LECTURE NOTES

ON

SWITCH GEAR AND PROTECTIVE DEVICES

Name of the course: Diploma in Electrical Engineering.

(6^{th} Semester)

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Switch Gear & Protection

Electrical energy is needed in every field & purpose like heating, lighting, industries, hospitals, domestic appliances etc. Therefore inorder to provide a large amount of energy efficiently, 3 things are needed i.e switching, controlling & protecting. Otherwise if there is a failure then it may cause damage to appliances & equipments. Therefore the apparatus which is used for switching, controlling & protecting the electrical ckt & equipments is called switch gear.

For ex :- Circuit breaker is a vital switching & controlling device which can be operated manually or automatically during fault condn like short ckt or open current. Therefore switch gear perform carrying, making & breaking the normal load current like a switch & clearing the fault in the power system. It also has provision of metering & regulating various electrical parameter like current, voltage, frequency, phase Angle etc

Essential features of switch gear :-

There are different essential features of switch gear such as • complete reliability

- Discrimination.
- Quick operation.
- Provision for manual control.
- Provision for Automatic Control.

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Complete reliability :-
Reliability means how smooth or trust worthy a system is. It means whenever a fault occurs in any part of the power system then the switch gear must operate to isolate the healthy part of the system from the faulty part.

Discrimination :-
It must be able to discriminate between the faulty section & healthy section accurately when fault occurs so it can isolate the faulty system without affecting the healthy section.

Quick Operation :-
When fault occurs on any ~~system~~ section of the power system then the switch gear must be able to operate quickly so that the electrical equipments can be saved from damage.

Provision for manual control
A switch gear must have provision for manual control. If the electrical control fails then the necessary operation can be carried out manually

Provision for Automatic Control :-
A switch gear must have provision for automatic control & by the help of instruments. The instruments may be ammeters, voltmeters, CT & PT, for connecti

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to main switch board on a separate Instrument panel.

Switch Gear Equipments :-

Switch gear equipments are used for switching & interrupting currents under both normal & abnormal condn. The Instruments may be switches, fuse, circuit breakers, relays and other equipments.

Switch :-

A switch is a device which is used to open or close an electrical ckt in a proper way. It can be used under full load or no load condn.

When the contacts of a switch are open, an arc is produced in the air betn the contacts for high voltage & high current power system.

The switches are classified into 2 types i.e

1) Air break switch
2) Oil switch.

Air Break Switch :-

It is an air switch & is used to open a ckt under load. In this switch a special arching horns are provided to quench (choke down or accomodate) the arch which occurs during opening of a switch.

Arching horns are the piece of metals betn which the arch is formed during opening operation.

When the switch opens then the ~~arc~~ arch is lengthened and cooled and interupted

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Air break switches are generally used in outdoor circuits such as line supplying Industrial load from the main transmission line or feeder.

→ It is more reliable & effective as compared to other switch. It is operated manually or automatically by the help of handle. The max^m voltage range for this switches is upto 35 KV. The air break switches are classified into 2 types :-

(i) Single pole Air break Switch
(ii) multi pole Air break Switch / Gang operated A B S.

Single pole A B S is used for opening of only one conductor.

Gang switches are used for opening more than one conductors at a time.

The air break switch is installed in 2 ways i.e either vertically or horizontally & is placed on the top of the pole.

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Isolator :- Isolator / Disconnecting switch

It is essentially a knife switch & is designed to open a ckt under no load. Its main purpose is to isolate 1 portion of the circuit from other when there is no flow of current. It is generally used on both sides of circuit breaker. Inorder to protect the circuit breaker during repair or replacement.

These switches should never be opened until the circuit breaker has been opened and should always be closed before the ckt breaker is closed.

Isolators are used to complete a connection or isolate a connection for the foll^n fields :-

(i) Two energised transmission & distribution line. Transmission & distribution lines from substation equipment.

(ii) A distribution feeder ckt or branch ckt.

* Oil switch :-

An oil switch is a high voltage switch whose contacts are opened and closed inside oil. The switch is actually immersed in an oil bath which is contained in a steel tank. The reason for placing high voltage switches in oil is that the oil will break the ckt when the switch is opened.

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In high voltage, the separation of switch doesnot break the current flow suddenly and an arc is formed betn the contacts of switch. If the contacts are opened in oil, then the oil quench the arch and some oil is evaporated due to heat.

Therefore the effect of oil is is to cool and quench the arc that tends to form when the ckt is opened. These switches are used for high voltage and high current circuit.

FUSE

A fuse is an essential safety device that operates to provide over current protection for the electrical ckt.

It is made up of a metal wire of strips that melts when high current flows through it. It is always connected in series with the device.

When a high amount of current flows in a ckt due to any fault condn then, the fuse wire gets overheated and melts. It protects the device by isolating from the high current.

Types of ~~switch~~ fuse :-

Operation / Working of Fuse

The working principle of fuse depends on heating consequence of current that means according to flow of current, the heat is produced in the fuse.

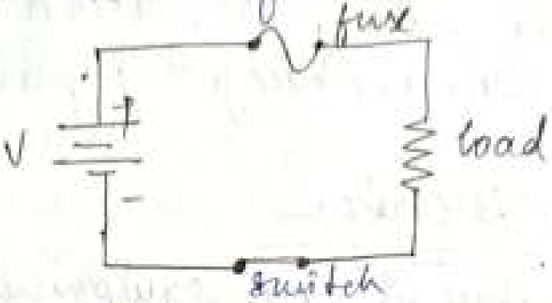

Figure shows the basic connection of fuse with the supply & load. When high amount of current flows towards load from the source then the fuse is melted & it disconnects the load from the source. The fuse material is made with copper, Zinc, Alluminium, Silver etc. The fuse can be replaced by a new fuse with an appropriate rating. The fuse rating is given by

$$\text{Fuse Rating } I = \frac{\text{Power}}{\text{Voltage}} \times 1.25$$

The unit of fuse rating is ampere.

Types of fuse :-

- Fuse
  - AC
    - HV fuse
      - Catridge type
      - Liquid type
      - Expulsion type
    - LV fuse
      - Catridge type
        - D-type
        - Link type
          - Bolted type
          - Knife blade
      - Dropout type fuse
      - Rewireable ~~type~~
      - Striker ~~type~~ fuse
  - DC

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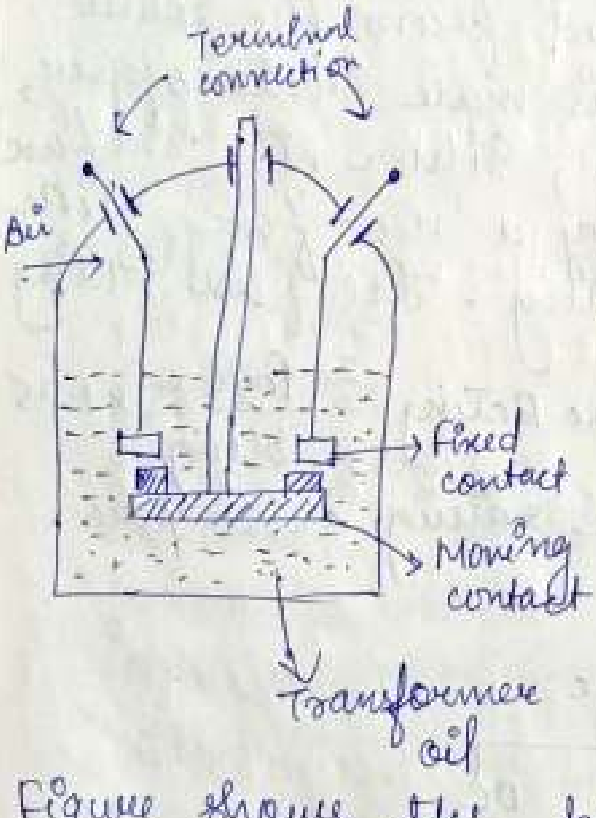
Applications of fuse :-

The different types of fuses are used in different applications in both electrical and electronics appliances like power transformer, AC, TV, Motor, stators, rectifiers, Printer, Power charger, grinder etc.

Circuit Breaker

A circuit breaker is an equipment which is used to open or close the ckt under no load, full load or fault condn.



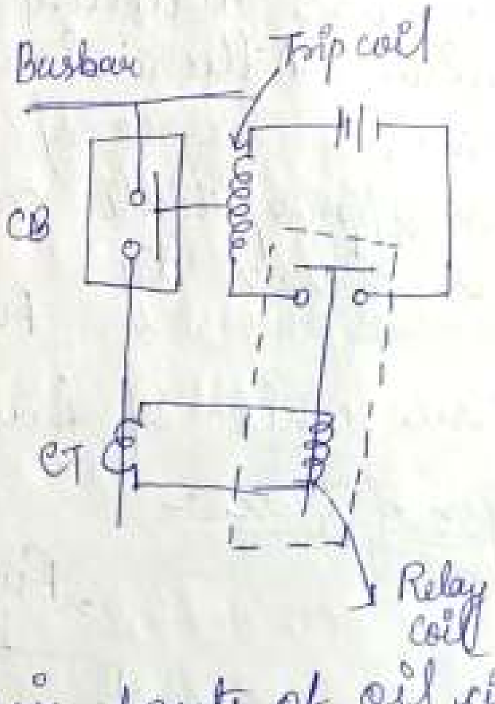


Figure shows the basic parts of oil circuit breaker & basic circuit with relay control. It consists of a moving & fixed contact which are enclosed in a strong metal tank and immersed in the transformer oil. Under normal operating condn the contacts are remain closed to each other & a full load current flows through the circuit breaker. When any fault occurs in the ckt, then an over-current flows throught CT. which energise the relay coil & the relay ckt becomes closed. Then the trip coil becomes energised & attracts the moving contact of circuit breaker. therefore the ckt breaker isolates the current path.

During isolation of moving contact some arch is produced which is quenched by the transformer oil.

Relay :- Relay is a device which detects the fault and provides a current towards ckt breaker for interruption of current flow. A relay has basically 3 parts such as primary winding of CT, secondary winding of CT & triping coil.

The primary winding of CT is connected in series with the ckt to be protected. The secondary winding of CT is connected to the relay operating coil. The trip coil is connected with the power supply & is energised when ckt is closed.

Under normal load condn, the emf

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produced in secondary winding of CT is very small so it is insufficient to close the relay contacts. When fault occurs a large current flows through the primary winding of CT which produces high emf in the secondary winding of CT. So, the relay operating coil is magnetised & the relay contacts are closed. Then the trip coil is energised and ~~pulled~~ pull down the moving contact of circuit Breaker & the ckt is protected by isolation.

Busbar Arrangement :-

Busbar is the copper rods or thin walled tubes which operates at a constant voltage. When more than 1 generators, or feeders are operating at same voltage then they are connected directly to the busbar. The busbar arrangement are used in power ~~system~~ station or substation.

There are different busbar systems such as :- single busbar system, single busbar system with sectionalis Duplicate busbar system

Single Busbar system :-

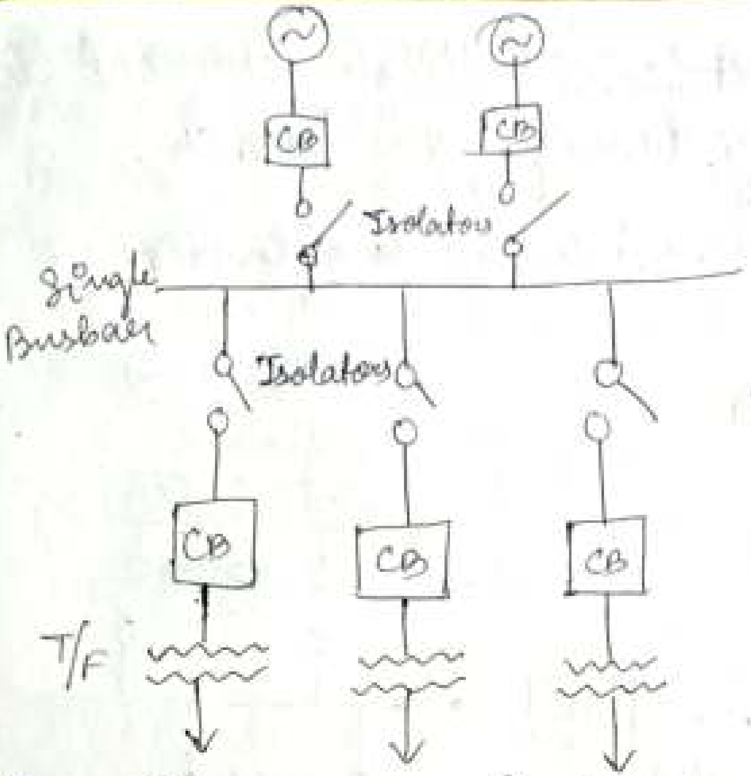

Figure shows the single bus system which is used for power system.. It is also used in small outdoor station having few ~~in~~ outgoing & Encoming feeders.
It consists of generator, outgoing lines, circuit breakers, Isolators & transformers which are connected to the busbar. The Isolator permit to isolate the feeder from the busbar for maintanance purpose.

Advantages :-

1) It has simple structure & operation
2) It has low Initial cost.
3) It requires less maintanance.

Disadvantages :-

1) It cannot be repaired or cleaned easily
2) If fault occurs ~~in~~ in the busbar then the whole system is interupted.

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3) During fault condn high current flows which may damage the busbar.

* Single busbar with sectionalisation :-

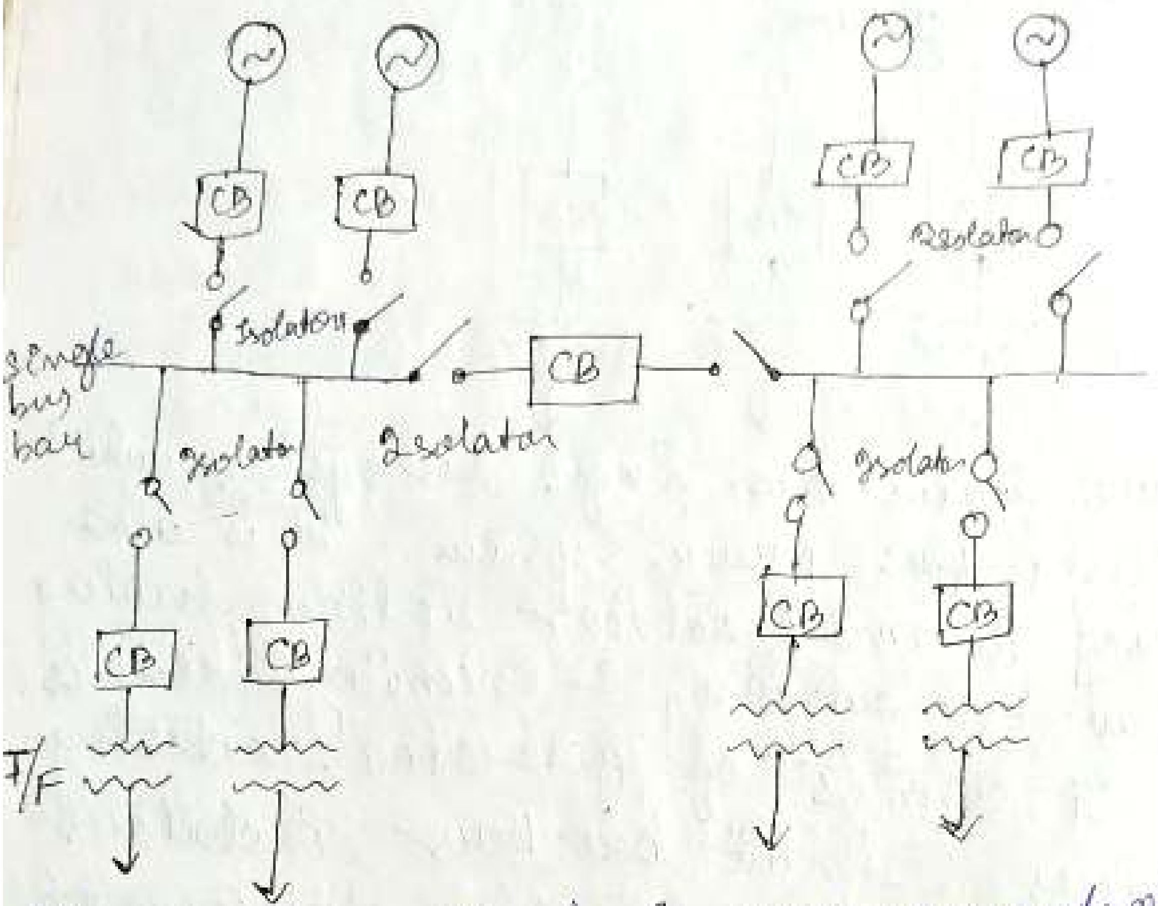

Figure shows the basic arrangement of single busbar system with sectionalisation. In large generating station it is used with different sections so that fault on any section of the busbar will not cause the complete shutdown. There are 3 basic advantages for this system such as the faulty section can be detected & isolated without affecting other ~~system~~ section.

If fault occurs in one feeder then the other section has limited rating

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current so, circuit breaker can be easily operated.

- Repairs & Maintanance work can be done easily section wise.
- The sections are interconnected to each other through the circuit breaker & isolator. If fault occurs in any section then, the circuit breaker isolates this section from others.

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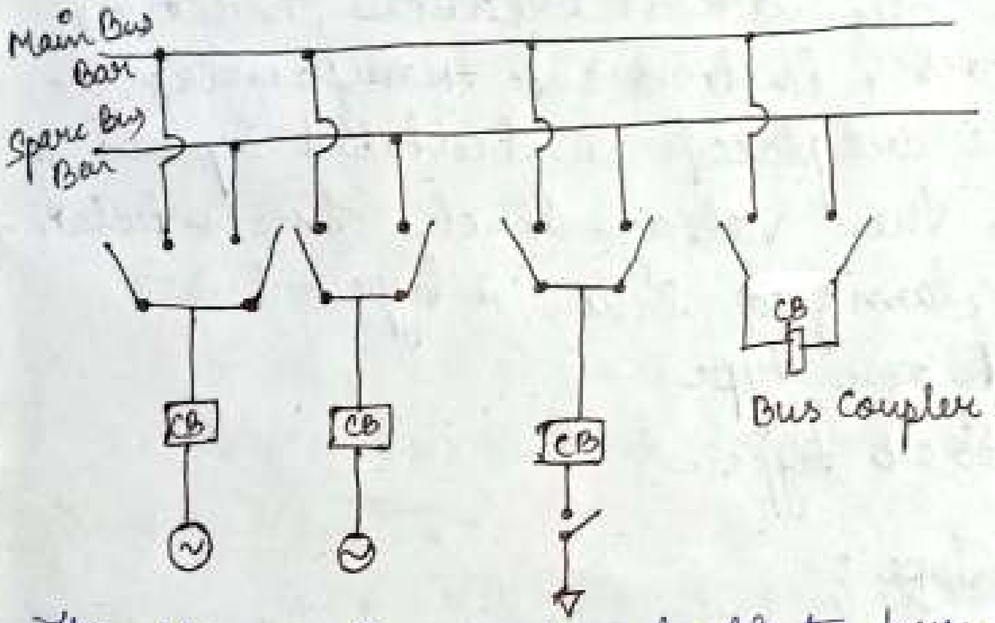
Duplicate Busbar :-

In large station the maintanance and repair work is obtained without breakdown of supply. This can be performed by using a duplicate busbar system. A duplicate busbar is a spare busbar which is used during the maintanance & repair work of main bus bar line.



The figure shows the duplicate bus bar system. It consists of 2 busbars (i) Main Busbar
(ii) Spare Busbar

When any system of the main busbar becomes failure & it has to be repaired. Then the total load of the main busbar is shifted to the spare busbar.

Advantages :-

(i) It gives easy repairing & maintainan work which is to be carried on main bus bar

(ii) The testing of feeder circuit and circuit breaker can be done by putting them on the spare busbar.

(iii) If a fault occurs in the busbar then, continuity of supply is obtained by spare busbar.

Switch Gear Accomodation :-

The main components of switch gear system are circuit breakers, switches, busbars, instrument transformers etc. These are placed or installed depending upon the voltage level. The installation is classified into 2 types i.e.

(i) Outdoor type.

(ii) Indoor type.

Outdoor Type :-

The switch gear equipments are installed outdoor for a voltage beyond 66kV. It is because the voltage is very high for the clearance betn conductors and the space required for switch, circuit breaker, Transformer & other equipments.

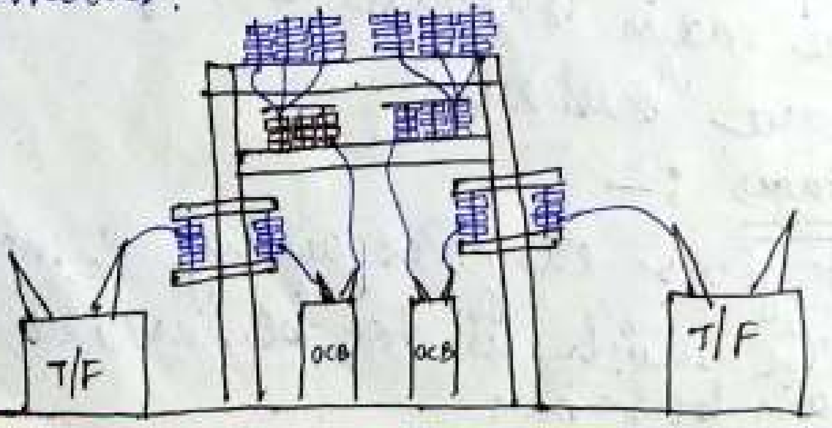


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Figure shows a typical outdoor substation with switch gear equipment. The equipments are installed openly due to high voltage rating.

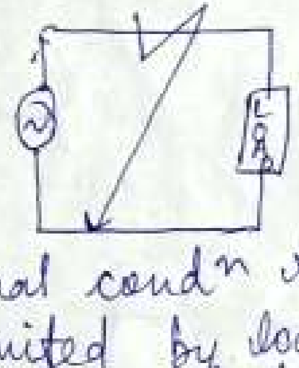
* Indoor Type

→ The switchgear equipments are installed for a voltage below 66KV. It is because of low voltage. The indoor switchgear is generally like metal clad type. In this type of construction all the switch gear equipments are completely enclosed in an earthed metal casing.

It is obtained for a definite localization and restricted to any fault place.

Short Circuit :-

When a fault occurs on a network, a large current flows in one or more phases then short circuit is said to be occured



Under normal condn the current in the ckt is limited by load impedance. If load terminals get shorted due to any reason then the impedance becomes zero and a high amount of current flows through the short path which is called short circuit current. When short circuit occurs, the voltage at the fault point is reduced to 0 with a high amount of current. but in overload cond^n, the voltage at the overload point may be low but not zero.

Cause of short ckt :-

(i) A short ckt in power system is the result of abnormal cond^n in the system. It may be caused due to internal or external effects (ii) the internal effects are caused due to the breakdown of equipments or transmission lines, from deterioration of insulation in generator, transformer etc. Such troubles may be due to aging of insulations, inadequate design or improper installation (iii) the external effects are caused due to insulation failure by lightening ~~surge~~ surge, overloading of equipments, mechanica damage by public etc.

Effect of short ckt

1) Due to short circuit, a high amoun of current flows which cause excessi heating & due to this heat fire or explosion of insulation occurs

2) Due to short ckt, a low voltage is obtained in the power system which

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affects the motor & generator installed in the power system.

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Reason for calculating short ckt current :-

The short ckt current is calculated so that the suitable switch gear element may be installed to protect the device. The magnitude of short ckt current determines the installation & location of protective system.

The magnitude of short ckt current determine the size of the protective device.

The calculation of short ckt current enables the proper selection of busbars, ~~cities~~ CTS etc
(Current Transformer)

Faults in a power system

When 2 or more conductors have potential difference with a connection then fault occurs. These faults may be caused by sudden failure of equipment, accidental damage, short ckt to overall lines or by insulation failure resulting from lightening.

There are 2 types of fault in 3ϕ system such as,

(i) Symmetrical faults.

(ii) Unsymmetrical faults.

In symmetrical faults, the fault current have 120° phase displacement with each other with equal magnitude.

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The most common example of symmetrical fault is when all 3 conductors of 3ϕ line are joined together.
The unsymmetrical faults are the unequal line currents with unequal phase displacement. The unsymmetrical fault may be single line to ground fault or line to line fault or double line to ground fault.

Symmetrical fault Calculation :-

The fault in the power system which gives equal fault current in the lines with 120° displacement is called symmetrical fault.
The symmetrical fault occurs when all the 3 conductors of 3 phase system are joined together.

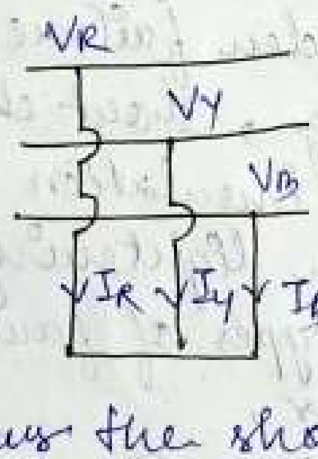

Figure shows the short circuiting of three terminals of 3ϕ system. The fault currents in 3ϕ system i.e I_R, I_Y & I_B have equal magnitude & 120° displacement. Due to balanced nature of fault, one phase is considered for fault calculation.

Limitation of fault current:-

i) When a short ckt occurs at any point on the system, the short ckt current is limited by the impedance of the system

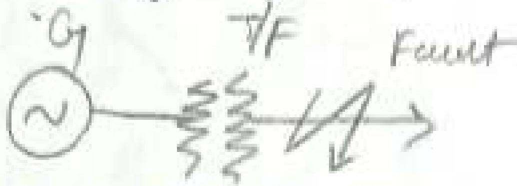

Figure shows a fault occurs on the feeder ~~at point~~ then the short ckt current becomes high and flows from the generating station.

(ii) This fault current can be minimized by increasing the impedance of the generator or by using T/F or by providing an impedance betⁿ the line & the generator

(ii) The fault current is limited by a reactive element, so the total reactance calculation exceeds the resistance of the line cables by 3 times.

Percentage reactance:-

The reactance of generator, transformers or reactors is always expressed in %age reactance. It is the %age of total phase voltage drop in the ckt in the presence of full load current. It is given by,

$$\% X = \frac{IX}{V} \times 100$$

I = Full load current

X = Reactance / phase

V = Phase voltage.

It is also given by, $\% X = \frac{(KVA) X}{10 (KV)^2}$

The short circuit current is given by,

$$I_{sc} = \frac{V}{X} \Rightarrow I \times \frac{100}{\% X}$$

$$\Rightarrow \boxed{I_{sc} = I \times \frac{100}{\% X}}$$

Percentage Reactance & Base KVA

The percentage reactance of an equipment depends on its KVA rating. Therefore it is neccessary to find the %age reactance of elements on a common KVA rating. This common KVA rating is known as Base KVA.

The value of Base KVA may be

(i) Equal to the KVA rating of largest plant.

(ii) Equal to the total plant capacity.

(iii) Equal to any arbitary value.

(iv) $\% X \text{ of base KVA} = \frac{\text{Base KVA}}{\text{Rated KVA}} \times \% X \text{ of rated KVA}$

$$\Rightarrow \frac{\% X \text{ of base KVA}}{\% X \text{ of rated KVA}} = \frac{\text{Base KVA}}{\text{Rated KVA}}$$

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Short Ckt KVA :-

The product of system voltage and short ckt current at the point of fault is expressed in KVA is known as short ckt KVA.

Let V is normal phase voltage.

I is full load current at Base KVA.

%X is % age reactance at Base KVA.

We know that $I_{sc} = I \times \frac{100}{\%X}$

Short Ckt KVA for 3ϕ $= \frac{3 V I_{sc}}{1000}$

$= \frac{3 \times V \times I \times 100}{1000 \times \%X}$

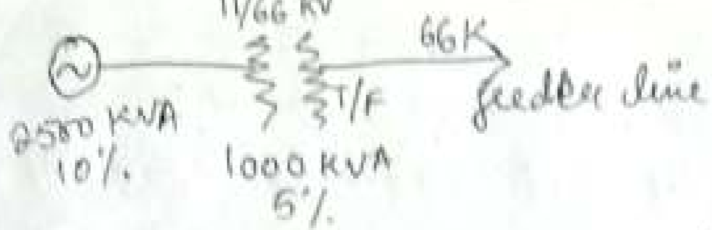
or

$\frac{3VI}{1000} \times \frac{100}{\%X}$

$= \text{Base KVA} \times \frac{100}{\%X}$

$$\text{Short Ckt KVA} = \text{Base KVA} \times \frac{100}{\%X}$$

Q For ex:- Consider a three phase transmission line which is operating at 66 KV and takes power from 1000 KVA transformer with 5% reactance. It takes the power from generating station of 2500 KVA with 10% reactance as show in the figure :



Let 2500 KVA is a common base KVA

Reactance of T/F at 2500 KVA $= \frac{\text{Base KVA}}{\text{Rated KVA}} \times \%X$ of rated KVA

$= \frac{2500}{1000} \times 5 = 12.5\%$

Reactance of Gen. at 2500 KVA

$= \frac{\text{Base KVA}}{\text{Rated KVA}} \times \%X$ of rated KVA

$= \frac{2500}{2500} \times 10 = 10\%$

Total Reactance $= 12.5 + 10$
$= 22.5\%$

The full load current with respect to 2500 KVA by $P = \sqrt{3} VI$

$$I = \frac{P}{\sqrt{3} \times V} = \frac{2500 \text{ KVA}}{\sqrt{3} \times 66 \text{ KV}}$$

$$= \frac{2500 \times 1000}{\sqrt{3} \times 66 \times 1000}$$

$$= 21.87 A$$

The short circuit current is given by

$$I_{sc} = I \times \frac{100}{\%X}$$

$$= 21.87 \times \frac{100}{22.5} = 97.2 A.$$

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Case-2

Let the base Power is 6000 KVA

Reactance of T/F at 6000 KVA = $\frac{\text{Base KVA}}{\text{Rated KVA}} \times \%X$ of rated KVA

$= \frac{6000}{1000} \times 5$

$= 30\%$

Reactance of gen. of 6000 KVA = $\frac{6000}{2500} \times 10$

$= 24\%$

Total Reactance = 24 + 30

= 54%

Power = $\sqrt{3} VI$

$I = \frac{P}{\sqrt{3} V} = \frac{6000 \text{ KVA}}{\sqrt{3} \times 66 \text{ KV}} = 52.48 A$

$I_{sc} = I \times \frac{100}{\%X}$

$= 52.48 \times \frac{100}{54}$

$= 97.19 A$

→ Therefore the short ckt current remain same for any base KVA. According to this short ckt current the switch gear elements are chosen.

Reactor control of short circuit current

Reactors are the switch gear elements which is connected in series with the system to limit the short ckt current to a value for which the circuit breaker can handle.

→ The reactor performs the foll^n action

* The reactor limits the flow of I_{sc} & protect the equipment from over heating

* Reactors can isolate the protective device and finds the troubles at fault

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point in the power system. It increases the continuity of supply.

* It permit the installation of circuit breake of low rating.
* A reactor is a coil of many turns designed to provide large inductance as compare to its ohmic resistance.

Location of Reactors

The reactors are connected in 3 parts
(i) In series with each Generator
(ii) In series with feeder.
(iii) In busbar.

Generator Reactor

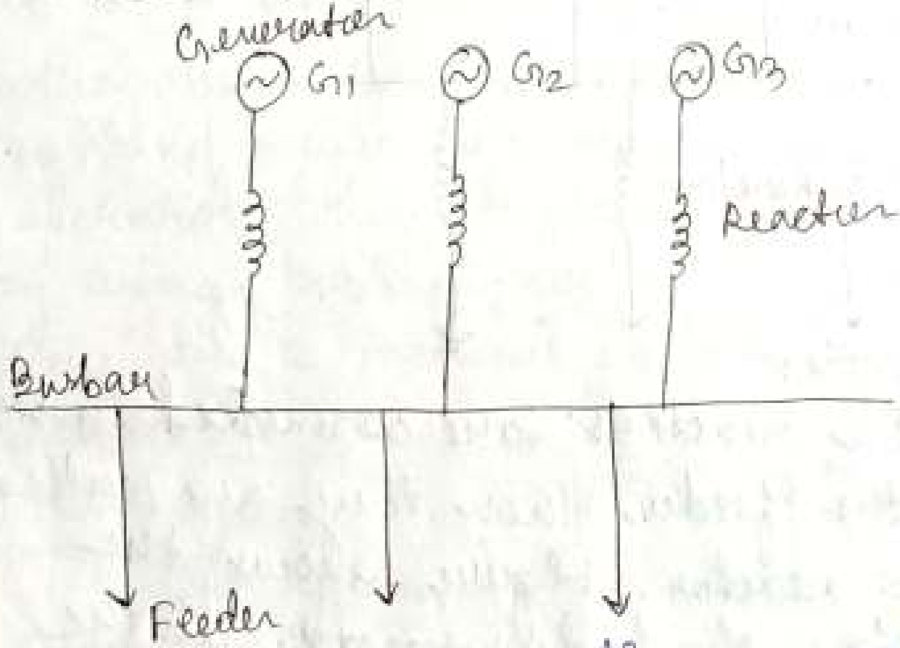

Figure shows the one line connection of reactors with the Generators. The reactor switch are connected with series with generator is known as generator reactor
The reactor protects the generator in the case of short circuit fault.

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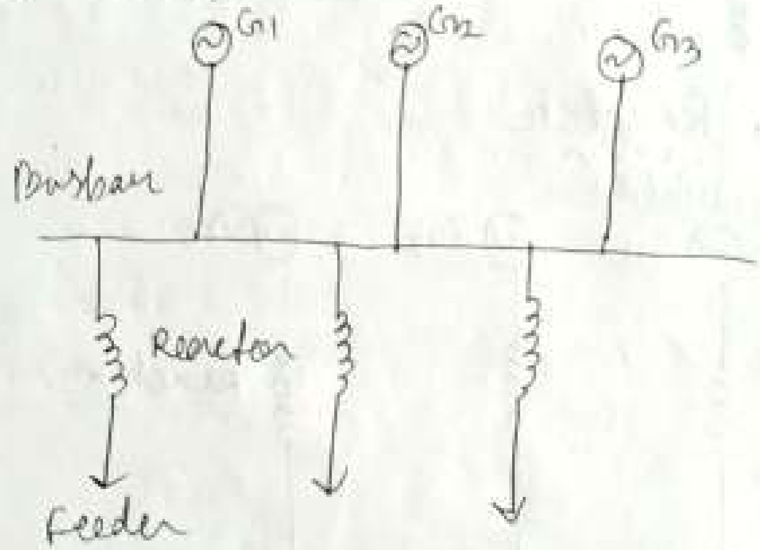
Disadvantages

There is a constant voltage drop and power loss in the reactors during normal operation.

If any fault occurs at busbar or feeder then the voltage at busbar will be reduce to low value so the generator are affected.

→ If fault occurs in any feeder then the continuity of supply is affected

Feeder Reactor



When the reactors are connected in series with the feeder then they are called feeder reactor. Figure shows the connection of feeder reactor in the system.

When any fault occurs in the feeder then the reactor limit the current and the feeder ~~sea~~ voltage drop cannot affect the busbar voltage so generators are not affected

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→ The fault on a feeder will not affect the other feeders. So continuity of power supply is maintainance.

Disadvantages

There is a constant voltage drop and power loss in the reactors during normal operation.

→ If fault occurs in busbar then the reactors cannot protect it so the generators are affected.

→ If the no. of generator is increase then the size of the feeder reactor will have to increase to keep the ratings within a limited range.

Busbar Reactor

In the above two reactors, the voltage drop and power loss occurs during normal operation. This problem can be overcome by using busbar reactor.

→ There are 2 methods in busbar reactor such as :-

i) Ring System

(ii) Tie Bar System.

i) Ring System

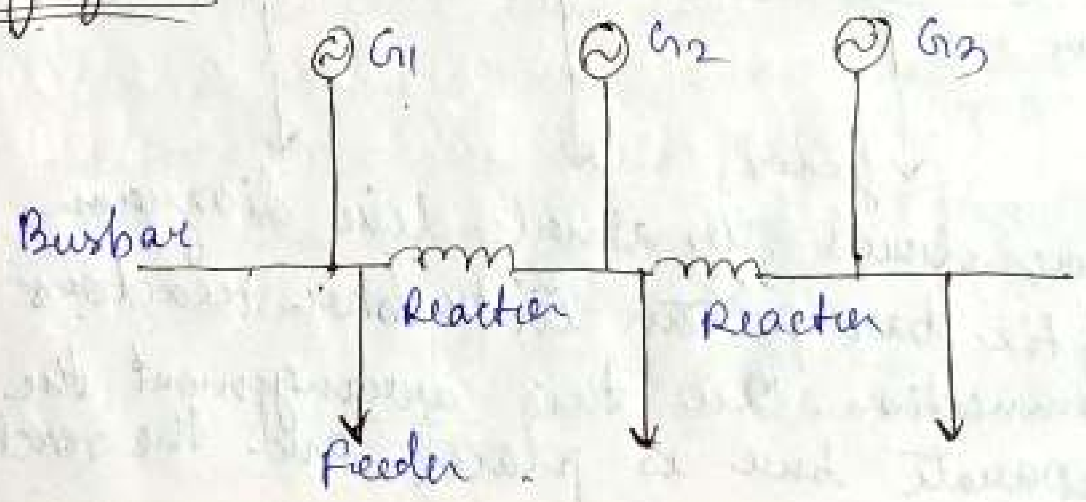

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Figure shows single line diagram of ring type busbar reactor connection. In this arrangement one feeder is fed by one generator only.

→ Under normal condn of operation, each generator will supply its own section of load and a very little power loss and voltage drop in the reactors.

→ If any fault occurs in one feeder then only one generator is affected & the other generators will safe from fault current due to reactors.

→ During fault; the faulty section is isolated and again re-installed after repairing.

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Tie bar System

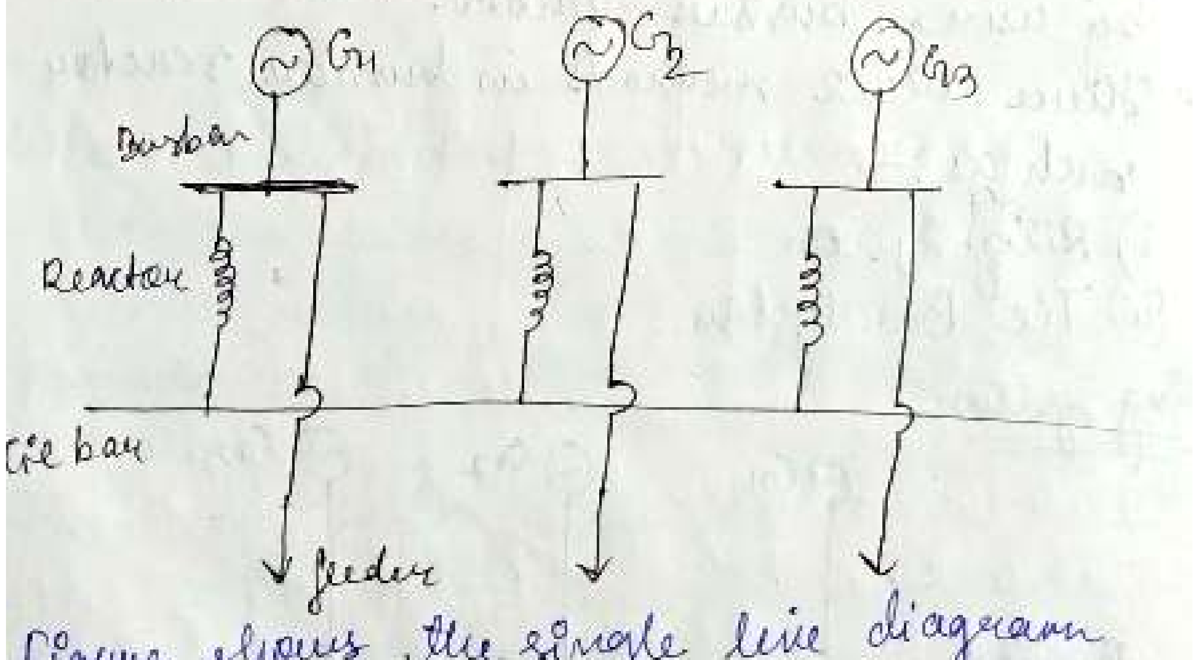

Figure shows the single line diagram of tie bar system in busbar reactors connection. In this arrangement the separate bar is placed and the reactors are connected the busbar and tie-bar.

→ In this arrangement reactors are placed in series between each sections so half of the reactance is used to control the fault current.

→ In this arrangement an additional generator can be connected to the system without requiring any changes of existing system.

Steps for symmetrical fault Calculation :-

→ Draw a single line diagram of the complete network indicating the rating voltage & percentage reactance of each element.

→ Consider a numerical base KVA value, convert all percentage reactance with respect to all base KVA value.

→ Draw the reactance diagram of 1-ϕ to the neutral. Indicate the % reactance with respect to base KVA. The transformer in the system should be represented by a series reactance.

→ Find the total % of reactance upto the fault point

→ Find the full load current with respect to base KVA & normal system voltage at the fault point.

→ Find the short ckt current & short ckt KVA by using formula,

$I_{sc} = I \times \frac{100}{\%X}$, $SC\ KVA = Base\ KVA \times \frac{100}{\%X}$

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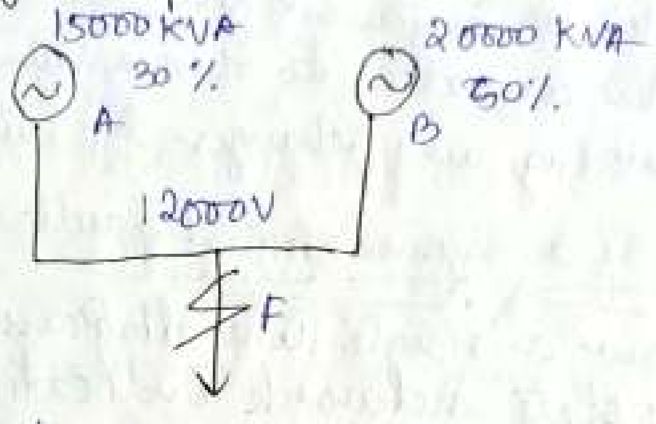
Q Figure shows a single line diagram of three phase system. The % reactance of each alternator is based on its own capacity. Find the short ckt current at the fault point & short ckt KVA



Choose the base KVA as 25000 KVA

Reactance of A at 25000 KVA = $\frac{\text{Base KVA}}{\text{Rated KVA}} \times \% X$

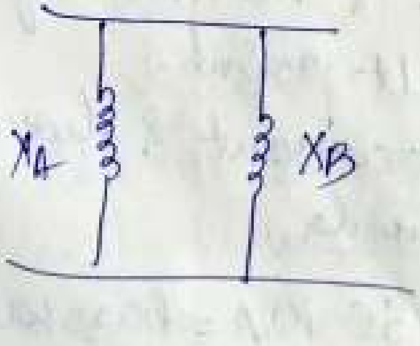
$= \frac{25000 \text{ KVA}}{15000 \text{ KVA}} \times 30\%$

$= 50\%$

Reactance of B at 25000 KVA = $\frac{\text{Base KVA}}{\text{Rated KVA}} \times \% X$

$= \frac{25000 \text{ KVA}}{20000 \text{ KVA}} \times 50\%$

$= 62.5\%$



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Total Reactance,

$$X = X_A \parallel X_B$$

$$= \frac{X_A \cdot X_B}{X_A + X_B} = \frac{50 \times 62.5}{50 + 62.5} = 27.77\%$$

$$\text{Full load current (I)} = \frac{\text{Base KVA}}{\text{Rated Voltage}}$$

$$P = \sqrt{3} V_L I_L = \frac{25000 \text{ KVA}}{\sqrt{3} \times 12000 \text{ V}} = \frac{25000 \times 10^3 \text{ VA}}{\sqrt{3} \times 12000 \text{ V}}$$

$$= 1202.81 \text{ A}$$

$$I_{sc} = 1202.81 \times \frac{100}{27.77}$$

$$= 4331.32 \text{ A}$$

$$\text{SC KVA} = \text{Base KVA} \times \frac{100}{\% X}$$

$$= 25000 \times \frac{100}{27.77}$$

$$= 90025.20 \text{ KVA}$$

Q. A three phase transmission line operating at 10KV and having a resistance of 1Ω & reactance of 4Ω is connected to the generating station busbars through 5MVA step up T/F having a reactance of 5%. The busbars are supplied by a 10MVA alternator having 10% reactance. Calculate the short ckt KVA fed to symmetrical fault betn phase if it occurs.

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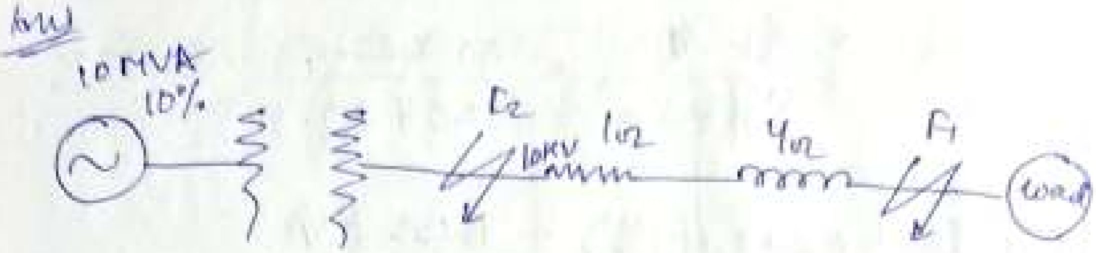
i) At the load end of transmission line
ii) At the high voltage terminals of T/F.

Ans



Choose the base KVA 10000 KVA

$$\% X_A = \frac{\text{Base KVA}}{\text{Rated KVA}} \times \% X$$

$$= \frac{10000 \text{ KVA}}{10 \times 10^6} \times 10$$

$$= 10\%$$

$$\% X_T = \frac{10000}{5 \times 10^6} \times 5$$

$$= 10\%$$

$$\% X = \frac{(\text{KVA}) X}{10 (\text{KV})^2} = \frac{1000 \times 4}{10 \times (10)^2}$$

$$= 40\%$$

$$\% R = \frac{10000 \times 1}{10 \times (10)^2} = 10\%$$

Total Reactance

$$\% X = X_A + X_T + X_L$$

$$= 10 + 10 + 40$$

$$= 60\%$$

$\% R = 10\%$

% of Impedance

$$\%Z = \sqrt{R^2 + X^2}$$

$$= \sqrt{10^2 + 60^2}$$

$$= 60.82\%$$

$$S.C\ KVA = Base\ KVA \times \frac{100}{\%Z}$$

$$= 10000 \times \frac{100}{60.82\%}$$

$$= 16441.95\ KVA$$

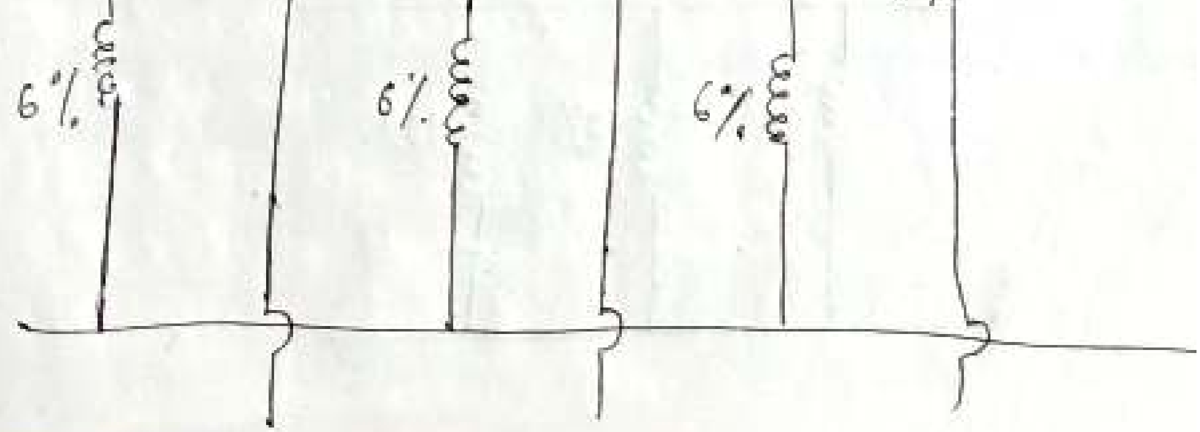
$$SC\ KVA = 10000 \times \frac{100}{20} = 50000\ KVA.$$

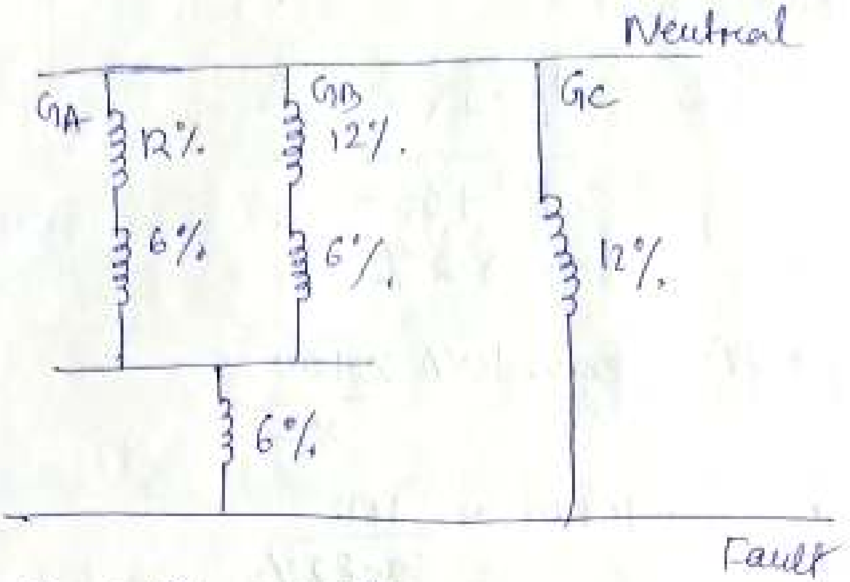
Q A Generating station has three section busbars connected with a tie-bar through 6% reactors rated at 5000 KVA. Each generator is of 5000 KVA with 12% reactance and is connected to one section of busbars. Find the total steady i/p to a dead short-ckt betn the lines on one of the sections of busbars

i) With Reactors

ii) Without Reactors.

i)





12% + 16% = 18%

18% + 18% = 18/2 = 9%

9% + 6% = 15%

15% ∥ 12% = $\frac{15 \times 12}{15+12}$ = $\frac{100}{27}$ %

= 6.67%

% X = 6.67%

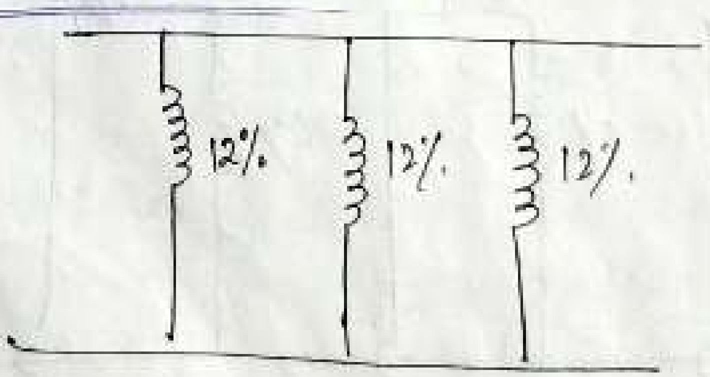
Base KVA = 5000 KVA

S.C KVA = $\frac{5000 \times 100}{6.67}$

= 74962 KVA

= 75 MVA

(ii) Without reactor :-



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$\%X = 12/3 = 4$

Base KVA = 5000 KVA.

S.C KVA = $5000 \times \frac{100}{4}$

= 125000 KVA

= 125 MVA

FUSE

A fuse is a short piece of metal which is inserted in a circuit for protection purpose that means if high amount of current flows through it then it melts and isolate the circuit.

→ The fuse element is generally made up of silver, Cu etc which has low melting point, least deteriaration & high conductivity.

→ The fuse element is always connected in series with the circuit.

→ Under normal operating condition the temperature of the fuse element remain below the melting point so it carries normal current without over heating.

→ When any short ckt or overload occur then current flows.

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Important Terms in Fuse :-

* Current Rating :- It is the maximum amount of current that can flow through the fuse element without overheating or melting.

→ The current depends upon the material used, contacts of fuse holder temperature & surrounding of the fuse.

* Fusing Current :- It is the minimum amount of current at which the fuse element melts and disconnects the circuit for protection. The fusing current is always greater than the current rating of the ~~fus~~ fuse.

→ Consider a fuse wire having diameter of 'd' and the fusing current is 'I'. The fusing current is given by $I = Kd^{3/2}$ where K is called fuse constant. The value of K depends on the material used for fuse material.

Material	Value of K
Cu	2530
Al	1873
Tin	405.5
Pb	340.6

The fusing current depends upon the various factor such as :-

(i) Material of fuse elements.
(ii) Diameter of the element
(iii) Size & location of the terminals.
(iv) Type of enclosure used.

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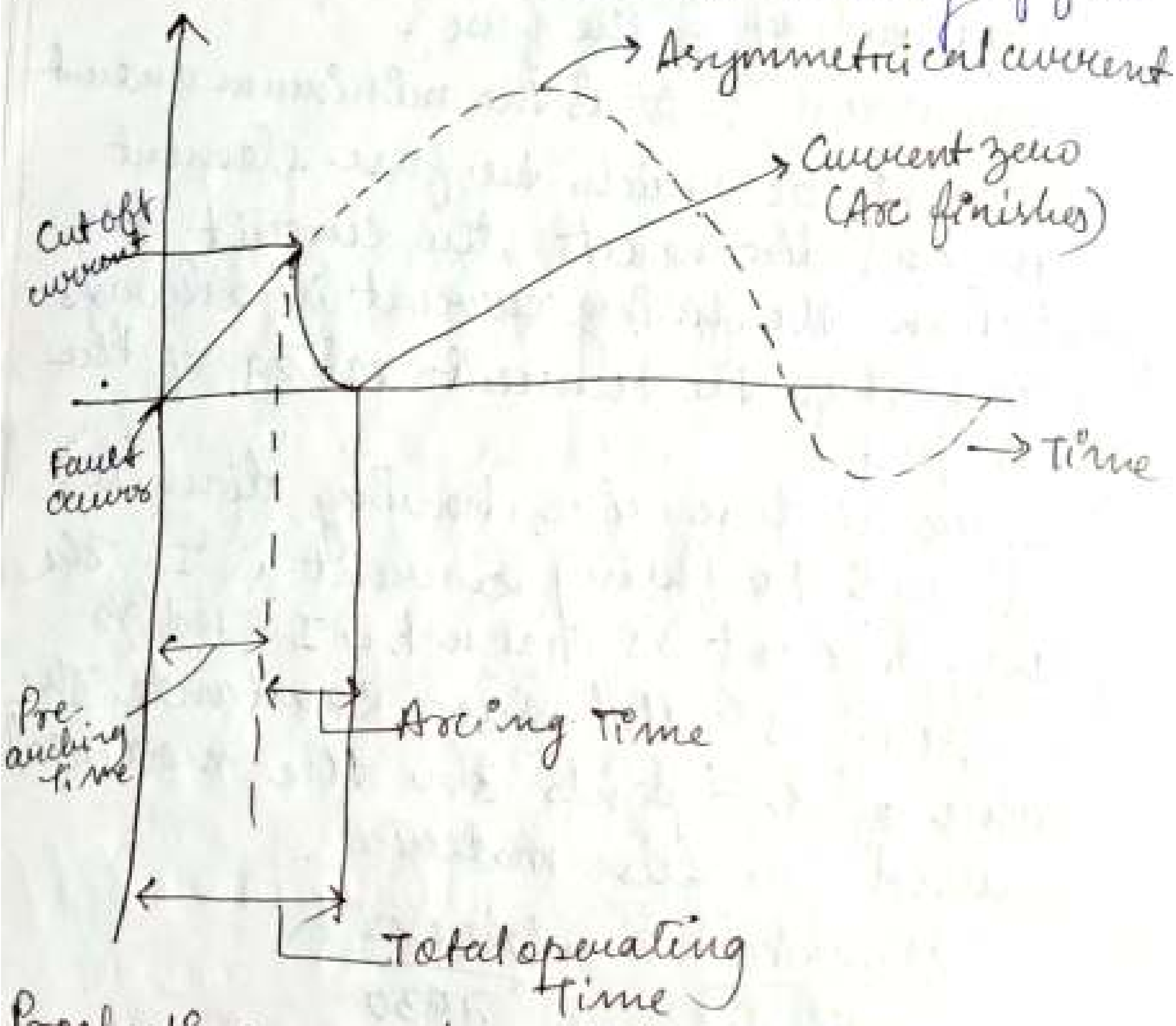
Fusing factor :- It is the ratio of min^m fusing current to the current rating of fuse element. It is given by

$$\text{Fusing factor} = \frac{\text{Min}^m \text{ fusing current}}{\text{Current rating of fuse}}$$



Prospective current :- It is the RMS value of fault current obtained in the first loop if the fuse is replaced by a conductor with negligible resistance.

Cut off current :- It is the max^m value of fault current which flows through the fuse before melting of fuse.
This current depends upon the current rating of fuse, prospective current &

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asymmetric of short ckt current.

* Prearching Time :- It is the time between the instant when fault occurs and the instant when cut off current occurs
→ The time from the start of fault to the instant of arc is called prearcing time. It is generally very small about 1 milli second.

Arcing Time :- It is the time between the instant when pre-arcing time ends & the instant when arc is finished.

Total Operating Time :- It is the summation of prearcing time & arcing time. It is generally very small i.e 2 millisecond which is less than circuit breaker.

Breaking Capacity :- It is the RMS value of ac component of max^m prospective current for which the fuse can be operated at rated voltage.

Types of fuse :-

Generally there are 2 types of fuse
1) Low voltage fuse
2) High " "

Low voltage fuse

The fuse which has less operating voltage is known as L.V.F. It is of 2 types :-
1) Semi enclosed rewirable fuse.
2) High rupturing capacity fuse (HRC)

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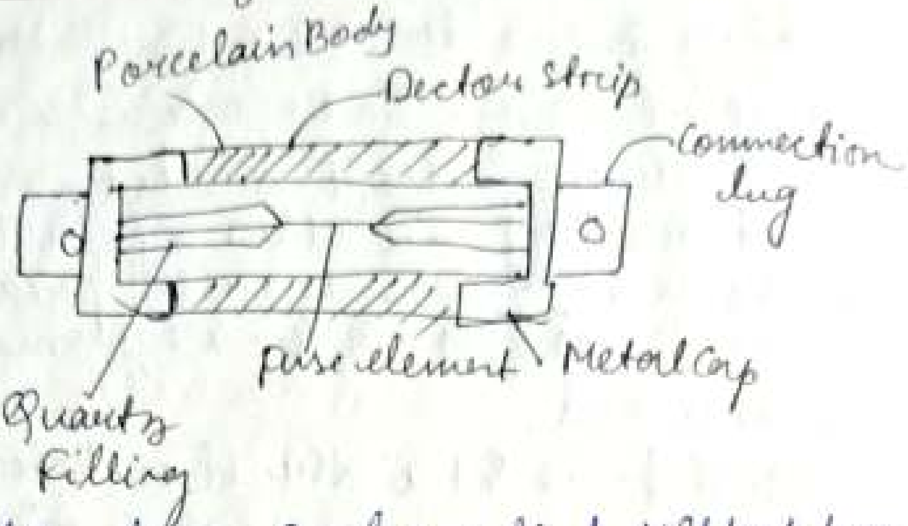
Semi-enclosed fuse



Rewirable fuse is also called Kit Kat type fuse. It is used where low value of fault current is to be interrupted.
It consists of a base and a fuse carrier. The base is made up of porcelain material and carries the fixed contacts with the incoming & outgoing phases. The fuse carrier is also made up of porcelain materials & holds the tinned copper fuse element between its terminal.
→ When fault occurs then the fuse elements is blown out & the circuit is interrupted.
→ The fuse carrier is taken out from the base & the blown out fuse element is replaced by new fuse element & then the fuse carrier is re inserted into the base.

Advantages
It protects the circuit very quickly.
The replacement of fuse is very easy
The cost of replacement is very less.

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Disadvantages

→ There is a possibility to re-insert of wrong wire as a fuse element.

→ It has low breaking capacity so it cannot be used for high fault level.

→ The fuse element can be deteriorated due to oxidation.

→ Accurate calibration of fuse element cannot be possible for the wire of the fuse element

Application :-

- Semi ~~cond~~ enclosed rewirable fuses are made upto 500A of rated current. It has low breaking capacity so these are used in domestic & lighting loads

HRC (High Rupturing Capacity) Catridge fuse:

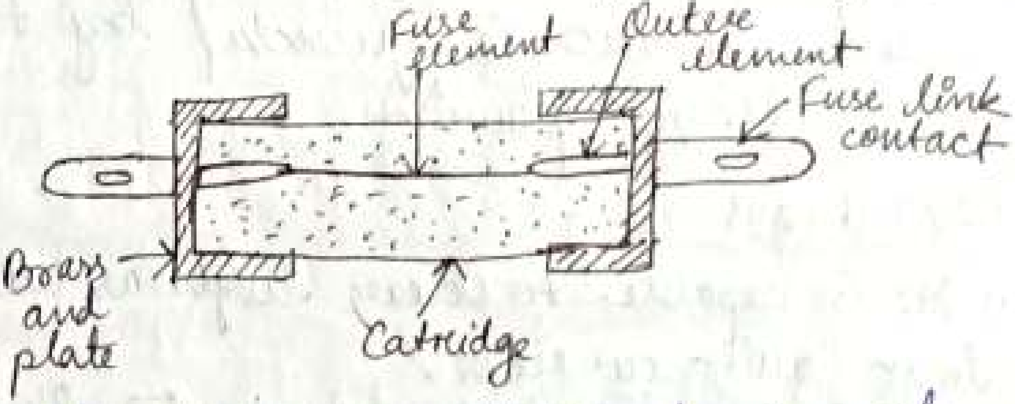

Figure shows the cross sectional view of HRC Catridge fuse. It consists of a heat resisting ceramic body having metal end caps, A silver current carrying elements is connected betn the two metal caps. This element is called fuse element. The space within the body inside the metal caps, powder is filled which is made up of chalk,

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plaster of Paris, Quartz or Marble Dust. This powder acts as an arc quenching and cooling medium. Under normal condⁿ, the normal current flows through the fuse element. So, the temperature is obtained below its melting point. When fault occurs, then the current flows through the fuse element increases. So, the temp. rises above the melting point. Therefore more heat is produced and the fuse element is melted. The chemical reacⁿ betⁿ fuse element & filling powder provides in high resistance for the current and the arc is quenched by the filling powder.

Advantages

1) It is capable to clear high as well as low fault current.
2) It donot ~~deteriorate~~ deteriorate with age.
3) It has high speed of operation.
4) It donot require maintanance.
5) It is inexpensive than other interrupting device with same rating.
6) It permit consistence performance

Disadvantages

1) It cannot be repairable.

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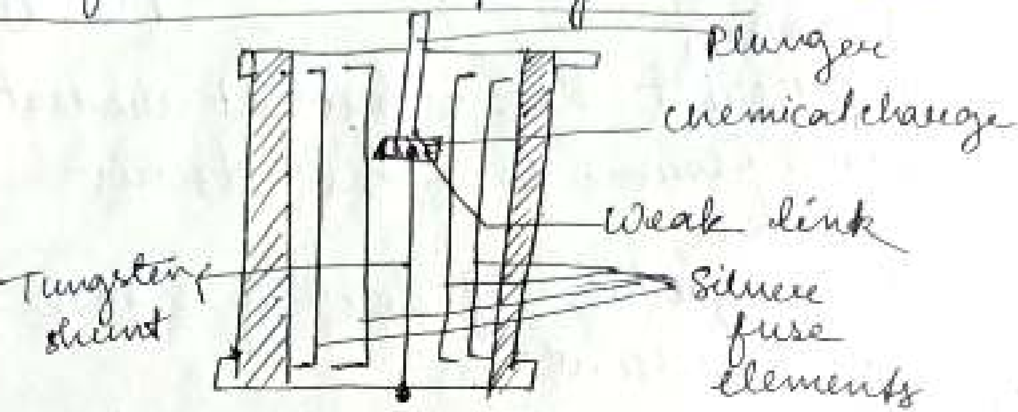
3) The heat produced by the arc may affect the associated switch.

HRC fuse with triping device :-



The figure shows the basic crossectional view of HRC fuse with tripping device. The body of the fuse is of ceramic material with two metallic cap. The triping device causes the operation of circuit breaker under a fault condition. The silver fuse elements are connected betn the metallic ends and a plunger is used to connect the circuit breaker with the fuse. When fault occurs the silver fuse element is blown out first and then the current is transferred to the tungsten wire. The weak link connected to the plunger provides an outward force for the plunger so that the circuit breaker is connected to the Tungsten wire

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Advantages.

1. It can be used in 3 phase system efficiently due to its tripping mechanism
2. It permits the short ckt current to be flown towards circuit breaker
3. It is capable of dealing small fault current.
4. It can operate by 16000A to 30,000 Ampere at 440V.

Disadvantages

1. It cannot be repairable.
2. Heat produced by the arc may affect the associated switch

High voltage Fuse

The fuse which is used for protection of device operating at high voltage is known as high voltage fuse.

It is of 3 types such as :-

1) Catridge type
2) Liquid type
3) Metal Clad fuse.

Catridge type :-

This is similar of low voltage HRC catridge type fuse. Same design is employed to the fuse element

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which is wound in the form of helics to avoid corona effects.

→ On some design there are two fuse elements connected in ||el. i.e 1 for low resistance (silver wire) & other for high resistance (Tungsten wire). Under normal cond^n, normal current flows through the fuse element, when fault occurs then the low resistance element is blown out first & the high resistive element reduces its resistance and then it breaks the ckt.

High voltage catridge fuse is used upto 33KV with breaking capacity about ~~800~~ 8700 A. The current rating of this fuse is about 200A at 6.6 KV, and 11KV, 50A at 33KV.

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