GOVERNMENT POLYTECHNIC, DHENKANAL

LECTURE NOTES
ON
SWITCH GEAR AND PROTECTIVE DEVICE

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Introduction to Switchgear

→ The greatest demand of electrical energy is a notable feature of modern civilisation.

→ The importance of electric supply in everyday life has reached such a stage that it is needed to protect the power system from harm, during fault conditions and to ensure maximum continuity of supply.

→ For this purpose, switch ON or OFF generators, transmission lines, distributors and other equipment under both normal and abnormal conditions. This is achieved by an apparatus called switchgear.

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

→ A switchgear consists of ~~switchgear~~ switching & protecting devices such as:

(1) Switches
(2) Fuses
(3) Circuit breakers
(4) Relays, etc.

→ The switchgear detects the fault and disconnects the unhealthy sections from the system.

→ Switchgear protects the system from damage and ensures continuity of supply.

→ Simplest form of switchgear

Tumbler switch + ordinary fuse.

→ Moderate form of switchgear (For high current rating)

switch + HRC (High Rupturing Capacity) fuse

→ In order to interrupt heavy fault currents, automatic circuit breakers are used.

→ ~~Cirb~~ Circuit Breaker

A circuit breaker is a switchgear which can open or close an electrical circuit under both normal and abnormal conditions.

(1.1) ESSENTIAL FEATURES OF SWITCHGEAR

① Complete Reliability:

→ The switchgear is added to the power system to improve the reliability.

→ When fault occurs on any part of the power-system, the switchgear must operate to isolate the

(ii) Absolutely certain discrimination

→ When fault occurs on any part of the power system, the switchgear must be able to discriminate between the faulty section and 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 done 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 voltage and current transformers for connecting to the main switchboard or a seperate instrument panel.

(1.2) Switchgear Equipment

* Switchgear covers a wide range of equipment concerned with switching and interrupting currents under both normal and abnormal conditions.

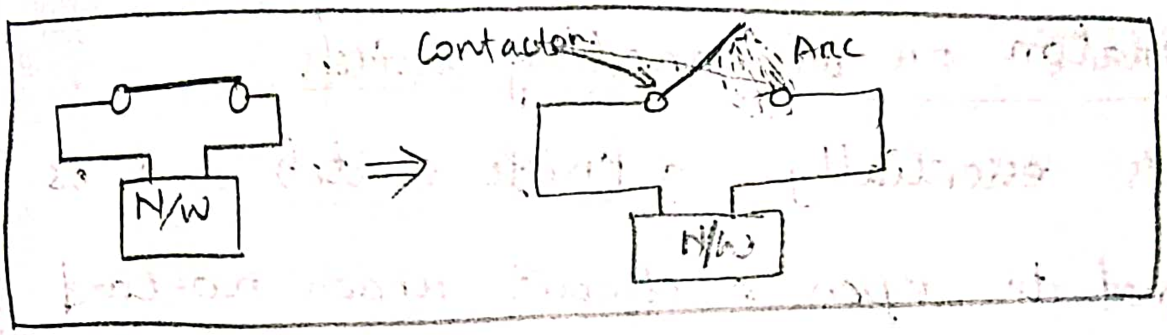
It includes
(1) switches
(2) Fuses
(3) circuit breakers
(4) relays and other equipments

(1) SWITCHES

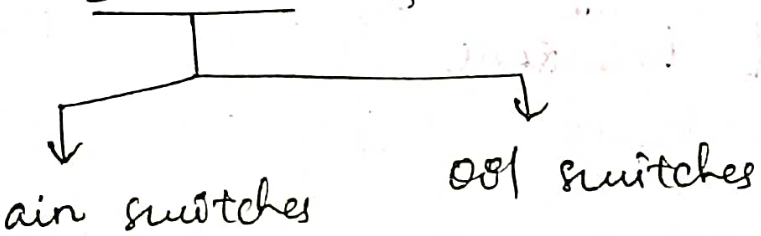
→ It is a device which is used to open or close an electrical circuit.

→ It can be ~~operated~~ used under full-load or no-load conditions.

→ When the contacts of a switch are opened, an arc is produced in the air between the contacts. This is true for circuits of high voltage and current capacity.



→ Switches



(1) ~~Air switches~~ Air-break switch

Arcing horns → They are pieces of metals between which arc is formed during opening operation.

→ It is an air switch and is designed to open a circuit under load.

→ Special arcing horns are provided to quench the arc during opening the switch.

→ After open the switch, the arcing horns spreads the arc. ~~Then the air~~ Gradually the arc is lengthened, cooled and interrupted.

→ Air break switches are generally used outdoor for circuits of medium capacity such as lines supplying an industrial load from a main transmission line or feeder.

(ii) Isolator or disconnecting switch

→ It is essentially a knife switch and is designed to open a circuit under no-load

→ Such switches are generally used on both sides of circuit breakers.

(iii) Oil switches

→ The contacts of such switches are opened under oil, usually transformer oil.

→ The effect of oil is to cool and quench the arc.

→ These switches are used for circuits of high voltage and large current carrying capacities.

(2) FUSES

→ A fuse is a short piece of wire or thin strip which ~~which~~ melts when excessive current flows through it for sufficient time.

→ It is connected in series with the circuit to be protected.

→ Under normal operating conditions, the fuse element is at a temperature below its melting point. When a short circuit or overload occurs, the current through the fuse element increases beyond its rated capacity. This raises the temperature and the fuse element melts, disconnecting the circuit protected by it.

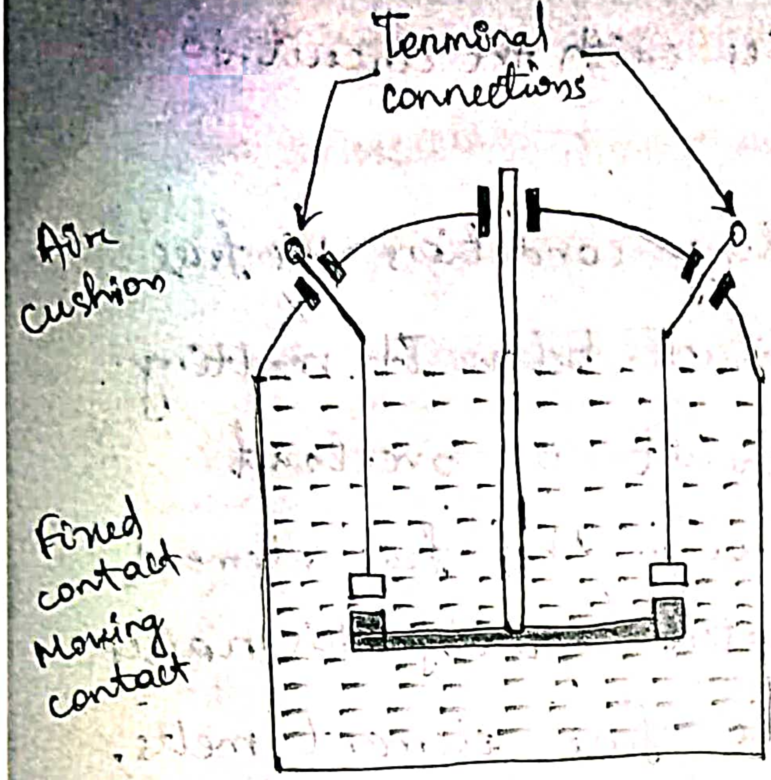
→ A fuse protects the machines and equipment from damage due to excessive currents.

NOTE
A fuse can detect/sense and break/interrupt the circuit under short-circuit or overload condition.

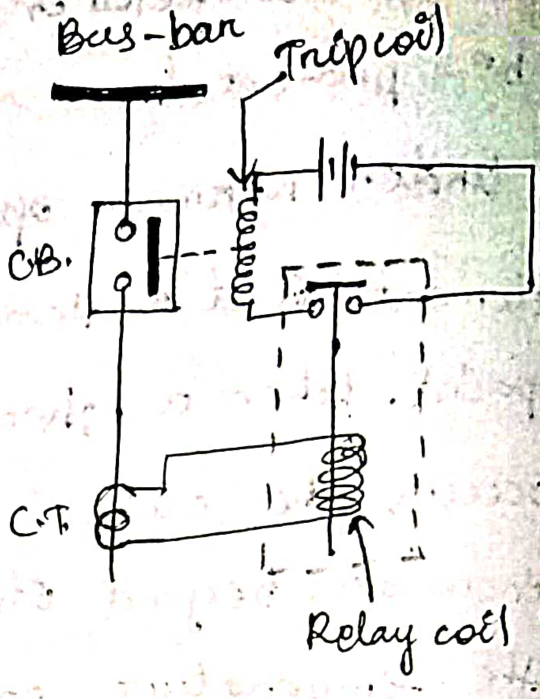
③ Circuit Breakers

→ It is an equipment which can open or close a circuit under all conditions (no-load, full-load and fault conditions).

→ It can be operated manually under normal conditions and automatically under fault conditions.



(Fig-1)



(Fig-II)

→ Fig-1 shows the parts of a typical oil circuit breaker.

→ The circuit breaker consists of moving and fixed contacts enclosed in strong metal tank and immersed in oil, known as transformer oil.

→ Fig-II shows circuit breaker control by a relay circuit.

→ <u>Operation</u>

→ Under normal operating conditions, the contacts remain closed and the circuit breaker carries the full load current continuously.

→ In this condition, the emf in the secondary winding of of C.T. is insufficient to operate the trip coil of the breaker but the contacts can be opened by manual or remote control.

→ When a fault occurs, the resulting overcurrent in the C.T. primary winding increases the secondary emf.

This energises the trip coil of the breaker. and moving contacts are pulled down, thus opening the contacts. The arc produced during the opening operation is quenched by the oil.

NOTE Hence the circuit breaker does the actual circuit interruption.

(4) RELAYS

→ A relay is a device which detects (sense) the fault and supplies information to the breaker for circuit interruption.

→ Fig-11 shows a typical relay circuit. It can be divided into 3 parts

(i) The primary winding of a C.T. which is connected in series with the circuit to be protected. The primary winding often consists of the main conductor itself.

(2) The second circuit is the secondary winding of C.T. connected to the relay operating coil.

(3) The third ckt is the tripping circuit which consists of a source of supply, trip coil of ckt breaker and the relay stationary contacts.

OPERATION

Under normal load conditions

→ secondary emf of CT is small.

→ ~~The~~ Due to that, the relay coil is not energised or fully magnetised.

~~Under~~ When fault occurs

→ Primary current of CT increases and secondary ~~of~~ voltage of CT increases. Then the relay coil is energised to close the trip ckt.

→ Then ~~as~~ the trip coil will energised by the battery voltage and hence it opens the contacts of CB.

(1.3) Bus-Bar Arrangement

Busbars → It is a copper rod or thin walled tubes and operate at constant voltage.

→ When a number of generators or feeders operating at the same voltage have to be directly connected electrically, bus bars are used as the common electrical

NOTE: All the diagrams refer to 3-phase arrangement but are shown in single-phase for simplicity.

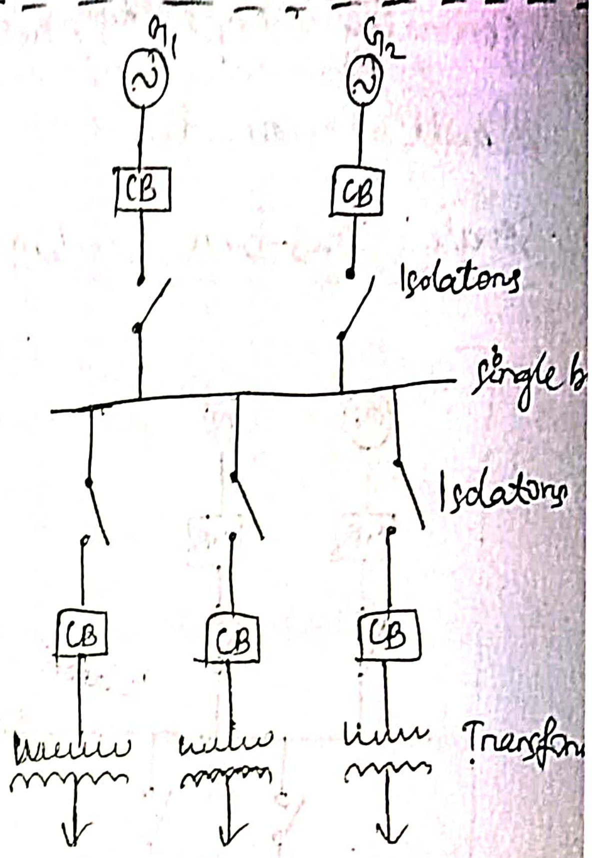
① Single Bus-bar System

→ It is used for power stations

→ It is also used in small outdoor stations having relatively few outgoing or incoming feeders and lines.

→ Fig (a) shows the single busbar system for a typical power station.

→ The generators, outgoing lines and transformers are connected to the bus-bar



(Fig.-A)

→ Each generator and feeder is controlled by a CB.

→ The isolator allow to isolate the generators, feeders and CB from the bus-bar for maintenance.

Advantages

→ Low initial cost

→ Less maintenance

→ Simple operation.

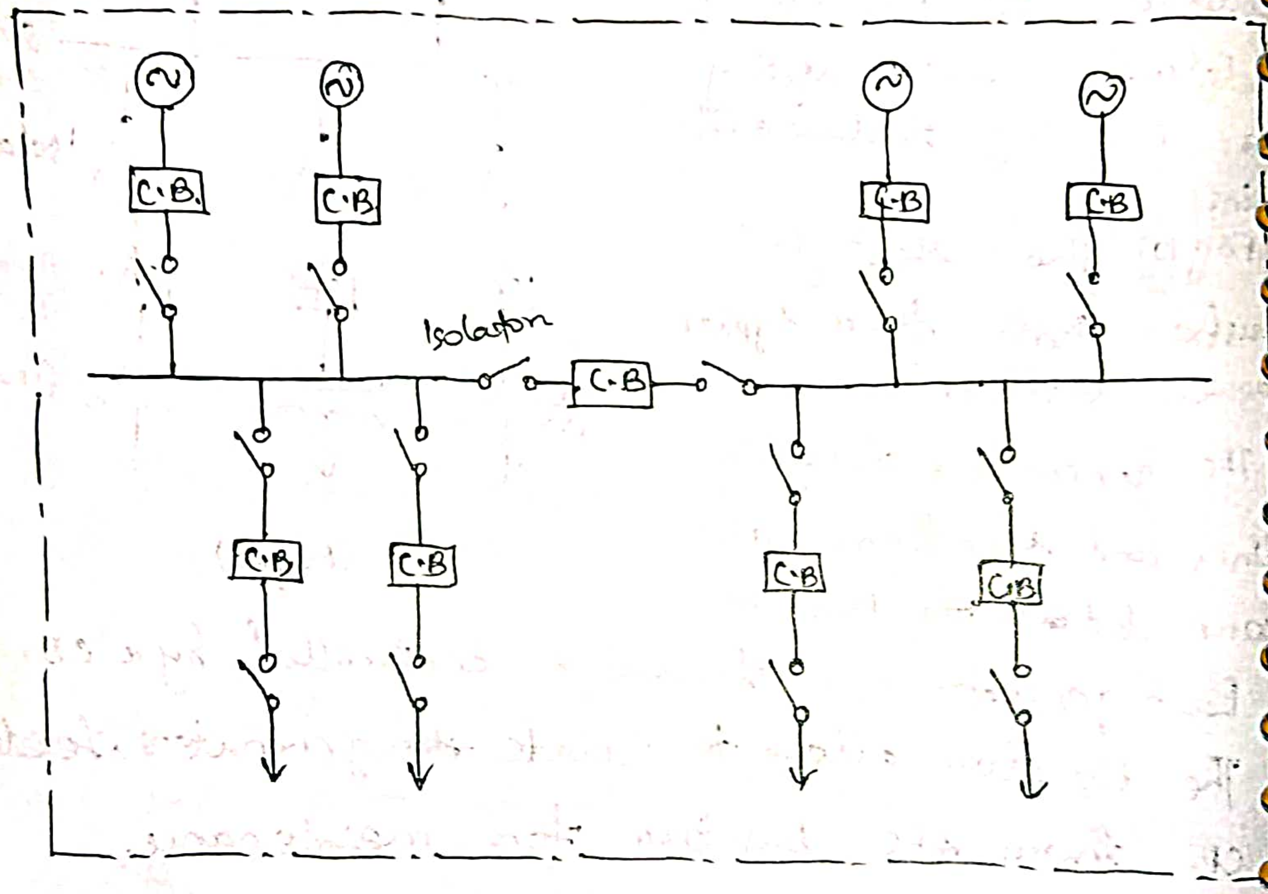
Disadvantages

→ The busbar cannot be cleaned, repaired or tested without de-energising the whole system.

→ If a fault occurs on the bus-bar itself, there is complete interruption of supply.

→ Any fault on the system is fed by all the generating capacity, resulting in very large fault currents.

② <u>single bus-bar system with sectionalisation</u>



→ In large generating stations where several units are installed, it is a common practice to sectionalise the bus so that fault on any section of the bus-bar will not cause complete shut down.

→ The above fig. shows the bus-bars divided into two sections connected by a CB and isolators.

Advantages

(1) If a fault occurs on any section of the bus-bar, that section can be isolated without affecting the supply to other sections.

(2) If a fault occurs on any feeder, the fault current is much lower than with unsectionalised bus-bar.
This permits the use of CB of lower capacity in the feeders.

(3) Repairs and maintenance of any section of the bus-bar can be carried out by de-energising that section only, eliminating the possibility of complete shut-down.

(3) Duplicate Bus-bar system

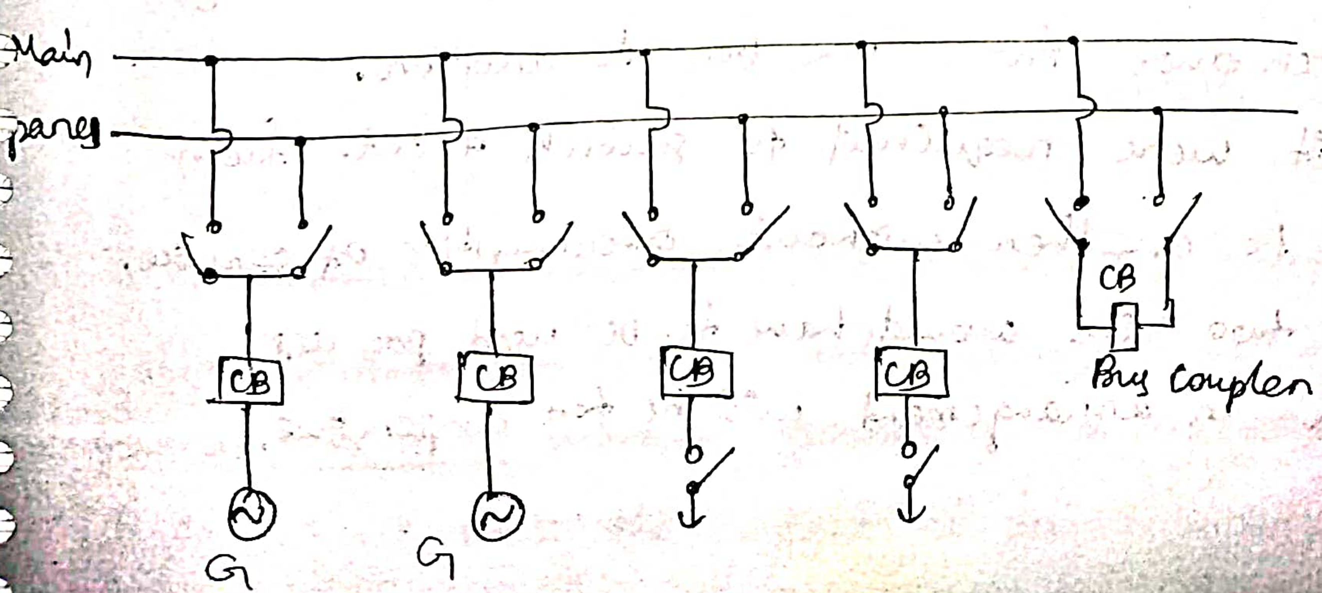


Fig (a)

→ Duplicate busbars is used to achieve the continue of supply during breakdown & maintenance

→ It is used in important stations (Large stations)

→ This system consist of two bus-bars,

(1) Main bus-bar

(2) spare bus-bar.

→ Each generator and feeder may be connected to both main & spare bus-bar with the help of bus coupler.

→ The bus-coupler consist of circuit breaker & isolators.

→ The duplicate bus-bar system is shown in the fig (a).

→ In this scheme, service is interrupted during switch over from one bus to another.

→ If it were required to switch a ckt. from one to another without interruption of service, then two CBs would have to be used per ckt.

Such an arrangement will be too expensive.

Advantages

→ If repair and maintenance is required on the main bus, then the entire load can be transferred to the spare bus. Hence the continuity of supply need not be interrupted.

→ The testing of feeder ckt. breakers can be done by putting them on spare bus-bars, thus keeping the main bus-bar undisturbed.

→ If a fault occurs on the bus-bars, the continuity of supply to the circuit can be maintained by transferring it to the ~~main~~ other bus-bar.

④ SWITCHGEAR ACCOMMODATION

The main ~~component~~ components of a switchgear are

① CB (2) Switches

③ bus-bars

④ Instrument transformers. (5) Instruments (Ammeter & voltmeters)

→ It is necessary to house the switchgear in power stations and substations in such a way so as to safeguard personnel during operation and maintenance.

→ It is ensure that the effects of fault on any section of the gear are a occur. a limited region.

→ Depending upon the voltage to be handled, swi[tchgear]
may be broadly classified into two types
(i) Outdoor type
(ii) Indoor type.

(1) Outdoor type

→ For voltages more than 66KV, switchgear equip-
ment is installed outdoor.

→ It is because for such voltages, the clearance
between the conductors and the space required
for switches, circuit breakers, transformers & other equipment become so great that it is not economical to install all such equipment indoor.

(2) Indoor Type

→ For voltages below 66KV, switchgear is gene[rally]
installed indoor because of economic considerations.

→ All live parts are completely enclosed in an earthed metal casing.

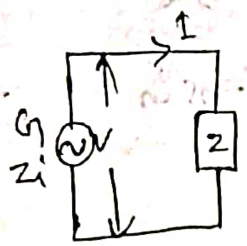
→ This switchgear is generally of metal-clad type.

(1.5) SHORT CIRCUIT

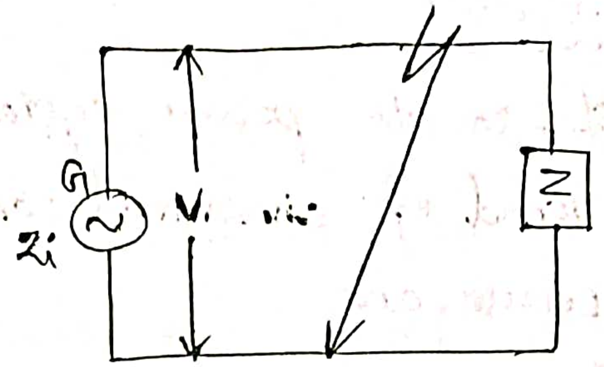
→ Whenever a fault occurs on a network, if a large current flows in one or more phases, a **short-circuit** is said to have occurred.

→ When a short-circuit occurs, a heavy current called short circuit current flows through the circuit.

→ Ex:-



Fig(a)



Fig(b)

The figure(a) shows a single phase generator of voltage V & internal impedance Z_i is supplying to a Load Z.

Under normal conditions, the current in the ckt. is limited by load impedance Z.

If the load terminals get shorted due to any reason as illustrate in fig(b). The ckt. impedance is reduced to very low value.

Normal condition

$$I = \frac{V}{Z_i + Z}$$

Short-circuit condition

$$I = \frac{V}{Z_i} = \text{very high value}$$

because internal impedance is very low.

→ Therefore a large current flows through the circuit. This is called short-circuit current.

→ When a short circuit occurs, the voltage at fault point is reduced to zero and the current is abnormally high, flows to the point of fault.

Causes of Short circuit

A short circuit in the power system is the result of some kind of abnormal conditions in the system. The causes are

(i) Internal effects

→ Breakdown of equipment or transmission lines.

→ Defect of insulation in a generator, transformer, etc.

→ Ageing of insulation, inadequate design or improper installation.

(ii) External effects

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.

→ Insulation failure due to lightning surges.

→ Overloading of equipment causing excessive heating

→ Mechanical damage by publ...

* EFFECTS OF SHORT CIRCUIT

→ Fire or explosion due to excessive heat from over current

→ Considerable damage occurs to the system due to formation of arc

→ The 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.

(1.6) SHORT-CIRCUIT CURRENTS

Most of the failures on the power system lead to short circuit fault and cause heavy current to flow in the system.

The calculations of these short-circuit currents are important for the following reasons.

(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 currents so that switchgear of suitable rating may be installed to interrupt them.

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

(iii) The magnitudes 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 (eg: bus-bars, CT, etc) so that they can withstand the forces that arise due to the occurrance of short circuits.

1.7 FAULTS IN A POWER SYSTEM

→ A fault occurs when two or more conductors that normally operate with a potential difference come in contact with each other.

→ These faults may be caused by sudden failure of a piece of equipment, accidental damage or short-circuit to overhead lines or by insulation failure resulting from ~~lighting~~ lightning surges.

→ Irrespective of the causes, the faults in a 3-phase system can be classified into two types.

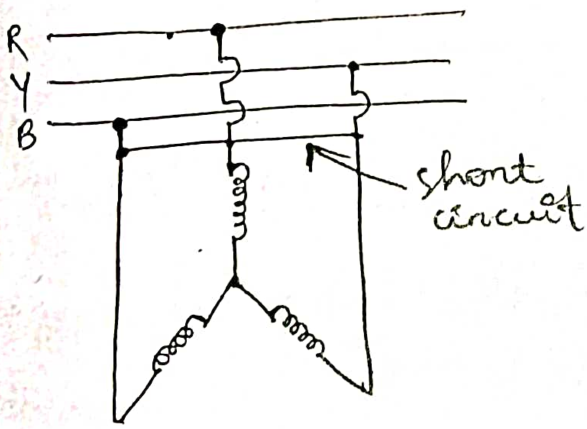
(i) Symmetrical faults

(ii) Unsymmetrical faults.

(i) Symmetrical faults

The fault which give rise to equal fault currents with 120° displacement is called a symmetrical fault.

EX:- When all the 3 conductors of a 3-phase line are brought together simultaneously into a short-circuit condition.



(ii) Unsymmetrical faults

The fault which give rise to unequal line currents with unequal displacement are called unsymmetrical faults.

The unsymmetrical faults are 3 types

1. Single line to ground fault (L-G)
2. Line to Line (L-L) fault
3. Double line to ground (L-L-G) fault.

→ Maximum occurring fault is unsymmetrical fault.

→ But the symmetrical fault is happen very rarely but very severe.

→ Most commonly single line to ground (L-G) fault occur.

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