13

Installation and Maintenance

Introduction—Maintenance of circuit Breaker—Contact—Arc Control Devices—Insulators —Operating Mechanism—Relays—SF_6 Gas—Oil—Safety—Installation—Erection—Drawout type switchgear —Control panels—Outdoor breaker

13.1. INTRODUCTION

The switchgear and protective relaying system should be always alert to operate against an unexpected fault. Switchgear which was in quiescent state has to operate immediately. For such an operation regular and detailed maintenance is necessary. The lack of maintenance may result in failure in operation.

The Switchgear manufacturer supplies "Instruction Manual of Installation, Operation and Maintenance.' These manuals should be carefully studied by trained maintenance staff. The code of practice booklets published by the standards institution, regulations of electrical installations are also useful. Detailed programme of maintenance of switchgear should be prepared with predetermined intervals between inspections. The period may be one to three months for switchgear operation frequently and six months to twelve months of switchgear operating rarely. Further, it is unwise to leave the circuit-breaker close for a period longer than six months without opening, because the mechanism may become sluggish and contacts may need cleaning. Hence during the periodic maintenance, the circuit-breaker is purposely opened and closed by manual command.

The maintenance schedule is usually in the form of log sheets on which weeks, months of the year are tabulated. Each equipment in the sub-station or the plant is provided with a column. The maintenance period is indicated against each equipment. Further each major equipment is provided with a history card. The details about inspection, operation and remarks are written in these cards.

The spares, tools and instruments are important for maintenance duty. The spares are kept in stock with proper inventory control.

The maintenance work is done by trained staff according to the schedule. In case of difficult jobs the manufacturer is consulted. Operation and maintenance staff should be trained.

13.2. BREAK DOWN MAINTENANCE VERSUS PREVENTIVE MAINTENANCE

Maintenance is classified in two categories as follows :

— Breakdown or corrective maintenance

— Preventive maintenance

(1) *The breakdown on Corrective Maintenance* activities are undertaken after failure of an equipment. Such maintenance results in outage of circuit and supply. In general, it consists of locating the trouble, repair and recommissioning.

(2) *The Preventive Maintenance* is undertaken to ensure smooth and efficient working of a system, equipment. Preventive maintenance is undertaken as per schedule before breakdown of a system or machine takes place.

* Please refer : "Testing, Commissioning, Operation and Maintenance of Electrical Equipment" — Book by Khanna Publishers.

A performance record of each equipment is maintained and basing decisions on the service life of the equipment and the total number hours of service, it has put in. Repairs or replacements are made to ensure that no breakdown occurs at any time during the service.

Preventive maintenance is carried out in planned manner. Breakdown maintenance is carried out as and when necessary.

For Switchgear and protective equipment, preventive maintenance is recommended because failure of a switchgear cannot be permitted.

13.3. INSPECTION, SERVICING, OVERHAUL

Maintenance covers a wide range of activities aimed at keeping the equipment in perfect working condition for performing its function as per assigned duties. The choice of activities and schedule depends upon local requirements.

1. Inspection. The refers to the maintenance activity which comprises careful observation/scrutiny of the equipment without dismantling it. It usually includes visual and operational checks.

2. Servicing. This refers to cleaning, adjustment, lubrication and other maintenance functions without dismantling the equipment.

3. Examination. This refers to inspection with necessary dismantling, measurements and non-destructive tests to obtain data regarding the condition of components/sub-assemblies.

4. Overhaul. This refers to the work done with the objective of repairing/replacing worn-out parts and defective parts. The equipment, sub-assemblies are dismantled partly or completely. The condition of components is inspected. Dimensions of worn-out components are measured. The components worn-out beyond acceptable limit are replaced. The assembly is followed by functional checks and measurements to ensure satisfactory operation.

13.4. GUIDELINES FOR MAINTENANCE OF SWITCHGEAR

The requirement of inspection, servicing, examination and overhaul vary with

— Environmental aspects such as dust, chemical fumes, moisture/humidity, ambient temperature variations, etc.

— Operating duty; frequency of operation, rated current.

— Switching duty severity, *e.g.* repeated operations.

Manufacturer gives general guideline. It is not possible to obtain exact maintenance schedule meeting local requirement of each site. Hence maintenance schedule is determined after initial periodic inspection at each site. In case of switchgear and control and protection panels; distinction should be made between the maintenance of fixed devices like busbars, insulators enclosures and maintenance of switching devices like circuit breaker, isolator, earthing switch, contactor etc. having moving parts.

The fixed parts need regular inspection and servicing for removing dust, damp, corrosion etc.

Moving parts need regular inspection and periodic replacement of worn-out parts. The functional readiness of switching devices should also be ensured.

The maintenance of switching devices is related mainly with the wearing out of contacts, deterioration of quenching medium and mechanism components. The maintenance requirements of vacuum circuit breakers and SF_6 circuit-breakers are quite modest as compared with those of oil circuit-breakers, minimum oil-circuit-breakers. In vacuum circuit breakers, the interrupter is a permanently sealed unit and the contacts have long switching life. Puffer type SF_6 circuit-breakers have long switching life and the gas does not need replacement. Hence the present trend is to use maintenance free vacuum and SF_6 circuit-breakers.

Table 13.1 gives recommendation regarding the period of maintenance of contacts and quenching medium in terms of numbers of load operations and number of short circuit operations on rated short-circuit breaking current. The schedule should be established for each site by checking the contacts of one pole after every three months observing the rate of erosion.

During every breaking operation, contact looses and some material and the quenching medium gets decomposed. The decomposed products get deposited on the internal insulating parts of the circuit breakers. The deterioration of contacts and internal insulation is proportional i^2n, where i is breaking current in kA and n is the number of breaking operation. After cumulative $\Sigma i^2 n = K$, the contacts, internal insulation and the quenching medium needs inspection/servicing. The value of K depends upon the type of circuit breakers (Refer Table 13.1).

Table 13.1 Maintenance of Quenching Medium Contacts

Type of C.B.	*Maintenance of Quenching Medium*		*Replacement of contacts*		$K \Sigma i^2 n$
	Load Operation*	*Fault Operation*	*Load** Operation*	*Fault Operation*	
Air C.B.	—	—	3000	10 to 15	—
Bulk Oil C.B.	2000	6	2000	6	2000
MOCB	1000	3	1000	6	1000
Air Blast C.B.	—	—	15,000	25	15,000
SF_6 C.B.	5000	25	15,000	25	15,000
V.C.B.*	—	—	20,000	100	20,000

* Shelf life 20 years.

** Mechanical Endurance Test should be performed with specified number of operations on no load to confirm suitability of mechanism.

Table 13.2. Maintenance of Contacts

Type of C.B.	*Life of Contacts*	
	Number of load operations on rated load current	*Number of fault operations on rated short-circuit current*
VCB	10,000	50-100
SF_6	4,000	15-25
MOCB	1,000	3-6
Air break CB	1,000	1-6
Air Blast CB	4,000	15-25

13.5. FIELD QUALITY PLANS (FQP)

The activities in the field (site) include :

- — Receipt and Storage of Equipment
- — Civil Works
- — Installation (Erection)
- — Testing & Commissioning
- — Operation and Maintenance; Trouble Shooting
- — Overhauling
- — Replacement after expiry of Life/Obsolecence

As per *ISO 9000 recommendations,* the customer's requirements for field services should be fulfilled and well-documented.

Field Quality plans contain : documents, instructions, data, drawings, formats for above, list of spares, list of tools/facilities, "Do's and Donots", Safety precautions, etc. should be prepared

by the manufacturer and sufficient copies should be given to each site. Customers operating staff should be trained in every activity. Following sections are guidelines for preparations of FQP.

13.6. MAINTENANCE OF CIRCUIT BREAKERS

Steps in Maintenance of Circuit Breakers

1. General Inspection. Observe the circuit-breaker visually. Note the cleanliness, terminals, earth connections, readings of counters, levels of quenching medium (in case of Oil Circuit-breakers) pressure of quenching medium in case of SF_6 circuit breakers etc.

2. Cleaning and Drying. Use trichloroethylene or other cleaning agent recommended by manufacturer. The fluid should be compatible with the surface to be cleaned.

Use air-pressure jet (3 kgf/cm^2) for cleaning.

Use clean cloth which does not leave fibres or particles on the surface.

Care should be taken to avoid falling of dust, iron particles, nutbolts washers etc. inside the breaker. Avoid water, moisture or dampness during the cleaning.

Congealed lubricants should be removed by means of solvents. The rolling and sliding surfaces should be cleaned, relubricated.

Before assembly of the circuit-breaker, the interrupter support porcelain components etc. should be cleaned in dry clean atmosphere.

After assembly, evacuate the breaker pole to remove moisture, dust particles etc. and then fill oil or SF_6 gas.

Internal dust and moisture causes gradual deposits on internal surface resulting in gradual increase of surface leakage currents and internal flashover due to tracking. Hence cleaning and drying is important.

Grooves for O-rings on flanges should be cleaned with trichloroethylene, air jet so as to remove hardened grease and dust. Such a dust or grease will make the uneven sitting of the new O-ring and cause gradual leakage of SF_6 gas/oil.

No dust, chalk-marks fibres, hard grease etc. is allowed on the O-ring grooves.

Terminals should be cleaned of dust, oxide coating if any by emery paper without iron particles.

3. Insulation Surface. Inspect visually, carefully for signs of cracks, tracking or any other defects.

Clean the internal surfaces and external insulating surfaces as mentioned in 2 above.

Insulation should be free from electrical or mechanical defects.

Perform insulation resistance measurement tests after cleaning and assembly. Insulation resistance measurement gives indication about the health of insulation.

In case of oil circuit-breakers and minimum oil circuit-breakers, the internal insulation should be cleaned thoroughly by means of trichloroethylene, clean cloth and air jet. The deposition of sludge and carbon particles, conducting dust particles shall be removed before reassembly.

In case of SF_6 circuit-breaker, the decomposition products (gray colour) get deposited on internal surfaces of insulators. These are non-conducting when dry. If the circuit-breaker is dismantled during moist atmosphere, these surfaces are not cleaned before assembly, the internal flashover is likely to occur despite the good properties of SF_6 gas.

In case of vacuum interrupters only external cleaning is possible.

In case of air blast circuit-breakers, no internal cleaning is generally necessary as fresh medium is used for arc-quenching. In case of porcelain-clad outdoor vacuum circuit-breaker, the pole units should be internally clean and dry to avoid internal flash-over by tracking.

Glass fibre pull rods should be cleaned thoroughly.

Particular attention should be paid to the nozzles, arc control pots. arc control plates. They should be cleaned. If burnt or disfigured, replace them.

After cleaning and drying measure insulation resistance by Megaohm-meter (Megger) between :

— Two terminals of each interrupter.
— between the terminal and earth.

4. Drying. Circuit breaker pole can be internally dried by circulating dry hot air or by evacuating to 2 mm of mercury.

In case of SF_6 circuit-breaker or porcelain clad vacuum circuit-breaker, the drying of pole units should be carried out before filling SF_6 gas or dry nitrogen.

SF_6 gas or dry nitrogen does not remove the water drops and dust deposited on the internal surface. Hence drying and evacuating is necessary.

A small portable vacuum pump with teflon hose is connected to the valve. The breaker is kept under vacuum for a few hours. Thereafter the SF_6 gas/dry nitrogen is filled.

The moisture is eliminated due to application of vacuum.

Drying is recommended before filling of fresh SF_6 gas/nitrogen/oil in the breaker.

5. Interrupter. Study the operation and maintenance manual of the circuit-breaker.

Note the important settings and measurements of moving contact, other movable parts with reference to fixed flanges and the allowed tolerance in the settings. Check simultaneous touch of 3 poles if slow closing and three lamp method.

Main activities in the interrupter maintenance include :

— Observation, cleaning, replacement of main/arcing contacts ; PTFE nozzles, arc-control pot plates etc.
— Cleaning the other parts as well.
— Replacing hardened O-rings, worn-out sliding parts.
— Removal of carbon/metallic decomposed products.
— Cleaning of venting systems to ensure free passage of oil/gases. The vents should be made free but not enlarged.
— Cleaning terminals and sliding contact surfaces.
— Assembly with proper settings of components.

6. Mechanism. Check operation 'open' ; 'close' ; 'closing followed by opening' locally. If operation O. C. CO are satisfactory the mechanism is satisfactory and does not need any major repair/maintenance.

Check operation counter. If the mechanism has operated more than 1000 times, it needs very close observation and may need overhaul. Check the condition of springs and dashpots. Two important tests to determine the health of the operating mechanism, linkages and moving contact settings include :

— Checking simultaneous opening and closing of 3 poles.
— Checking no-load times *vs.* travel characteristics of moving contact for O, CO, O-CO operations.

(*a*) **Method of obtaining Time-Travel Characteristic on no-load.** In case of MOCB or SF_6 CB poles, this characteristic is extremely important because the breaking capacity is related with the time/travel characteristics of moving contact. No-load characteristic gives sufficient indication about the health of mechanism linkages.

For satisfactory arc interruption the moving contact should open and travel with optimum characteristic.

* Insulators of circuit-breakers installed in heavily polluted areas and sea-shores need frequent external cleaning.

Slow initial movement indicates excessive friction between sliding parts.

Slow movement during middle of stroke indicates very high dynamic load during arc quenching.

Slow movement during final part of the stoke indicates excessive damping or low energy of operating mechanism during opening.

A straight rod is connected to the moving contact or movable part (contact or mechanism). This rod is in turn connected to the curvo-roller or rectilinear transducer (Travel Recorder).

Curvo-roller is a specially designed motor driven drum mounted on the top-hood of the MOCB. The pencil attached to the rod fixed on the moving contact touches the paper on the drum. The motor is driven electrically. The drum rotates at known speed. The graph sheet fixed on the drum has definite circumferential speed. During the opening stroke and closing strokes, the pencil gives the time/travel characteristic making on the graph sheet on the curvo-roller.

For high speed SF_6 circuit-breaker the curvo rollers are not suitable.

Rectilinear transducer is fitted suitably on the breaker frame. It has a cylindrical resistance with internal moving piston. The piston is attached to the rod with and swivel joint at the end.

The swivel joint and rod of the rectilinear transducer are connected to the moving rod attached to the contact movement system. In case of SF_6 or oil CB, a suitable rectilinear seal should be designed to permit movement without leakage of SF_6/oil.

The rectilinear transducer is connected like a potentiometer. The central terminal gives variation proportional to the travel of the contact.

The output is given to UV recorder. The trace of Time/Travel is obtained on U.V. Recorder. The trip signal/closing signal is also recorded simultaneously.

The Time/Travel characteristic should match with that obtained in the manufacturer works.

(*b*) **Method of checking the Contact Setting.** Follow manufacturer's instruction booklet. In case of MOCB and SF_6 ; measurement of distance from the top flange surface to the tip of closed contact may be possible.

In case of vacuum interrupter, a gauge with pointer may have been provided by the manufacturer to indicate contact erosion.

Measurement of Contact Resistance

The resistance between terminals of each interrupter and each pole is measured by means of micro-ohm meter.

The resistance across one pole is $(n \times r)$ where r is resistance per contact-pair/joint and n is number of contact-pairs/joints in series per pole.

A pair of contacts has a resistance of about 15 micro-ohms.

Contact resistance is inversely proportional to the contact pressure. Low contact pressure may be due to week springs or worn out contacts. High contact resistance causes excessive heating of contacts while carrying normal current and possible welding during through short-circuit.

(*c*) **Mechanical Assembly.** Check that all the nut bolts are in their position and check their tightness.

Check circlips, split pins.

Clear and lubricate sparingly.

Oil dashpots should be checked for current level and operation. Air Dashpots should be checked for current operation.

Clean inspect and replace worn-out parts during overhauls.

In case of spring operated mechanism check the ratchet wheels and prawls for broken or chipped teeth.

Valves of pneumatic mechanism or hydraulic mechanism should not be disturbed unless the diagnostic tests indicate the need for their checks.

(*d*) **Inter-pole linkages.** For ensuring simultaneous operation of 3 poles (within pole discrepancy of 5 milliseconds), the inter pole linkages should be checked for deterioration of springs other components. Linkage pins circlips, nut-bolts, etc. should be checked. Verify that fixings are tight and pivot pins are secure.

Maloperation of mechanism, interpole linkage, dashpots etc. can be revealed by the time/travel record of 3 poles plotted on UV recorder as described earlier.

Congealed lubricants should be removed from sliding, rolling surfaces. The parts should be relubricated as per the instruction of the manufacturer.

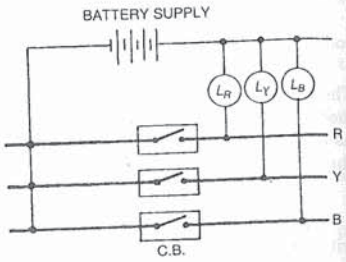

Fig. 13.1 Method of checking simultaneous contact meeting during slow closing.

Method of Checking Simultaneous Contact Touch

The moving contacts of each phase should meet the fixed contact practically simultaneously. At electrical method of checking the contacts is illustrated in Fig. 13.1. A low voltage supply, lamps are needed. Simultaneous glowing of lamps indicates simultaneous making of contacts.

7. Main Connections. Ensure that good contact is maintained and connections are right and secure.

8. Secondary Wiring and Fuses. Ensure tight and secure connections, cleanliness and freedom from dust and moisture. Heater in the cabinet should be checked and repaired, if necessary.

9. Earth Connection. The main and secondary earth connection should be tight and free from dust and rust.

10. Heater. The heater provided in the control cabinet should be in working condition.

11. Shutters. The shutters mechanism in metal-clad medium voltage Switchgear should be verified after pulling out of drawout unit and de-energizing the busbars.

12. Busbars and Busbar Chambers. The busbars and the busbar chambers should be checked for cleanliness of insulators, tightness of joints and freedom from dust, damp and foreign materials/insects etc.

There shall not be any loose joints or signs of overheating, melting, sparking.

13. Auxiliary Switches, Indicating Devices and Interlocks. Auxiliary switches shall be kept in clean an sound condition because the correct functioning of other items of equipment, including protective gear depends on auxiliary switch.

Inspect the contacts and clean or renew if necessary, where possible verify correct contact force and correct timing of contacts. Indicating devices such as mechanical ON and OFF indicators, semaphores etc. shall be inspected to ensure that they are in good order and operating correctly.

Interlocks and locking devices shall receive particular attention especially those associated with earthing and testing facilities. A defective or worn device may result in a dangerous condition. It shall be verified that any incorrect operation is satisfactorily inhibited lubricate as necessary.

Particular attention shall be paid to the required timing of the auxiliary contacts controlling the trip circuit.

14. Isolating Contacts. Clean inspect for signs of overheating, renew or recondition if necessary, lubricate as required.

15. Overload devices and Protective Relays. Routine maintenance should be carried out at correct intervals.

16. Instruments and Protective Transformer. Routine maintenance should be carried out according to instructions.

17. Control Relays or Contractors. Inspect mechanical parts for free movement with control and main solenoid or motor circuit isolated clean arc chutes. Inspect contacts and renew, if necessary.

Any flexible braids shall be inspected, especially for fraying at the terminations and renewed if necessary. Where exposed to external atmosphere, the braids shall be treated with a suitable protective compound which will not impair their flexibility.

18. Pressure Gauges and Pressure Switches. The readings of pressure gauges are checked against a standard gauge.

The operation of pressure switches should be checked against their setting.

19. Final Verification. Before returning to service after the overhaul, the circuit-breaker is subjected to operational checks by performing C, O, CO operation from local control cabinet and from the control room.

Simultaneous touching of the contacts of three-phases is verified.

Insulation resistance is measured between the terminals of open interrupter and between the lower terminal and earth.

Insulation resistance of auxiliary wiring is also measured.

13.7. TYPICAL MAINTENANCE RECORD CARD

History card is kept for each circuit breaker.

Circuit breaker S.N.

Make

Brake

Inspection date

Permit to work number

Component	*Observation*	*Action taken*	*Initials*
Mechanism			
Linkages			
Insulation			
Quenching			
Medium			
Main contacts			
Arcing contacts			
Terminals			
Final verification			

13.8. MAINTENANCE OF AIR BREAK CIRCUIT BREAKER, FUSEGEAR FOR LOW AND MEDIUM VOLTAGES

The schedule of maintenance depends upon the frequency of load operations and fault operations. For frequent load operations/fault operations, maintenance requirement is high. For indoor, dust-free installation with infrequent load operation, the following schedule is recommended :

— Inspect as often as possible with maximum internal of 12 months.
— Examine at 5 years interval.
— Overhaul when examination and diagnostic tests indicate need. Maximum interval of 15 years.

Table 13.3 Maintenance for Vacuum Circuit-Breaker

Clause	*Maintenance operation*	*Routine Maintenance*		
		Inspection	*Examination*	*Post fault maintenance*
1.	Operation check		×	
2.	General inspection		×	
3.	Cleaning		×	×
4.	Opening device (trip)		×	
5.	Insulation	×	×	
6.	Circuit-breaker enclosure (Interrupter)		×	
7.	Main connections		×	
8.	Secondary wiring and fuses		×	
9.	Mechanism		×	
10.	Auxiliary switches, indicating devices and interlocks		×	
11.	Shutters	×	×	
12.	Switching spouts	×	×	×
13.	Isolating contacts	×	×	
14.	Vacuum interrupter		×	×
15.	Isolating and earthing switchgear		×	
16.	Earth connection	×	×	
17.	Overload devices and protective relays	×	×	
18.	Instrument protective transformers		×	
19.	Control relays or contactors		×	
20.	Busbars and busbar chambers		×	
21.	Final verification	×	×	

13.9. MAINTENANCE OF VACUUM CIRCUIT-BREAKER

Vacuum interrupter is sealed for life and does not require any replacement of contacts for several thousands load operations and about 50 operations on rated short-circuit. Mechanism needs periodic lubrication as recommended by the manufacturer. The other parts need cleaning and general inspection.

13.10. MAINTENANCE OF SF_6 CIRCUIT-BREAKER

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_2F_2, SF_4 moisture etc. The gas can be used again after regeneration.

For installation and maintenance of SF_6 circuit-breaker a gas handling unit is necessary. This consists of a vacuum pump, valves, pipings, a compressor and a service tank.

The SF_6 gas in the breaker gets decomposed during quenching process. Most of the lower fluorides recombine, but some remain (S_2F_2, SF_4 etc.) in the decomposed form. They are partly absorbed by

activated alumina filters and dissicants. SF_6 gas subjected to arcing becomes corrosive, irritant and has bad odour. It should not be inhaled or left in atmosphere. It is collected into service tank of gas handling unit by means of the compressor.

The breaker poles are not dismantled before reclaiming the SF_6 gas in the service tank of the gas handling unit.

Spare cylinders of SF_6 gas in sufficient quantity should be arranged in advance before starting the maintenance work of SF_6 circuit-breakers.

If the sub-station has only a few SF_6 circuit-breakers, the simple smaller gas handling unit is adequate. For large sub-stations having several SF_6 filled equipment, a larger gas handling unit is necessary. A chemical laboratory for testing SF_6 gas is also recommended.

Pole Unit and Interrupter. At a suitable interval one interrupter per pole to be examined to establish the rate of burning and erosion of the contacts and the general condition in order to assess the necessity for further maintenance etc. This work must be carried out under dry weather conditions and precautions taken to avoid the ingress of any moisture dirt into the pole units.

Slight burning of copper or copper alloy contacts should not cause any trouble but heavier burning should be removed with a fine file (emery or carborundum paper should not be used). Copper alloy and other arc resisting metal contacts should be inspected for any signs of excessive burning. In general, considerable burning of contacts can be tolerated before replacement becomes necessary but it is recommended that here contacts require dressing, the minimum amount of material shall be removed and the manufacturers recommended profile maintained.

It is imperative that the force between contact shall not be materially reduced. Any burning away from the arcing area should be noted and investigated. Transfer contacts shall be inspected for any signs of a burning and cleaned as necessary.

The nozzle of the interrupter is usually made from PTFE. It shall be examined for excessive burning or erosion and this can be done by comparison with a new nozzle. In general the dimensions and profile of the nozzle are not as critical in SF_6 circuit-breaker and, therefore, a greater amount erosion can be tolerated before replacement becomes necessary (5%).

However, the manufacturers recommendations in this respect should be carefully followed.

The insulation adjacent to the arcing area should be cleaned as necessary. Burning of this insulation will indicate a misplaced arc and if found this must be investigated.

The entire interrupter is generally filled with thin dust of erosion of Teflon nozzle combined with fluorides of contact material. This dust is insulating when not exposed to SF_6 gas. Immediately after dismantling of the breaker, this dust absorbs moisture and becomes conducting. Hence it should be wiped-out completely by means of air-jet, cloth, trychloroethelene. This cleaning is essential resistance goes down and internal flashover occurs during the normal closed position between the live part and earth due to surface tracking along internal insulation.

The important steps in the maintenance of SF_6 circuit-breaker include internal cleaning and replacement of SF_6 gas.

The operating linkages should not be disturbed unless diagnostic tests or a visual examination indicate that this is necessary. The setting dimensions should be verified.

Filters and Dessicants. Filters (activated alumina) are installed in SF_6 circuit-breaker to filter out or adsorb some of the breakdown products. As a last operations prior to closing up the chambers of the circuit-breaker the filters and dessicants should be replaced. Under no circumstances should untreated filter or dessicant material removed from the circuit-breaker after service be heated.

Table 13.4 Maintenance for SF_6 Circuit-Breakers

Clause	*Maintenance operation*	*Routine Maintenance*		
		Inspection	*Examination and overhaul*	*Post fault maintenance*
1.	Operational checks	×	×	
2.	General Inspection	×	×	
3.	Cleaning		×	×
4.	Opening device (Trip)	×	×	
5.	Circuit-breaker enclosure		×	
6.	Gas system	×	×	
7.	Sulphur hexafluoride gas	×	×	×
8.	Insulation	×	×	×
9.	Local control kiosk	×	×	
10.	Pressure gauges		×	
11.	Pressure switches		×	
12.	Main connection		×	
13.	Secondary wiring and fuses		×	
14.	Earth connection,		×	
15.	SF_6 gas heater		×	
16.	Interpole linkages	×	×	
17.	Main mechanism		×	
18.	Auxiliary switches indicating devices and interlocks		×	
19.	Interrupters		×	×
20.	Local air receives and pressure vessels		×	
21.	Filters and desiccants		×	
22.	Overload devices and protective relays	×	×	
23.	Instrument and protective transformers		×	
24.	Control relay or contactors		×	
25.	Busbars and Busbar chambers		×	
26.	Final verification	×	×	×

13.11. INSULATION RESISTANCE MEASUREMENT

It is the responsibility of the user to ensure that the insulation of electrical switchgear has been tested and the result recorded before commissioning the equipment. During the life of electrical equipment insulation resistance testing will give a good indication of the condition of the equipment and if these tests are recorded can help in deciding maintenance requirement for the whole equipment.

13.12. INSULATION RESISTANCE MEASUREMENT AT SITE

Insulation resistance is measured by means of Megaohm meter (Megger). The megger comprise a megaohm meter with built-in d.c. generator. The minimum reading is zero and maximum is infinity. The scale is in megaohms. The two terminals of megger are connected across the insulation *i.e.* one to the conductor and other to earth body. The handle is rotated by hand or motor. The insulation resistance indicated by the pointer in megaohms.

For h.v. switchgear 1000 V or 5000 V (d.c.) megger is preferred. The insulation resistance of h.v. circuit-breaker is very high (above 10000 megaohms of infinity).

Insulation resistance of control circuit, trip circuit, relay circuit, secondary circuit, etc. is measured by means of 500 V megger. Value obtained should not be less than 1 megaohm.

For primary circuit, the insulation resistance is tested with the breaker closed ; between lower terminal and earthed frame for each interrupter.

With breaker open, insulation resistance is measured between terminals of each interrupter.

Test voltages of Insulation-resistance. The voltage which could be applied to primary insulation when making resistance test varies according to the voltage rating of the switchgear.

Table 13.5. Test Voltages for Meggering

3-phase system rating of primary insulating of switchgear	*Test voltage recommended for insulation resistance test (to earth and between phases) kV (d.c.)*
Upto 1 kV	1
Above 1 kV 3.6 kV	2
Above 3.6 kV to 12 kV	5
Above 12 kV	5

13.13. LIKELY TROUBLES AND ESSENTIAL PERIODIC CHECKS TO AVOID THEM

The point to be checked during the periodic maintenance include the following :

(*a*) The operating mechanism of the circuit-breaker should be in good working condition both mechanically and electrically.

(*b*) Insulation resistance phase to ground of each pole should be above 2000 mega ohms, (upto 1.1 kV); 10,000 mega-ohms for above 36 kV.

(*c*) Contact pressure is important. When the contact pressure is enough even a line contact can pass normal current without overheating. The resistance of pole unit should be less than 50 micro-ohms.

Trip circuit and battery supply. Maintenance of the trip circuit and battery supply is essential for the satisfactory operation of all protective relays. The battery should be inspected daily for correct voltage, specific-gravity etc. and it should be kept on trickle charge. The inter-cell connectors should be in good condition. There should be a pilot lamp or alarm indication to draw the attention of the operator, if the trip coil battery voltage falls below certain limits.

(*d*) Every relay should be tested once in six months, with suitable testing set and the records of such tests should be logged in a maintenance resistor. During tests a check should be made if any of the overload or time setting on the relay require change due to the increase or decrease in the load conditions since the date of last test.

Following defects are possible :

(*a*) Improper contact or misalignment of the contact prongs of the trip battery circuits, between the cubicle and the drawout truck.

(*b*) Point in an auxiliary wiring of supply from battery, or discharged battery.

(*c*) Circuit-breaker operating mechanism not being sluggish due to mechanical defects, or stiffness due to dust or rust, lack of lubrication, etc.

(*d*) Wrong CT or VT connections.

(*e*) Wrong relay settings for the load conditions.

Table 3.6. Common Troubles and Remedial Actions

	Trouble	*Possible causes*	*Possible Remedial Actions*
1.	Low insulation Resistance (below 2000 Mega-ohms) between — Phase terminal and earthed frame, with breaker closed — Phase terminals of a pole.	— Moisture — Dirty insulation surface internal and/or external — Poor oil — Carbon/copper particles sticking to internal surface	— Circulate dry hot air or oil through the breaker pole for 4 to 6 hours. — Dismantle, clean, reassemble Insulation resistance should be above, 2000 Megaohm, for 1.1 kV and above 10,000 megaohms above 36 kV
2.	Resistance between Terminals of Pole too high (above 100 micro-ohms) (15 micro-ohm per joint/contact)	— Reduced contact pressure — Loose connections — Contact surface damaged due to repeated operations — Insufficient contact wipe — Oxide film on contact surface	— Dismantle, repair and assemble again. If necessary, replace the contacts
3.	Unequal contact Wipe and Travel in 3-pole Measured from top surface of interrupter flange and the contact tip by a simple rod with — breaker open — breaker closed	— Contact erosion due to repeated load operations or short-circuit operations — Unequal length due to wrong adjustments of linkages.	— Inspect contact tips — Replace if badly eroded — Adjust contact if lengths are unequal in three pole
4.	One of the pole does not close	— Pull rod for contact damaged — One the links of that pole broken — Contact of that pole severely damaged.	— Dismantle the pole and repair the defect
5.	Breaker operation too Slow During opening (Timing from trip command to contact separation instant too large (60 ms instead of says 40 ms)	— Excessive friction in the pole unit. — Contact grip too high — Trip coil operation sluggish. — Low battery voltage, hence higher trip coil pick-up-time	— Identify the cause — Take Remedial action.
6.	Breaker does not operate on Electrical command	— Open control circuit — Spring defective — Trip circuit open — Trip latch/coil defective — Spring not changed — If breaker operates with manual operation of trip release, the mechanism is O.K.	— Check control circuit — Check closing spring visually — Identify the cause and take remedial action — Check supply to spring changing motor. — Check pressure switches, relays, control wiring.

13.14. INSTALLATION OF DRAWOUT METALCLAD SWITCHGEAR

(*a*) **Preliminary Preparation.** The preliminary preparations include study of drawings acceptance, report checking certificates and test reports of the equipment, completion of civil engineering work arranging the tools, lifting gears etc. organising the labour, prepare the schedule of installation, peparing sequence cards for erection of major items etc. Such cards indicate the sequence of operation items involved, procedure in brief etc.

Sequence Card for Erection of Switchgear Equipment

S.No.	*Operation*	*Tools, Lifting gear etc.*	*Drawing No.*	*Technique & productive*

The drawing include

1. Circuit diagrams of the plant.
2. Civil Engineering plans, foundation plans etc.
3. Dimension drawings of equipment.

(*a*) Location of switchgear. The switchgear may be

(*i*) indoor ;

(*ii*) outdoor.

For medium voltages from 3.3 to 24 kV indoor switchgear is popular. (Refer Ch. 15)

(*b*) Indoor switchgear should be located in a clean, dry room free from vermins, snakes, moisture, dust etc. Floor should be dry and levelled. The floor should withstand load of about 1000 kg/m^2 (200 lb/sq. ft). Enough space should be left in front and in the rear of the switchgear as recommended by the manufacturer. About 1.7 metres in front and 0.7 m in the rear of 11 kV drawout switchgear.

The following points are kept in mind :

1. Fire-proof doors, roof, ceiling etc.
2. Sealing of cable ducts.
3. Sub-division of switchgear.
4. Installation of fire-fighting apparatus.

(*c*) **Unpacking.** The equipment is packed in crates and is brought to site by railway and motor truck. Packages are lowered on the site by means of rope, hoist or crane carefully. Care is taken that they are always held in upright position throughout. On unpacking, the items are checked against the list.

Further the items are carefully inspected visually. If any damage is found, the matter should be informed to the manufacturer and insurance company immediately, and the damaged equipment should be given to insurance company.

(*d*) **Foundation.** The foundation is prepared according to the foundation plan. Holes are provided for grouting of foundation bolt. Trenches and passages are provided for cables and other piping. The floor should be correctly levelled and marked according to the drawing.

(*e*) **Erection.** The equipment is installed according to the procedure mentioned in the instruction manual. Some types of lifting device, special tools etc. may be necessary. The assembly is erected vertically. The vertically is checked by means of spirit level. If necessary, packing pieces are added in the base plate for obtaining proper level. After doing necessary adjustment and checking the level, the concrete mixture is poured into holes around foundation bolts and the nuts are tightened. It should be remembered that porcelain insulator columns are weak in tension. During erection, they should not be shifted under assembled state without stiffners. Stiffners are removed after assembly. Circuit-breaker should be dried out before filling gas/oil.

(*e*) **Relays.** It is advisable *not* to adjust the relay-mechanism. The faulty relay should be sent to the manufacturer since relay repair is as a specialized job.

Contacts of relay should be inspected for any sign of burning where necessary, glass paper should be used for cleaning. All the terminals of the relay should be checked for tightness. The wiring should be checked for security.

(*f*) **Bus-bars earthing connections.** The bus-bar contacts and making surfaces of connectors should be cleaned with emery paper or smooth file. The bus-bars assembled as soon as they are cleaned.

(*g*) **Connection of main cable.** Refer Sec. 15.21-Sub-section : Cable termination.

(*h*) **Earthing.** The earthing bar of the switchgear, the metallic non-current carrying part are connected to station earthing system. The risers are brought out from earthing system upto the equipment earthing points.

Safety. The maintenance work should be carried out with written permission of responsible people. A scheme should be adopted to issue permit card authorising the maintenance work to be done. Steps should be taken by concerned authorities to ensure safety. These steps include :

1. Isolation of the part from live parts during the period of maintenance. No switching on by mistake.

2. Danger notice such as the one given below should be placed.

3. The neighbouring point should be locked to avoid switching by a third person.

4. **Earthing.** The work equipment and conductors should be earthed by means of earthing connections, from both ends.

5. Proper tools, safety devices should be provided to the electricians.

6. The electricians should be well trained.

7. First-aid should be available.

8. Switching on should be allowed only after completion of work after cancellation of the permit by the authority.

Death can be caused even on 400 V installations, because negligence or accident.

13.15. SAFETY PROCEDURES

1. Follow the safety rules faithfully.

2. Take permission from authorised person for doing specific work.

3. Make sure of switch-off the supply from both ends. The switching-off and switching-on should be as per safety rules and with prior permission of the authorised person.

The repair/maintenance work of High Voltage Apparatus should not be undertaken unless the apparatus is made DEAD and Isolators are open and locked.

4. Place caution notice and danger notices near the work place and near the switching terminals.

WATCH ; DON'T SWITCH-ON MEN AT WORK

DANGER 440 V DON'T TOUCH

5. Keep barriers, ropes around the section under maintenance to clearly indicate maintenance zone and boundary of the neighbouring live zone.

6. Earth the various metallic parts of structures, bus sections, conducting parts etc. at two or more places before commencing the maintenance work.

7. Be familiar with circuit and auxiliary supply circuits. Switch-off both.

The recommended precautions to be taken before working on High Voltage apparatus (Above 650 V).

No person shall undertake any repairs, maintenance, cleaning, alteration of such works, on any part of High Voltage Apparatus unless such parts of the apparatus are : **Dead.**

Isolated and all practicable steps taken to lock off from live conductors :

Efficiently connected to earth at all points of disconnections of supply to such apparatus, or between such points, and the point (s) of work ; (Caution Notices fixed ;

Screened where necessary to prevent Danger and Danger Notice fixed ;

Released for work by the issue of a 'Permit to Work' or 'Sanction-for-Test'

And unless such person is fully conversant with the nature and also the extend of the work to be done.

It is the duty of the person issuing the Permit-to-Work or Sanction for Test to ensure that the foregoing provisions are complied with.

(*a*) Cleaning and painting of earthes metal enclosures, connections of circuits to or from live high voltage systems live line testing and live insulator washing may be carried out by only in accordance with the special instructions relating to these purpose issued by the Chief Engineer.

(*b*) Live Line Work on high voltage overhead line may be carried out in accordance with rule.

(*c*) Where the design of apparatus precludes the strict compliance with all details of these precautions, the work shall be carried out to the instructions of a Senior Authorised Person who must be present, and after agreement with the Control Engineer.

8. Check the **Safety Clearances** between nearest live points and other physical objects during maintenance. (*e.g.* ladders, platforms, lifting devices, metal-bars, etc.) Safety clearances must always be maintained. Otherwise the flashovers can result. Keep screens between live zones and maintenance zones.

9. Recommended precautions to be taken before working on Medium and Low Voltage systems.

Medium Voltage : 1 to 36 kV

Low Voltage : below 1000 V

Precautions to be taken before working on Medium and Low Voltage Systems. The consequences of shock or serious burns from short circuit associated with medium or low voltage systems may be serious or, in some circumstances fatal. Wherever practicable, therefore, work on **medium and low Voltage Apparatus,** conductors and equipment shall be done while they are dead and earthed.

When working on dead **medium and low Voltage Apparatus** suitable precautions should be taken by screening or other means avoid danger for inadvertent contact with live conductors with the working zone.

It is not always possible to make dead of earth **Medium and Low Voltage Apparatus.** All work on *Medium and Low Voltages Apparatus* must be carried out as if it were live unless it is provided dead earth from all the ends.

When working on *live Medium and Low Voltage Apparatus* suitable precautions should be taken by screening or other means to avoid danger from inadvertent contact with live conductors of earthed metal work.

Work on live *Medium and Low Voltage Apparatus* conductors or equipment should be undertaken only by a *Competent Person.*

Note. Attention is drawn to the fact that certain statutory requirements **Prohibit work on live medium and low voltage apparatus conductors or equipment.**

13.16. INSTALLATION OF OUTDOOR CIRCUIT-BREAKERS

Outdoor circuit-breakers are mounted on pre-fabricated galvanised steel structures.

The important steps in the installation include the following :

Receipt and storage

The packing cases are inspected and stored in indoor/covered stored in a planned location. Indoor equipment are stored indoor, outdoor equipment are stored outdoor.

Civil Works. These are carried out as a part of civil works. The foundation plan is decided on the basis of requirements of the clearness and the base of the equipment/structure. Pockets are provided for grouting the foundations bolts. Cables are laid on trays located in the cable trenches.

Earthing mat is made welded iron rod mesh and is burried in the yard of depth of upto 1 metre. The risers are brought up upto earthing point on the structure, equipment base.

The installations work is started after completions of foundations.

1. Check the readiness of foundations and their dimensions as per the drawings. Check the locations of holes for grouting with reference to foundation plan.
2. Check the level of foundation surface.
3. Place the base frame/structure of the circuit-breaker in position. Place foundation nuts spring washers and tighten. Make connection of earthing riser to the structure.
4. Assemble operating mechanism in its position.
5. Assemble support porcelains and interrupting heads.
6. Place the O-seals with care while assembly 5.
7. Join the links in the mechanism with the links in the pole units as explained in manufacturer's Instruction Book.
8. Give auxiliary supplies to mechanism.
   — for motor
   — for trip circuit and closing circuit.
9. Tighten all the bolts and other hardware. Remove packings.
10. If provision available, operate slow opening and slow closing.
11. Measure Insulation Resistance. Dry-out the pole units if necessary.
12. Fill quenching medium after drying out operation. Check leakage and ensure leakage free assembly.
13. Operate 'C and O' with manual initiation of releases.
14. Operate C.O. with electrical command. Measure Timings. Check simultaneous operations of 3 poles.
15. Try O-CO operations with electrical command.
16. Measure insulation Resistance and resistance between terminals of poles.
17. Make terminal connection, earthing connections.
18. Operate breaker from local control panel.
19. Operate the breaker from control-room by operators instructions and then by operating the relevent relays.

The breaker is ready for putting into service.

Precommissioning Checks/Tests

These are performed in accordance with the agreed field quality plan and include :

— Leakage tests
— Operation C, O, CO
— Time/contact travel characteristics

— Time tests
— Insulation resistance test on main and auxiliary circuits
— Measurement of low resistance between terminals of pole
— Checking of earthing connection
— Operation of breaker from local control cabinet.
— Operation of breaker from control room by manual command; by relay command.

The gas pressure should remain unchanged for at least a month (at given ambient temperature).

QUESTIONS

1. State the difference between :
   — Breakdown maintenance and preventive maintenance
   — Servicing and overhaul
2. State the step in installation of and outdoor Circuit Breaker.
3. Describe the steps in installation of an indoor metal clad switchgear.
4. State Commissioning checks on a 6.6 kV or 3.3 kV metal-clad switchgear.
5. Explain in detail the following for a circuit Breaker :
   — Procedure of Insulation Resistance Test at site
   — Procedure of High Voltage Test at site
   — Method of checking simultaneous contact touch
6. Prepare a check list for routine maintenance of an SF_6 Circuit Breaker.