Introduction to Switchgear

Definition of Switchgear

A **switchgear** or **electrical switchgear** is a generic term which includes all the switching devices associated with mainly power system protection. It also includes all devices associated with control, metering and regulating of electrical power system. Assembly of such devices in a logical manner forms switchgear.

The apparatus used for switching, controlling and protecting the electrical circuits and equipment is known as switchgear.

Switchgear and Protection

The switch is used to manually open and close the electrical circuit in our home and electrical fuse is used to protect our household electrical circuit from over current and short circuit faults. In same way every electrical circuit including high voltage electrical power system needs switching and protective devices. But in high voltage and extra high voltage system, these switching and protective scheme becomes complicated one for high fault current interruption in safe and secure way.
Switchgear protection plays a vital role in modern power system network, right from generation through transmission to distribution end. The current interruption device or switching device is called circuit breaker in **Switchgear protection** system. The circuit breaker can be operated manually as when required and it is also operated during over current and short circuit or any other faults in the system by sensing the abnormality of system.

Switchgear has to perform the function of carrying, making and breaking the normal load current like a switch and it has to perform the function of clearing the fault in addition to that it also has provision of metering and regulating the various parameters of electrical power system. Thus the circuit breaker includes circuit breaker, current transformer, voltage transformer, protection relay, measuring instrument, electrical switch, electrical, miniature circuit breaker, lightening arrestor or surge arrestor, isolator and other associated equipment.

The essential features of switchgear are :

(*i*) Complete reliability. With the continued trend of interconnection and the increasing capacity of generating stations, the need for a reliable switchgear has become of paramount importance. This is not surprising because switchgear is added to the power system to improve the reliabil- ity. When fault occurs on any part of the power system, the switchgear must operate to isolate the faulty section from the remainder circuit.

(*ii*) Absolutely certain discrimination. When fault occurs on any section of the power system, the switchgear must be able to discriminate between the faulty section and the healthy section. It should isolate the faulty section from the system without affecting the healthy section. This will ensure continuity of supply.

(*iii*) Quick operation. When fault occurs on any part of the power system, the switchgear must operate quickly so that no damage is done to generators, transformers and other equipment by the short-circuit currents. If fault is not cleared by switchgear quickly, it is likely to spread into healthy parts, thus endangering complete shut down of the system.

(*iv*) Provision for manual control. A switchgear must have provision for manual control. In case the electrical (or electronics) control fails, the necessary operation can be carried out through manual control.

(*v*) Provision for instruments. There must be provision for instruments which may be required. These may be in the form of ammeter or voltmeter on the unit itself or the necessary current and voltage transformers for connecting to the main switchboard or a separate instrument panel

What is meant by reliability?

Reliability can be defines as...

>> If your lights came on, reliability was met.

>> If a major line is lost and the system remains stable, reliability was met.

>> If a generation source is lost and the system remains stable, reliability was met.

* It is more complicated in reality, but if it is not met, the provider can be fined.

Switchgear equipment :-

a) Switches (Air-break switch, Isolator of disconnecting switch, Oil switch)

b) Fuses c) Circuit breaker d) Relay e) DC supply and communication channel

Short Circuit :-

Whenever a fault occurs on a network such that a large current flows in one or more phases, a short-circuit is said to have occurred. When a short circuit occurs, a heavy current called short circuit current flows through the circuit. This can be beautifully illustrated by referring to Fig. 16.6 where a single phase generator of voltage V and internal impedance Z i is supplying to a load Z .

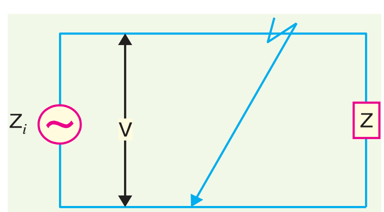

Fig. 16.6

<u>Causes of short-circuit :</u> A short circuit in the power system is the result of some kind of abnor- mal conditions in the system. It may be caused due to internal and/or external effects.

(*i*) ***Internal effects*** are caused by breakdown of equipment or transmission lines, from deterio- ration of insulation in a generator, transformer *etc*. Such troubles may be due to ageing of insulation, inadequate design or improper installation.

(*ii*) ***External effects*** causing short circuit include insulation failure due to lightning surges, over- loading of equipment causing excessive heating; mechanical damage by public *etc*.

Effects of short-circuit.

When a short-circuit occurs, the current in the system increases to an abnormally high value while the system voltage decreases to a low value.

(*i*) The heavy current due to short-circuit causes excessive heating which may result in fire or explosion. Sometimes short-circuit takes the form of an arc and causes considerable damage to the system. For example, an arc on a transmission line not cleared quickly will burn the conductor severely causing it to break, resulting in a long time interruption of the line.

(*ii*) The low voltage created by the fault has a very harmful effect on the service rendered by the power system. If the voltage remains low for even a few seconds, the consumers' motors may be shut down and generators on the power system may become unstable.

Due to above detrimental effects of short-circuit, it is desirable and necessary to disconnect the faulty section and restore normal voltage and current conditions as quickly as possible.

Importance of short circuit current analysis:-

(*i*) A short-circuit on the power system is cleared by a circuit breaker or a fuse. It is necessary, therefore, to know the maximum possible values of short-circuit current so that switchgear of suitable rating may be installed to interrupt them.

(*ii*) The magnitude of short-circuit current determines the setting and sometimes the types and location of protective system.

(*iii*) The magnitude of short-circuit current determines the size of the protective reactors which must be inserted in the system so that the circuit breaker is able to withstand the fault current.

(*iv*) The calculation of short-circuit currents enables us to make proper selection of the associated apparatus (*e.g.* bus-bars, current transformers etc.) so that they can withstand the forces that arise due to the occurrence of short circuits.

Circuit Breaker

The interruption of electric power circuits has always been an essential function, especially in cases of overloads or short circuits when immediate interruption of the current flow becomes necessary as a protective measure.

In earliest times, circuits could be broken only by separation of contacts in air followed by drawing the resulting electric arc out to such a length that it can no longer be maintained. This means of interruption soon became inadequate and special devices called 'circuit breakers' had to be developed.

The basic problem has been to control and quench or extinguish the high power arc, which necessarily occurs at the separating contacts of a breaker when opening high current circuits. The problem of arc extinction is worsened when the power factor is low, that is, when the voltage and current are significantly out-of-phase.

Functions of Circuit Breakers

The following is a list of functions that circuit breakers must be able to adequately perform:

- CLOSE onto and maintain full load current for long periods.
- Automatically disconnect the full load current.
- Interrupt and disconnect fault currents from the system.
- Withstand full rated voltage across it when OPEN.
- CLOSE onto a fault and immediately re-open to clear that fault.
- Carry short circuit fault current for a period of time.
- Withstand the effects of arcing at the contact surfaces.

HV circuit breakers contain the contacts within a sealed enclosure, with an insulating dielectric surrounding the contacts and other ancillary parts of the circuit breaker. Despite the range of types of circuit breakers available they all share common principles; they all have to provide two main functionalities which are inter-related:

- Electrical functionality (Interrupter, or contacts)
- Mechanical functionality (Mechanism for tripping and closing the breaker)

The difference between these two functions is shown in the graphic (Figure 1) which illustrates these two aspects of the circuit breaker.

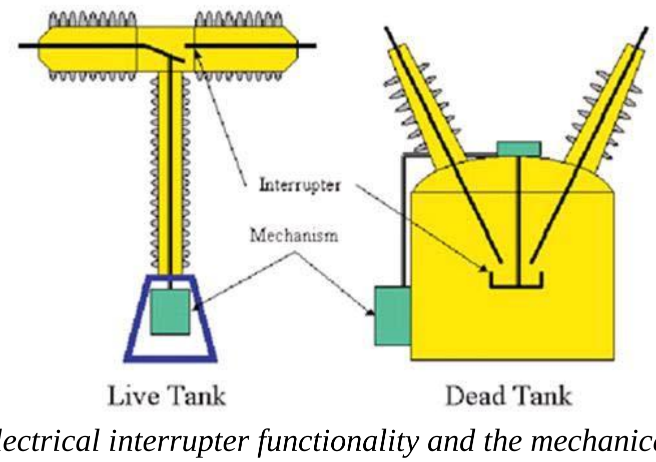

Figure 1: The electrical interrupter functionality and the mechanical functionality of circuit breakers.

Types of Circuit Breaker:

According to their arc quenching media the circuit breaker can be divided as

1) Oil Circuit Breaker
2) Air Circuit Breaker
3) SF6 Circuit Breaker
4) Vacuum Circuit Breaker

According to their services the circuit breaker can be divided as

1) Outdoor Circuit Breaker
2) Indoor Breaker

According to the operating mechanism of circuit breaker they can be divided as

1) Spring operated Circuit Breaker
2) Pneumatic Circuit Breaker
3) Hydraulic Circuit Breaker

According to the voltage level of installation types of circuit breaker **are referred as**

1) High Voltage Circuit Breaker
2) Medium Voltage Circuit Breaker
3) Low Voltage Circuit Breaker

Low voltage circuit breakers

Low voltage (less than 1000 V_{AC}) types are common in domestic, commercial and industrial application, and include:

- MCB (Miniature Circuit Breaker)—rated current not more than 100 A. Trip characteristics normally not adjustable. Thermal or thermal-magnetic operation. Breakers illustrated above are in this category.
- MCCB (Molded Case Circuit Breaker)—rated current up to 2500 A. Thermal or thermal-magnetic operation. Trip current may be adjustable in larger ratings.

Relays

In electrical engineering, a **protective relay** is an electromechanical apparatus, often with more than one coil, designed to calculate operating conditions on an electrical circuit and trip circuit breakers when a fault is detected. Unlike switching type relays with fixed and usually ill-defined operating voltage thresholds and operating times, protective relays have well-established, selectable, time/current (or other operating parameter) operating characteristics. Protection relays may use arrays of induction disks, shaded-pole magnets, operating and restraint coils, solenoid-type operators, telephone-relay contacts, and phase-shifting networks. Protection relays respond to such conditions as over-current, over-voltage, reverse power flow, over- and under- frequency.

Types of Relay:

Types of protection relays are mainly based on their characteristic, logic, on actuating parameter and operation mechanism.

Electromagnetic Attraction Type Relays

1. Solenoid Type
2. Attracted Armature Type
3. Balanced Beam Type

Induction Type Relays

1. Induction Disc Type
2. Induction Cup Type

Directional Type Relays

1. Reverse Current Type
2. Reverse Power Type

Timing Based Relay

1. Instantaneous Type
2. Definite Time Lag Type
3. Inverse Time Lag Type

Distance Type Relays

1. Impedance Type
2. Reactance Type
3. Admittance Type

Differential Type Relays

1.Current Differential Type
2. Voltage Differential Type

Other Types Of Relays

1. Under Voltage, Current, Power Relay
2. Over Voltage, Current, Power Relay
3. Thermal Relay
4. Rectifier Relay
5. Permanent Magnet Moving Coil Relay
6. Static Relay
7. Gas Operated Relay

Some examples of Mechanical Relay are

1. Thermal
    (a) OT Trip (Oil Temperature Trip)
    (b) WT Trip (Winding Temperature Trip)
    (C) Bearing Temp Trip etc.
2. Float Type
    (a) Buchholz
    (b) OSR
    (c) PRV
    (d) Water level Controls etc.
3. Pressure Switches.
4. Mechanical Interlocks.
5. Pole discrepancy Relay.