Type Circuit-breaker with Single flow of Quenching Medium

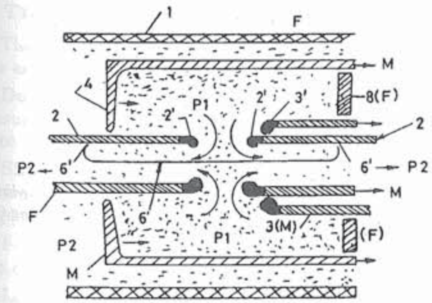
This flow pattern illustrated in Fig. 7.4 was first conceived during 1950s. Earlier puffer type circuit breakers were with single flow pattern.



1. Enclosure
2. Fixed contact stem
2'. Arcing contact tip
3. Hollow contact tube (M)
3'. Arcing contact tip
4. Puffer cylinder
5. Insulating Nozzle (PTFE) convergent divergent
6. The Arc
6'. SF_6 Gas
7. Fixed Piston
8. Fixed Piston

M = MOVING, F = FIXED

Fig. 7.4. (*a*) Arc Extinction in Single Pressure type puffer C.B. with insulating Nozzle. (Further details in Fig. 7.5 a-d)

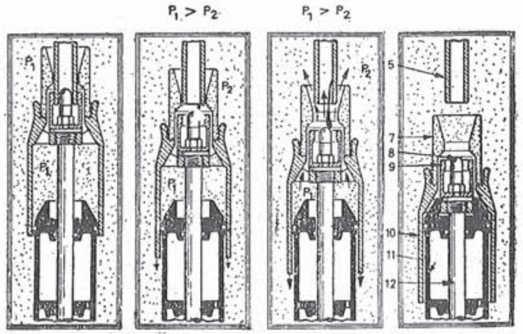


1. Enclosure (F)
2. Fixed contact tubes (F)
2'. Graphic Nozzles (F)
3. Hollow conductor tube (M)
4. Puffer Cylinder (M)
5. SF_6 Gas
6. The Arc
6'. Arc-Roots (M)
7. Fixed Piston
8. Fixed Piston

H = MOVING, F = FIXED

Fig. 7.4. (*b*) Arc Extinction in Single Pressure Puffer type SF_6 C.B. with Conducting Nozzles. (Further details in Fig. 7.12)

Fig. 7.5 (*a*) "Four stages of Puffer Action—Single Flow" explains the arc quenching process. When breaker is fully closed, the pressure in the puffer cylinder P_1 is equal to that outside the cylinder.



Contact closed $P_1 = P_1$ | Contacts separate nozzle about to open | Nozzel open flow starts | Arc quenches breaker fully open

Fig. 7.5. (*a*) Four stages of Puffer Action-Single flow.

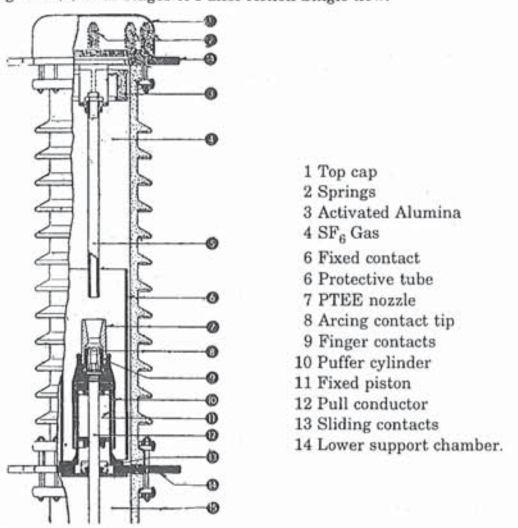
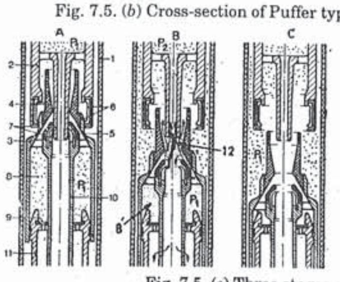


Fig. 7.5. (*b*) Cross-section of Puffer type SF_6 Interrupter. (Courtesy : Magrini)



1. Enclosure (Insulating tube)
2. Fixed contact holder
3. Puffer Cylinder
4. Insulating Nozzle (PTFE)
5. Insulating Cap
6. Parallel path for normal current flow
7. Normal path for current flow
8. Gas trapped between 3 and 11
8′. Compressed Gas
9. Valve for gas inlet during closing
10. Moving contact tube
11. Fixed Piston
12. Arc

Fig. 7.5. (*c*) Three stages of puffer action-Double Flow

A Breaker fully close B Contact Separate, Arcing present C Arc Quenched

During opening stroke puffer-cylinder and moving contact tube start moving. Gas gets compressed within puffer cylinder ($P_1 > P_2$). After a certain travel, contact separates arc is drawn. However compressed gas flows from higher pressure P_1 to lower pressure P_2 through the nozzle. Fig. 7.5 (*d*) gives pressure characteristics.

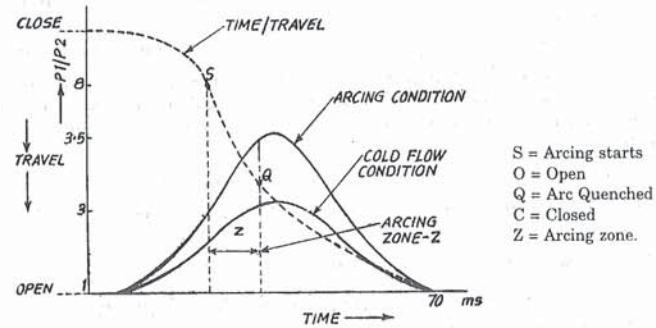


Fig. 7.5. (*d*) Explaining Puffer Principle.

Single flow pattern has limited quenching ability and is used for lower breaking currents. Fig. 7.5 (*b*) gives a cross-sectional view of an interrupter developed during early sixties.

7.5.2. Double Flow of Quenching Medium

In the second generation of puffer type circuit-breakers, the flow pattern was improved. The flow of quenching gas from puffer cylinder was made to flow in forward direction (like in single flow) through nozzle and also through hollow contact tube in inverse direction. Double flow gives lengthening of arc through hollow contact tubes and removes heat of arc more efficiently. Double flow pattern gives almost one-and-half times the breaking capacity compared with the single flow. Fig 7.5 (*c*) explains the flow pattern in double flow technique. All puffer type circuit-breakers of today employ double flow pattern.

Part—II Outdoor SF_6 Circuit-Breakers

7.6. TYPES DESIGN

The SF_6 circuit-breaker have been developed by several manufacturers and several designs have emerged. The types of circuit-breakers can be broadly identified as:

Double Pressure type. In which, the gas from high pressure system is released into the low pressure system through a nozzle, during the arc extinction processes. This design has become obsolete.

Single Pressure Puffer type. In which the gas is compressed by the moving cylinder system and is released through a nozzle while extinguishing the arc. This design is most popular over wide range of voltages from 3.6 kV to 760 kV. [Sec. 7.51].

Furthermore, in both the double pressure and single pressure designs the circuit-breakers have been developed in following two types of indoor and outdoor designs.

Live Tank design. In which the interrupters are supported on porcelain insulators (Fig. 7.7).

Dead Tank design. In which the interrupters installed within SF_6 gas-filled tank at earth potential (Fig. 7.8). This configuration is used in GIS, (Sec. T.13)

Single pressure puffer type live tank breakers are being preferred for conventional outdoor switchyards.

Puffer Principle. Refer Fig. 7.5 *a* to *d*. As the puffer cylinder moves downrwards for the opening stroke, the pressure ratio P_1/P_2 rises as shown in Fig. 7.5 (*d*). The pressure rise depends upon the throat-diameter of nozzle and speed of puffer cylinder. The pressure ratio P_1/P_2 increases to about five during opening condition. The compressed gas is released through the convergent-divergent nozzle (7). The arc is quenched at a current zero. For higher interrupting ability, the flow pattern is optimised.

Single pressure puffer type SF_6 circuit-breakers are sealed units filled with SF_6 gas at a pressure 5 kgf/cm^2. Both dead-tank and live tank designs have been developed for voltages from 3.3 to 760 kV and breaking currents from 20 to 80 kA. The designs are being continuously optimized for higher capacity per interrupter. There are two types of designs in single pressure puffer type SF_6 circuit-breakers.

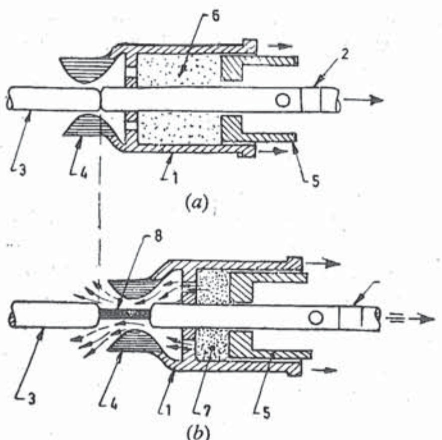
— Puffer type SF_6 breaker with insulating nozzle (Figs. 7.5-7.6).

— Puffer type SF_6 circuit breaker with conducting nozzle (Ref. Fig. 7.12)

7.7. SINGLE PRESSURE PUFFER TYPE SF_6 CIRCUIT-BREAKER

These circuit-breaker employ a novel principle of puffer action illustrated in Fig. (7.5 *b*, *c*, *d*).

Fig 7.6 (*a*) illustrates the fully closed position of the interrupter. The moving cylinder (1) is coupled with the movable conductor (2) against the fixed piston (5) and there is a relative movement between (1) and (5) and the gas is compressed in the cavity (6). This trapped gas is released through the nozzle (4), during arc extinction process. During the travel of the moving contact (2) and movable cylinder (1) the gas puffs over the arc and reduces the arc diameter by axial convection and radial dissipation. At current zero, the arc diameter becomes too small and the arc gets extinguished. The puffing action continues for some time even after the arc extinction and the contact space is filled with cool, fresh gas.



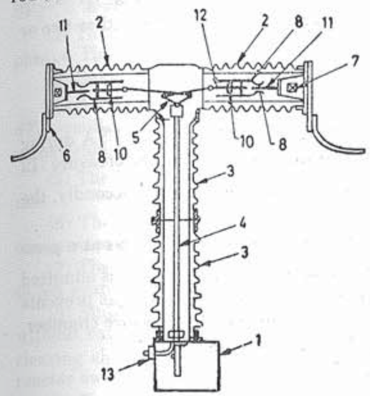
(1) Movable cylinder (puffer cylinder)
(2) Moving contact
(3) Fixed contact
(4) Insulating nozzle
(5) Fixed piston
(6) Gas trapped in before compression
(7) Compressed gas between 1 and 5
(8) The arc-being extinguished by puffer action.

SF_6 gas   Compressed gas SF_6

(*a*) Breaker fully closed (*b*) Contacts separated, puffing action in progress.
Fig. 7.6. Puffer action principle.

Fig 7.7 (*a*) illustrates the configuration of a 245 kV/420 kV single pressure puffer SF_6 circuit-breaker. The two interrupters (2) are mounted on the hollow support insulators (3). The principle

of arc interruption is illustrated in Fig 7.6. The operating mechanism (1) installed at the base of the insulator is linked with the movable contact in the interrupter by means of insulating operating rod (4) and a link-mechanism (5).



Item No.
1. Operating mechanism (pneumatic or hydraulic)
2. Interrupter.
3. Hollow support insulators (porcelain)
(Items 2 and 3: Filled with SF_6 gas at 5 kgf/cm^2)
4. Insulating operating rod (glass fibre).
5. Linkage between (4) and (12).
6. Terminals.
7. Filters. (Activated alumina)
8. Movable (puffer) cylinder.
9. Nozzle (insulating material).
10. Fixed piston.
11. Fixed contact.
12. Moving contact (move with 8)
13. Gas inlet and monitoring system.

Fig. 7.7. (*a*) One pole of a 245 kV puffer type SF_6 C.B.

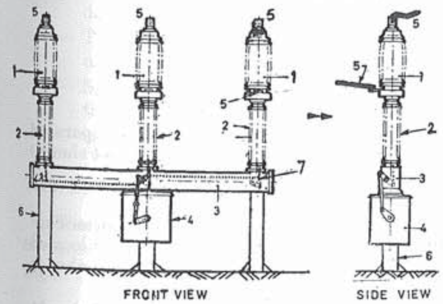
The circuit-breaker is filled with SF_6 gas at a pressure of about 5 kgf/cm^2. During the opening operation, the operating rod (4) is pulled down-wards by the operating mechanism. The link-mechanism (5) converts the vertical motion into horizontal motion. The contact and the movable cylinder in interrupter are moved against the fixed piston (10).

Break-time upto 3 cycles can be achieved by puffer principle described above. For achieving 2 cycle break time, differential piston is used in which the puffer-cylinder and piston move in opposite direction thus reducing total stroke and time of travel.

7.7.1. Configuration of a single Pressure Puffer Type EHV Circuit-Breaker

Fig 7.7 (*b*) illustrates the typical configuration of 145 SF_6 circuit-breaker having one interruption per pole Fig 7.7 (*a*) illustrates configuration of one pole of a 245 kV SF_6 circuit-breaker.

Referring to Fig. 7.7 (*b*), there are three identical poles mounted on a common base tube (3). Gas is filled permanently in all the three poles and the base tube. The sealing is provided by O-rings squeezed between porcelain and flanges.



1. Interrupter
2. Support Hollow Porcelain
(Items 1 and 2: Filled with SF_6 gas 5 kgf/cm^2)
3. Base Tube
4. Mechanism Housing and Control Cabinet, Gas Inlet System : Hydraulic/Spring/Pneumatic Mechanism
5. Terminals
6. Support Structure
7. Linkages

Fig. 7.7. (*b*) Configuration of an outdoor Puffer Type 145 kV SF_6 Circuit-Breaker.

The operating mechanism (4) is linked with moving contacts in the interrupters *via* insulating glass fibre rods. In this configuration, during closing operation it is pushed upwards.

A 245 kV circuit-breaker has generally one or two interrupters per pole [Refer Fig. 7.7 (*a*)].

Configuration of 420 kV SF_6 circuit-breakers follows same philosophy but it has either two or four interrupter per pole depending upon the design, rated breaking current.

7.8. DOUBLE PRESSURE DEAD TANK SF_6 C.B. (NOW OBSOLETE)

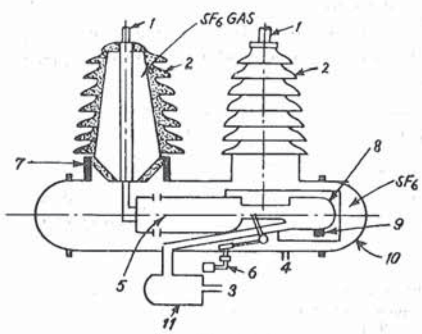
Double-pressure type of SF_6 circuit-breakers were developed by Westing-house USA during 1950's. The double pressure SF_6 circuit-breakers had a disadvantages that at higher pressure (12 kg/cm^2; heaters were necessary during lower ambient temperatures (below 15°C). Secondly, the design was complicated and costly.

The gas follows a closed circuit. An auxiliary tank or gas reservoir contains SF_6 gas at a pressure of about 14 kg/cm^2. During the arc extinction the gas from high pressure chamber is admitted to the low pressure chamber by opening of a valve. The arc is extinguished and the gas prevents restriking of arc. The compressor pumps back the excess SF_6 gas from the low pressure chamber, back to the high pressure chamber.

The operating mechanisms are pneumatic or electro-hydraulic.

The breaker has three identical poles.

Referring to Fig. 7.8 the SF_6 gas system is as follows. The gas from compressor (not shown in the figure) is let into the auxiliary high pressure reservoir 11 through inlet 3. From this reservoir, it is admitted in main SF_6 reservoir 8 at pressure of about 14 kg/cm^2. The gas is admitted in the arc extinction chamber 5, just before contact separation. The gas comes in the L.P. cylinder 10.



1. Connection terminals.
2. Bushing
3. SF_6 inlet 14 kgf/cm^2
4. SF_6 outlet 2 kgf/cm^2.
5. Arc extinction chamber.
6. Operating links.
7. Lower insulator
8. Main SF_6 reservoirs 14 kgf/cm^2.
9. Activated alumina
10. Low pressure chamber 2 kgf/cm^2, at earth potential.
11. Auxiliary H.P. reservoir

Fig. 7.8. One pole of a double pressure, dead tank type SF_6 C.B.

The current enters from 1, and leaves from terminal. The contacts (not shown) are separated in chamber 5. SF_6 gas from the low pressure chamber is pumped back by compressor (not shown) to auxiliary chamber.

The current carrying parts are the following :

The terminals 1, 1 are connected to the neighbouring equipment. From 1, the conductors are taken through bushings 2, 2. The arc extinction chamber (5) is multi break type and is located centrally in the tank. The chamber housing is made of dielectric material and the chamber is mounted on insulator supports.

The moving contacts are pulled apart from the fixed contacts by means of insulating links. At the same time valves on the high pressure cylinders are opened and the gas from high pressure tank flows towards the low pressure reservoir through nozzles. The arc is extinguished by has flow.

7.9. MERITS OF SF_6 CIRCUIT-BREAKERS

(1) Outdoor EHV SF_6 has less number of interrupters per pole than ABCB and MOCB. Outdoor SF_6 CB is simple less costly, maintenance free and compact.

(2) The gas is non-inflammable and chemically stable. The decomposition products are not explosive. Hence there is no danger of fire or explosion.

(3) Same gas is recirculated in the circuit. Hence requirement of SF_6 gas is small.*

(4) Ample overload margin. For the same size of conductors, the current carrying ability of SF_6 circuit-breakers is about 1.5 times that of air blast circuit-breakers because of superior heat transferability of SF_6 gas.

(5) The breaker is silent and does not make sound like air-blast-circuit breaker during operation.

(6) The sealed construction avoids the contamination by moisture, dust, sand etc. No costly compressed air system like ABCB.

(7) The maintenance required is minimum. The breaker may need maintenance once in four to ten years.

(8) Ability to interrupt low and high fault currents, magnetising currents, capacitive current, without excessive over-voltages. The SF_6 gas circuit-breaker can perform the various duties like clearing short-line faults, opening unloaded transmission lines capacitor switching transformer, reactor switching etc. much smoothly.

(9) Excellent insulating arc extinguishing physical and chemical properties of SF_6 gas is the greater advantage of SF_6 breakers.

(10) No frequent contact replacement.

Contact corrosion is very small due to inertness of SF_6 gas. Hence contacts do not suffer oxidation.

(11) No over-voltage problems.

Due to particular properties of SF_6 gas the arc is extinguished at natural current zero without current chopping and associated over-voltage originating in circuit-breakers.

7.10. SOME DEMERITS OF SF_6 CIRCUIT-BREAKER

— Sealing problems arise. Imperfect joints lead to leakage of gas.

— Arced SF_6 gas is poisonous and should not be in inhaled or let-out.

— Influx of moisture in the breaker is very harmful to SF_6 gas circuit-breakers. Several failures are reported due to this cause.

— Mechanism of higher energy level is necessary for puffer type SF_6 breakers. Lower speeds due to friction, misalignment can cause failure of breaker.

— The internal parts should be cleaned thoroughly during periodic maintenance under clean, dry environment. Dust of Teflon and sulfides should be removed.

— Special facilities are needed for transporting the gas, transferring the gas and maintaining the quality of gas. The deterioration of quality of the gas affects the reliability of the SF_6 circuit breaker.

7.11. SF_6 FILLED LOAD BREAK SWITCHES

The remarkable arc extinguishing properties of SF_6 can be exploited for various switching equipments such as load break switches, starters, controllers etc. The first SF_6 interrupter containing SF_6 gas at 3 atm. was built in 1953 which had a sealed chamber. The arc was drawn by moving

* One triple, pole 145 kV SF_6 C.B. requires only about 30 kg of SF_6 gas for first filling. No replacement is required for five years.

the contact and at the same time SF_6 gas flowed closed to the arc by virtue of a piston and cylinder arrangement. These load break switches rated from 15 to 161 kV and the break current of 600 A at 0.5 to 1 power factors. Transformer magnetising current can be easily interrupted by SF_6 switches. The capacitor banks can be switched off easily with SF_6 switches.

7.12. GAS MONITORING AND GAS HANDLING SYSTEMS

SF_6 circuit breakers are provided with gas monitoring system. The gas monitoring system comprises temperature compensated pressure switches. Provision for filling and removing gas, provision for heating the gas etc. The pressure switches are arranged such that for a certain reduction in pressure an alarm is sounded and for further reduction in pressure the circuit-breaker gets locked.

The gas handling unit is used for filling the SF_6 gas in the breaker and for reclaiming the SF_6 gas from the breaker. The gas handling unit comprises a vacuum pump, a compressor, an auxiliary receiver, gas-filtering units, valves and piping. Before filling the gas the circuit breaker is evacuated by means of the vacuum pump. After achieving a certain degree of evacuation, the gas from gas cylinders is filled into the circuit breaker.

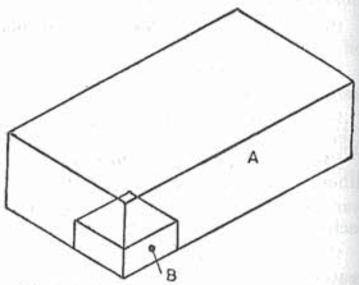


Fig. 7.9. Comparison of space requirement of 245 kV substation.
(A) Conventional (B) SF_6 Metalclad.

While reclaiming the gas from the circuit breaker, the compressor is used for transferring the gas from the circuit-breaker to the auxiliary receiver.

Part III—SF_6 GIS

7.13. INTRODUCTION TO SF_6 SWITCHGEAR (GIS)

SF_6 gas insulated metalclad switchgear is also called Gas Insulated Substation (GIS) and is preferred for 12kV, 36kV, 72.5kV, 145 kV, 245 kV, 420 kV and above. In such a substation, the various equipment like circuit-breakers. Bus bars, Isolators, Load break switches. Current-transformers, Voltage transformers, Earthing switches etc. are housed in separate metal enclosed modules filled with SF_6 gas. The SF_6 gas provides the phase to ground insulation. As the dielectric strength of SF_6 gas is higher than air, the clearances required are smaller. Hence the overall size of each equipment and the complete sub-station is reduced.

The various modules are factory assembled and are filled with SF_6 gas. Thereafter, they are taken to site for final assembly. Such sub-stations are compact and can be installed conveniently on any floor of a multi-streyed building or in an underground sub-station.

As the units are factory assembled, the installation time is substantially reduced. Such installations are preferred in composition cities, industrial townships, hydro-stations—where land is very costly and higher cost of SF_6 insulated switchgear is justified by saving to reduction in floor-area requirement.

SF_6 insulated switchgear is also preferred in heavily polluted areas where dust, chemical fumes and salt layers can cause frequent flashovers in conventional outdoor sub-stations.

* Normal Pressure: 5 to 6 kgf/cm^2 gauge
Alarm at : 4.5 kg/cm^2
Automatic Trip of Lockout : 4 kgf/cm^2

7.14. ADVANTAGES

(*a*) *Compactness.* The space occupied by SF_6 installation is only about 10% of that of a conventional outdoor sub-station (Refer Fig. 7.6). High cost is partly compensated by saving in cost of space.

(*b*) *Protection from pollution.* The moisture, pollution, dust etc., have little influence on SF_6 insulated sub-stations. However, to facilitate installation and maintenance, such substations are generally housed inside a small building. The construction of the building need not be very strong like conventional power houses.

(*c*) *Reduced Switching overvoltages.* The overvoltages while closing and opening line, cables motors capacitors etc. are low.

(*d*) *Reduced Installation Time.* The principle of building-block construction (modular construction) reduces the installation time to a few weeks. Conventional sub-stations require a few months for installation.

(*e*) *Superior Arc Interruption.* SF_6 gas is used in the circuit-breaker unit for arc quenching. This type of breaker can interrupt current without overvoltages and with minimum acing time. Contacts have long life and the breaker is maintenance free.

(*f*) The gas pressure (4 kgf/cm^2) is relatively low and does not pose serious leakage problems.

(*g*) *Increased Safety.* As the enclosures are at earth potential, there is no possibility of accidental contact by service personnel to live parts.

7.15. DEMERITS OF SF_6 INSULATED SWITCHGEAR

(*a*) High cost compared to conventional outdoor sub-station.

(*b*) Excessive damage in case of internal fault. Long outage periods as repair of damaged part at site may be difficult.

(*c*) Requirements of cleanliness are very stringent. Dust or moisture can cause internal flashovers.

(*d*) Such sub-stations generally indoor. They need a separate building. This is generally not required for conventional outdoor sub-stations.

(*e*) Procurement of gas and supply of gas to site is problematic. Adequate stock of gas must be maintained.

7.16. GENERAL CONSTRUCTIONAL FEATURES OF SF_6-GAS INSULATED SWITCHGEAR (GIS) (Fig 7.10)

In this type of switchgear, SF_6 gas at a pressure above atmospheric pressure (5 or 6 kg/cm^2) is used as a dielectric insulating medium as well as for arc quenching in the circuit breaker chamber. The pressure in the C.B. chamber is generally higher. Its range of application extends from voltage ratings of 7.2 kV upto 800 kV.

The main components of GIS (Fig 7.10 a-e) are bus-bars, circuit breakers, disconnectors (Isolators), earthing switch, instrument transformers (Current Transformers, Electro-magnetic Voltage Transformer), surge arrestors, Insulators, Interfaces & other monitoring devices contained in an enclosure filled with SF_6 gas. GIS is generally subdivided into separately monitored zones/modules like circuit breaker, main bus, termination, voltage transformers, etc.

The conductors of busbars are fabricated from aluminium tubular sections which are joined between different sections by using plug-in-tulip contacts which fit automatically during field connections. Enclosures are made of non-magnetic material, commonly used material is Aluminium, stainless steel enclosures are also being manufactured. As the resistance of stainless steel is higher that of aluminium the losses in stainless enclosures in therefore higher.

The Circuit Breakers have Pneumatic of Hydraulic operating mechanism with one to four breakers per pole depending on the voltage & current rating or rupturing capacity. The operating mechanism of the circuit breaker is designed for adequate capacity which should be enough for two close/open operations.

Disconnector-switches/Isolators, as in the case of conventional Air Insulated Switchgear, are provided for Isolating the system/section for Inspection/maintenance of the equipment. These are either pneumatically or D.C. motor operated suitable for three-phase gang operation. They are designed to meet the requirement of breaking capacitive charging, Transformer & Reactor (wherever provided) magnetization current and the loop current.

Earthing or grounding switches are provided for grounding of the switchgear to ensure that the accumulated static charges are discharged to earth before start of any inspection or maintenance work. Two types of earthing switches are commonly provided ; (*i*) Slow moving & (*ii*) High speed ; slow moving switches are used where the operator can visually verify that the section of the switchgear or bus to be grounded has been isolated by opening the above mentioned disconnectors. At such locations such as at bus connections, transformer bushing connections where it is not usually possible to usually verify that the section has been isolated or can not be isolated, high speed earthing switches are used. Provision for automatic opening of these High speed Earthing Switches exists after complete discharge (1 second to 10 seconds). For locations where ground switches of either type can not be installed like at the entrance of bushing terminal, the grounding can be accomplished by using a hot stick.

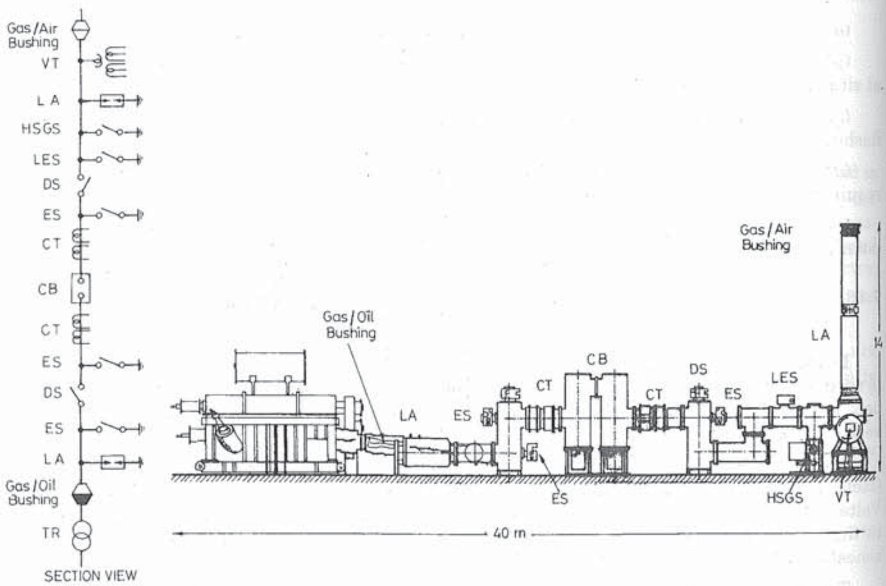


Fig. 7.10. (Main Components of GIS)

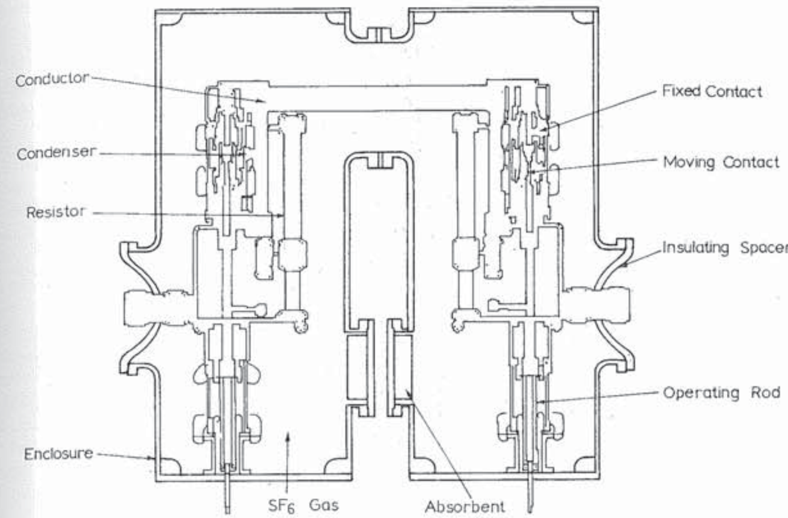


Fig. 7.10 (*a*) Circuit Breaker

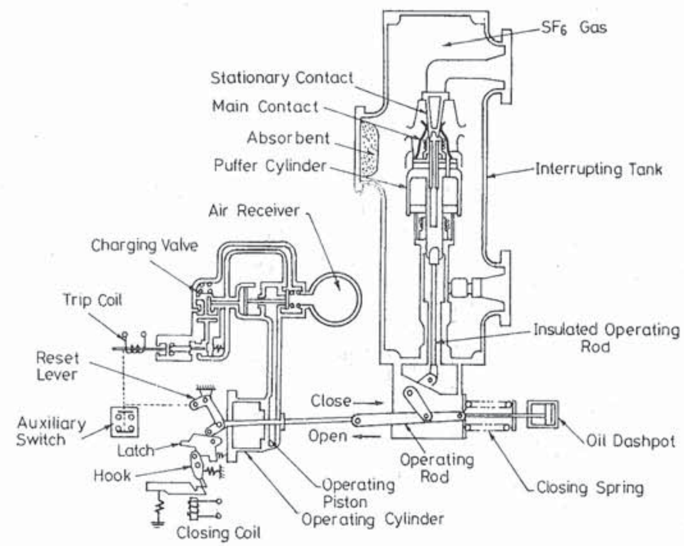


Fig. 7.10 (*b*)

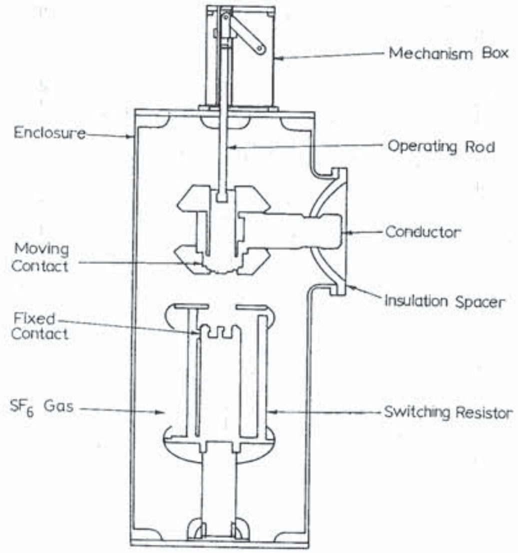


Fig. 7.10 (*c*) Disconnecting switch

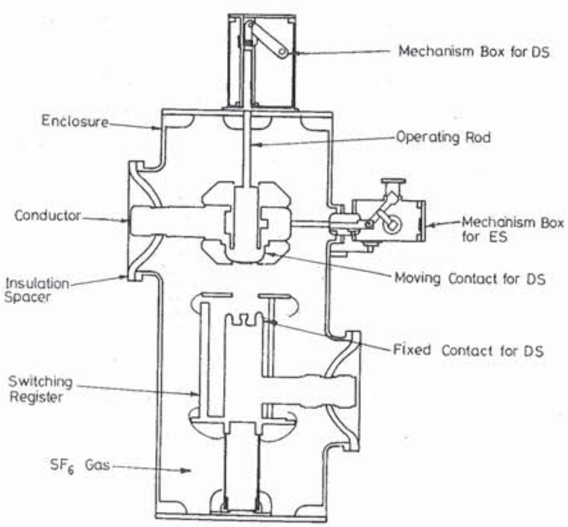


Fig. 7.10 (*d*) Disconnecting and Earthing switch

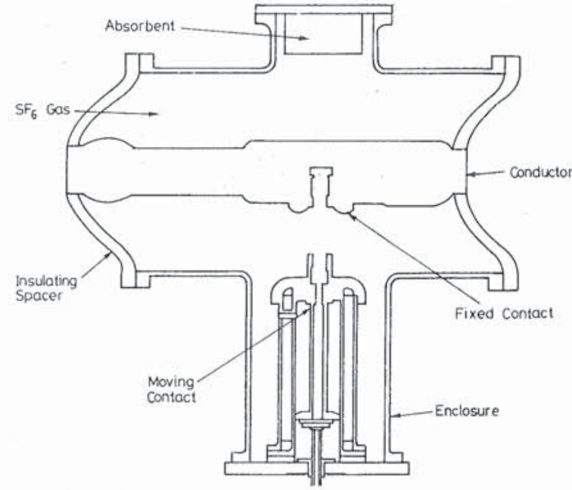


Fig. 7.10 (*e*) High speed ground switch

A mechanical indicator fixed to the operating shaft inside the operating mechanism provides a visual means of checking isolator position.

Instrument Transformers are metal enclosed cast resin type. They are used to meet the requirement of metering. Protection, synchronization etc. These are usually mounted externally to minimize the effect of electro-magnetic transient or enclosure current. Externally mounted construction also offers ease of installation or dismantling and maintenance.

Digital instrument transformers have now been developed in which electrically measured value (voltage or current) is converted to digital or optical signal while still at high voltage.

Insulators are the key components of the type of switchgear. It is said that the health of the GIS depends on its insulators and purity of SF6 gas. These insulators are made of epoxy resin. Normally, two types of insulators are used, Tripost or Conical. Tripost or conical insulators are used to support the conductor to the enclosure. In addition, one or more movable tripost insulators are rigidly attached to the conductor for thermal expansion. Conical Insulators are used as gas barriers to divide the system into separate gas zones / modules.

Surge arrestors are provided to protect the switchgear from high transient voltage and also to regulate the duration and amplitude of follow current. The location and number of Surge Arrestors is based on Insulation Co-ordination studies / surge analysis. Generally, station type, heavy duty, SF6 gas insulated, gapless, metal oxide (Zno) surge arresters are used.

Interfaces (Fig. 7.11, *a, b, c*).

GIS has to be connected to Transformer (oil filled bushing), XLPE cable or outdoor transmission lines. GIS connected directly to a transformer requires oil-SF6 transformer bushing to keep the SF6 gas separate from the transformer insulating oil.

Bellows are provide near the transformer bushing to compensate for alignment errors and to absorb vibration. For connecting to over-head transmission lines, porcelain gas-to-air bushings are used. The cable sealing end is provided to connect the cable, wherever provided. The cabling sealing end can accommodate any kind of cable with conductor X-section upto 2000 mm^2. Isolating contacts and connection facilities are provided for testing the cables.

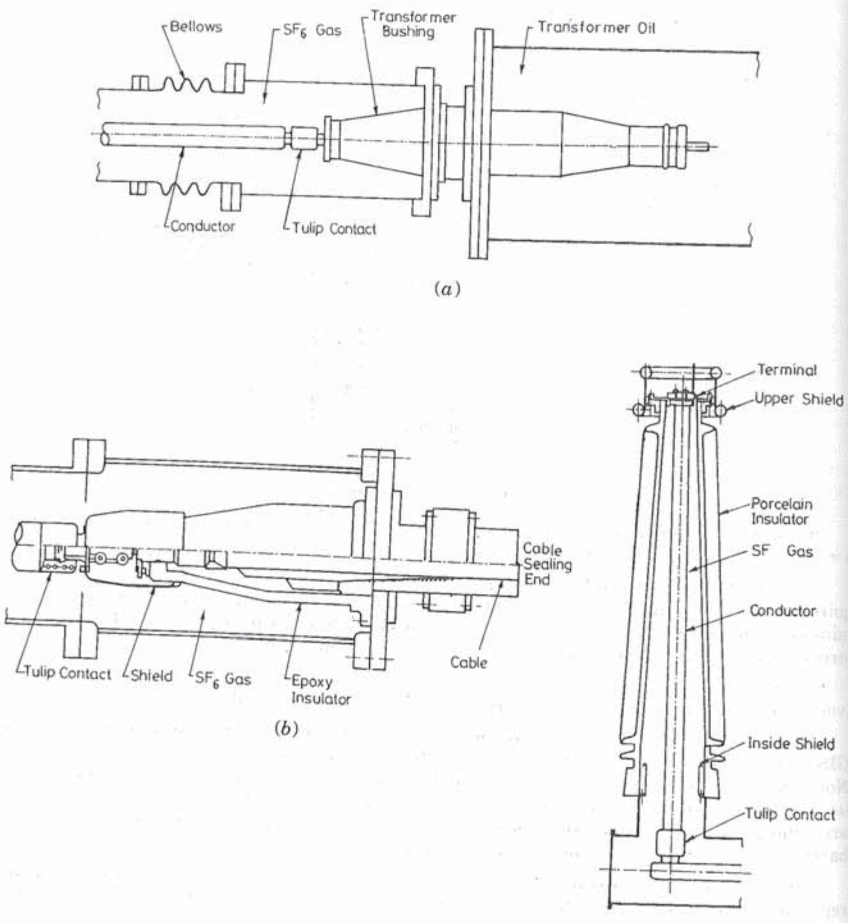


Fig. 7.11.

7.17. GAS MONITORING

The operation of GIS depends upon the pressure and the purity of the gas. Each GIS section is, therefore, provided with a gas density monitoring system. Since the relative dielectric strength of the gas depends on its density rather than pressure, and, density depends on temperature, factory set temperature compensated gas density switches are provided with contacts for alarm and trip. Leakage of gas does take place, 1% per-annum leakage is generally guaranteed. For leakage of very low rate, the gas is automatically admitted through solenoid valves.

Arcing causes the decomposition of the small amounts of the SF6 gas which recombines almost completely into SF6. The decomposition products react with water; So, the moisture content of the gas, particularly in the circuit breaker chamber has to be controlled. This is done by using drying

(molecular) filters. Moisture content, upto 300 ppm can be allowed under exceptional conditions, beyond the value, the gas needs to be subjected to drying process.

Each bay/module is provided with a Local or Bay Control Cubicle containing all the equipment needed for control, interlocking, signaling, supervision and auxiliary power supply. The Local Control Cubicles (LCC) can be connected to Control Room for remote control and signaling.

Grounding : IEE - 80 -"Guide for safety in Alternating Current Sub-station Grounding" is generally followed for grounding of the GIS.

The grounding system to be provided has to limit the potential gradient to acceptable values of assure safe voltage for step & touch, under both normal and abnormal operating conditions external to the GIS assembly. The design of the grounding shall be such as to secure the requirements of protective relaying and also satisfy the provisions necessary for telephone and communication facilities. Particular attention is to be given to the bonding and the grounding of metallic high magnitude enclosures as these enclosures carry high magnitude Induced Currents and these currents have to be confined to specific paths so as to avoid circulating currents. Precautions have to be taken to prevent excessive currents being induced into adjacent frames, structures or reinforcing steel and to avoid current loops via other station equipment, such as transformers etc.

Partial Discharge Monitoring

Partial Discharge (P.D.) monitoring system is provided for high sensitivity monitoring of Partial Discharge Phenomenon in GIS to assure high reliability and efficient preventive maintenance activities.

There are two types of Partial Discharge Monitoring System - On-line and stand alone; Stand alone system is preferred. The P.D. monitoring system initiates alarm when the partial discharge level exceeds the pre-set level which varies from 2.0 pc to 5.0 pc. However, this is subject to expenuine regarding interpretation of the measured values.

The system as shown in Fig. 7.12 consists of external sensors, Measuring unit and Man-Machine Interface; Connection between the external sensor and the PDM is by screened co-axial cable. The PDM kit kept as close as possible to the GIS (within 20 m length) and on the mobile trolley to move easily. The sensor unit is UHF type antenna with a frequency range of 9 KHz to 1.5 GHz. Measurement unit consists of spectrum analyzer, amplifier unit & switching module. Man-machine interface consists of a computer and other normal accessories / devices for data monitoring, recording and print outs. Other types of mobile partial discharge monitoring systems are also being manufactured.

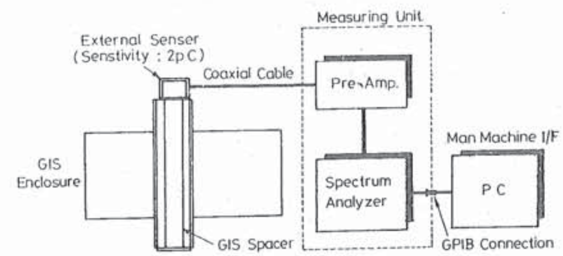


Fig. 7.12. Overall System Configuration of Stand alone Partial Discharge Monitoring System of GIS

Factory Acceptance Testing

GIS equipment should be tested in accordance with ANSI C37.122 and ANSI C37.09 or IEC 517. The various tests include :

— Rated continuous current thermal test
— Dielectric withstand tests
— Lightning impulse tests
— Mechanical life tests
— Mechanical bushing test including cantilever loading capability
— Pressure tests
— Circuit breaker sound level limits
— Short circuit current interrupting test
— Switching impulse tests
— Insulator tests
— Partial discharge tests

— Current and voltage transformer ratio, phase angle and polarity tests
— Nameplate checks
— Gas leakage tests
— Resistors, heaters and coil check test of control mechanisms
— Control and secondary wiring check and continuity tests
— Clearance and mechanical adjustment test
— Mechanical tests on operational assemblies
— Timing tests on operational assemblies
— Timing tests on operational assemblies
— Rated low-frequency withstand voltage tests on control and secondary wiring
— Gas monitoring system alarm contact test
— Finish requirements
— Stored energy system tests
— Interlocking operation tests

Field Acceptance Testing

Field acceptance testing is performed in accordance with ANSI C37.122 or IEC 517 as applicable on the completely assembled GIS assembly. The following tests are included :

— Gas leak or tightness check
— Gas moisture tests
— Continuity tests
— Operational tests
— Grounding tests
— Current transformer ratio and polarity tests
— Voltage transformer ratio and polarity tests
— Voltage tests on control and auxiliary circuits

LOSS MEASUREMENT & TEMPERATURE RISE TESTS OF CONDUCTOR AND ENCLOSURE

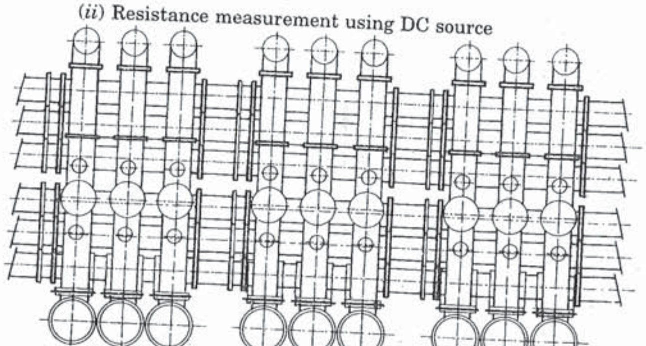
Loss Measurement Test

When current flows through the conductors, it induces emf in the enclosure resulting in the circulation of current in the enclosure. This loss in the energy is converted into heat. The magnitude of this heat loss depends on current flowing through the conductor, the clearance between conductor and enclosure, the material & thickness (Resistance) of the enclosure. The loss, both in conductor & enclosure, have to be kept within such limits so as not to cause temperature rise more than allowed by the relevant applicable standards. The value of losses and temperature rise are generally to be guaranteed by the manufacturer and hence are verified by the Purchaser.

The following two methods are employed for measurement of conductor and enclosure losses.

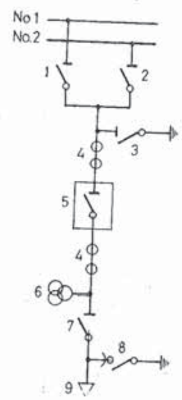
(*i*) Watt-meter method

(*ii*) Resistance measurement using DC source



Double-bus type 420 kV GIS (Layout-Plan)

1. Busbar disconnector, 2. Busbar disconnector, 3. Maintenance earthing device 4. Current transformer, 5. Circuit breaker, 6. Voltage transformer, 7. Line disconnector, 8. Line earthing switch, 9. Cable sealing end.



Single line diagram

Fig. 7.13.

Temperature rise of conductor and enclosure is measured at rated current, rated SF6 gas pressure and at ambient temperature by using thermo couples.

The details of routine and field tests generally followed in Gas Insulated Switchgear are given in Section A & section B respectively.

Ratings of GIS Switchgear

Rated Voltage	*Rated BII, KV*	*Rated INT, KA*	*Rated Normal Current A*					
123	550	12.5	800	1250				
		20		1250	1600	2000		
		25		1250	1600	2000		
		40			1600	2000		
145	650	12.5	800	1250				
		20		1250	1600	2000		
		25		1250	1600	2000		
		31.5		1250	1600	2000	3150	
		40			1600	2000	3150	
		50				2000	3150	
170	750	12.5	800	1250				
		20		1250	1600	2000		
		31.5		1250	1600	2000	3150	
		40			1600	2000	3150	
		50			1600	2000	3150	
245	1050	20		1250	1600	2000		
		31.5		1250	1600	2000		
		40			1600	2000	3150	
		50				2000	3150	
300	1050	16		1250	1600			
		20		1250	1600	2000		
		31.5			1600	2000	3150	
		50			1600	2000	3150	
362	1175	20				2000		
		31.5				2000		
		40			1600	2000	3150	
420	1425	20			1600	2000		
		31.5			1600	2000		
		40			1600	2000	3150	
		50				2000	3150	4000
525	1550	40				2000	3150	
765	2100	40				2000	3150	

7.18. GAS FILLING AND MONITORING SYSTEM FOR SF_6 SWITCHGEAR

Gas tightness is basic requirement of SF_6 insulated sub-stations. The entire sub-station is divided into separate compartments. The gas pressure in each compartment is monitored separately. The gas monitoring system comprises temperature compensated pressure switches. The setting in such that when density of gas (related with temperature and pressure) reduces below safe level, an alarm is sounded. Further reduction in pressure gives a tripping command. Normally the leakage rate should be less than 1% per year. For leakage of very low rate, the setting of density monitors is such that the gas from SF_6 gas cylinders is automatically admitted in the modules to make-up the loss. The gas filling system consists of high pressure tank (6 to 10 kgf/cm^2 for circuit-breaker modules and low pressure tank for other modules. When gas pressure in the modules drops down the gas from tank is automatically admitted by solenoid valves. The SF_6 gas from cylinders can automatically go to tanks on opening the valves and regulators.

Typical Ratings of SF_6 Insulated Switchgear (GIS)

Rated Voltage kV	36	72	145	245	400	500
Rated currents Amp.	1200 to 2000	1200 to 2000	2000 to 3000	2000 to 4000	2000 to 4000	2000 to 4000
Rated Breaking current kA	32	32	32	50	50	50
Breaking capacity MVA	1800	3500	7500	10,000	35,000	50,000
Operating Time Cycles	3	3	3	2.3	2	2
Power frequency Voltage withstand kV_{rms}	75	160	275	460	680	840
Impulse Voltage withstand kV_p, peak	170	400	550	1050	1425	1800

7.19. TRANSPORTATION AND HANDLING OF SF_6 GAS

The SF_6 gas is transported liquid form in cylinders of various sizes (15 kg, 40 kg and 100 kg).

The gas cylinder has a valve on the top. When this valve is manually opened, the SF_6 is released through the valve in gaseous form. The necessary heat for conversion from liquid to gas is taken from atmosphere. In cold countries it becomes necessary to keep the gas cylinder in hot water to convert liquid into gas. But such heating is not necessary in India during summer.

The circuit-breaker is provided with a gas valve and gas monitoring system. A braided teflon hose is connected between the gas cylinder, gas handling unit and the circuit breaker valve. Before filling the gas, the circuit-breaker is evacuated and the air and moisture must be removed from inside the breaker. After evacuated to about 2 mm of mercury, the gas from the cylinder is admitted into the breaker. The pressure of gas in the breaker is indicated on the pressure gauge. When the desired pressure is reached, the gas valve on the breaker is closed.

During periodic maintenance, the gas sample from SF_6 circuit breaker is collected and tested for moisture and other impurities (IEC 376). The gas is circulated through filters containing activated alumina. The activated alumina absorbs the impurities like $S_2 F_2$, SF_4, moisture etc. The gas can be used again after regeneration.

7.20. GAS TRANSFER UNITS

These are employed primarily to erection and maintenance large SF_6 equipment such as circuit-breakers and GIS. During the maintenance it is necessary in most instances, to remove the SF_6 gas from the equipment. Because SF_6 is a relatively expensive gas, it is desirable to collect the gas during periods of maintenances and to recharge the equipment after the maintenance.

Functions of SF_6 Handling Unit

1. On initial start up, the unit evacuates itself.
2. The unit is connected, by means of a flexible hose, to the equipment to be serviced. After equalisation of pressure between the transfer unit and equipment, the SF_6 is pumped to the storage tank of transfer unit. The refrigeration system is energized to obtain liquefaction of the SF_6 gas.
3. The vacuum pump is energized ensuring complete transfer of SF_6 gas to storage tanks.
4. After maintenance the transfer-unit evacuated the service equipment prior to charging with SF_6 gas.
5. The tank heater is energized to boil off the SF_6 gas and recharge the equipment. This is for low ambient temperature.
6. If the transfer unit is equipped with an SF_6 purifier and gas dryer the gas is processed prior to recharging the serviced equipment by internal circulation through filters.

Features

— Transfer, stores, reclaims, and purifies 99.5% of the SF_6 gas.
— No lubricating oil contamination. All transfer units contain exclusive 4-step oil separation process.
— Automatically controlled refrigeration system.
— Convenient central control panel. All switches, gauges and instruments located for case of operation.
— Hand valves conveniently grouped on either side of control panel.
— Trailer mounted for portability. Can be towed.

The gas handling unit is used for filling the SF_6 gas in the breaker and for reclaiming the SF_6 gas from the breaker. The gas handling unit comprises a vacuum pump., compressor, an auxiliary receiver, gas-filtering units, valves and piping. Before filling the gas, the circuit-breaker is evacuated by means of the vacuum pump. After achieving a certain degree of evacuation, the gas from cylinders is filled into the circuit-breaker.

Gas transfer units for SF_6 gas are available is various forms for various applications.

1. Simple gas transfer unit comprises only a vacuum pump with valves. It is useful in evacuating the circuit-breaker to remove moisture and air. Such a unit is sufficient in most of the cases where only a few circuit-breakers are installed.

2. **Medium gas transfer unit.** This comprises a vacuum pump compressor and valves with piping. It can perform the following functions:

(*a*) Evacuating the breaker.
(*b*) Transferring the gas from the cylinder to the breaker.
(*c*) Reclaiming the gas from the breaker into another tank.

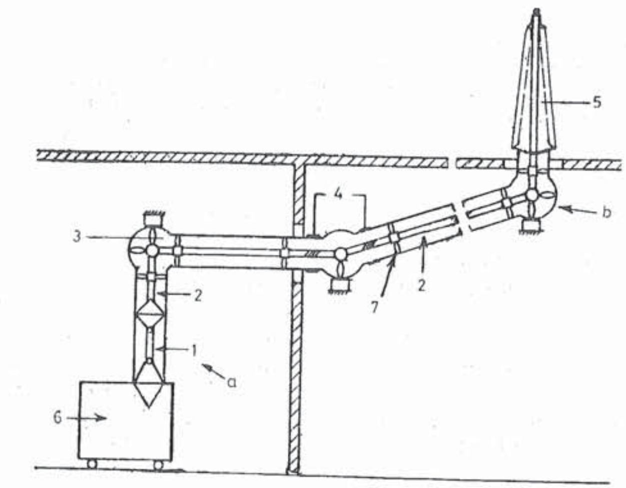
3. **Large Gas Transfer Unit.** It has the following components :

(*a*) SF_6 gas compressor
(*b*) Vacuum pump
(*c*) Gas storage tank
(*d*) Filter units containing activated alumina.

7.21. SF_6 INSULATED EHV TRANSMISSION CABLES (GIC)

The conventional transmission lines from generating station to receiving-station are outdoor overhead lines. The connection between the underground power-station and remote outdoor switchyard is generally made by high voltage oil filed cable usually 145 kV or above.

In recent years such connections are made by means of SF_6 gas Insulated metal enclosed cables (GIC). GIC is preferred for connection between step-up transformer and the outdoor switchgear. The three phases are enclosed in separate enclosures filled with SF_6 at 4.5 kg/cm^2. Conductors are supported on epoxy insulators, Fxpansion joints are provided by plug-in contacts. [Fig. 7.14].



1. Oil/SF_6 Bushing
2. GIC
3. 90° bend, ball joint
4. Expansion joint
5. SF_6/Air Bushing
6. Transformer
7. Support insulators

Fig. 7.14. A 420 kV, SF_6 Gas Insulated Cable (GIC) SF_6 Gas pressure; kg/cm^2 Absolute [*Courtesy* Brown Boveri.]

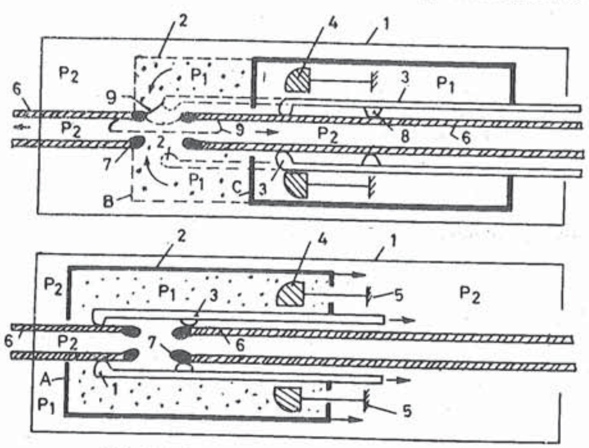
Summary

SF_6 circuit-breakers are preferred for rated voltages of 3.3 kV, to 760 kV, SF_6 filled switchgear (GIS) and cables (GIC) are preferred for sub-stations. Puffer type single pressure SF_6 circuit-breakers employing puffer principle have higher interrupting capacity per interrupter (60 kA at 245 kV).

Note : 1. SF_6 circuit-breakers are now preferred for indoor metalclad switchgear rated 3.3 kV to 36 kV. (Refer Ch. 15).

2. SF_6 outdoor circuit-breakers are now preferred for rated voltages from 36 kV to 760 kV.

3. SF_6 GIS has been developed for wide range from 3.3 kV to 760 kV.



1. A. Fully closed
   B. Contact separated
   C. Full open
2. Puffer cylinder
3. Moving contact tube
4. Fixed piston
5. Support for 4
6. Fixed Nozzle
7. Conducing nozzles
8. Finger contacts on 3
9. Arc drawn into 6
10. Gas flow

Fig. 7.15. Three stages of Puffer Action in Interrupter with fixed conducting nozzles. (Courtesy: Siemens, West Germany.)

4. In outdoor EHV range SF_6 CB is the most popular, cheaper and satisfactory type of breaker. It has made MOCBs and ABCBs obsolete.

The puffer cylinder (2) moves towards right (A → B → C →) along with the moving contact tube (3). The gas compressed in (2) is released through conducting tubes (6 – 6) as the art (9) is drawn. The arc (9) is driven in two directions axially in the tubes (6 – 6). The conducting nozzles at the tips of conducting tubes (7) made of graphite accelerate the arc roots into the tubes. The arc is quenched by cooling and lengthening in the tubes. Fresh SF gas between the two fixed nozzles gives the dielectric recovery, the hot gas is driven away.

QUESTIONS

1. Explain briefly the arc extinction process in SF_6 circuit-breakers.
2. Explain the following terms regarding SF_6 gas
   — Electronegativity
   — Arc time constant.
   Discuss the merits and limitation of SF_6 gas as insulating and arc quenching medium.
3. Explain the principle of puffer type SF_6 circuit-breaker.
   With the help of sketches explain the configuration of a puffer type SF_6 circuit-breaker.
4. Explain the procedure to filling SF_6 gas in a circuit-breaker.
5. What are the applications of SF_6 gas ?
6. Describe arc quenching process in puffer type SF_6 circuit-breaker.
7. Explain precautions to be taken to avoid dust, moisture, leakage in case of SF_6 circuit-breakers.
8. Explain the difference between a conventional outdoor substation and an GIS.

Units of Gas Pressure :

SI Unit of pressure : 1 Newton per meter-squared
1 Nm^{-2}

Conversion factors :

1 atmosphere = 1 atm = 101325 Nm^{-2}

1 bar = 10^5 Nm^{-2}

1 kilogram force = 1 kgf = 9.806 N

1 atm = 101.325 kNm^{-2} = 1.01325 bar

1 atm at standard temp and pressure = 760 mm of mercury.

1 torr = 1/760 mm of mercury = 133.32 Nm^{-2}.

7-A

Routine, Site/Field Testing of GIS

7.22. ROUTINE TESTING OF GIS

Purpose : The routine tests serve the purpose of knowing any defects and deviations in material, during assembly of component/device or manufacturing faults. These tests ensure that the product is in accordance with the equipment specifications/relevant standards and shall meet the specific environmental & operating conditions. The routine tests are made on each apparatus or device or on each transport unit or on a complete bay at the manufacturers works.

These Routine Tests are performed in accordance with the provision of various standards and guidelines. Wherever deviations exist between such standards, the method and input values and the results are then mutually agreed between the purchaser and the supplier.

The various applicable standards generally followed for main components of GIS is given below:

Item/Equipment	Applicable Standards
Gas Insulated Switchgear assembly	IEC 60517
	IEC 60694
	IEEE C:37.122
Circuit Breaker	IEC 60056
Disconnecting Switch and Earthing Switch	IEC 60129
Current Transformer	IEC 60044-1
	IEC 60185
Voltage Transformer	IEC 60044-2
	IEC 60186
Lightning Arrestor	IEC 60099-4 & IEC 60517
SF_6-Air Bushing	IEC 60137

The main tests generally specified for various components are as follows:

(a) Routine Tests on Surge Arrester (Metal Oxide Type)

— Residual Voltage Test
— Visual & Dimensional Check
— Gas leakage test on housing
— Insulation Resistance Test
— Measurement of the operating current at max. Continuous Operating Voltage
— Leakage Current Test
— Measurement of Reference Voltage
— Partial discharge measurement test at 1.05 × max. continuous operating voltage

Partial discharge levels are measured at phase voltage × 1.05 after prestressing at 390 kV (for 420 kV) for 10 seconds.

— SF_6 gas leakage tests.

(By accumulation method, using gas leak detector)

Surge Arrestor Component testing during their manufacture comprise:

— Pressure test and gas tightness test on enclosures. Each enclosure is subjected to two times design pressure for 1 minute.
— Dielectric test on barrier insulators *e.g.* for 420 kV switchgear, ac voltage of 680 kV, 50 Hz is applied for 60 seconds.
— Dielectric test on foil insulated grading tubes where ever applicable.
— Each individual Metal oxide disc is subjected to the following routine tests:
— Loading with high energy (3 × 3 rectangular waves)
— Measurement of residual voltage and rated discharge current
— Measurement of Watt-loss at 50 Hz Service voltage
— Current sharing check on Metal oxide columns in case of multi-column arresters

(b) Routine Tests on Voltage Transformer

— Induced over-voltage withstand test
— Lightning Impulse Voltage Test
— Switching Impulse Voltage Test
— Power frequency test on secondary windings
— Partial discharge measurement test
— Voltage error and phase displacement tests, verification of terminal markings
— Pressure test and gas lightness (leakage) test on enclosure

(c) Routine Tests on each Disconnecting Switch & Earthing Switch

— Visual inspection, Wiring check
— Mechanical operation tests.
— Measurement of insulation resistance of auxiliary and control circuit
— Power frequency voltage withstand test on auxiliary, control circuit and main circuit
— Measurement of the resistance of the main circuit
— Measurement of motor current
— Interlock Test
— Gas leakage test

(d) Routine Test on Current Transformer

— Visual, Dimensional check including verification of terminal markings
— Polarity check
— Power frequency withstand test on secondary windings
— Inter-turn over-voltage test
— Determination of errors
— Measurement of excitation characteristics
— Secondary winding resistance test
— Turns Ratio Test
— Composite Error Test

High voltage dielectric tests are performed subsequently on these current transformers on their mounting / integration with GIS module / Transport Unit.

(e) Tests on SF_6-air bushings

The following tests in accordance to IEC 137 are performed by the manufacturer.

— Measurement of the dielectric dissipation factor and the capacitance at ambient temperature.
— Power frequency voltage withstand test (dry) for one minute at rated SF_6 gas pressure (at 20°C).

— Measurement of the partial discharge quantity at $1.5 \times U_m/\sqrt{3}$ and at minimum rated gas pressure (at 20°C) (value to be less than 5 pc).
— Gas lightness of cast enclosure by filling it with Helium gas and detect any leakage followed by vacuum/pressure rise test and sniffing tests on welds & joints.
— Pressure test on enclosure; each enclosure is subjected to 2 times design pressure for one minute.
— Pressure test on complete bushing with 1.5 × rated operating pressure during 15 minutes.
— Gas tightness test on complete bushing.
— Resistance measurement test as per the procedure in IEC 694.

(*f*) **Routine Tests on Circuit Breaker Unit**
— Check of correct wiring & visual inspection
— Measurement of coil resistance
— Mechanical operation & timing test
— Measurement of minimum operating voltage and pressure
— Measurement of motor current
— Stored energy test
— Oil leakage test
— Safety valve operation test
— Measurement of oil pressure switch operating pressure
— Measurement of gas density switch operating pressure
— Measurement of insulation resistance of main circuit, auxiliary circuit and control circuit
— Voltage test of auxiliary and control circuit
— Power frequency voltage withstand test on the main circuit

(*g*) **Routine tests on assembled/Transport Section**
— Visual Inspection
— Gas leakage test
— Operating Mechanism fluid leakage test
— Measurement of the resistance of the main circuit
— Power frequency voltage withstand test on the main circuit
— Partial discharge test
— Power frequency voltage withstand test on auxiliary and control circuit of Bay (Local) control cubicle
— Correct wiring & interlock test
— Measurement of gas density switch operating pressure
— Mechanical operation test
— Corrosion protection test

When testing according to IEEC 37.122, for pressure tests on enclosures, and for protection tests on circuit breakers (ANSI/IEEE C37.09-1979) some deviations may have to be taken into account. Also, following additional test will also have to be carried out.

— Current transformer and linear coupler transformer tests as per ANSI C 57.

A description of the procedure being following with regard to important tests as indicated above is briefly described hereunder:

1. **Visual Inspection.** The complete bays/shipping sections are visually inspected. Dimensional checks are made as per the layout drawings. The name plate markings are checked and compared with the drawings.

2. **Power frequency voltage tests on the main circuit, including partial discharge measurement.** They are made on complete apparatus including at least one insulator of each type transport units or complete bays in accordance with IEC 694, IEC 517 & IEC 60. It has to be ensured that the place of testing is dry, clean with adequate ventilation. The test voltages are supplied normally by metal clad test transformers directly flanged to the tested apparatus. During the test, the SF_6 gas pressure is maintained at its minimum value, test voltages are generally as per the following table.

Max. Voltage, (kV)	145	245	420	800
Applied Voltage at 50 Hz, (kV)	325	440	680	960

The test values do vary, *e.g.* for 420 kV, 520 kV test voltage is also used. The test voltage is applied for 60 to 72 seconds depending on nominal voltage frequency 50 Hz or 60 Hz.

The measurement of partial discharge as per IEC requirement is $1.1 \times$ Max. voltage/3. However, some manufacturers perform with descending voltage at $1.05 \times U_m/\sqrt{3}$. The acceptable value of partial discharge is less than 10 pc; The actual values are even less than 3 pc. When testing with a coupling capacitor, a minimum capacitance of 1000 F is provided.

Di-electric Tests on auxiliary and Control Circuits

The test, as per IEC-694, involves application of 2.0 kV, 50Hz voltage for one-minute between the auxiliary and control circuits connected together as a whole and the base of the switching device.

Measurement of the resistance of the main circuits

The test involves measurement of resistance on bus-joints, circuit breaker, disconnectors, earthing switch contacts so as to verify proper contact alignment.

This test is made in accordance with IEC:694; A d.c. current is passed across the said contacts & voltage drop measured to calculate the contact resistance.

Resistance value of close and trip solenoid coils and their series resistors are measured by digital multi meters and value obtained compared with the specified limits.

Gas density Test

This is an important test to determine the dielectric integrity of the switchgear, gas density is measured at rated pressure and ambient temperature.

Pressure Tests

These tests are undertaken on GIS enclosures and barrier insulators.

Enclosures : The tests are done as per IEC 517. However, the general practice is to subject the enclosure to 2 times design pressure for 1 minute.

Barrier Insulators : These insulators are routine tested with water pressure at 1200 kpa for 1 minute.

Gas leakage tests

This test is performed as per IEC-517 and is intended to verify that the leakage of the gas is within the permissible limits *i.e.* less 1-percent per annum.

In the above test, vessels are checked on porosity by filling with Helium gas and detecting the leakage of the gas by appropriate detectors; Subsequently, the vessel or transport unit is evacuated to less than 100 Pa pressure, then the vacuum pump is disconnected and pressure rise observed; The equipment is then filled with SF6 gas at rated pressure and sniffing tests are made on each joint, flanges, screw joints, gas fittings, welded seam etc. to verify/smell any leakages. Other method, called the accumulation method involves wrapping of plastic sheets around the mutually agreed locations of flanges, screw joints, gas fittings and notice any accumulation of gas in the plastic wraps which are left wrapped for 12 to 15 hours. The gas contents, if any, are measured by gas leakage detector.

Mechanical Operation Test

The intent of the above tests is to ensure that the switching devices comply with the stipulated operating conditions and that the mechanical interlocks and switching devices operate, open/close properly within the specified limits of auxiliary voltage, pressure etc.

Each switching device is subjected to a minimum of 50 operating cycles with the interlocks placed as per the requirement; for each switching devices details are as under:

Circuit-breaker

The tests are performed as per IEC 60056. A minimum of 50 close/open operations are made at ambient room temperature and at different operating mechanism pressures.

Switching times are measured and the time travel diagram is recorded, smoothness of the circuit open/close operation at different pressures of the operating mechanism is also checked.

Timing Test of Circuit Breaker

Closing time, opening time, asynchronisation time of the three poles and operating system pressure drop after each operation at different pressures & control voltages are measured. Also, recharging time of the hydraulic mechanism after one closing and opening operation at rated pressure are measured and compared with the permissible limits.

Also, minimum DC control voltage at which the gas circuit breaker can be electrically operated is measured to see that the CB operates at minimum DC auxiliary voltage. This operation test shall preferably be carried at minimum pressure of the operating mechanism (Hydraulic of Pneumatic).

The CB shall also be tested for stored energy under the specified operating sequence without oil pump operation. The operating system has also to be tested for leakage test by setting it at the rated pressure and other pumps switched off. The drop in pressure shall be measured after one hour. Then the pump shall be run continuously and operating pressure of the safety valves checked.

Disconnector and earthing switch

The intention is to verify that the disconnectors and earthing switches open and close correctly. Switches and their respective drive mechanisms are normally tested separately and subsequently together after complete assembly. Ten number operations each at minimum and maximum auxiliary voltage and 50 Nos. at rated voltage are performed for closing as well as opening; closing time of disconnector is also measured.

Tests on main circuit components

Normally 70 close/open operations are made. The torque of the motor as well as main circuit resistance are measured after completion of 70 operations.

Motor currents drawn at rated voltage, maximum and minimum voltage are also measured.

Tests on drives : The drives are tested under specified torque on simulators :

In this test, 50 close/open cycles each at rated supply voltage and rated pressure of compressed gas; 10 close/open cycles at specified minimum aux. supply voltage, 10-close/open cycles at max. supply voltage are employed.

After, completion of above close/open cycles, travel times and resistance of electrical parts are measured.

Tests on Switches

These tests are made either in the factory in case of complete bays as well as site to check their correct operations.

Tests of Auxiliary Electrical and Hydraulic Devices

The purpose is to verify that the electrical, hydraulic and other interlocks together with control devices operate satisfactorily and in the pre-determined sequence of operation under all conditions of use/operation and under the limits as specified for auxiliary supply.

The test is made in accordance with IEC-517.

Corrosion Protection Test

The dry film thickness (microns) of the paint (wherever applicable) is measured and compared with the stipulated values.

Verification of the correct wiring

The purpose is to verify that the wiring conforms with the diagram and prescribed requirements.

Wiring of complete bays and integrated control panels is checked which include:

— Correctness of all apparatus and of their installation
— Wiring check
— Dielectric Tests on aux. & control circuits
— Check of main circuits
— Completeness check
— Safety check while handling/transport

Checks/Tests on CTs

Polarity of the CTs is checked by inductive method; For power frequency withstand test on secondary windings, a voltage of 3000 volts, 50 Hz is applied for 60 seconds between secondary windings and earth as per IEC-60044-1, 60185; To verify the inter-turn voltage requirements, rms value equal to rated primary current at rated frequency is applied for one minute to the primary winding of the CT, with secondary open circuited so as to produce stipulated value (4.5 kV peak) of voltage at secondary terminal.

With primary winding open circuited, a voltage equal to ten times the r.m.s. value of the specified e.m.f. is applied for one minute to the secondary terminal provided that the r.m.s. value of the secondary current does not exceed the rated current and CT is checked for withstanding the applied test voltage (Applicable to PS-class CTs).

Determination of errors

Rated Current is passed through the CT to be tested and a standard (authenticated & calibrated CT), the secondary winding current is then compared with the Standard CT & current error and phase displacement measured and compared with the limits given in IEC 60044-1 & 60185.

Measurement of excitation characteristics

Excitation current is injected to the secondary circuit, with primary winding open circuited; Excitation current and voltage are measured at typical three points upto excitation current of 1 Amp/5 Amp, as the case may be.

Secondary Winding Resistance Measurement

Resistance values of the secondary winding are measured by digital multi-meters and compared with the design/specified values.

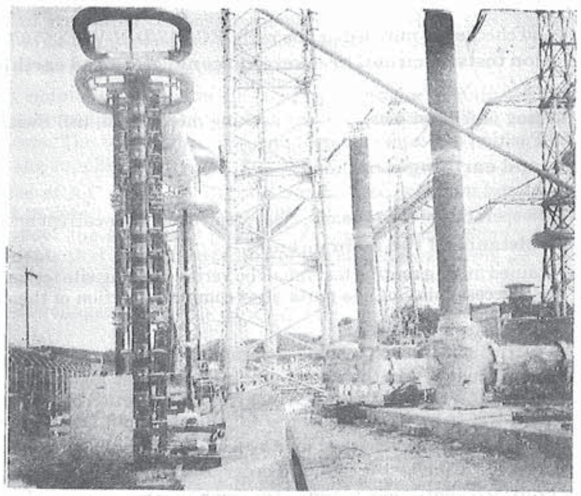


Fig. 7A.1. Site Test (Oscillating Impulse Test).

Turn Ratio and Composite Error Test

Difference between the rated and actual turns ratio expressed as percentage is checked and turns ratio errors obtained as such are compared with the specified limits.

The composite error at rated accuracy limit in terms of the percentage of primary currents for different accuracy class of CTs is checked and compared with the specified limits.

Lightning Impulse, Switching Impulse and Accuracy Tests for Voltage Transformers (VTs)

Three positive and three negative pulses of specified lightning impulse test voltage (1425 kV for 400 kV) are injected maintaining the SF6 gas pressure at its minimum value.

For switching impulse test, fifteen positive and fifteen negative pulses of the specified switching impulse test voltage (1050 kV for 400 kV) are injected keeping the SF_6 gas pressure at its minimum value.

Voltage error and phase displacement values are measured by comparing the same with a standard VT.

7.23. SITE/FIELD TESTING OF GIS (Refer Fig. 7A.1)

Purpose : Immediately after erection and physical check up of various assemblies, GIS is subjected to various tests to check the di-electric strength of the complete switchgear and also to detect any damage during transportation, storage or handling, presence of foreign particles, moisture content etc. to avoid the possibility of difficulty in charging the system to its rated max. voltage or to detect the possibility of likely reason of internal fault on commissioning. The site tests are supplementary to the routine tests.

The various main site tests include:

— Mechanical operation on circuit breakers, disconnectors and earthing switches.

— Measurement of the resistance of the main circuits.

— SF_6 gas leakage tests

— Moisture content tests

— Checks for correct wiring, proper functioning of the interlocks, control, measuring protective and regulating equipment including heating and lighting.

— High voltage tests on the main circuit.

Earthing Test

The aforesaid tests and checks are pursued in line with IEC-517/DIN-VDE0670/IEEEC37, 122.

Mechanical operation tests on circuit breakers, disconnectors and earthing switches.

For circuit breakers

— Checking and testing of (*i*) Pump control, (*ii*) Locking mechanism, (*iii*) Switching times of main circuit, (*iv*) Position indicator

For disconnectors and earthing switches

— Correct adjustment and indicator position check

— 5 number close/open operation of drive motors, measurement of motor current and running time.

Measurement of the resistance of the main circuits

Resistance values obtained during routine tests shall be verified during site testing to the extent practicable in view of the inaccessibility of live parts after complete erection of the switchgear.

SF_6 gas leakage test

These tests shall be carried out on each module separately.

In this test, the gas is evacuated and the rise of pressure noted for about one hour after the shutting off of the vacuum pump; Very fast pressure rise gives an indication of leak or higher moisture content; If the vacuum test is satisfactory, SF_6 is filled in to about 50% of the rated filling pressure, the joints made at site are then checked for any leakage with SF_6 gas detector or sniffer. The pressure is also monitored. If the test is found in order, the equipment is filled with SF_6 gas to achieve the rated pressure. All joints, inlets, vents, gas coupling piping etc. are then again checked by using gas sniffers.

Moisture content testing/dew point measurement of SF_6 gas

SF_6 gas used in GIS shall meet the requirement of IEC 376 (1974) - "Specification and acceptance of new sulphur hexaflouride".

The GIS sealed assembly is evacuated and the gas is filled up to the rated pressure. The assembly has to be then tested for moisture content as specified by the manufacturer, in line with IEC-376.

The tests for detection of moisture content are generally confined to ten percent of the gas compartments of different modules selected at random. The tests are done generally after 3-4 weeks after filling the compartments with the gas to allow for stabilization of the moisture.

In case moisture content in any of the compartments is found to be more than the admissible limits, it is advisable to go for testing of all other compartments.

Checks and verifications

Other checks and verifications are made to examine the proper functioning of the measuring, protective, regulating equipment, heating & lighting, interlocks and grounding.

First the individual bays are checked/tested vis-a-vis the above mentioned aspects. This is followed by checking of interconnection of the bays. It is important to check that the switching and motor operating devices operate satisfactorily under the maximum and minimum specified limits of auxiliary and control voltage and operating system works satisfactory under minimum operating pressure.

The interlocks are placed in position as per the approved relevant drawings to examine the operation of the switching devices which is repeated 5 times.

Current transformers are checked by current impulses to check the correctness of the polarity and by buzzer for correct and intact wiring. This check has to be made immediately before mounting the current transformers.

Some purchasers, also check and measure the CT ratio and its magnetization characteristic. For this a special testing facility is required and, therefore, purchaser has to consult the supplier in advance. This test is done with CT in mounted position and the current is injected through earthing switches.

Continuity of grounding connections is very important for GIS. The grounding connections, therefore, have to be scrupulously checked for electrical continuity.

High voltage tests on the main circuits

This test is normally made after the switchgear has been fully erected and gas filled at the rated density and moisture content found within the specified limits and successful completion of all other site tests. The test method and the tested voltage need to be agreed upon between the purchaser and the supplier.

The purpose of A.C. HV test is to detect the presence of conducting particles within the switchgear and to detect, to some large extent, abnormal dielectric strength. A successful test in an assurance about the absence of potentially damaging conducting particles, contamination or floating components that may cause failure of the switchgear during service.

Type of test voltages :

Types of test voltages are :-

— AC voltage

— Oscillating lightning impulse

— Oscillating Switching Impulse

— DC voltage

Switching Impulse Voltage

Test with switching impulse voltages are useful to detect the presence of contaminations as well as abnormal field configurations. This involves simple test equipment but oscillating switching impulse voltage is not as sensitive as AC voltage test. Some manufacturers, based on their experience employ switching impulses with oscillating wave forms with a time crest in the range of 150 μs to 10 ms.

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.

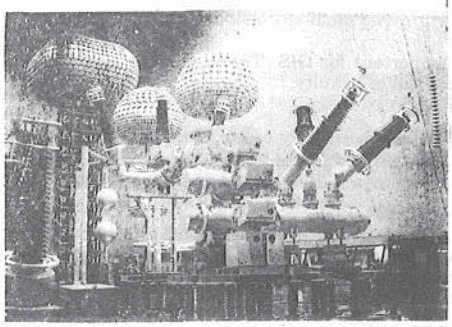
— For lower voltages upto 400 kV, AC voltage may be preferred for field testing; In addition, in case complete bays have been transported and assembled on site, a partial discharge measurement may also be pursued. The second choice may be to use oscillating switching impulse voltage. For this, no partial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



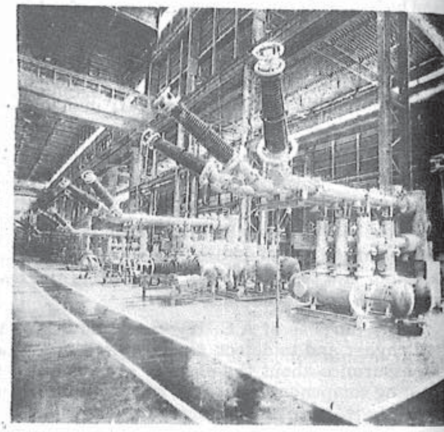


Fig. 7A.2. Factory testing process.

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:

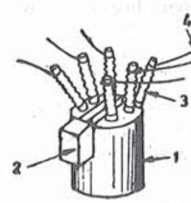
(1) Short Contact Life, (2) Frequent Maintenance (3) Possibility of Explosion. (4) Larger arcing time for small currents (5) Prone to restrikes.

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

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

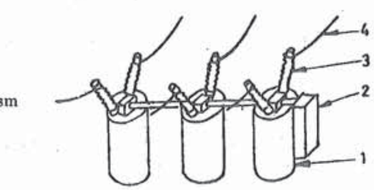
Oil circuit-breakers were widely used for rated upto 72.5 kV before 1960.

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.



1. Tank
2. Operating mechanism
3. Bushing
4. Terminal

(*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.