Chapter 1 // Introduction to Switch // Gear //

Dt - 11/12/19

{SGPD}

* **Switch Gear :-** The apparatus use for switching, controlling & protecting the electrical ckt & equipment is known as switch gear.

→ It is assencially consist of switching and protecting device such as switches, fuses, ckt breaker & relays etc.

→ During normal operating condⁿ switch gear permits to s/w on or off the electrical equipment.

→ In case of fault condⁿ the s/w gear detect the fault & disconnect the unhealthy section from the system.

⇒ **Essential features of switch gear :-**

The essential features of s/w gear are:-

1. Complite reliability :-

* The requirment of s/w gear is more & more important bcz of the interconnection & increasing capacity of generating station.

→ S/w gear is use to the power system for improve reliability. If the fault occured on an any part of the power system they must operate to isolate the faulte section from the normal section.

2. Apsolutely certain discrimination :-

In fault occur on any section of power system the s/w gear must be the able to discrimination betn the faulty section & the healthy section.

→ It will ensure continuety of power supply.

3. Quick Operation :-

When fault occurs of any part of the power system the s/w gear must operates quickly so that no damage is done to generator, t/f & other equipment.

→ If the fault is not clear by s/w gear quickly it is spread into healthy parts & thus complite shut - down of the system occurs.

4. Provission for manual controll :-

A s/w gear must have provision for manual control. In case the electrical (Electronics) control fails the necessary ope. can be carried out through manual control.

5. Provision for Instrument :-

There must be provision for instrument which may be required.

* Switch Gear Equipment :-

The s/w gear cover all the apparatus & equipments employed for switching, protecting, controlling the electrical power system.

→ It includes s/w, fuses, ckt breaker, isolator relay, potential t/f (PT), CT & lightning arrestor etc.

→ **Switch** :- S/w is a most simplest device to on or off the electrical ckt & equipments.
→ It is design to operate manually and can't protect to electrical system for any fault.
→ The S/ws are use for low voltage application
→ The S/w may be classified into the following catagory
(i) Air S/w
ii) Oil S/w

i(a) **Air break switch** :-
→ It is an air S/w & it is design to open a ckt under load.
→ In this S/w the special arcing horns are provided to open the S/w.
→ Arcing horns are piece of metal betn which arc is form during opening operation
→ As the S/w open this horns are spread farther and farther so the arc is interrupted. This S/w generally use out-doors.

(b) → **Isolator and disconnecting switch** :-
This S/w is design to open a ckt under no load. its main purpose is to isolate one portion of the ckt from the other.
→ This S/ws are generally use on bothe side of ckt breaker in order to repaire & replacement of ckt breaker.

ii) **Oil switch** :- The contacts of this S/ws are open under oil i.e. t/b oil.

→ This switches are used for ckt of HV & large current carrying capacity.

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* **Fuse :-** (fault condition)

→ A fuse is a short piece of wire is melts when excessive current flow through it.

→ It is inserted in series with the ckt.

→ Under normal operating condition the fuse element is at a temperature below its melting point, so it carries normal load current without over heating.

→ When a short ckt overload occur the current through the fuse element is increase, this rises the temperature & the fuse element melts

* **Circuit breaker :-**

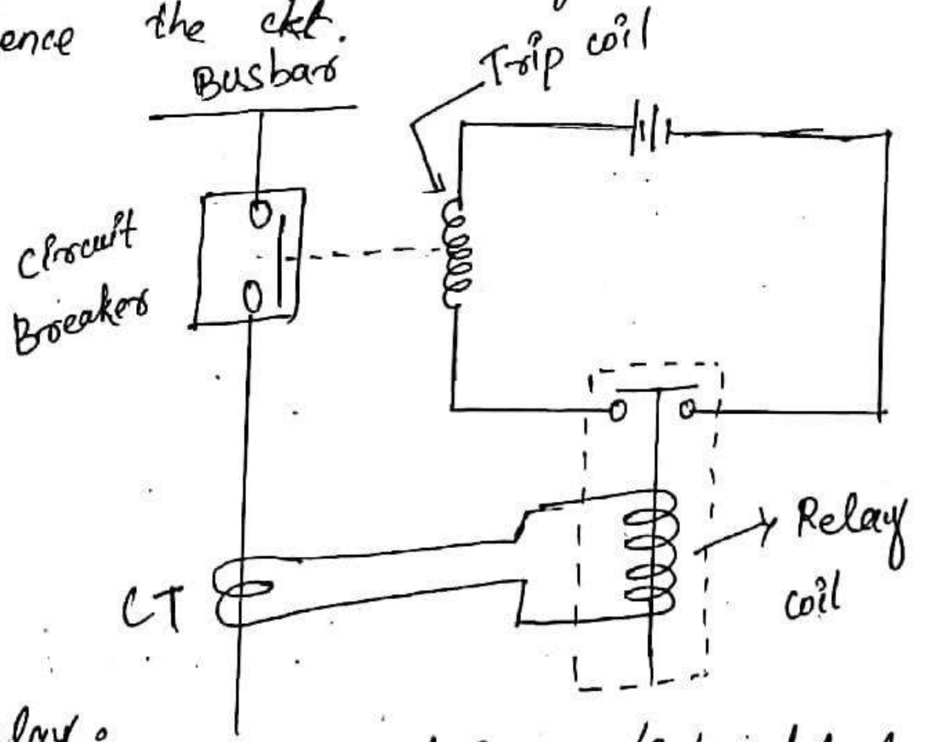
→ A ckt breaker is an equipment which can open or close a ckt under all condition that is $\underbrace{\text{no load, full load}}_{\text{Normal}}$ & fault (auto) condition.

→ It is design to operate manually under normal condition & auto-matically under fault condition.

→ The circuit breaker consist of 2 types of contact ;
⟨1⟩ Moving contact
⟨2⟩ Fixed contact

→ Under normal operation condⁿ the contact of ∧ C.B. remain closed and it carries the normal full load current, in this case the EMF of the secondary wind of the CT is in-sufficient to operate the trip coil of the breaker.

→ When a fault occur over current in the CT primary wind increase the emf in the secondary wind these energies the trip coil of the breaker & the moving contact are pulled down thus the opening of contact & hence the ckt.



* Relay :-

A relay is device which detect the fault & supply information to the Ckt breaker. for ckt introuption.

→ It can be devided into 3 parts ;

i) The primary cond of the CT which is connected in series. with the ckt.

ii) The second ckt & the secondarycond of the CT which is connᶜ to the relay operating coil

iii) The 3rd ckt is the tripping ckt which consist of a source to supply the trip coil.

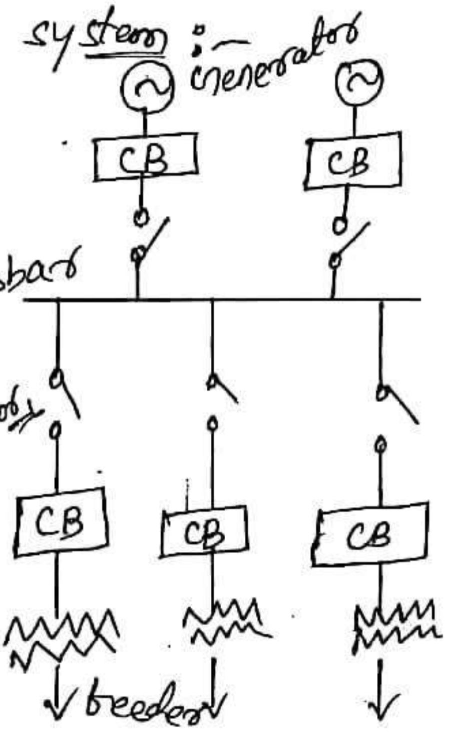
* Busbar Arrangement :-

When a no. of generator or feeders operating at a same voltage and directly conn^c electrically, busbars are used as the common electrical component.

→ The busbars are copper rods or thin tubes which are operated at constant voltage.

→ There are some imp. busbar arrangement used in power station, these are :-

i) Single busbar system :-



→ The single busbar system has the simplest design.

→ and is use ~~for~~ the power station.

→ It is also used in small outdoor station having few no. of out going & incoming feeders & generators.

→ Here the generators, out-going lines and t/f are connected to the single busbar.

→ Each generator & feeder is controlled by a ckt breakers. The Esalator permits to isolate the generator & feeder & ckt breakers from the busbar for maintainance.

⇒ Advantage :-

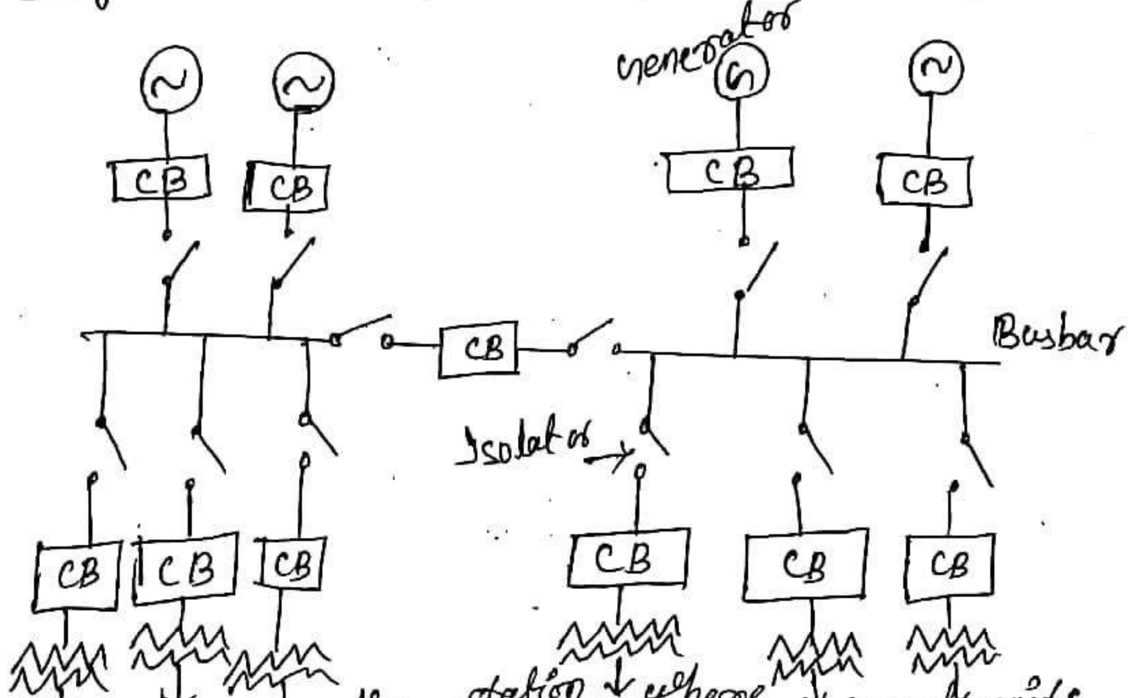
→ This type of arrangements are low initial cost, less maintaince & simple operation.

⇒ Disadvantage :-

→ The busbar can't be clean, repaire or tested without de-energising the whole system.

→ If a fault occur in a busbar there is complite intrrruption of the supply.

ii) Single busbar system with sectionalization :-



→ In large generating station where several units are installed, the single busbar system with sectionalization bus is used, so that the fault on any section of the busbar ~~dewl~~ will not cause complite short down.

→ Here the busbar devided into 2 section & connc by a ckt breaker & Isolator.

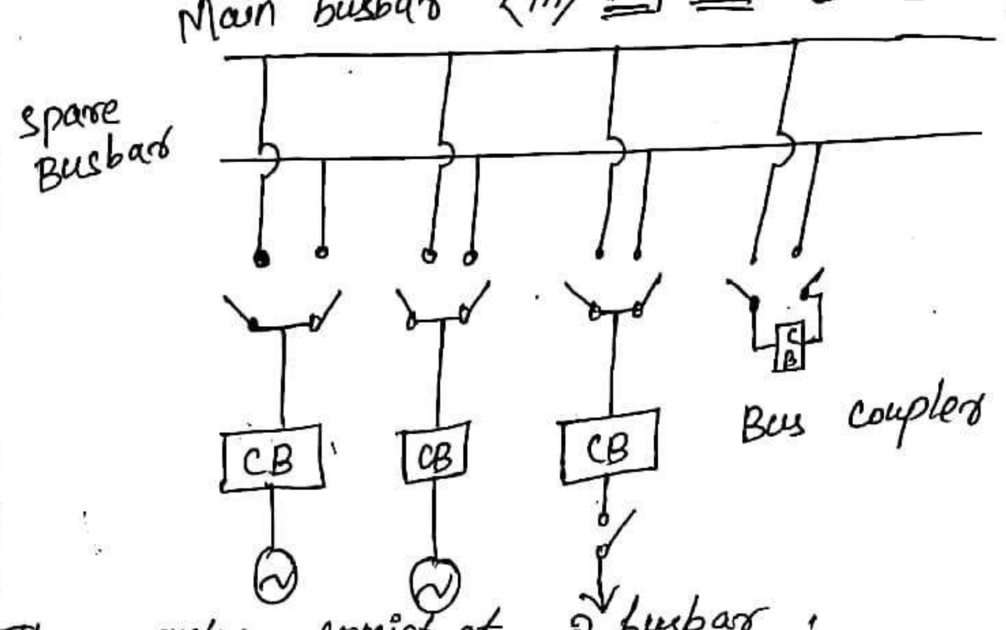
* Advantage :-

i) If a fault occur on any section of the busbar that can be isolated without affecting the supply to the other section.

ii) This permits the use of CB. of lower capacity in the feeder.

iii) Repair & maintainance of any section of the busbar can be carried at by de-energized other section.

(iii) Duplicate Busbar System:



→ The system consist of 2 busbar ;
(i) Main Busbar
(ii) Spare (add) ''

→ Each generator & feeder conn to either busbar with the help of bus coupler, which is consist of CB. & isolators

→ Advantage :-

→ If repaire & maintainance to be carried on the main busbar. the supply need not be Interrupt as the entaire load can be transfered to the spare busbar.

→ The testing of feeder & CB can be done by putting them on the spare busbar.

→ If a fault occur in one busbar the continuety of the supply to the ckt can be maintaine by transferring it to the other busbar.

→ **Switch Gear Accomodation.** —
Depending upon the voltage to be handle the s/w gear may be classified into 2 type ; (a) Out-door type
(b) In-door ''

(a) **Out - door** :-

→ For the voltage beyond 66KV S/w gear
equipments are installed out-door.
→ It is because for such voltage (HV) the
clearance betn conductors & the space required
for S/w, CB, t/f & other equipment becomes
so large.

(b) **In - door type** :-
The voltage below 66KV S/w gear is
generally installed in-door.

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* **Short Circuit** :- on a n/w such
→ When ever a fault occurs in one or more
that a large current flows
phases a short ckt is to be occur.
a heavy current
→ When a short ckt occurs through the
called short ckt current flows
circuit.

* **Cause of short ckt** :- power system is the
A short ckt in a kind of abnormal condition in
result of some
the system. cause due to external or internal
→ It may be
effect.

(a) **Internal Effect** :- The internal effects are
caused by break-down of equipments or
transmission like, deterioration of insulation in
a generator, t/f etc. due to ageing of
→ Such trouble may be improper
insulation inadequite design or
installation. The external effect
(b) **External effect** :- includes insulation
causing short ckt
failure due to lightning search over-loads

of equipment and mech. damage by public.

* **Effect of short ckt :-** When a short ckt occurs the current in the system increase to an abnormal high value will the system voltage decreases to a low value.

→ The heavy current due to the short ckt causes excessive heating which may result in fire. Some times the short ckt causes damage to the system.

* **Fault in a power system :-**

→ A Fault occur when a 2 or more conductor that normally operate of a Potential difference come in contact with each other.

→ The fault in a 3ϕ systen can be classified into 2 main catagories,

(1) Symentrical fault
(2) Unsymentrical ,,

(1) **Symentrical fault :-** The fault which gives rise to the symentrical fault current (i.e. equal fault current with 120° displacement) is called symentrical fault.

→ The most common example of this system is when all the 3 conductor of the 3ϕ line are brought together symultaniously into a short ckt condition.

(2) **Un-symentrical fault :-** Which give rise to unsymentrical current (i.e. unequal line current with unequal displacement) are called Unsymentrical fault.

4. This faults are ;

(i) single line to ground fault (ii) double line to ground

(iii) Line to line fault

Ch-2 || Symmentrical Fault || Dt-13/12/19
|| Calculation ||

* Symmentrical fault :-

→ The fault which gives rise to the symmentrical fault current (i.e. equal fault current with 120° displacement) is called symmetrical fault.

→ Ex:- 3 ϕ fault.

* Limitation of fault current:-

→ Excessive heating

→ Resulting fire or explo

→ Reduction in voltage causes mis-operation of rotating a machine.

→ Power outage if generator protection system operates.

* Percentage Reactance :-

The reactance of a generator, t/f, reactor is usually expressed in percentage reactance.

→ The percentage reactance of a ckt is defined as the percentage reactance voltage drop in the ckt when the total full load current is flowing.

$$\boxed{\% x = \frac{Ix}{V} \times 100}$$

→ where, I → Full load current

V → Phase voltage

x → Reactance in ohm per phase

* Pecentage Resistance :-

The resistance of a generator, t/f, reactor is usually expressed in % resistance.

→ The % resistance of a ckt is defined as the total v valtage drop in the ckt when the resistive full load current is flowing.

$$\boxed{\%R = \frac{IR}{V} \times 100}$$

* **Percentage Impedance** :- It is the sum effect of % of resistance and % reactance.

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* **% x** :-

$$\% x = \frac{Ix}{V} \times 100$$

$$\Rightarrow x = \frac{\% x \, V}{I \times 100}$$

$$\Rightarrow x = \frac{\% x \times V \times V}{I \times 100 \times V}$$

$$\Rightarrow x = \frac{\% x \times \frac{V}{1000} \times \frac{V}{1000} \times 1000 \times 1000}{I \times 100 \times V}$$

$$\Rightarrow x = \frac{\% x \times KV \times KV \times 1000}{I \times 100 \times KV}$$

$$\boxed{\frac{V}{1000} = KV}$$

$$\Rightarrow x = \frac{\% x (KV)^2 \times \cancel{1000}^{10}}{KVA \times \cancel{100}}$$

$$\Rightarrow x = \frac{\% x \, (KV)^2 \times 10}{KVA}$$

$$\Rightarrow \boxed{\% x = \frac{x \times KVA}{10 \times (KV)^2}}$$

* **Base KVA** :-
The % x of diff'r m/c depends upon the KVA ratings.

⇒ Generally the various equipment use in th power system have diff KVA rating, therefore it is necessary to find the %x of all the elements on a common KVA rating. These common KVA rating. Is known as Base KVA.

Imp

$$\boxed{\text{The } \%x \text{ at base KVA} = \frac{\text{Base KVA}}{\text{Rated KVA}} \times \%x \text{ at rated KVA}}$$

* Short ckt KVA :-

$$\boxed{S.C.\ KVA = \text{Base KVA} \times \frac{100}{\%x}}$$

→ Short ckt current $(I_{sc}) = \frac{V}{x}$

$$\Rightarrow I_{sc} = \frac{\cancel{V} \times I \times 100}{\%x \times \cancel{V}} \qquad \left[\because x = \frac{\%x \times V}{100 I}\right]$$

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

→ We know,

Short ckt KVA $= \frac{3 V I_{sc}}{1000}$

→ Put the value of Isc & we get ;

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

$$\boxed{S.C.\ KVA = \text{Base kVA} \times \frac{100}{\%x}}$$

* Steps for symentrical fault calculation:-

→ Draw the single line diagram indicated all rated quantities.

→ Choose a convenient base KVA & convert all %x to this base value.

→ Draw the reactance diagram using the new reactance obtained & find the total %x.

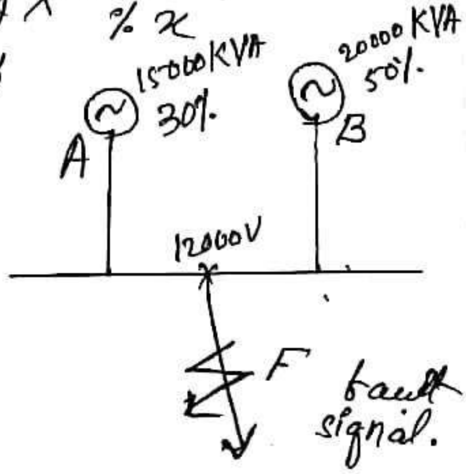
→ Find the full load current corresponding to the full load base KVA.

→ Find the Short ckt current (I_{sc}) by using the formula; $I_{sc} = \frac{I \times 100}{\% x}$

→ Find the S.C. KVA by using the formula i.e. S.C KVA = Base KVA × $\frac{100}{\% x}$

Q) The figure shows of a 3ϕ system;

Find I_{sc} that will flow into a complete 3ϕ ckt at fault (F).



* Base KVA = 20,000

→ We know,

→ for 'A':- % x of base KVA = $\frac{\text{Base KVA}}{\text{Rated KVA}} \times \% x$ at rated KVA

$= \frac{20,000}{15000} \times 30\%$

$= 40\%$

→ For 'B':-

% x of Base KVA $= \cancel{\frac{20,000}{20,000}} \times 50\%$

$= 50\%$

→ Total % x $= 50\% // 40\%$

$= \frac{50 \times 40}{50 + 40} = 22.22$

→ $I = \frac{\text{Base KVA}}{\sqrt{3} \times V}$

$\Rightarrow I = \frac{20,000 \times 10^3}{\sqrt{3} \times 12000} = 962.25$ Amp.

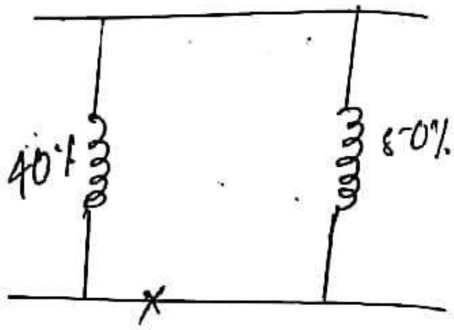
⇒ Short ckt current $(I_{sc}) = \frac{I \times 100}{x\%}$

$$\Rightarrow I_{sc} = \frac{902.25 \times 100}{22.22} = 4330.5 \text{ Amp}$$

⇒ Short ckt KVA = Base KVA $\times \frac{100}{\% x}$

$$= 20,000 \times \frac{100'}{22.22}$$

$$= 90009.00$$



19) Assume ;

Base KVA = 10,000

for 'A' Alternator

% x at base KVA = $\frac{\text{Base KVA}}{\text{Rated KVA}} \times$ % x at rated KVA

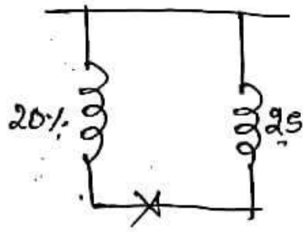
$$= \frac{2 \times \cancel{10000}}{\cancel{15000}_{3}} \times \overset{10}{\cancel{30}}\%$$

$$= 20\%$$

for 'B' Alter

% x at base KVA = $\frac{\cancel{10000}}{\cancel{20000}_{2}} \times \overset{25}{\cancel{50}}\%$

$$= 25\%$$



total % X

$$\frac{20\times25}{20+25} = \frac{500}{45} = 11.11\%$$

$$\Rightarrow I = \frac{\text{Base KVA}\times}{\sqrt{3}\times V} = \frac{10000\times10^3}{\sqrt{3}\times12\times10^3}$$

$$= 481.125$$

$$S.C\ I = \frac{I\times100}{\%X} = \frac{481.125\times100}{11.11}$$

$$= 4330.5\ \text{Amp}$$

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

$$= 10{,}000\times\frac{100}{11.11}$$

$$= 90009$$

2) A 3φ transm line operates at 10KV & having a R of 1Ω & X of 4Ω is conne to the generating station busbar through 5MVA step-up t/f, having a X of 5%. The busbars are supplied by a 10MVA altern having 10% reactance. Calculate the S.C. KVA fed to the symmetrical betn phases if it occurs (i) At the load & other transmission line.

(ii) At the high voltage terminal of the t/f.

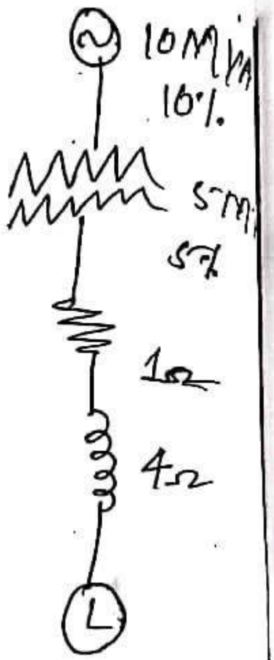
V = 10KV 5MVA = 5×10^6 VA

= 5,000,000

= 5000 KVA

10MVA = 10,000KVA

we know,



→ $\% x = \frac{X \times KVA}{10 \times (KV)^2}$

$= \frac{4 \times 10{,}000}{10 \times (10)^2}$

$= 40\%$

→ $\% R = \frac{R \times KVA}{10 \times (KV)^2}$

$= \frac{1 \times 10{,}000}{10 \times (10)^2} = 10\%$

Base KVA = 10×10^3 KVA

→ **For alternator :-**

$\% x$ at base KVA = $\frac{\text{Base KVA}}{\text{Rated KVA}} \times \% x$ at rated KVA

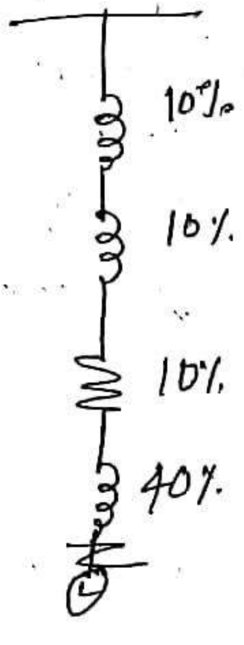
$= \frac{\cancel{10 \times 10^3}}{\cancel{10 \times 10^3}} \times 10\%$

$= 10\%$

→ **For transformer :-**

$\% x$ at base KVA = $\frac{\cancel{10}^{2} \times \cancel{10}^3}{\cancel{5} \times \cancel{10}^3} \times 5\%$

$= 10\%$



→ Total resistence ($\% R$) = 10%

→ $\% X = 10\% + 10\% + 40\%$

$= 60\%$

→ Percentage Impedance ($\% Z$) = $\sqrt{(10)^2 + (60)^2}$

$= 60.82\%$

→ Current (I) = $\frac{P}{\sqrt{3} \times V}$

$= \frac{\cancel{10} \times 10^3}{\sqrt{3} \times \cancel{10}} = 577.35$ Amp

→ Short ckt current $(I_{sc}) = \frac{I \times 100}{Z\%}$

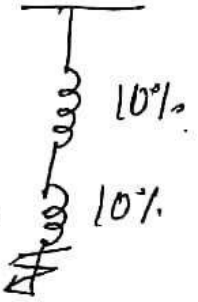
$= \frac{577.35 \times 100}{60.82}$

$= 949.276$ Amp

→ Short ckt KVA $=$ Base KVA $\times \frac{100}{\% Z}$

$= 10,000 \times \frac{100}{60.82}$

$= 16441.9$



ii) $\% X$ total $= 10\% + 10\% = 20\%$.

→ $I_{sc} = \frac{I \times 100}{X\%}$

$= \frac{577.35 \times 100}{20}$

$= 2886.75$ Amp

→ S.C. KVA $= 10,000 \times \frac{100}{\% X}$

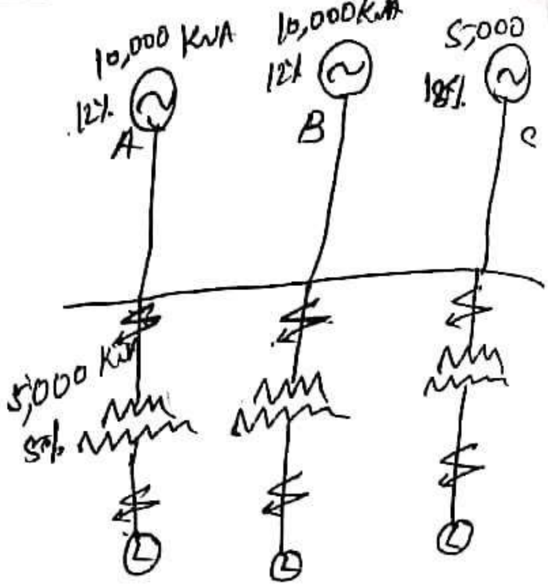
$= 10,000 \times \frac{100}{20}$

$= 50,000$

3) A plant capacity of a 3ϕ generating station
consist of two 10,000 KVA generators of
reactance 12% each & one 5,000KVA generator
of reactance 18%. The generators are conn^c to
the station busbar from which load is
taken through three 5,000KVA step up tfs
each having X of 5%. Determine the
max^m fault MVA which the CB
(i) low voltage side
ii) High voltage " of the tfs

V = 11 KV

Base KVA = 10,000



→ For 'A' alternator;

⇒ % x at Base kVA =

$$\frac{\cancel{10,000}}{\cancel{10,000}} \times 12\%$$

$= 12\%$

→ For 'B' alternator;

$\% x$ at Base KVA $= \frac{\cancel{10,000}}{\cancel{10,000}} \times 12\% = 12\%.$

→ For 'C' alternator;

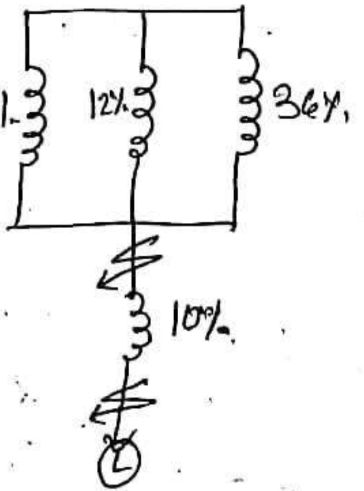
$\% x$ at Base KVA $= \frac{\overset{2}{\cancel{10,000}}}{\underset{1}{\cancel{5,000}}} \times 18\% = 36\%.$

→ For transformer;

$\% x$ at Base KVA $= \frac{\overset{2}{\cancel{10,000}}}{\underset{1}{\cancel{5,000}}} \times 5\% = 10\%$

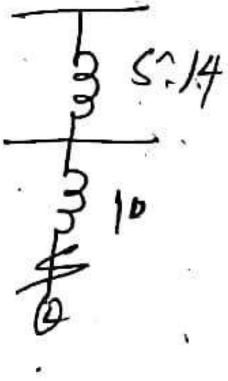
12%||12%||36%.

$$\frac{12 \times 12}{12+12} = \frac{144}{24} = 6\%.$$



→ Total reactance $\frac{6 \times 36}{6+36} = \frac{216}{42} = 5.14\%.$

→ Total reactance → 5.14 + 10 = 15.14



→ For low voltage side

→ $I = \frac{10,000 \times \cancel{10^3}}{\sqrt{3} \times 11 \times \cancel{10^3}} = 524.86$

→ $I_{sc} = \frac{524.86 \times 100}{15.14} = 3466.7$ Amp

→ S.C. KVA $= 10,000 \times \frac{100}{15.14}$

$= 66050.19$ KVA

→ For low voltage side → $\frac{10,000 \times 100}{5.14}$

$= 194552.52$

$= 194.5$ MVA

→ For high voltag side $= 66.05$ MVA

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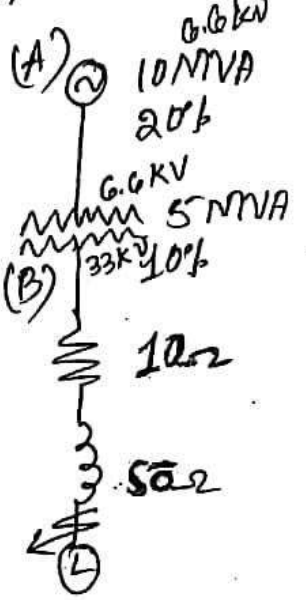
Q1

A 10MVA, 6.6KV 3ϕ Y-conn^c alternator having X of 20% is conn^c through a 5MVA 6.6KV/33KV t/f of 10% X to a transmission line having a R & X of per conductor per km of 0.2Ω & 1Ω respectively. A 50KM along the line, a S.C. occurs betn the 3 conductors, find the S.C. current.



For total 50KM ⇒ $0.2 \times 50 = 10\Omega = R$

$X = 1 \times 50 = 50\Omega$

→ For alternator,

10MVA = 10,000KVA

→ For t/f,

5MVA = 5,000KVA

→ Assume, Base kVA = 10,000KVA

(A) % x at Base KVA $= \frac{10,000}{10,000} \times 20\% = 20\%$

(B) % x at Base kVA $= \frac{\cancel{10,000}^{2}}{\cancel{5,000}_{1}} \times 10\% = 20\%$

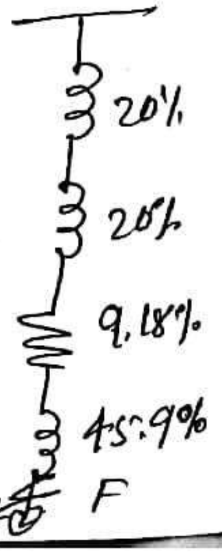
→ We know,

→ $\%x = \frac{X \times KVA \text{ at Base}}{10 \times (KV)^2}$

$\%x = \frac{50 \times 10,000}{10 \times (33)^2} = 45.9\%$

→ $R\% = \frac{R \times KVA}{10 \times (kV)^2} = \frac{10 \times 10,000}{10 \times 33^2}$

$= 9.18\%$



$\% \, x_{total} = 20 + 20 + 45.9 = 85.9$

→ $\% \, Z = \sqrt{(R)^2 + (X)^2}$

$= \sqrt{(9.18)^2 + (85.9)^2}$

$= 86.369\% = 86.37\%$

→ current $(I) = \dfrac{P}{\sqrt{3} \times V}$

$= \dfrac{10,000}{\sqrt{3} \times 6.6} = 874.77 \, A$

→ Short ckt current $(I_{sc}) = \dfrac{I \times 100}{Z\%}$

→ $I_{sc} = \dfrac{874.77 \times 100}{86.37\%} = 1012.69A$

→ Short ckt KVA = Base KVA $\times \dfrac{100}{\% Z}$

$= 10,000 \times \dfrac{100}{86.37\%}$

$= 11578.1$ KVA

$= 11.578$ MVA

* **Reactor control of I_{sc} :-**

→ The I_{sc} can be limited by increasing the total system impedance, but practically a power system has large reactance as compare to its resistance so, generally addition of reactance are prefered over addition of resistance.

→ The reactors which are used for limiting the I_{sc} of a power system are known as current limiting reactor or series reactor.

→

* Advantage :—

→ The reactor limits the flow of S.C current (Isc) & thus protect the equipment from over heating as well as from failure.

→ There are permits the installation of ckt breakers of lower rating.

* Disadvantage :—

→ Additional %x increase the total X or Z of the system.

→ This increase the reactive voltage drop which decrease the P.F. (cosϕ).

→ The voltage regulation is also poor (less).

→ For this reason the reactors are generally used in large interconnected system, but not preferable for small system.

* Location of Reactor :—

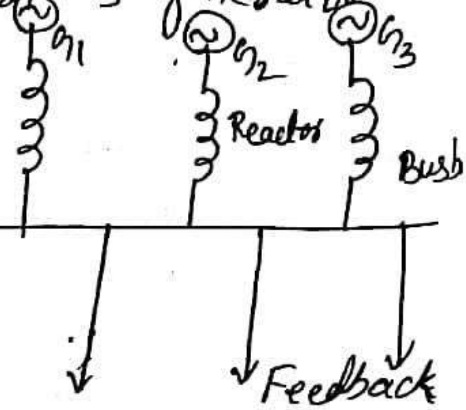
The Isc limiting reactor may be connc in series with :—

1. Generators
2. Feeder
3. Busbar (Generator & feeder common point)

* Generator Reactor :—

When the reactors are connc in series with each generators they are known as generator reactor.

→ Here the X of reactor are considered to be a part of % X of the generator.



→ It protect a generator against I_{sc} in case of fault.

⇒ **Advantage** :- → It is simple.

⇒ **Disadvantage** :-

→ There is a constant voltag drop & power loss in the reactor during normal operation.

→ If a busbar or feeder fault occurs closed to the busbar, the voltage at the busbar will be reduce to a low value there by causing the generator to fall out of step.

→ If a fault occurs on any feeder the continuity of power supply is to be effected.

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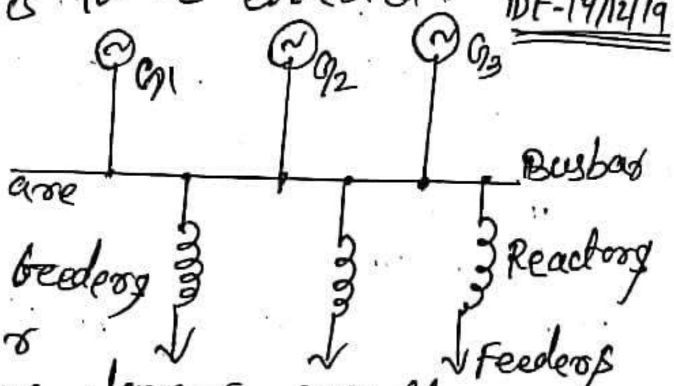
* Feeder Reactor :-



→ When the reactors are conn^c in series with feeders are known as feeder reactor. In this case larger capacity reactor or more no. of reactors are used as most of the short ckt occurs on feeders.

⇒ **Advantage** :-

→ If a fault occur on any feeder the voltage drop in its reactor will not effect the busbar voltage.

→ The fault on any feeder will not effect other feeders.

⇒ **Disadvantage** :-

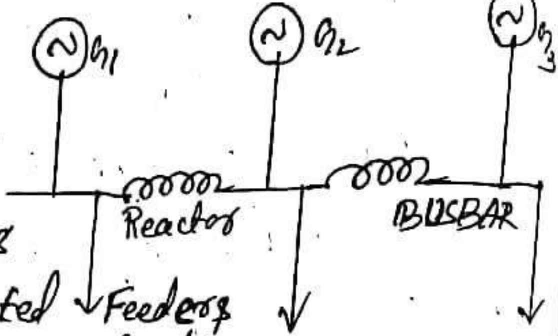
→ There is a constant voltage drop & power loss in the reactor during normal operation.

→ If a S.C. occurs at busbar no protection is provided to the generator.

→ If the no. of generator is increase the size of feeder reactor will have to be increase to keep the s.c. current (I_{sc}) with in the rating of the feeders.

*** Busbar Reactor :-** (1) Ring system
→ It is 2 types :- (2) Tiebar system

1) Ring System :-



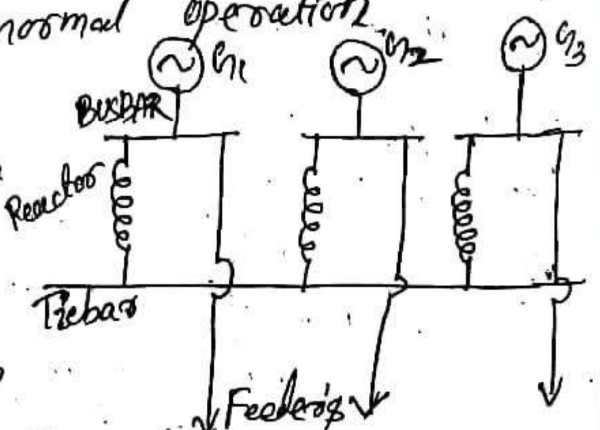
→ In this system busbar is devided into no. of sections & these sections are connected through reactor as shown in fig..

→ Generally one feeder is fed from one generator only.

→ Under normal operating condⁿ each generator will supply its own section of the load, this result in low power loss & voltage drop in the reactor.

→ **Advantage :-**
→ If a fault occurs on any feeder, only one generator feeds the fault current while the current which feeds the fault from other generator is small due to the presents of reactor. Therefore only that section of the busbar is effected & the other section will able to continue in normal operation.

(2) Tiebar System :-



→ In this system two reactors are connᶜ in series with in the individual bus section

→ The outgoing feeders are taken

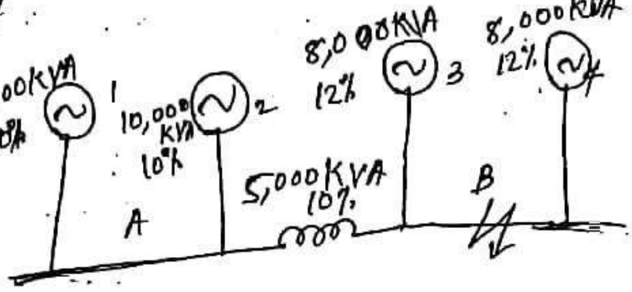
from reactor side of generating units & the reactors are connc in betn individual bus section & it common tiebar system.

* Advantage:-

→ The system has advantage of using smaller capacitive reactor.

* Disadvantage:-

→ This system is required additional busbar i.e tiebar.



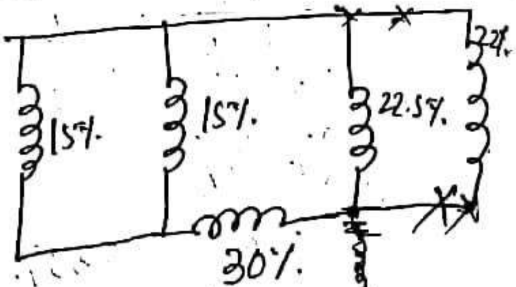
Q) The section busbar A & B are linked by a busbar reactor rated at 5000KVA with 10% reactance. On busbar A there are 2 generator each of 10,000 KVA with 10% react and on be 2 generator each of 8,000KVA with 12% x, find the steady MVA (S.C.) fed into a dead s.c. betn all phase on B with busbar reactor in the ckt.

Assume; Base KVA = 15,000 KVA

→ % x at Base KVA (A) = $\frac{\cancel{15,000}^{3}}{\cancel{10,000}_{2}} \times \cancel{10}^{5}\% = 15\%$

→ % x at Base KVA (B) = $\frac{15,000}{8000} \times 12\% = 22.5\%$

→ % x at base KVA (Reactor) = $\frac{\cancel{15,000}^{3}}{\cancel{5,000}_{1}} \times 10\% = 30\%$



(15 // 15)

$\frac{15 \times 15}{15 + 15} = 7.5$

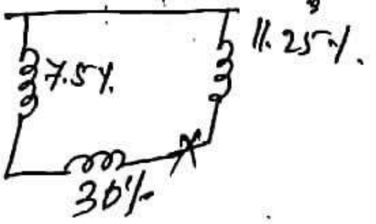
(22.5 × 22.5)

$\frac{22.5 \times 22.5}{22.5 + 22.5} = 11.25$

$30 + 7.5 = 37.5\%$

37.5 // 11.25

$\frac{37.5 \times 11.25}{37.5 + 11.25} = 8.65\%$



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

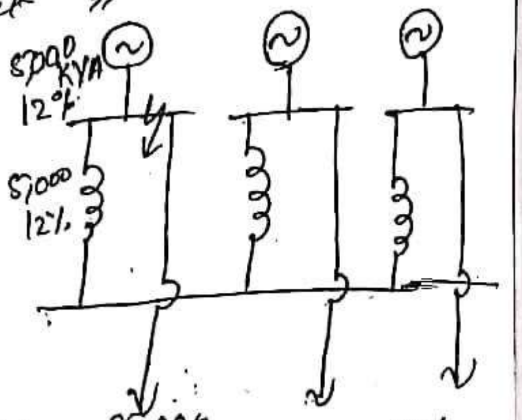
$$= 15,000 \times \frac{100}{8.65} = 173410.4\ KVA$$

$$= 173.41\ MVA$$

Q6) A generating station has 3 section busbar conn with a tiebar through 6% reactors rated at 5,000 KVA. Each generator is 5,000 KVA with 12% reactance. Find the total S.C. MVA when a S.C. occurs betn the lines on one of the section of the busbar (1) With reactor
(2) Without "

→ Assume;

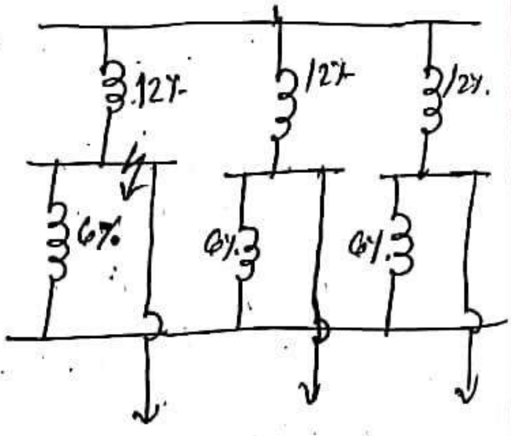
Base KVA = 5,000



→ % x for generator at Base KVA $= \frac{5,000}{5,000} \times 12\%$

$= 12\%$

→ % x at reactance base KVA $= \frac{5,000}{5,000} \times 6\% = 6\%$



12+6

= 18 %

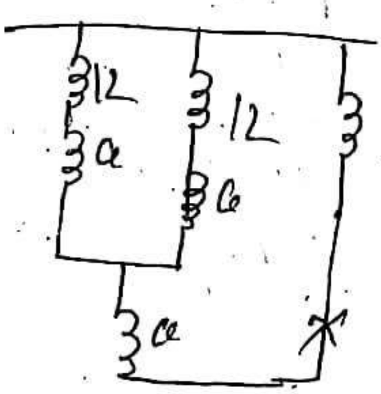
18 ∥ 18

$= \frac{18 \times 18}{18+18} = 9\%$

9 + 6 = 15%

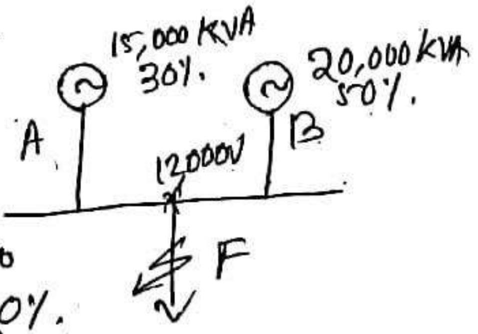
∴ 15% ∥ 12%

$\frac{15 \times 12}{15+12} = 6.66\%$



$$S.C \text{ at Base KVA} = \frac{5,000 \times 100}{6.66} = 75075 \text{ KVA} = 75 \text{ MVA}$$

—o—



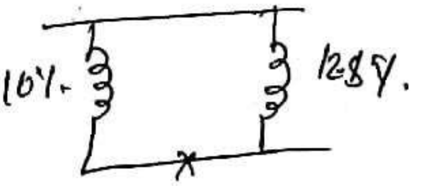
Q1) Assume,

→ Base KVA = 5,000 KVA

$$\rightarrow \% x \text{ at Base kVA (for A)} = \frac{\cancel{5,000}^{1}}{\cancel{15,000}_{3}} \times \cancel{30}^{10}\% = 10\%.$$

$$\rightarrow \% x \text{ at Base KVA (for B)} = \frac{\cancel{5,000}}{\cancel{20,000}_{4}} \times 50\% = 12.5\%$$

10% // 12.5%



$$\frac{10 \times 12.5}{10+12.5} = 5.55\%$$

$$\rightarrow I = \frac{\text{Base KVA}}{\sqrt{3} \times V} = \frac{5,000 \times 10^3}{\sqrt{3} \times 12000} = 240.56 \text{ Amp}$$

$$\rightarrow I_{sc} = \frac{I \times 100}{x\%} = \frac{240.56 \times 100}{5.55} = 4334 \text{ Amp}$$

$$\rightarrow \text{Short ckt KVA} = \frac{\text{Base kVA} \times 100}{x\%}$$

$$= 5,000 \times \frac{100}{5.55} = 90090.$$

Q2) Assume, Base KVA = 15,000 KVA

10MVA = 10,000 KVA

5MVA = 5,000 MVA

$$\rightarrow \% x \text{ at generator} = \frac{\cancel{15,000}^{3}}{\cancel{10,000}_{2}} \times \cancel{10}^{5}\% = 15\%.$$

$$\rightarrow \% x \text{ at t/f} = \frac{\cancel{15,000}^{3}}{\cancel{5,000}} \times 5\% = 15\%.$$

$$\rightarrow \% x = \frac{KVA \times x}{10 \times (kV)^2} = \frac{15,000 \times 4}{10 \times (10)^2} = 60\%$$

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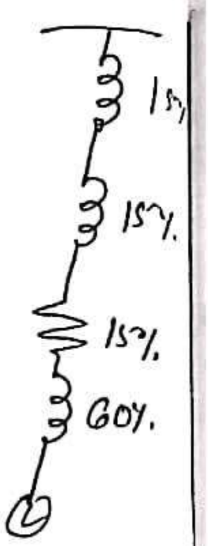
→ $\%R = \frac{R \times KVA}{10 \times (KV)^2} = \frac{1 \times 15000}{10 \times (10)^2} = 15\%$



→ Total $\%x = 60+15+15 = 90\%$

→ $\%Z = \sqrt{(\%R)^2+(\%x)^2}$

$= \sqrt{(90)^2+(15)^2} = 91.24\%$

→ $I = \frac{\text{Base kVA}}{\sqrt{3} \times V} = \frac{15,000 \times 10^3}{\sqrt{3} \times 10 \times 10^3}$

→ $= 866 \text{ Amp}$

$I_{sc} = \frac{I \times 100}{Z\%} = \frac{866 \times 100}{91.24} = 949.14 \text{ Amp}$

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

$= 15,00 \times \frac{100}{91.24} = 16440 \text{ KVA}$

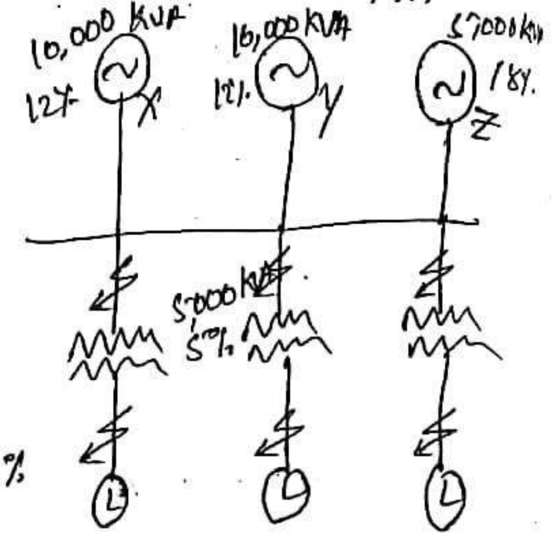
$= 16.44 \text{ MVA}$

Q3)

→ $V = 11kV$,

→ Assume,

Base kVA = 5,000 KVA



→ % x at Base kVA for X

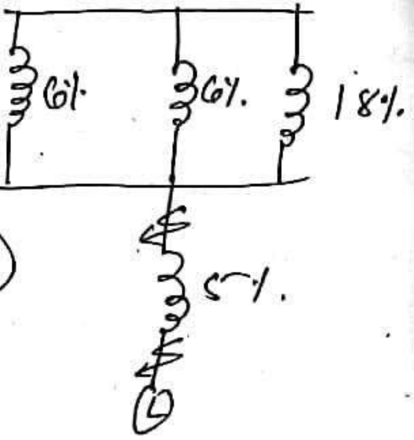
generator $= \frac{\cancel{5,000}}{\cancel{10,000}_{2}} \times \overset{6}{\cancel{12}}\% = 6\%$

→ % x for Y generator $= \frac{5,000}{10,000} \times 12\% = 6\%$

→ % x for Z generator $= \frac{5,000}{5,000} \times 18\% = 18\%$

→ % x at Base kVA (for t/f) $= \frac{5,000}{5,000} \times 5\% = 5\%$

$6\% \parallel 6\% \parallel 18\%$



$$= \frac{6\times6}{6+6} = 3\%$$

$$\frac{3\times18}{3+18} = 2.57\%$$ (for low voltage side)

→ for high voltage side = 2.57+5
= 7.57%

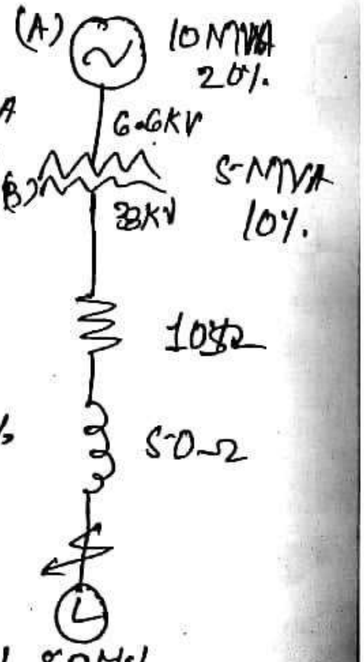
→ $I = \frac{5{,}000\times\cancel{10^3}}{\sqrt{3}\times11\times\cancel{10^3}} = 262.43$ Amp

→ $I_{sc} = \frac{I\times100}{\%x} = \frac{262.43\times106}{7.57} = 3466.7$

→ Short ckt KVA = $5{,}000\times\frac{100}{7.57}$ = 66050.19 KVA
(for high voltag side) = 66.05 MVA

→ $I_{sc} = \frac{262.43\times100}{2.57} = 10211.28$ AMP

→ Short ckt KVA = $5{,}000\times\frac{100}{2.57}$ = 194552.5 KVA
(for lower voltage side) = 194.55 MVA.



Q4) $0.2\times50 = 10\Omega = R$, 10MVA = 10,000 KVA
$1\times50 = 50\Omega = X$, 5MVA = 5,000KVA

→ Assume, Base KVA = 20,000KVA

→ %x at Base kVA = $\frac{\cancel{20{,}000}^{2}}{\cancel{10{,}000}_{1}}\times20\% = 40\%$
(for A)

→ %x for B = $\frac{\cancel{20{,}000}^{4}}{\cancel{5{,}000}_{1}} = 10\% = 40\%$

→ $\%x = \frac{X\times KVA}{10\times(KV)^2} = \frac{50\times20{,}000}{10\times(33^2} = 91.827\%$

→ $\%R = \frac{10\times20{,}000}{10\times(33)^2} = 18.36\%$

→ Total $\% x = 40 + 40 + 91.82 = 171.82\%$

→ $\% Z = \sqrt{(171.82)^2 + (18.36)^2} = 172.79\%$

→ $I = \frac{20,000 \times \cancel{10^3}}{\sqrt{3} \times 6.6 \times \cancel{10^3}} = 1749.54$ Amp.

→ $I_{sc} = \frac{I \times 100}{\% Z} = \frac{1749.54 \times 100}{172.79} = 1012.5$ Amp.

→ S.C. kVA $= 20,000 \times \frac{100\cancel{.85}}{172.79} = 11574.7$ KVA

$= 11.57$ MVA

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Q) A 3ϕ 20MVA, 10KV alternator has internal reactance of 5% & neglizible resistance, find the external x per ph. to be connc in series with the alternator, so the s.c current (I_{sc}) does not exceeds 8 times the full load current.

→ $I_{sc} = 8 \times$ full load current (I)   20MVA = 20,000 KVA

→ $I = \dfrac{20{,}000 \times 10^3}{\sqrt{3} \times 10 \times 10^3} = 1154.7$ Amp

→ $I_{sc} = 1154.7 \times 8 = 9237.6$ Amp

$$\boxed{\begin{aligned} I_{sc} &= I \times 8 \\ \Rightarrow \frac{I}{I_{sc}} &= \frac{1}{8} \\ \Rightarrow \frac{I_{sc}}{I} &= 8 \end{aligned}}$$

→ We know, $I_{sc} = \dfrac{I \times 100}{\%\, x}$

$\Rightarrow \%\, x = \dfrac{I \times 100}{I_{sc}} = \dfrac{1154.7 \times 100}{9234.6} = 12.5\%$

→ External Reactance $= 12.5\% - 5\% = 7.5\%$

→ $x\% = \dfrac{x \times KVA}{10 \times (KV)^2} \Rightarrow x = \dfrac{\%\, x \times (KV)^2 \times 10}{KVA} = 0.375$

(or)

→ We know,

$\%\, x = \dfrac{I X}{V_{ph}} \times 100$ $V_{ph} = \dfrac{10 \times 10^3}{\sqrt{3}} = 5773.5$

$\Rightarrow x = \dfrac{\%\, x \times V}{I \times 100} = \dfrac{7.5 \times 5773.5}{1154.7 \times 100} = 0.375\,\Omega$

Q) A 3ϕ 30MVA, 33KV alternator has internal x of 5% and neglizible reactance. Find the external, per phase to be connc in series alternator so the steady state current on short ckt does not exceed 10 times of the full load current.

$V = 33KV$ $I_{sc} = 10 \times$ full load current

Let, Base KVA = 15,000 KVA

$$30\,MVA = 30,000\,KVA$$

$$I = \frac{30,000 \times \cancel{10^3}}{33 \times \sqrt{3} \times \cancel{10^3}} = 5248.63 \text{ Amp}$$

$$I_{sc} = 10 \times 5248.63 = 52486.3 \text{ Amp}$$

$\Rightarrow$ We know,

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

$$\Rightarrow \%\, x = \frac{I \times 100}{I_{sc}} = \frac{5248.63}{52486.3} \times 100 = \frac{1}{1\cancel{0}} \times 1\cancel{0}0$$

$$= 10\%$$

$\Rightarrow$ External Reactance = 10 − 5 = 5%.

$$\Rightarrow \%\, x = \frac{I x}{V} \times 100$$

$$\Rightarrow x = \frac{\%\, x \times V_{ph}}{I \times 100}$$

$$\Rightarrow x = \frac{5 \times \frac{33,000}{\sqrt{3}}}{5248.63 \times 100} = 0.181\,\Omega$$

ch-3

FUSE

Dt- 03/01/2020

→ A fuse is a short piece of metal in-serted in the ckt which melts when excessive current flows through it and those break the ckt.

→ Principle of fuse :-

The fuse material generally made up on the material which having low melting point high conductivity & least deterioration due to oxidation.

→ Ex:- Silver, copper etc.

→ It is inserted in series with the ckt to be protected.

→ Under normal operating cond^n the fuse element is at temp. below its melting point.

→ Therefore it carries the normal current without over heating.

→ When a short ckt or over-loaded occurs the current through the fuse increase beyond its rated value.

→ They rises the temp. of fuse element & the fuse element melts disconn^c the ckt, which is protected by it.

→ In this the fuse protect the device, m/c equipment from damage due to the excessive current.

⇒ Advantage :-

→ It is the cheapest ~~form~~ of protection.

→ It req^r no maintainance.

→ It can break having short ckt current without noise or smoke.

→ Minimum time of operation can be made much shorted them the ckt breaker.

- It is operation is completely auto-matic unlike a ckt breaker which required an elaborate equipment for automatic action

Disadvantage:-

- Considirable time is lossed in re-wiring or replacing a fuse after operation.
- On heavy short ckt discrimination betn fuse is series can't be obtain unless their is sufficient diffr in the sizes of the fuse.
- The current time charactarstic of a fuse can't be always corredated protected equipment.

***Desirable characterstic of fuse element :-**

- The func of a fuse is to carry the normal current without over heating but when the current exceeds its normal value it rapidly heats up of to melting points & disconnd the ckt protected by it.
- In order to perform this func the fuse element should have following desirable characteristics.

1. Low melting point. Ex:- tin & lead.
2. High conducting copper & silver. oxidization.
3. Free from detoriation due to oxidation.
   Ex:- Silver
4. low cost. Ex:- lead, tin, copper.

*** Fuse Element Material :-**

- The most commonly used material ~~for~~ fuse element are lead, tin, copper, zinc & silver.
- For small current up to 10 amp, tin or

an alloy of leads & tin.

[lead = 37% & tin = 63%] is used for making the fuse element.

+ For larger current copper or silver is used.

* Important terms :- Dt - 09/01/2020

The following terms are much used in the analysis of fuse;

i) current rating of fuse element :-

→ It is the current which the fuse element can normally carry without over heating or melting.

+ It depends upon the temp. rise of the contacts of fuse holder, fuse material & surrounding of the fuse.

ii) Fusing current :- It is minimum current at which the fuse element melts & thus disconn the ckt protected by it.

+ Its value will be more than the current rating of the fuse element.

→ The approximate relation betn fusing current 'I' & diameter 'd' of a wire is $\boxed{I = Kd^{3/2}}$

+ The fusing current depends upon the various factor such as;

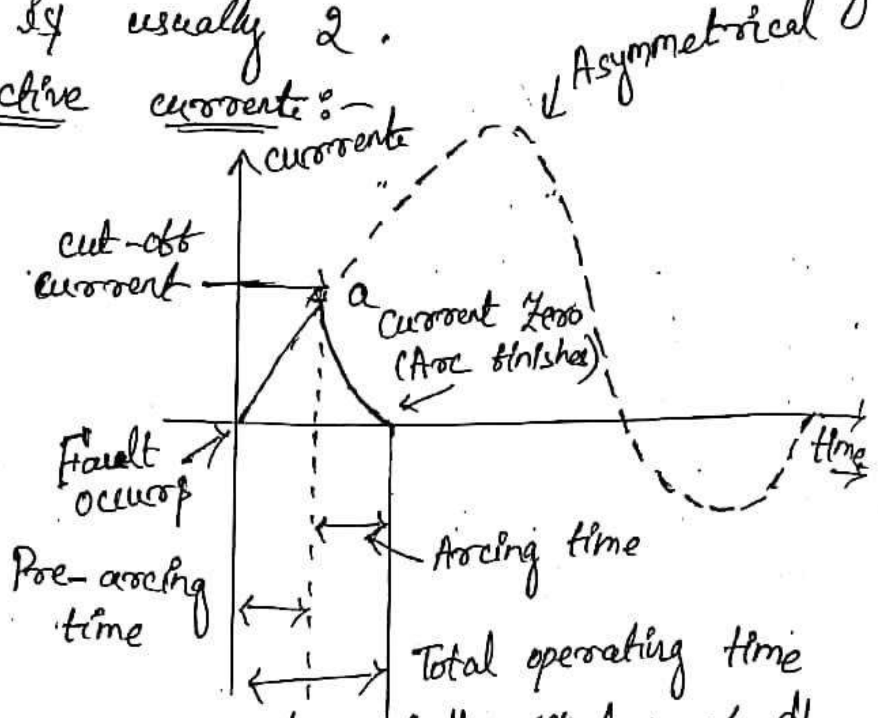
a) Material of fuse element.
b) Length
c) Diameter
d) Size & location of terminal
e) Types of enclosure.

iii) Fusing factor :- It is the ratio of minm fusing current to the current rating of fuse.

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

→ Its value is always more than one.
→ For cu. wire as the fuse element the fusing factor is usually 2.

v) Prospective current :-



→ It is the RMS value of the 1st loop of the fault current obtained if the fuse is replaced by an ordinary conductor of negligible R.

vi) Cut-off current :- It is a maxm value of the fault current actually reach before the fuse melt. It depends upon current rating of fuse & the value of prospective current.

vii) Pre-arcing time :-
It is the time betn the commencement of fault & the instant where the cut-off occurs. A typical value of prearcing time is 0.001 sec.

viii) Arcing time :- This is the time betn the end of pre-arcing time & the instant when the arc is extinguished.

ix) Total operating time :- It is the sum of pre-arcing time & arcing time. It may be noted that the ope. time of fuse is generally quite low i.e approximately 0.002 sec.

* Types of Fuse :- Fuse is the simple current interrupting. device ~~to~~ for protection against excessive current. In general it may classified into 2 types.

i) Low voltage fuse
ii) High " "

i) Low voltage fuse :-

(a) Semi - closed rewirable fuse.
(b) High repturing capacity cartridge fuse (HRC)

a) Semi-closed rewirable fuse :-

→ The rewirable fuse also known as type.

→ These are used where low value of fuse current are to be interrupted.

→ It consist of a base & a fuse carrier.

→ The base is of percelain & carries the fixed contact to which the incoming & outgoing of phase wires are connected.

→ The fuse carrier is also of perselain & holds the fuse element betn its terminal.

→ When fault occur the fuse element is blown out & the ckt is interrupted.

→ The fuse carrier is taken out & the fuse element is replaced by the new one & then the fuse carrier is inserted in the base to restore the supply.

→ This type ~~pt~~ fuse has 2 advantage;

i) The fuse carrier permits the replacement of fuse element without any danger.

ii) The cost of replacement is neglizible.

<u>Disadvantage</u>:-

i) There is a possibility of removal by the fuse wire of wrong size or by improper material

ii) This type of fuse has a low breaking capacity & hence it can't be use the ckt of high fault level

iii) The fuse element subjected to the deteriation due to oxidation through the continious heating of the element. Therefore after some time the current ratting of the fuse is decreased i.e the fuse operates at a lower currents than originaly rated.

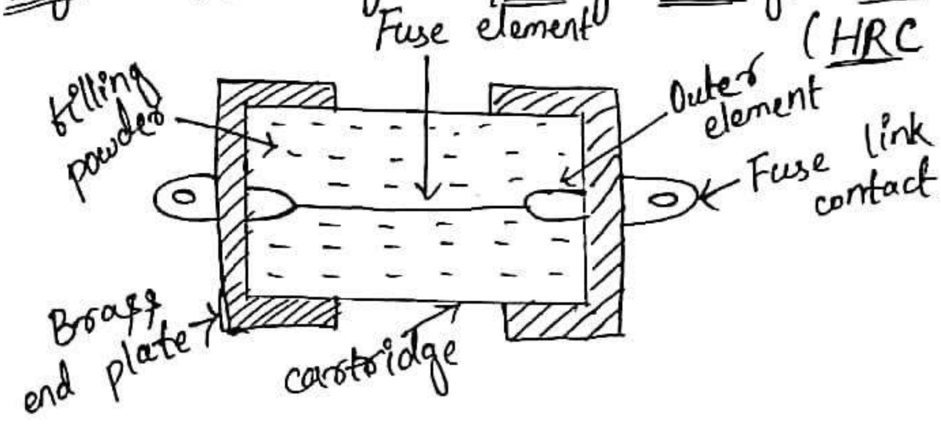
iv) The protective capacity of such fuse is uncertain.

v) The accurate callibration of fuse wire is not very much possible becz the fusing current depends upon the length of the fusing current.

→ The semi-encloses rewireable fuses are made upto 500 amp rated current but the breaking capacity is low i.e. on 400 volt service.

→ This type of fuse is limited to domestic & lighting load.
The use of

b) High reputuring capacity cartridge fuse :- (HRC fuse)



- → To overcome the disadvantage of semi enclosed re-wirable fuse, HRC cartridge fuse is use.
- → It consist of a heat resisting ceramic body having metal & caps to which is welded silver current carrying element.
- → The space with in the body surrounding the element ~~which~~ is completely packed with a filling powder....
- → The filling powder may be chalk, plaster of paris; quartz or marble dust etc. which are act as arc quenching medium.
- → Under normal load condition the fuse element is temp. below its melting pt. therefore, it carries the normal current without over heating.
- → When a fault occurs the current increase & the fuse element melts.
- → The heat produced in the process vaporise the melted silver element.
- → The chemical reaction betn the silver vapour & the filling powder results in the formation of high resistance, which helps quenching the arc.

* Advantage :-

i) These are capable of clearing high as well as low fault current.

ii) These are not detoriate with age.

iii) They have high speed of operation.

iv) They provide reliable distrimination.

v) They reqr no maintainance.

vi) They permit consistant performance.

* Disadvantage :-

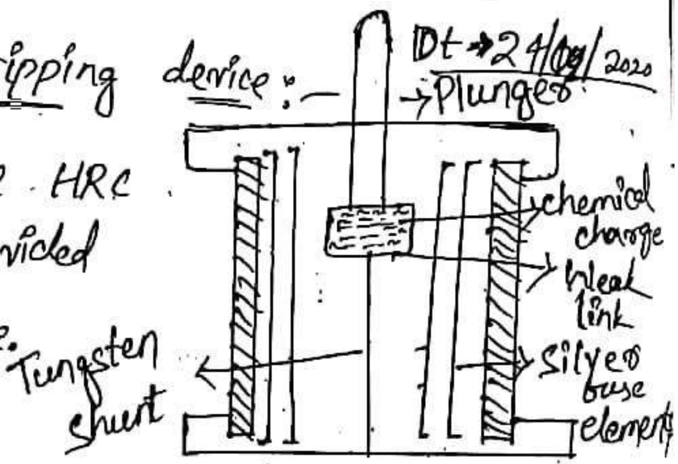
i) They have to be replace after each operation.

ii) Heat produce by the arc may effect the associated S/w.

*HRC fuse with tripping device :-

Dt → 24/09/2020

→ Here in this device HRC Cartridge fuse is provided with a tripping device.



→ When the fuse blows out under the fault cond the tripping device causes the ckt breaker to operate. The body of the fuse is of ceramic material with a metalic cap fixed at each end. At one end a plunger is connected which under fault conditions hits the tripping mechani of the ckt breaker & cause it to operate.

→ The Plunger is electrically through a fusable link, chemical charge & a tungston wire to the other end of the cap.

→ When a fault occurs the silver element at the 1st to be blown out & then the current is t/f to the tongsten wire.

→ The weak link in series with the tongsten wire gets fused & cause the chemical charge to be detonated. This forces the plungers outward to operate the ckt breaker.

→ **Adv.:—** In case of 1ϕ fault on a 3ϕ system the plunger operates the tripping mechanism of the C.B. to open all the 3ϕ & thus prevents single phasing.

→ The effect of full short ckt current need not be considered in the choice of CB.

→ **App :—**

→ **LV fuse :—**

→ The LV HRC fuse may be built with a breaking capacity of 16,000 Amp to 30,000 Amp at 440 volt.

→ They are extensively used in LV distribution system against over load & short ckt condn.

High voltage fuse :-

The LV fuse have normal current rating & breaking capacity there for they can't be successively use on HV fuse, so we use HV fuse for the HV ckt

(a) **Catridge type:-** This is similar to the LV catridge type except the special desing features.

→ Some design employ fuse element wound in the form of helix, so as to avoid corona effect at higher voltage.

- Some design there are 2 fuse element in parallel one is low resistance (silver) & the others of high R (tongsten wire)

→ Under normal load condⁿ the low R element carry the normal current but when the fault occur the Low R element is blown out & high R element reduce the short ckt current & finally break the ckt.

→ HV cartridge fuse are used upto 33kV with breaking capacity of 8700 Amp.

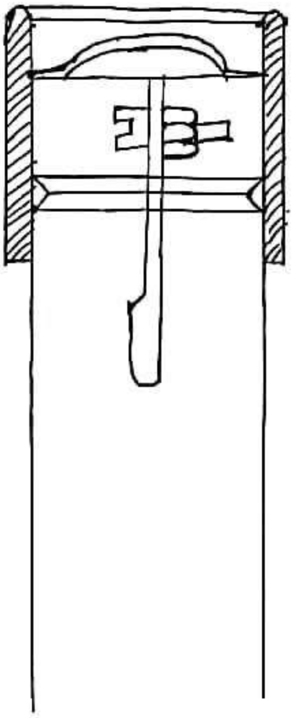
(b) Liquid type :-

→ These fuse are filled with carbon tetra cloride they may be used for the ckt rated current on the system upto 100 amp upto 132 KV & the breaking capacity of 6100 amp. It consist of a glass tube filled with carbon tetra cloride (CCl_4) solⁿ & sealled at both end with brass cap.

→ The fuse wire is sealed at one end of the tube & the other end ~~of~~ the wire is held by a strong phospherous bronze spiral spring fixed at the other end of of the glass tube.

→ When current exceeds the fuse wire is blown out

Q) A fuse wire of circular crossection has a radius of 0.8mm the wire blows off at a I of 8 Amp. Calculate the R of the wire that will blow off at a I of 1amp.



Sol

$r' = 0.8mm$

$I' = 8Amp$

$I'' = 1 amp$

$r'' = ?$

$K \to 1$

$$\boxed{\begin{aligned} I &= kd^{3/2} \\ \Rightarrow I^2 &= d^3 \end{aligned}}$$

$\Rightarrow$ Heat produced per sec = Heat loss per sec

$\Rightarrow I^2R = \text{Constant} \times \text{Eff. surface area}$

$\Rightarrow I^2R = \text{constant} \times d \times l$

$\Rightarrow I^2 \cdot \rho \frac{\cancel{l}}{A} = \text{constant} \times d \times \cancel{l}$

$\Rightarrow I^2 = K \times d^3$

$\Rightarrow I^2 \propto d^3$

$$\Rightarrow \left(\frac{I_2}{I_1}\right)^2 = \left(\frac{r_2}{r_1}\right)^3$$

$$\Rightarrow \left(\frac{1}{8}\right)^2 = \left(\frac{r}{0.8}\right)^3$$

$$\Rightarrow \frac{1}{64} = \frac{r^3}{0.514}$$

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$r^3 = 8 \times 10^{-3}$

$= 0.008$

$\Rightarrow r = \sqrt[3]{0.008} = 0.2mm.$

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Ch-4 Circuit Breaker

Dt-31/01/2020

→ A circuit breaker is a pi____ of equipment which can make or break on ckt either manually or by remote control under normal conditions. Breake a ckt automatically under fault condition.

→ Thus a ckt breaker in corporates manual as well as automatic control for switching function.

* **Operating Principle :-**

A ckt breaker essentially consist of a fixed contact & a moving contact under normal operating cond?. This contact remain close and it will not open automatically ________ and unless the system becomes faulty.

→ The contact can be opened manually whenever desired when a fault occure on any part of the system the trip coil of the ckt breaker get energised and the moving contact are pulled a part by some mechanism, thus the ckt will open.

* **Arc Phenomenon:-** When a short ckt occure a heavy current flows through the contact of ckt breaker before there open by the protecting system, at the instant. When the contact began to separate to contact area decrease rapidly & the large fault current cause increase large current density and hence raising temperature.

→ The heat produce and medium betn contact (usually the medium is oil or air) is sufficient to ionise the air or oil.

→ The ionised air or vapour act as a conductor and an arc is stuck betn the contact.

→ The potential diffr betn the contact is quite small & just sufficient to maintaine the arc.

→ The arc provided a low R. path & consiquintly the current in the ckt remain uninterrupted so long as the arc is persist.

→ During the arcing period the current flowing betn the contact depends upon the arc R greater the arc Resistance, the smaller in the current that flows betn the contact.

→ The arc R depends upon the following factors

* (i) Degree of ionisation :-

→ The arc R increase with the decrease of the no. of ionise particle betn the contact.

(ii) Length of the Arc :-

The arc R increase with the length of the arc i.e. separation of contact.

(iii) Cross-section area of arc :-

The arc R increase with decrease the crosectional area of the arc.

* Methods of Arc Extension :-

There are 2 methods of extinguiching (ଲିଭାଇବା) of arc in CB these are

(i) high R method

(ii) Low R , or current – 0 method

* **High R Method :-**

In this method the Arc R is increased
→ with time, so that current is reduced to a value
insufficient to maintaine the arc.
∴ the I is intrupted & the arc is extinguishing

→ The main dis.and. of this method is dissipation
high energy in the arc.
∴ It is employed only in dc ckt breaker & low
capacity AC ckt breaker.

⇒ The R of the arc may be increased by :

(a) Lengthening (↑) the arc :- The R of the arc
is dirc proportional to its length, the length
of the arc can be increase by increasing
the gap between that contacts.

(b) Cooling the arc :-
→ The cooling helps in the de-ionisation of the
medium beth the contact, this increase the arc R.

(c) Reducing the crossection area of the arc :-
→ If the area of crosection of arc is reduce,
the R of the arc increase. The crosection area
of the arc can be reduce by letting the arc
pass through a narrow opening or by having
smaller area of contact.

(d) Splitting (ଭାଗ) the Arc :-
R of the arc can be increase by
splitting the arc into a no. of smaller arc
inseries. The arc may be split by introducing
some conducting plate beth the 2 contact.

* **Low R method :-**

This method is employed for arc
extension in AC ckt only. In this method arc R

is kept low untill current is zero, where the arc extengishious naturally

→ In an AC systen the I drop to zero, after every half cycle. At every I zero the arc extinguish for a brief moment.

→ Now the medium betn the contact contain ion & electron so that it has small di-electric strength & can easily break-down by the rising contact voltage known as restriking voltage.

→ The de-ionise of the medium can be achived by

* lanthening of the gap:- The dielectric strength of the medium is proportional to the length of the gap betn the contact.

→ ∴ By opening the contact rapidly higher dielectric strength can be achived

* High Pressure:-
If the pressure of the arc is increase the density of charge particle constituting the discharge also increase. The increase density of particle cause higher rate of deionisation & consiquently dielectric strength of medium of contact is increase.

* Cooling:- The natural combination of ionise particles takes place more rapidly if they are allowed to cool.

→ ∴ dielectric strength of the medium can be increase by cooling the arc.

* Blast effect:- If the ionise particle betn the contact are swept away & replace by un-ionised

particle the dielectric strength of the medium can be increase & this may be achive by a gas blast or by forcing the oil betn the contact.

* **Classification of ckt breaker :-**

→ There are several way of classifing the CB. however the most generally way of classification is on the basic of medium used for arc extension.

→ Accordingly the ckt breaker may be classified into following type:-

* **Oil ckt breaker:-** Which employed some insulating oil for arc extension.

2) **Air blast CB** In which a high pressure air blast is used for estingiush arc.

3) **Sulfer hexa floride CB :- (SF_6) :-** In which SF_6 gas is used for arc extension.

4) **Vacuum CB :-** In which vacuum is use for arc extension.

1) **Oil ckt breaker :-**

In such CB some insulating oil is use as an arc quenching medium.

→ The contact are open under oil & the arc is strouck betn them.

→ The heat of the arc evaporate the surrounding oil & produce the gaslous hydrogen at high Pressure.

→ The H gas occupie a volume of 1000 times that of the oil decompose. The oil is ∴ pushed away from the arc & an expending H gas bubbles surround the arc region & adjucent portion of the contact.

→ The arc extension

→ ∴ The arc is extenglushes & the ckt current interrupted.

→ **Adv.:-**

⇒ Oil as an arc quenching medium are:-

i) It observe the arc energy to decompone the oil into gases.

ii) It act as an insulator & permit smaller clearanc beth the conductor.

→ **Dis. adv:-**

i) It is inflammable & there is a risk of fire

ii) It may from an explosive mixture with air.

→ **Types of oil CB:-**

The oil CB can be classified into following types.

(i) **Bulk oil ckt breaker:-** Which use a large quantity of oil

→ The oil has to serve to purpose,

(a) It extinguish the arc during opening of the contact.

(b) It insulate the current conducting part from one another

→ Such ckt breaker can be classified into 2 typ

(A) Plain break oil CB

(B) Arc control " "

(ii) Low oil CB :-

→ Which use min^{m} amount of oil, In such CB oil is used only for arc extinction.

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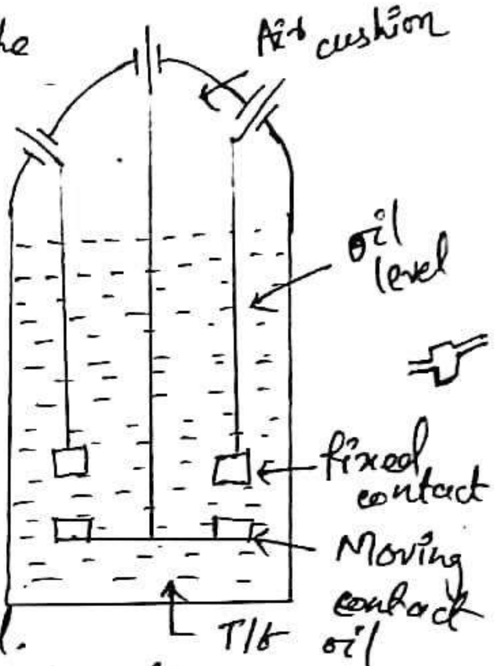
* Plain break oil CB :-

→ This ckt breaker involves the simple process of separating the contact under the oil.

→ There is no special system for arc control other than increase in length, caused by the separation of contact.

→ The arc extention occurs when a certain critial gap bet^{n} the contact is reached.



→ It has a very simple construction.

→ It consist of fixed & moving contact whichis enclosed in a tank containing oil upto a certain level. and an air cushion above the oil level.

→ The air cushion provide sufficient space fa allow for the reception of the arc gases with-out the generation of unsafe pressure.

→ Under normal operating cond^{n} the fixe & moving contact remain closed & the ckt breaker carry the normal ckt current.

→ When a fault occur the moving contact are pulled down by the protective system & an arc is strucked which vapourise the oil into hydrogen gas.

→ The arc extension is be by the following process;

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ii) 'H' gas bubble generated around the arc & cools the arc.

iii) As The arc lengthens due to the separating contact, the dielectric strength of the medium is increase. As the result the arc is extinguish & the ckt current intrupped

* **Dis. Adv.** :- There is no special control over the arc other than increase in length by separating the moving contact, ∴ for successful interruption long arc length is necessary

→ This breakers have long & inconsistance arcing time.

→ This breakers do not permit high speed interruption.

→ Due to this dis. adv. the plain break oil CB are used only for LV app..

* **Arc control oil CB** :-

→ It is necessary & desirable that the final arc extinction should occur while the contact gap is short. For this purpose some arc control is incorporated (use) & the breaker which are used the breaker is called as arc control CB.

→ There are 2 types of this CB;

i) Self blast oil CB

ii) Forced blast oil CB

i) **Self blast oil CB** :- It is the CB in which arc control is provided by internal means i.e. the arc itself is employed for its own extinction efficiently.

→ In this type of CB the gases produce during arcing are confind (ସୀମିତ) to a small volume by the use of insulating chambers or pot. surrounding the contact.

→ since the space available for arc gases is restricted by the chamber, a very high pressure is developed to force the oil & gas through the arc → to extinguish it.

→ The magnitude of pressure develope depends on the value of fault current to be intrupted.

→ When the pressure is generated by the arc itself ∴ such breaker some time called self generated pressure oil C.B..

→ There are several design of pressure chamber has been develope. These are;

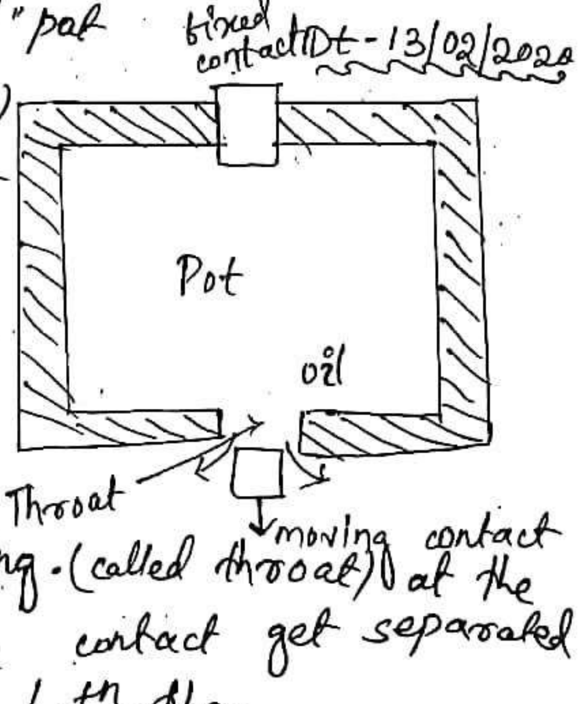
(i) Plain exploation pot
(ii) Cross jet exploation pot
(iii) Self componsated" pot

Dt - 13/02/2020

*** Self blast oil CB :-** (PEP)

i) Plain exploation pot :-

It is a rigid cylinders of insulating material & encloses the fixed & moving contact as shown in fig.



→ The moving contact is a cylinderical rod passing through a restricted opening.(called throat) at the bottom.

→ When a fault occurs the contact get separated & an arc is strouck betn them.

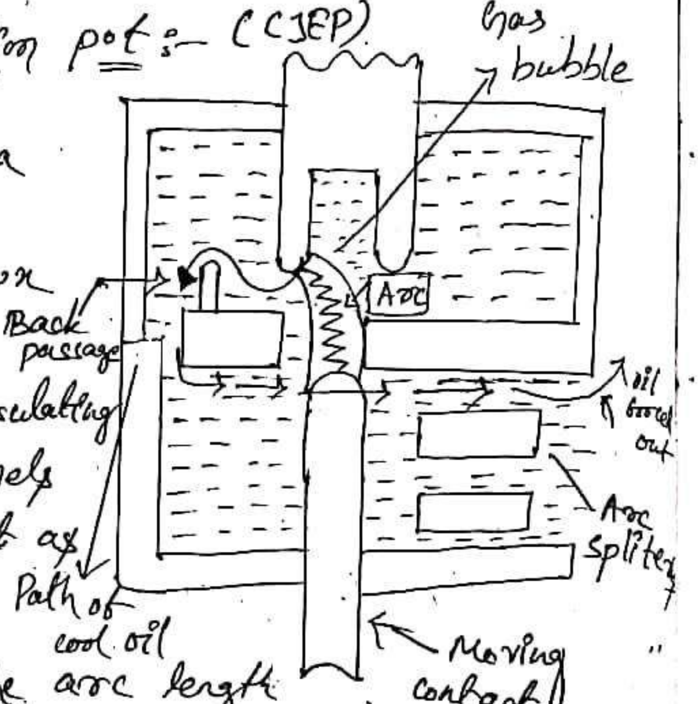
→ The heat of the arc decomposes oil into a gas at a very high pressure in the pot.

→ This high pressure forces the oil & gas around the arc & thus the arc is extinguished.

→ The principle limitation of this pot is it can't be used for very low or very high fault currents.

→ The plain exploation pot operation on moderate I_{sc} only.

ii) Cross jet exploation pot :- (CJEP)



→ This type of pot is a modification of Plain exploation pot as shown in fig.

→ It is made up of insulating material & has a channels on one side which act as as arc splitters.

→ It help in increase the arc length thus the arc is extinguish.

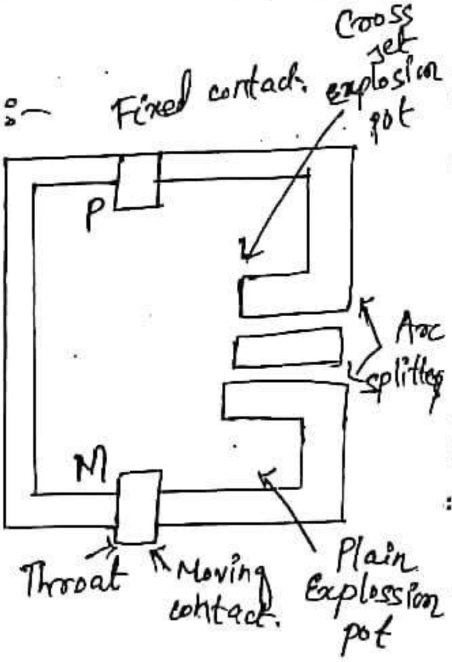
→ When a fault occur the moving contact of the CB begans to separate or start to separate as the moving constant is withdrawan, the arc is initially struck in the top of the pot.

→ The gas generated by the arc exert pressure on the oil, when the moving contact uncovers the arc spliter duct, fresh oil is force across the arc path.

→ ∴ The arc is driven into the arc spliter which increase the arc length. Thus the arc is extinguish:

→ This pot is quite effeciant for interrupting heavy fault current.

(ii) Self componsated exploation pot:-



This type of pot is a comb plain exploasion type pot & cross jet " " ".

→ ∴ It can interrupt low as well as heavy s.c. current (I_{sc})

→ It consist of 2 chambers the upper chamber is CJEP with two arc spliter duct, while the lower one is PEP.

→ When I_{sc} is heavy the rate of generation of gas is very high & the device behaves as a CJEP. A when the low I_{sc} the rate of gas generation is low or small.

→ When the moving contact comes out from the throat the arc is estingiushed by plain explosion pot action.

* Force blast oil CB :- In this arc control method is provided by mechanical means to the ckt breaker externally.

→ The major limitation of self blast oil CB is that the arcing time is long. to over come this limitation we use force blast oil CB in which the necessary pressure is produced by the external mechanical means which is independs of fault current.

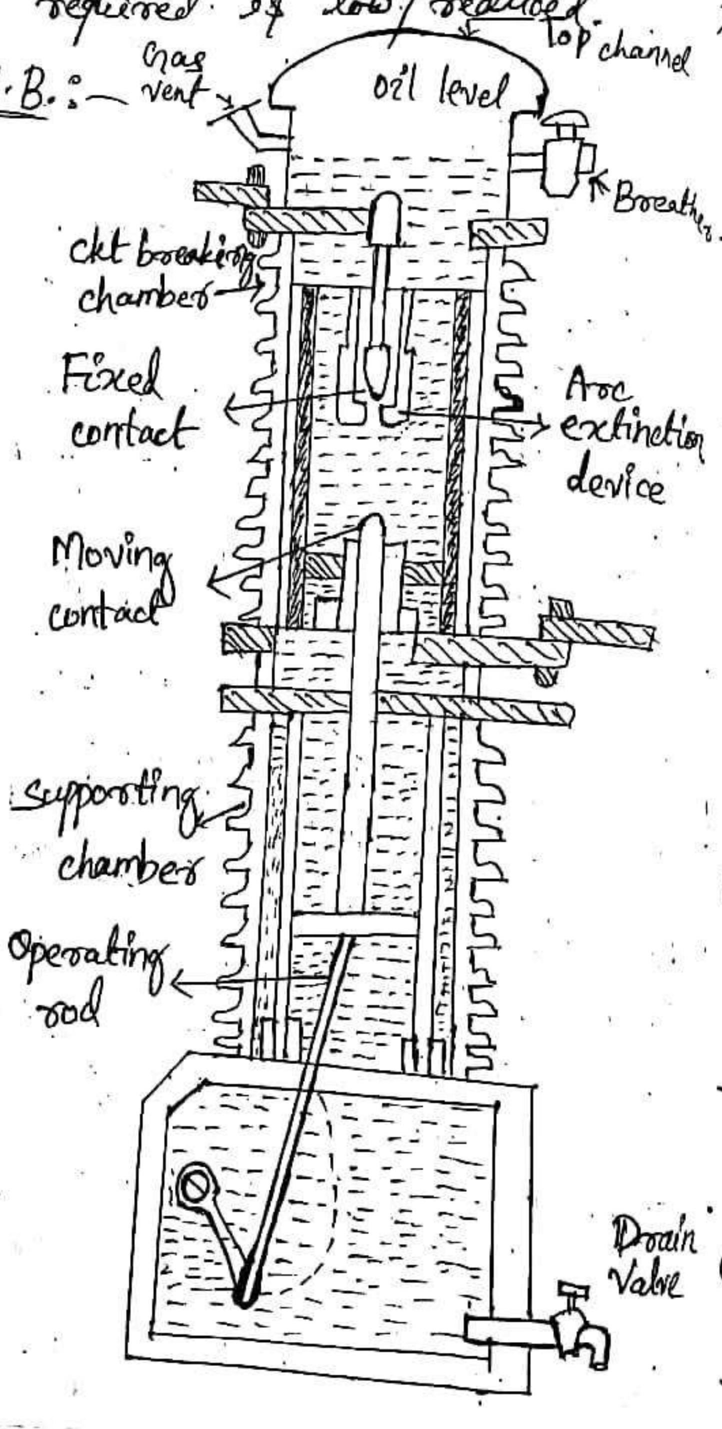
→ In a force blast oil CB oil pressure is created by the piston cylinder arrangement. The movement of piston is mechanically coupled to the moving contact.

→ When a fault occur the contact separated by the protective system & an arc is struck bet^n the fixed contact & moving contact. The piston forces a jet of oil toward the cont gap to extinguish the arc.

* **Adv**:- Since oil pressure depeloped is independ of fault current the performance at low current is more consistance than self blast oil C.B.

→ Quantity of oil required is low / reduced.

* **Low oil C.B.**:-



→ In the bulk oil CB the oil has to perform 2 func

(i) It act as an arc quenching medium

(ii) It insulates from the earth.

* for this reason the quantity of an oil in a bulk oil CB is very high.

→ But in case of low oil CB a small amount of oil is used as an arc quenching medium.

* Construction :-

→ There are 2 compartment separated from each other but both filled with oil. The upper chamber is the ckt breaking champer while the lower chamber is supporting chamber.

→ The 2 chamber by separated portion & oil from one chamber is prevented from mixing with other chamber.

→ This arrangement permits 2 adv. ;

i) The ckt breaking chamber reqr a small volume of oil which is enough for arc extension.

ii) The amount of oil is ~~to~~ be replace is reduced as the oil in the supporting chamber doesnot get contaminated by arc.

(a) Supporting chamber :-

→ It is a porcelain chamber mounted on a metal chamber. It is filled with oil which is separated from the oil in the ckt breaking chamber.

→ The oil inside the supporting chamber, porcelain & the bakilised paper is employed for insulation purpose.

(b) Ckt breaking chamber :- It is a porcelain encloser mounted on the top of the supporting chamber.

→ It is filled with oil & it has the following pa

(i) Upper & lower fixed contact

(ii) Moving contact

(iii) Turbulator

→ The moving contact is a hollow & include a cylinder which moves down over a fixed piston

→ The turbulator is an arc control device & has both axial & radial vent. The axial venting ensures the interruption of low current where as the radial venting help in the interruption of heavy current.

(c) Top chamber :- It is a metal chamber mounted on the ckt breaking chamber it provides expansion space for the oil in the ckt breaking chamber.

* Operation :- Under normal operating cond^n the moving contact remains closed with the fixed contact.

→ When a fault occur the moving contact is pulled down & an arc is struck betn the fixed contact & moving contact.

→ The arc energy vapourise the oil & produces gasing under high pressure. This action constrains the oil to pass through the central hole of the moving contact & results to forcing oil through the passage of the turbulator.

→ The process of turbulation which is used to successively quenching the arc.

* Adv. :- A Low oil ckt breaker has following adv. over a bulk oil CB;

(i) It reqr lesser quantity of oil, (ii) it reqr less space

iii) There is reduce risk of fire.
iv) Maintainance problem is reduce

* Dis.adv.:-
i) Due to smaller quantity of oil the degree of carbonisation is increase.
ii) There is a difficulty of removing the gases from the contact space in time.
iii) The di-electric strength of oil detoriates rapidly due to the high degree of carbonisation.

* Maintance of oil CB:-
The maintainance of oil CB generally concerned with the checking of contact & the dielectric strength of oil.
→ During the inspection of breaker following point to be taken.
1) Check the current carrying part & arcing contact, if the burning is sevious the contact should be replaced.
2) Check the dielectric strength of oil, if the oil is badly discolour it should be changed.
3) Check the oil level.
4) Check the insulation
5) Check closing & tripping mechanism.

* Air Blast ckt breaker:-
In this ckt breaker high pressure air blast used as arc quenching medium. The contact are opened in a flow of air blast establish by the opening of blast valve.
→ Air blast cool the arc & sweeps away the arcing product to the atmosphere
→ This rapidly increases the dielectric streng of medium beth the contact & prevent from

re-establishment of arc and the arc is estinguish & the flow of I is interrupted.

* Adv:-

→ The air blast CB has the following adv. over an oil CB & these are;

1. The risk of fire is eleminated.
2. The arcing product are completely removed by the air blast where as the oil deteriated with successive ope.
3. The arcing time is very small.
4. The energy supply for arc extinction is obtain from high pressure air & is independent of the I to be interruption.

* Disadv.:- The use of air as a quenching medium has the following disadvantage :-

↳ The air blast CB are very sensitive to the variation in the rate of rise of Re-striking voltage

↳ Considerable maintainence is reqd for the compressor plant which supply the air blast.

⇒ Types of air blast CB :-

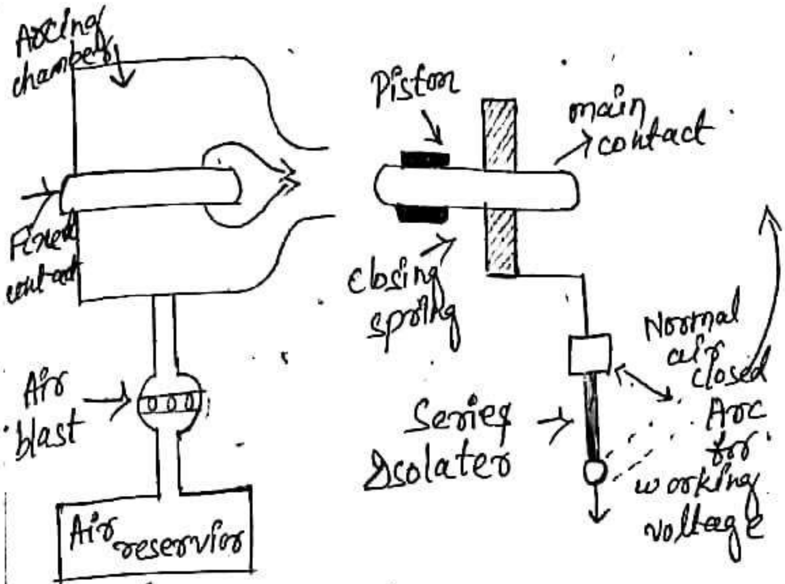
Depending upon the direction of the air blast to the arc, the air blast CB can be classified into 3 types; (a) Axial blast type

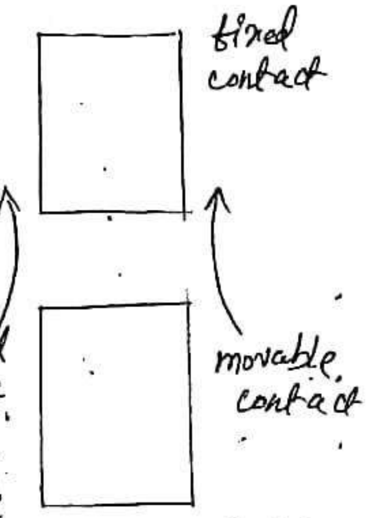
(b) Cross blast . (c) Radial blast .

(a) Axial Blast type :-

→ In which the air blast is directed along the arc path as shown in fig.

→ The fig. shows the essential part of air blast CB The fixed & moving contact are held in the close position by the spring under normal condn.





fig(1)

fig(2)

→ The air reservior is connc to the arcing chamber through an air valve. The air valve remain closed under normal operating condn but it opens automatically by tripping mechanism when a fault occur on the system.

→ When a fault occur the tripping impulse causes opening of air valve which connect the CB reservior to the arcing chamber.

→ The high pressure air entering the arcing chamber push away the moving contact against spring pressure.

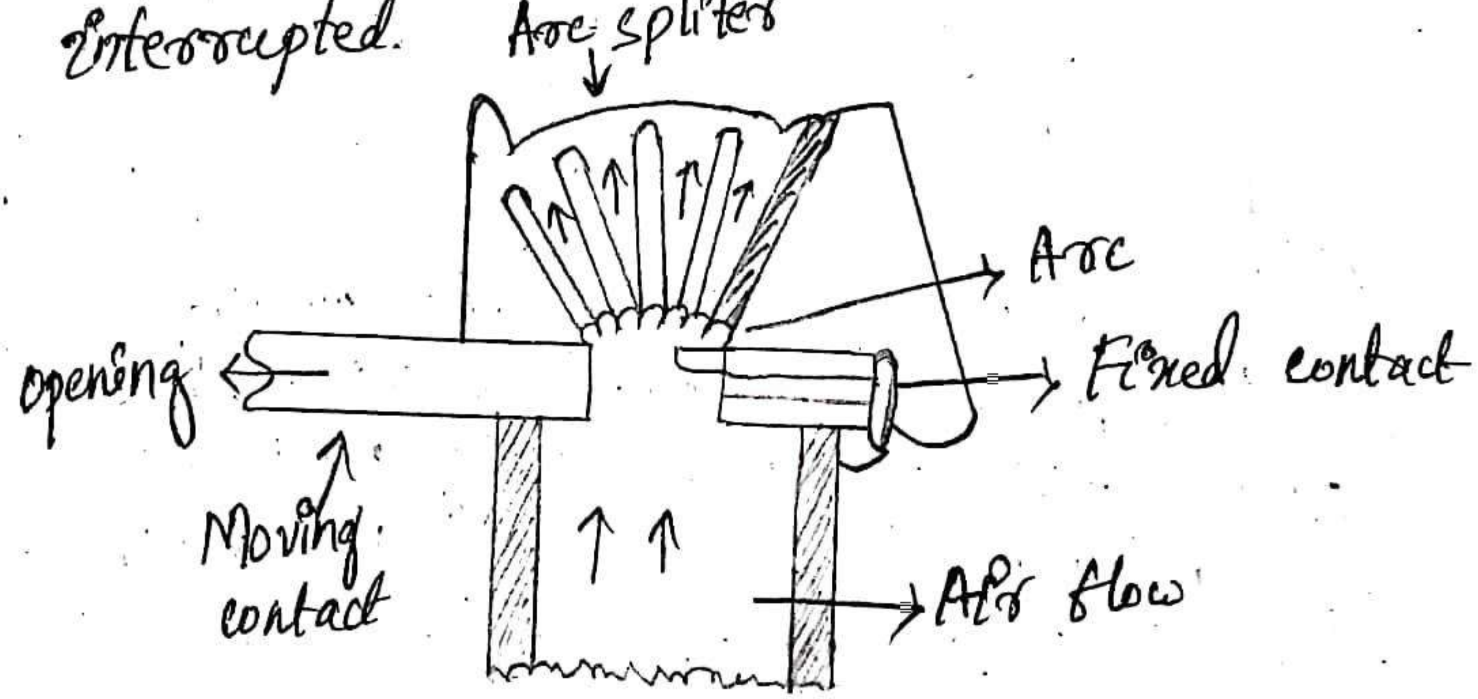
→ The moving contact is separated & an arc is produced and at the same time high pressure air blast flow along the arc and therefore, the arc is extinguished and the current flow interrupted.

(b) <u>Cross blast air blast CB</u>:-

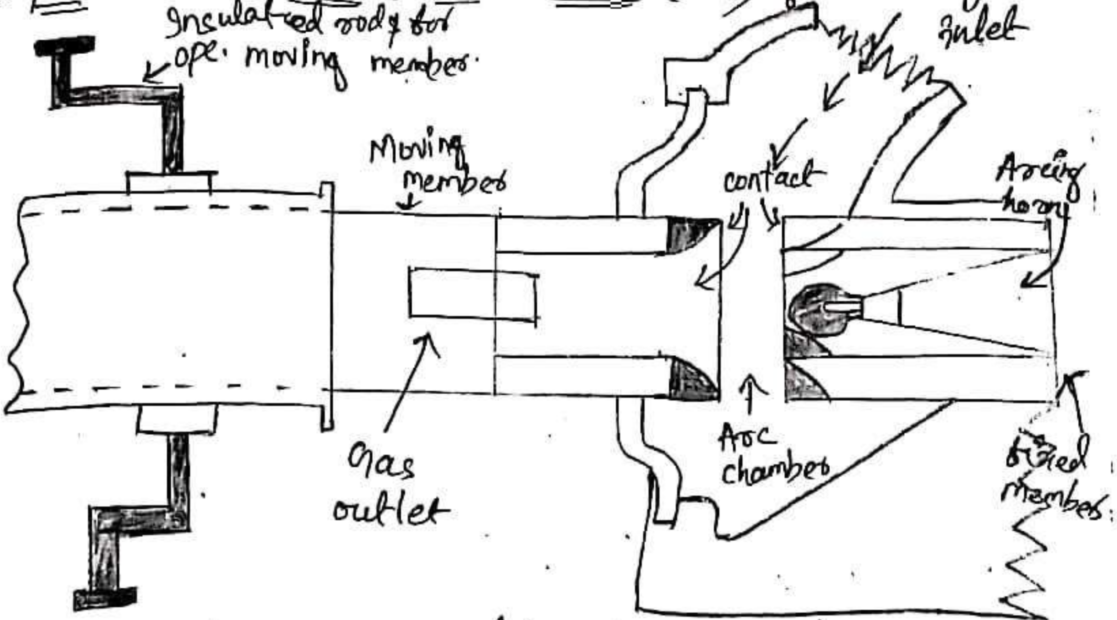
→ In this type of CB air blast is directed at right angle to the arc.

→ The cross blast lengthen and force the arc for arc extension.

- When the moving contact is separated, an arc is produced betn fixed & moving contact.
- The high pressure cross blast forces the arc into an arc spliter. The spliter serve to increase the length of the arc. This results the arc extension & the flow of current is interrupted.



* Sulpher Hexa-floride Ckt breaker (SF$_6$) :-



→A CB : - which uses sulpher hexafloroide or SF$_6$ gas as arc extinguish medium is known as SF$_6$ CB.

→The SF$_6$ gas is a very good dielectric material which can resist high potential.

→ SF$_6$ is an electro negative (-ive) gas & has a strong tendency to absorve ~~fee~~ electrons, when-ever the CB opens it contact an arc will formed betn the 2 contact at the same time a high pressure SF$_6$ gas pumped on the arc.

→The conducting free electron in the arc are rapidly captured by the gas to form relatively immobile -ve ion.

→This losses the conducting electron in the arc & quickly build up the insulation strength to extinguish the arc.

→The SF$_6$ CB are very effective for high power or high voltage ope..

* Construction:- The SF$_6$ CB consist of a fixed contact and a moving contact & closed in an arc interruption chamber which contain SF$_6$ gas.

→ This chamber is conn^c to the SF_6 gas reservoi
→ When the contact of CB are open the valve mechanism permit a high pressure SF_6 gas from the reservoir to blow foward arc interruption chamber. The fix contact & moving contact are hollow cylinderical arrangement. The moving contact contain rectangular holes in the side to permit the SF_6 gas out through these holes after blowing along the arc.

→ The tips of fixed contact & moving contact & arcing horn are coated with copper – Tungsten arc R material.

→ Since SF_6 is costly, it is recycled & reused by the suitable auxiliary system after each ope. of the ckt breaker.

★ Working :-

In the closed position of the breaker the contact remain surrounded by SF_6 gas at a pressure of 2.8 to 3.2 kg/cm²

→ When the breaker ope. the moving contact is separated from the fix contact & the arc is struck beth the contacts.

→ The movement of moving contact is synchronised with the opening of valve which permits SF_6 gas at pressure of 14 kg/cm² from the reservoi to arc introuption chamber.

→ The high pressure flow of SF_6 gas rapidly absorve the free e^- in the arc path & quickly build up high dielectric strength & causes the extinction of arc.

→ After the CB ope. the valve is closed by the action of spring.

* Adv. :—

→ Due to superior arc quenching property of SF_6 gas the SF_6 CB have many adv. over oil or air ckt breaker these are ;

1. Due to the superiour arc quenching property of SF_6 gas such CB have very short arcing time.
2. Since the dielectric strength of SF_6 gas is 2 to 3 times of air such breaker can interrupt large current.
3. The SF_6 gas CB gives noise less operation.
4. The closed gas encloser keep the interiour dry so that there is no moisture problem.

5. There is no risk of fire in such breaker becz SF_6 gas is non-inflammable ([illegible]).
6. The SF_6 CB have low maintainance cost and require min^m^ auxiliary equipment. since SF_6 CB are totally enclosed & seald from atmosphere, they are particularly suitable where exploation hazard([illegible]) exist.

* Dis-advantage :—

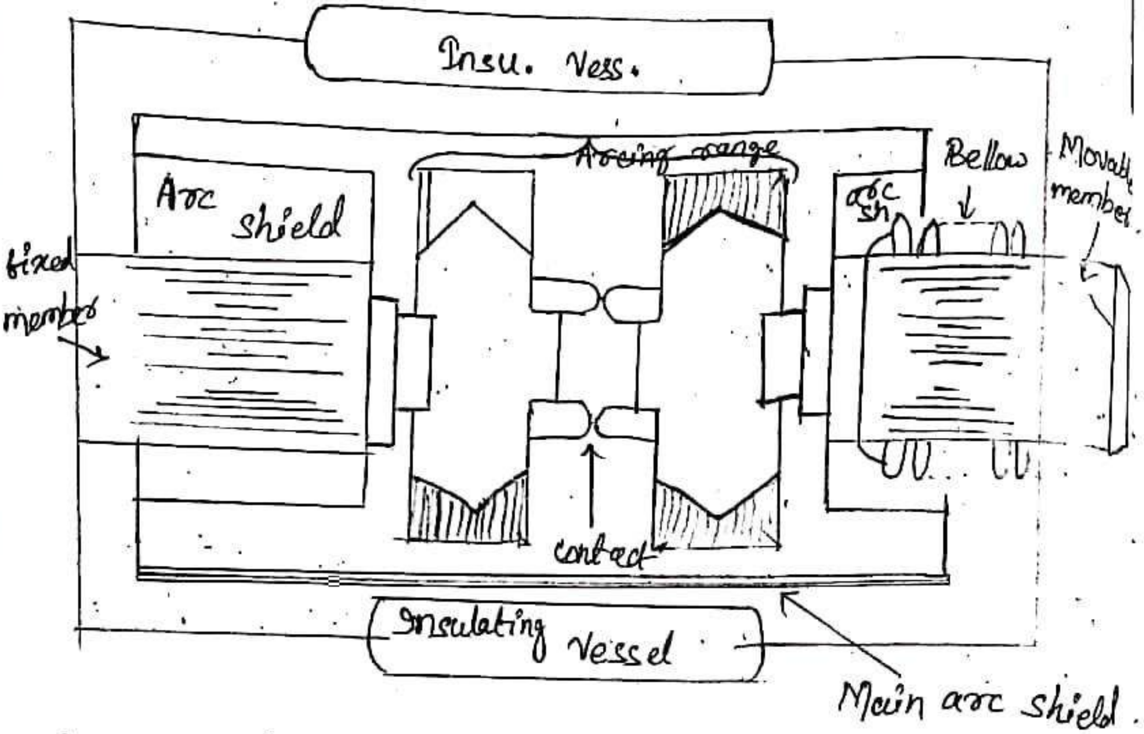
→ The SF_6 CB are costly due to the high cost of SF_6 gas.

→ Since SF_6 gas has to be reuse or recondi^n^ after every operation, additional equipment is reqr for this purpose.

* Application :—

→ The SF_6 CB have been developed for the voltag of 115 kV to 230 kV, Power rating of 10 MVA to 20MVA.

* Vacuum ckt breakers:- (VCB)



→ In such breaker vacuum is used as arc quenching medium, since vacuum offer the highest insulation strength it has superior arc quenching property then any other medium.

→ For ex, when contact of CB are opened in vacuum, the interruption occurs at 1st I zero with dielectric strength betn the contact building of at a rate of No. of times higher than the other CB.

* Operation:- When the contact of the breakers are opened in vacuum an arc is produce betn the contact by the ionisation of metal of the contact. However the arc is quickly extinguish becz the metalic vapour, electrons & ion produce during arc rapidly condense on the surface of the CB contact.

→ Resulting in quick recovery of dielectric strength. In the CB as shown as the arc is produced in vaccum it is quickly extinguish due to the 1st recovery of dielectric strength.

→ Construction :- It consist of fixed contacts, moving contact & arc shield mounted inside a vaccum chamber.

→ The movable member is connc to the control mechanism by stainless steel Bellows.

→ This enables the permanent sealing of the vaccum chamber so as to eleminate the probability of leakage.

→ A glass vessel, ceramic vessel is used as the outer insulating body. The arc shield prevent the detoriation of the internal dielectric strength.

* Adv. :- The vaccum CB have the following adv.

(i) They are compact, reliable & have longer life

(ii) There are no fire hazards.

(iii) They reqr little maintainance.

(iv) They can successively withstant the lighting surge.

(v) They have low arc energy.

(vi) It can interrupt the heavy fault I.

** The VCB are employed for outdoor application ranging from 22KV to 66KV. with a limitted rating of 6Q to 200MVA. This CB are suitable for the rural area.

Protective Relays

ch-5

* Relay should operate as fast possible in a fault condition but, if it should not operate so fast there should be occur in damage to the system.

* Fundamental requirement of protective relay :-

* Sensitivity :-
→ The ability of relay to operate or detect with a low value of actuating quantity.
→ Generally it is a function of volt ampere rating of relay coil i.e. if the rating is low the sensitivity is high.

* Reliability :- On the occurance of fault the operating mechanism of a relay must operate so that the ckt breaker can isolate the faulty part by obtaining information from the relay.

* Simplicity :- A relay construction should be simple, so that the cost is less & difficulty in maintenance can be avoided.

* Economic :- A relay should not be costly enough work by used in protective system.
→ In common practice total relaying cost should not more than 5% of the total coil, but cost can be compermized in case of important load & equipment.

* Types of Relay :-
→ According to the operation of a relay, the relay can classified into 2 types.

1. Electromagnetic Attraction type
2. Induction type

1. Electromagnetic Attraction type :- This type relay operated by the vartue of an armeture being

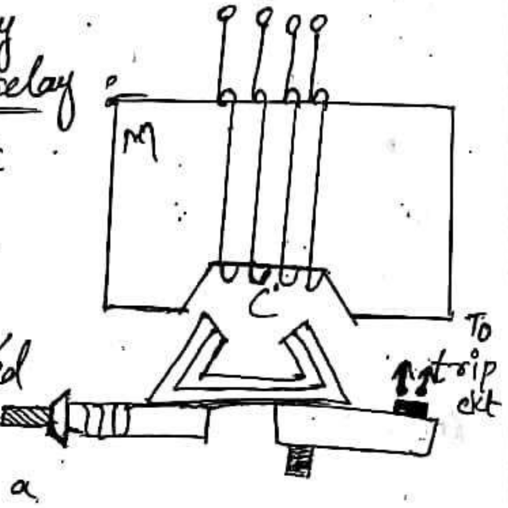
attracted to the poles of an electromagnet which is drawn into a solenoid.

→ Such relay can be operated by both A.C. or D.C quantity.

→ The important type of electromagnetic attraction types relay are :-

(i) Attraction armeture type relay
(ii) Solenoid type relay
(iii) Balanced beam type relay

i) Attraction armeture type relay :-



→ The fig. shows the schematic arrangement of an attracted armeture type relay.

→ It laminated electro-magnet (m) carrying a coil (C) & a laminated armeture.

→ The armeture is balanced by a counter weight & carries a pair of spring contact at its free end.

→ Under normal operating condition the current throw relay coil is such that the counter weight holds the armeture in the +ve as shown in fig..

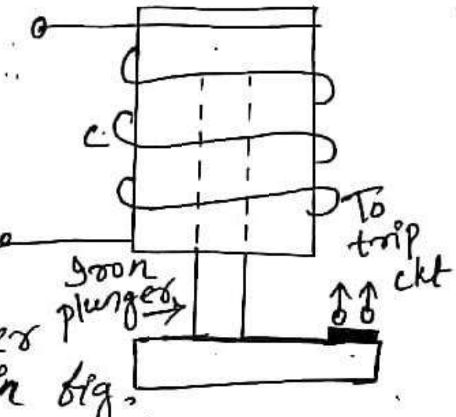
→ However when a short ckt occur the thrown relay coil is increase & the relay armeture is attracted upward.

→ The contact on the relay armeture attached to the relay frame this complete the trip ckt which result in the opening of the CB & therefore the faulty section can be disconnected from the healthy section.

→ The minimum current at which the relay armeture is attracted to close the trip ckt is called as peak-up current.

ii) Solenoid type relay :-

→ The fig. shows the schematic arrangement of solenoid type relay.

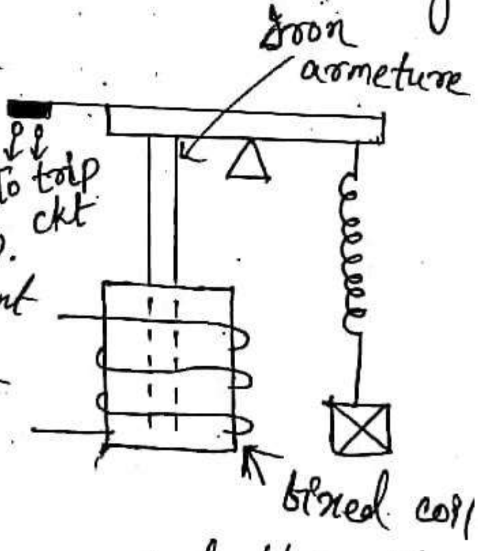


→ It consist of solenoid & movable iron plunger, as shown in fig. under normal operating condition the current throw the relay coil see is such that it holds the plunger by the spring as shown in fig.

→ When the fault occur the current through the relay coil becomes more than the peak up. value causing the plunger to be attracted to the solenoid.

→ The upward movement of the plunger close the trip ckt ~~&~~ thus the CB open & the faulty section can be disconnected from the healthy section.

iii) Balanced beam type relay:-



→ The fig. shows of a balanced beam type relay. It consist of an iron armeture & a balanced beam.

→ Under normal condition the current through the relay coil is such that the beam is at in the Horizontal position.

→ But when a fault occur the current through the relay coil becomes greater then the peak up value & the beam is attracted to closed the trip ckt this causes the opening of ckt breaker to isolate the faulty section.

2. Electromagnetic Induction type relay :-

* This type of relay operate on the principle of the electro-magnetic induction.

→ This type of relay mainly used for the purpose of AC quantity.

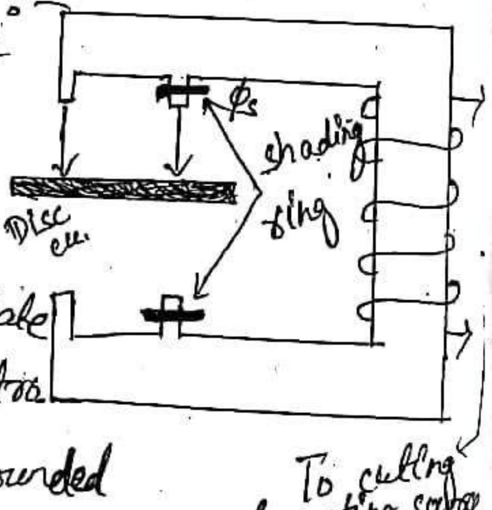
→ This relay basically operate when an alluminium disc bet^{n} 2 alternating magnetic field which has same frequency but separate phase displacement bet^{n} each other to rotate the disc.

* More is the phase displacement there will a more torque produced as the disc.

→ The following 3 type of structure commonly used for obtaining the phase difference in the fluctus & hence the operating torque in the induction relay this are :-

i. Shadded pole structure
ii. Watt-hour meter/double watt structure.
iii) Induction cup structure.

i) Shaddel pole structure :-



→ The general arrangement of shaded pole structure in shown fig.

→ It consist of an alluminium disc which is feed to rotate in the air gap of an electro magnet.

→ 1/2 of each pole is surrounded by a copper band which is known as shading ring

→ The alternating flux ϕ_s in the shading portion will produced the current in the ring lags behind the flux 'ϕ_u' in the unshadded portion by an angle.

'α', so the torque produced is given by

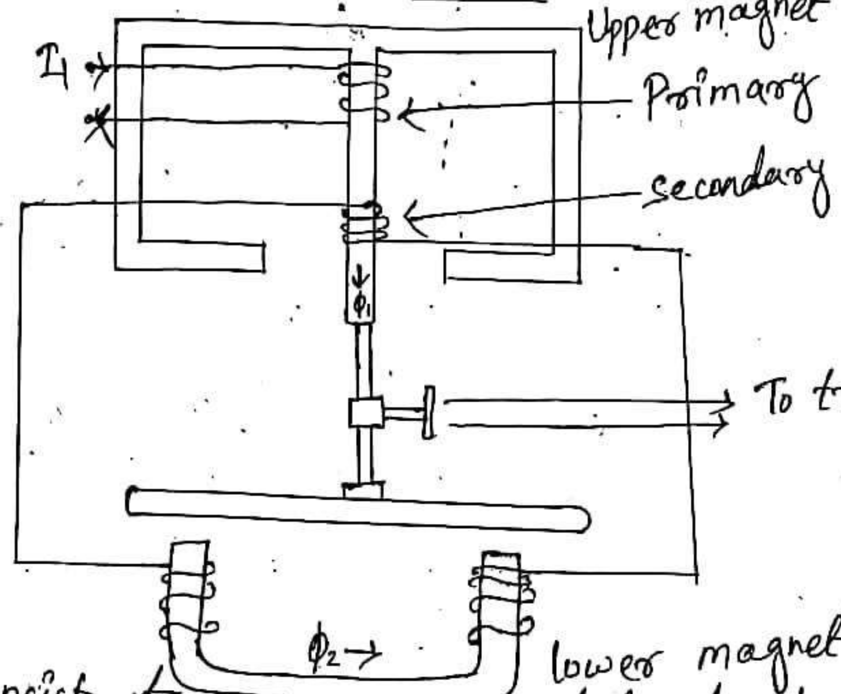
$$T \propto \phi_s \phi_u \sin\alpha$$

→ The fluxes 'ϕ_s' & 'ϕ_u' is directly proportional to the current 'I' in the relay coil.

$$T \propto I^2 \sin\alpha$$

$$I \propto \phi_c \ , \ I \propto \phi_u .$$

ii) <u>Watt</u>-<u>hour</u> <u>meter</u> <u>structure</u> :-



→ It consist of arrange to rotate freely beth the pole of 2 electro-magnet. The upper maget carries 2 winding i.e. the primary & secondary.

→ The primary winding carries the relay current while the secondary winding is connected to the winding of the lower magnet.

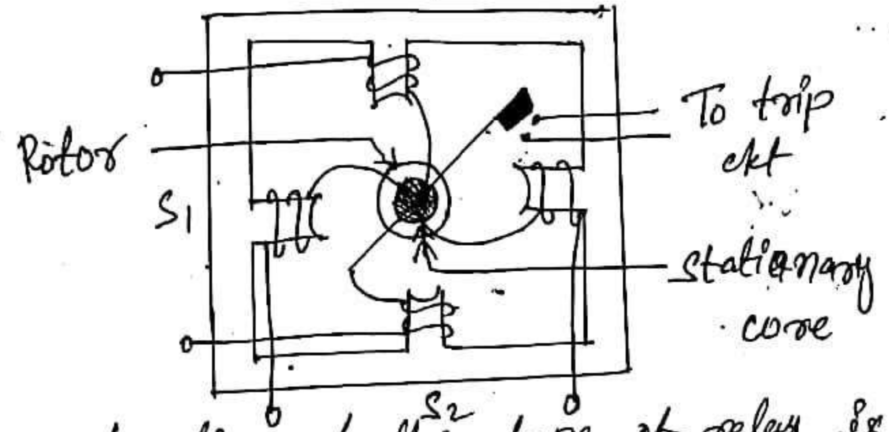
→ The primary current induced emf in the secondary wind & so current (I_2) circulate in it the flux (ϕ_2) induced in the lower magnet by the current (I_2) in the secondary winding of the upper magnet.

→ Flux 'ϕ_2' lags behing the 'ϕ_1' by an angle 'α', the 2 fluxes 'ϕ_1' & 'ϕ_2' differing in phase by 'α' which is produce the reqd torque on the disc.

→ The torque produce is proportional to '$\phi_1\phi_2\sin\alpha$'.

→ An important features of this type of relay is that its operation can be controlled by opening or closing the secondary wnd ckt.

(iii) Induction cup structure :-



→ The construction of this type of relay is similar to the construction of Induction motor.

→ The stator wnd is supplied from the actuating quantity.

→ The rotor core is kept stationary only the rotor conductor portion being move freely.

→ The moving element is a hollow cylinder rotor which turns on its exceeds.

→ The rotating field is produced by 2 pair of coil on the 4-poles.

→ The rotating field induced the current & provided the necessary torque.

→ If ϕ_1 & ϕ_2 represent the flux produced by the respective pair of coil.

→ Then the torque produce is proportional to $\phi_1\phi_2\sin\alpha$

where, α = phase difference beth the 2 flux

→ The Induction cup structure is more efficient torque producer, than the shadded pole or the watt-hour cup structure.

* Important ~~term~~ :-

→ Peak-up current :- It is the minimum current of the relay coil at which the relay starts to operate. It is expressed in Ampere.

⇒ Current setting :- A relay can be made to operate at different peak-up current by providing tappings in the operating coil, this is known as current setting value of each tap. For over current relay taping of 50% to 200% are provided with the tap of 25%.

* Peak up current = rated secondary current of CT × current setting.

Ex:- An over current relay having a current setting of 125% is connected to a supply through a CT of 400/5, then peak up current = 5 × 1.25 = 6.25.

⇒ Plug setting multiplier (PSM) :-

→ It is the ratio ~~of~~ fault current of the relay coil to the pick up current.

$$PSM = \frac{I_{fault}}{I_{pick\ up}} = \frac{I_{fault}}{\text{rated 2ndary current of CT} \times CS}$$

⇒ Time setting multiplier (TSM) :-

→ A relay can be adjusted the different operating time this adjustment is known as TSM.

→ The TSM is multiplied with the relay operating time Vs PSM time; get the actual operating time.

→ TSM generally expressed in second.

Scanned with CamScanner

* Differential Relay :-

→ This is the relay which operates the phasor difference at the 2 or more similar electrical quantity exceeds a predetermine value.

→ This type of relay is used where more sensitivity of the operation is required.

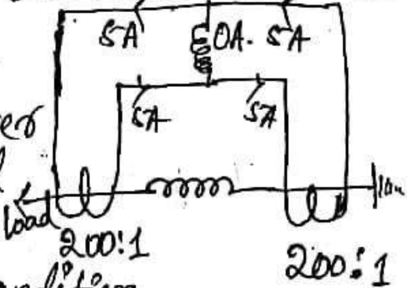
→ Depending upon the actuating quantity the differential relay can be divided into 2 types.

1 → Current balance protection system.
2 → Voltage balance protection system.

1) Current balance protection system :-

→ A base of idential CT are used on either side of the protected system, the 2ndary of CT are connected on series in such a way that they carry the same current in the same direction.

→ The operating coil of the over current relay is connected the CT secondary ckt.



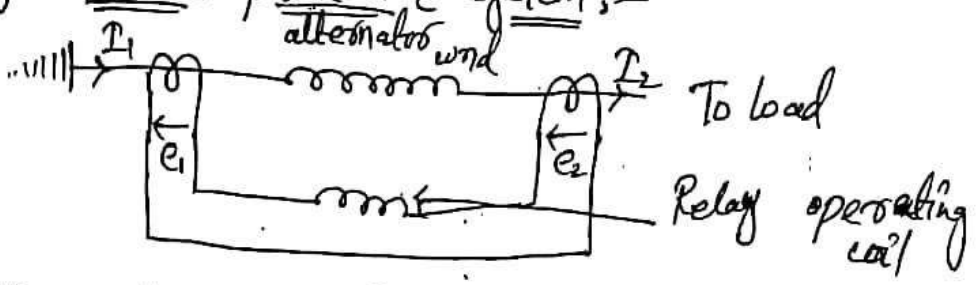
→ Under normal operating condition a normal current flows through the both the CT. i.e. the current flows through the 2 C.T. are equal.

→ As the current at the 2 C.T. are same there is no current flows through the relay coil so the relay can't be operate.

→ If a fault occure the secondary current of CT are not equal & the current flows through the relay coil & then the relay can be operated

* Disadvantage :- i) Exactly identical CT reqr.
ii) The accurate matching of can't be achive due to the pilot ckt impedance.

2) Voltage balance protection system :-



→ In this scheme of protection system two similar CT are connected on either end of the protected system by means of pilot wire.

→ Under normal condition equal current flows through the primary. wnd of the CT_2. Therefore the 2ndary voltage of thie & t/t are balanced to each other so no current flow through the relay operating current.

→ When the fault occure the protected one of the 2 primary of the C.T. will deffer from each other & the current flows through the relay operating coil which close the trip ckt.

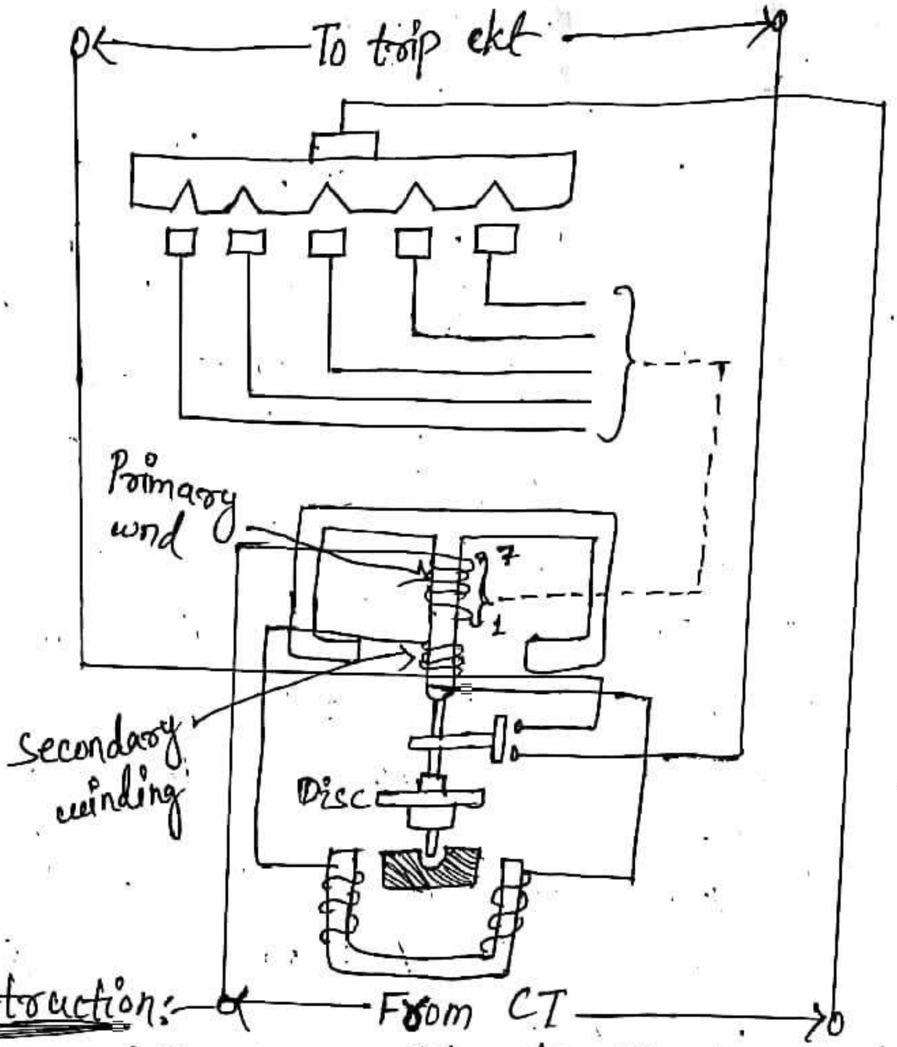
* Difference type of functional relay :-

→ Relay can classified into the following type according to there function.

i. Inductor type over current relay
ii. Induction type reverse direction power relay
iii. Distance relay
iv. Differential relay
v. Transtay relay

i) Induction type over current relay (Non-direction) :-

→ This types of relay operate on the induction principle. This relays are used in AC ckt only & can be operate for the fault current flows in either direction.



*Construction:

- → It consist of a metalic disc (Aluminium) which is free to rotate, In betn the poles of 2 electromagnet i.e. upper & lower magnet.
- → The upper electromagnet has the 2 wnd i.e. primary & secondary wnd.
- → The primary wnd is connected to a secondary of a CT in the line & is tap at a intervals.
- → The tappings are connc to a plug setting by which the no. of active turns of the relay operating coil varying for giving the desire current setting.
- → The secondary wnd is energized by induction from primary wnd & the secondary wnd is connected in series with the wnd of the lower magnet. The controlling torque is provided by a spring control.

→ **Operation :-**

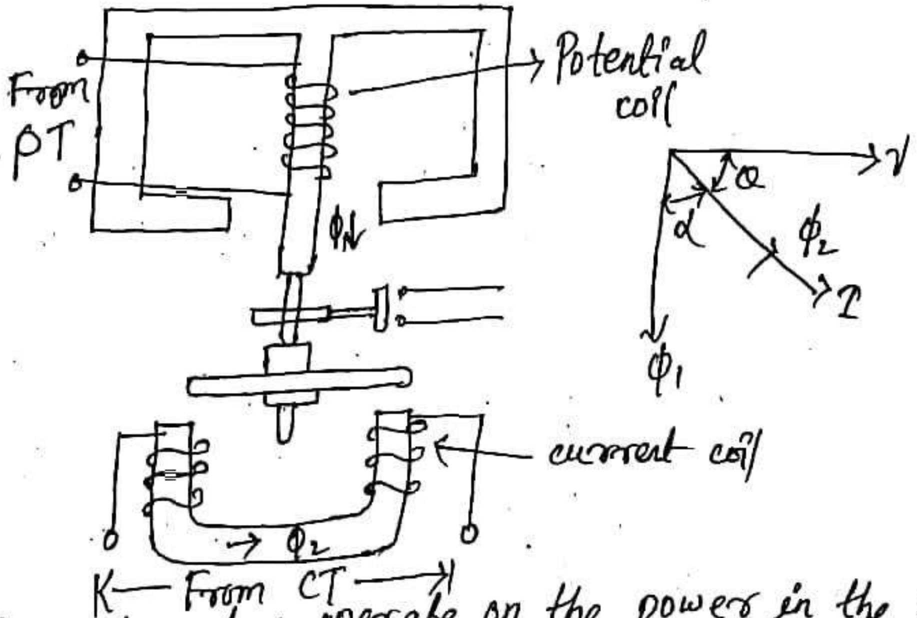
→ The deflecting torque on the alluminium disc is set up due to the Induction principle, this deflecting torque is opposed by the controlling torque which is provided by the spring.

→ Under normal operating condition the controlling torque is greater than the deflecting torque produced by the relay coil so the aluminium disc is remain stationary.

→ When the fault occur the current on the protected ckt exceeds, so the deflecting torque becomes greater than controlling torque, so the disc rotates.

→ When the disc has rotated the trip ckt closes & operate the C.B. which isolate the faulty section.

ii) Induction type direction power relay :-



→ This type of relay operate on the power in the ckt close in specific direction.

*** Construction :-**

→ It consist of aluminium disc which is free to rotate in both of poles of 2 electro-magnet. i.e upper & lower electro-magnet,

→ The upper electro-magnet carries a winding (called potential coil) on the central limb which is connected through a PT to the voltage source

- The lower magnet has a separate winding (called current coil) which is connected to the secondary of CT in the limb which is to be protected.
- The current coil is provided with a no. of tapping to provide different current setting.
- The controlling torque is provided by the spring control.

* Operation:— From the phasor diagram the flux ϕ_1 due to the current in the potential coil will be nearly 90° lagging behind the applied voltage 'V'.

- The flux ϕ_2 due to the current coil will be nearly in phase with an operating current 'I'.

$$T \propto \phi_1 \phi_2 \sin\alpha$$
$$\propto VI \sin(90-\theta)$$
$$\propto VI \cos\theta$$

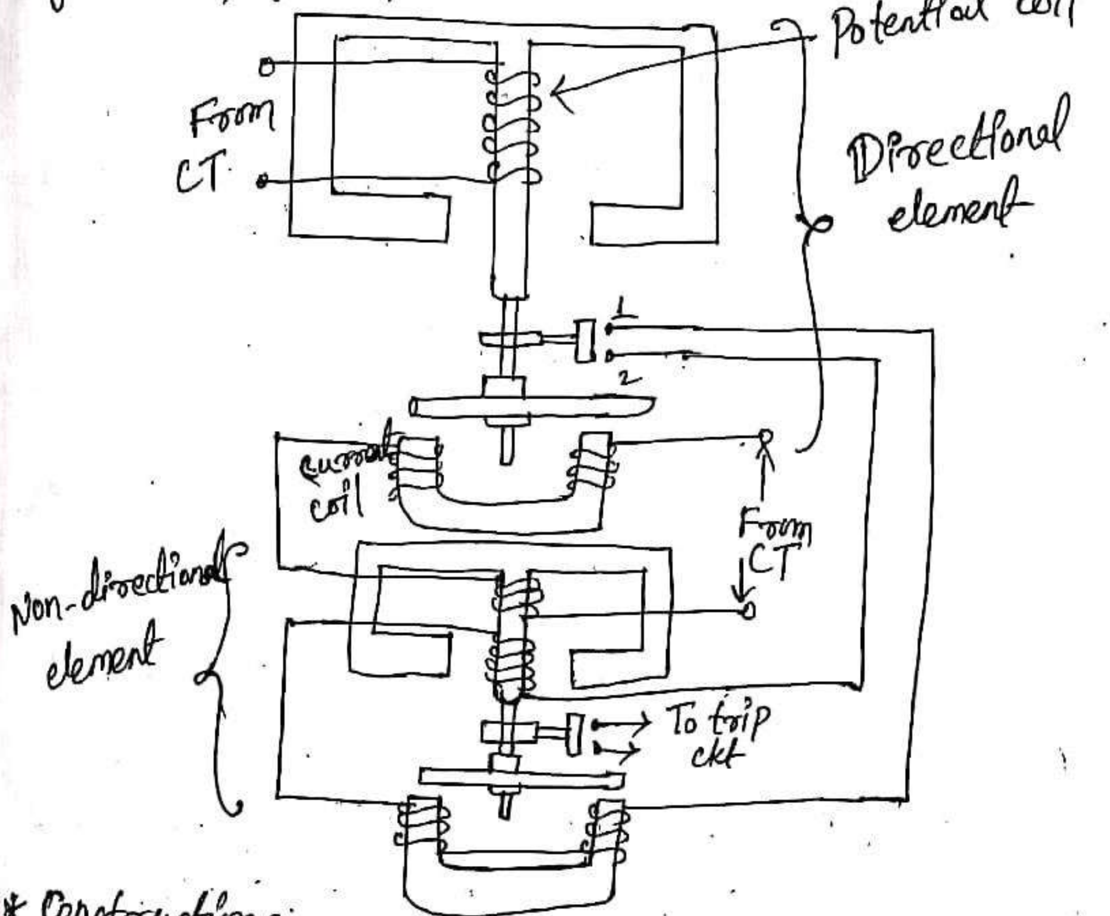
$T \propto$ Power in the circuit.

- It is clear that the direction of the deflecting torque on the disc depend upon the direction of the power flow in the ckt.
- When the power on the ckt flows on the normal direction the relay inoperative.
- When the fault occur the direction of current reverse, this reverse the direction of diflecting torque in the disc
- When the reverse deflecting torque becomes sufficient the disc rotates in the reverse direction & the moving contact close the trip ckt, this cause the operation of CB which disconnected the faulty section.

Induction type directional overcurrent relay:-

→ The directional power relay is on suitable for used as a protective relay under the short ckt condition.

→ When short ckt occur in the system voltage falls to a lower value so there may be insufficient torque difficulty is overcome in the directional over current relay which is independent of system voltage & power factor.



* **Construction:-**

→ It consist of 2 relay element i.e. directional element non-directional element.

e → **Directional element:-**

→ It is essentially a directional power relay which operates when a power flow in specific direction

→ The potential element of this element is connected through a PT.

→ Current coil of the element is enerzied through a CT this winding is carried over the upper magnet of the non-directional element.

↑ The trip contact (1 & 2) of the directional element are connected in series with the secondary ckt of the over current element. Therefore the directional element must operate first i.e. (contact 1 & 2 should close) in order to operate the over current element.

↑ Non-directional element:-

↑ It is an over-current element similar to a non-directional over current relay.

↑ The spindle of the disc of this element carries a moving contact which closes the trip ckt contact after the operation of directional element.

* Operation:-

↑ Under normal operating condition the power flow on the normal direction in the ckt.

↑ So the directional power relay does not operate therefore the over-current element does not operate.

↑ When a short ckt occure, there is a provision for the current or power to flow in the reverse direction, therefore the disc of the upper element rotate which closes the contact 1 & 2 this complete the ckt for over-current relay.

↑ So that the disc of the over current relay rotates & closes the trip ckt, this operates the ckt breaker which isolate the faulty / unhealthy section.

* Types of Protection :-

→ When a fault occurs on any part of electric power system it must be cleared quickly in order to avoid damage or interference with the rest of the system.

→ The protection scheme is divided into 2 classes these are (i) Primary Protection
(ii) Backup "

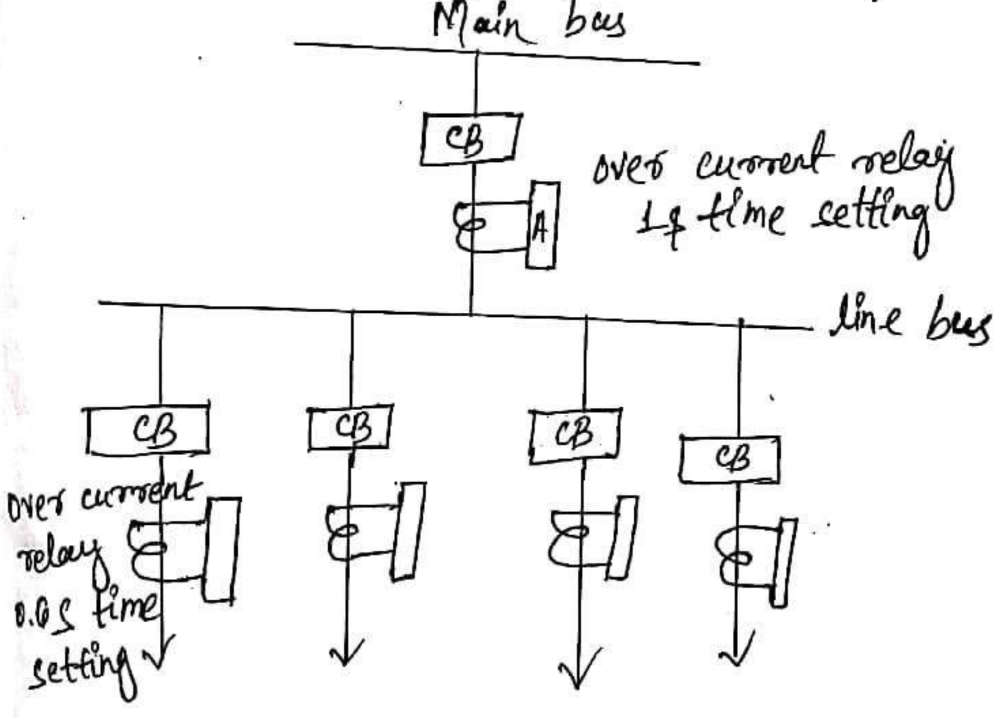
(i) Primary Protection :-

→ It is the protection scheme which is design to protect the component parts of the power system.

→ The fig. shows each line has an over current relay that protects the line.

→ If a fault occurs on any line it will be cleared by its relay & ckt breaker. This forms the primary or main protection.

→ However sometimes faults are not cleared by primary relay system because of trouble with in relay wiring system or breaker under such condn. back up protection required.



iii) **Backup Protection :-**

→ It is the second line deffence in case of failure of the primary protection.

→ It is design to operate with sufficient time delay so that primary relay will be given enough time to function.

→ Fig. shows that, Relay 'A' provides back up protection for each of the four line.

→ If a line fault is not cleared by its relay and breaker, the relay 'A' will operate after a definite time delay and clear the fault.

*

Dt- 06/03/20 {Protection of Electrical power // Ch-6
// equipment and lines }

→ The electric power system consist of several equipments & these are alternator, t/f, busbar, transmission line & other equipments.

→ It is desirable & neccessary to protect each element from a variety of fault conditions. *

* Protection of t/f :- The t/fs are the static device and totaly enclosed and generally oil immerssed ∴ there is a chance of fault occurring on them. so, this is neccessity to provide the adquite to automatic protection for t/f against any possible fault.

⇒ Common t/f fault :- The power t/f may suffer from;-

→ open ckt, over heating and short ckt etc.

→ An open ckt in 1ϕ of a 3ϕ t/f may cause undesirable heating. On the occurance of such fault the t/f can be disconnected manually from the system.

→ The short ckt on the t/f arise (create) from detoriation (loss) of insulation due to over heating. When an internal fault occur the t/f must be disconn quickly from the system. ∴ the relay protection is neccessary for internal fault.

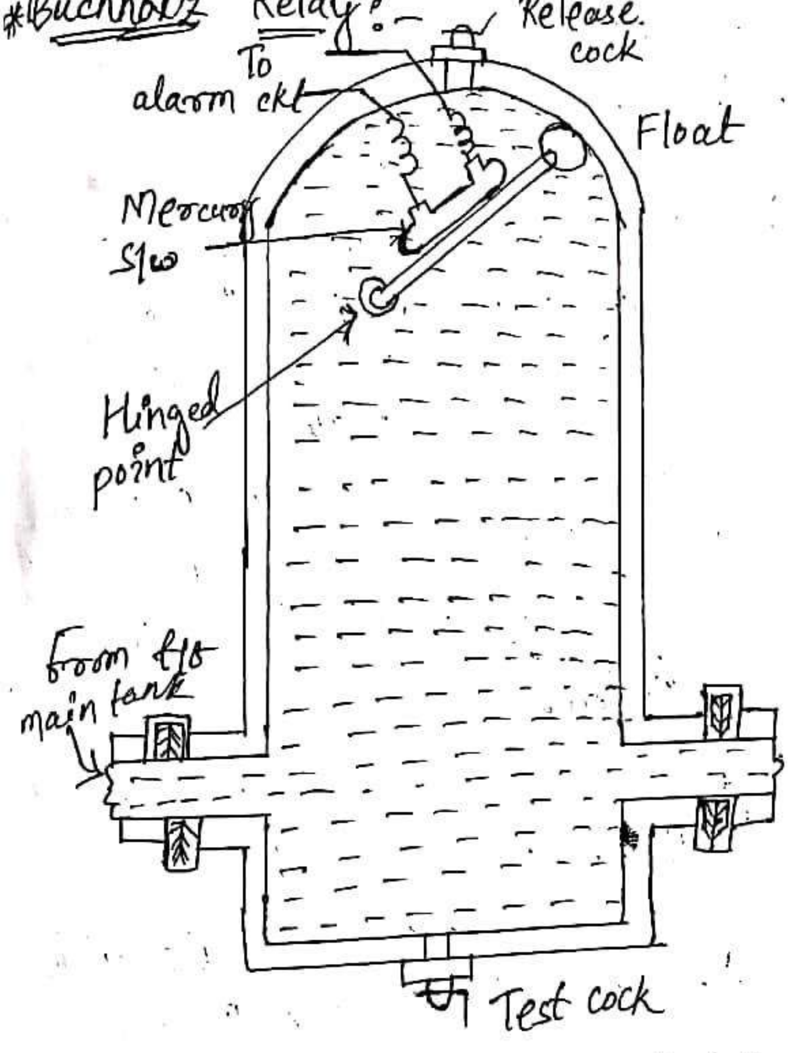
⇒ Protection system for t/f :- The principle relays and systems used for t/f protections are;

↳ Earth fault relay → (Providing the protection against arc fault only)

- ↳ Over I relay - (Providing the protection against phase to phase fault & over loading)
- ↳ Differential system or Circulating current system - (Providing protection against both earth & phase fault)
- ↳ Buchholz relay - (Providing protection against slow developing fault such as insulation failure of the wind, core heating, fall of oil level,)

Dt - 11/03/2020

#Buchholz Relay :-



> This relay is a gas actuated relay installed in oil immersed t/f for the protection of all kind of slow developing fault.

> It is used to give an alarm in case of slow developing fault in the t/f and it can be disconn^c from the t/f in the event of severe internal fault.

→ It is usually installed in the pipe connecting to the conservator to main tank.

→ The buchholz relay is used in the oil immersed t/f having the rating an ~~exces~~ of 750 KVA

* Construction :-

It takes the form of a domed vessel placed in the connecting pipe betn the main tank & conservator.

→ It has 2 element the upper element consist of a mercury type s/w attached to a float

→ The lower element contain a mercury switch mounted on a hinge type flap located in the direct path of the flow of oil from the t/f to the conservator tank.

→ The upper element closes an alarm ckt during the slow developing slot where as the lower element is arrang to trip the ckt breaker in case of severe fault.

* Operation :- In case of slow developing fault with in the t/f the heat due to the fault causes decomposition of some t/f oil in the main tank. The product of decomposition containe more than 70% of the Hydrogen-gas.

→ The H-gas is in light weight so it always tries to go into the conservator & in the process gets entrapped in the upper part of the relay chamber.

→ When a predetermined amount of gas gets accumulated it exerts sufficient pressure on the float to cause it to tilt. (move) and close the mercury s/w attached to it. This complete the alarm ckt to sound an alarm.

→ If a severe fault occur in the t/f an enourmous (high) amount of gas is generated in a main tank, & the oil in the main tank rushes (ଦୌଡ଼ିବା) towards the conservator via the buchholz relay and in doing so tilt the flap to close the contact of mercury s/w. This complete the trip ckt to open the ckt breaker which controlling the t/f.

→ **Advantage :-** 1. It is the simplest form of t/f protection.

2. It detect incipient (slow developing) fault at a much earlier stage than othe form of protection.

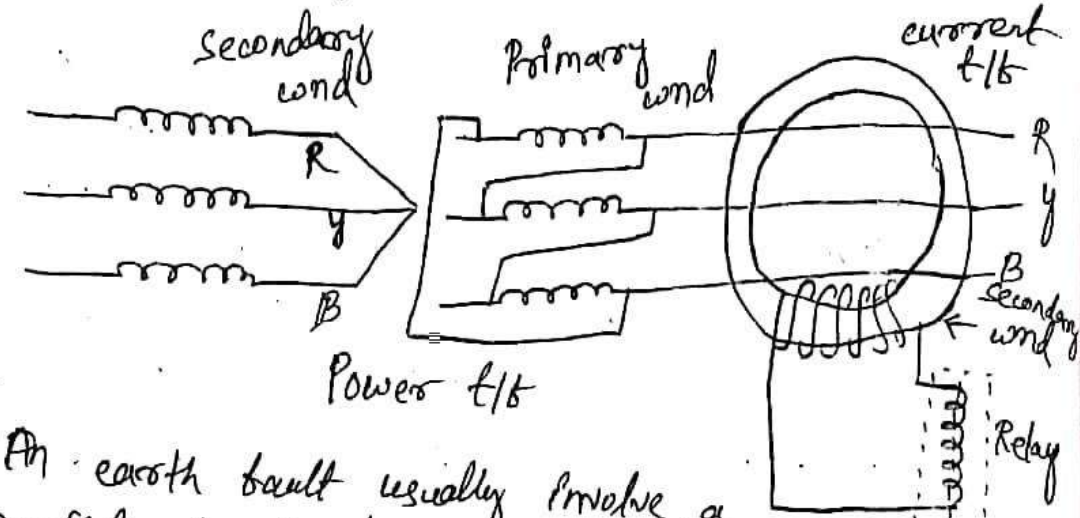
→ **Disadvantage :-**

1. It can only used with oil immersed t/f equipped with conservator tank.

2. The device can detect only fault below oil level in the t/f.

Dt - 12/03/2

* Earth fault or leakage protection :-



→ An earth fault usually involve a partial break down of wnd insulation to earth & the earth fault may continue for a long time & cause considirable damage before it develope the short ckt & remove from the system.

→ Under this case it is profitable to enploye earth fault relay in order to ensure the disconnc of earth fault in the early stage

→ An earth fault relay is essentially an over current relay & it is the method which provide the protection against earth fault in a t/f.

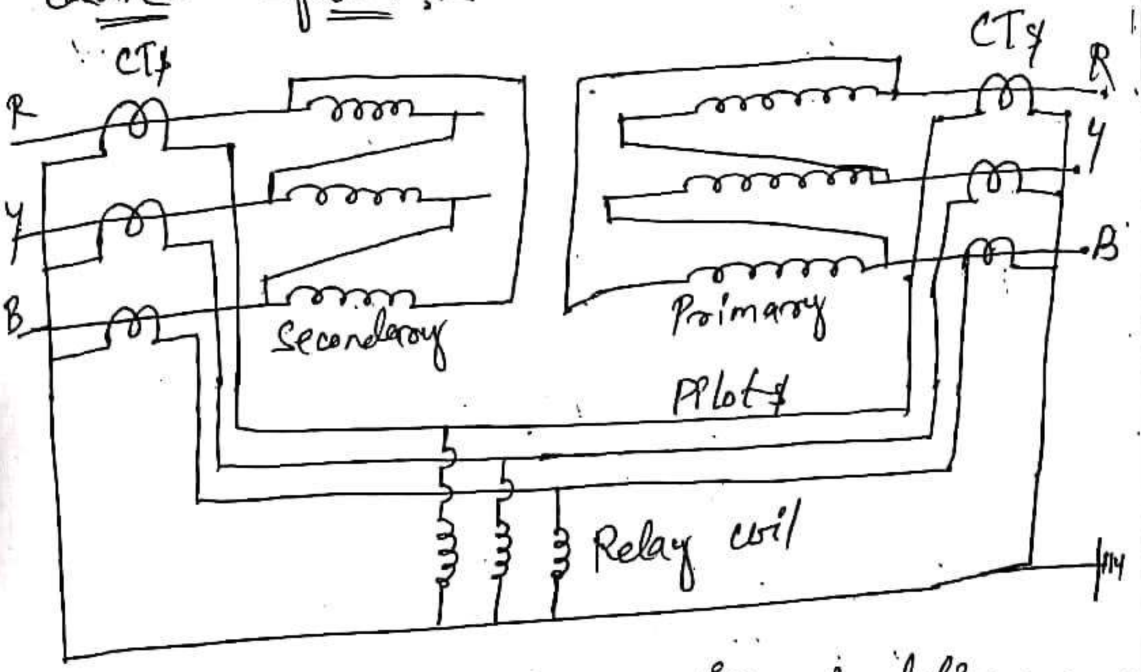
→ In this method the 3 lead of primary wnd of the power t/f are taken through the core of a current t/f.

→ The operating coil of the relay is connc to the secondary wnd of the current t/f.

→ Under normal condn the vector sum of the 3ϕ current is zero. & there is no resulting flux in the core of the current t/f ∴ no current flows through the relay & it remains inoperative.

→ On the occurrence of an earth fault the vector sum of 3φ current is no longer zero & the resultant current set up flux in the core of the CT which induced EMF in the secondary and this energies the relay coil to trip the ckt breaker and disconnect the faulty t/f from the system.

Differential protection system or circulating current system :-



→ The fig. shows the merz-price circulating current scheme. For the protection of a 3φ delta-delta t/f against phase to ground & φ to φ fault.

→ The CT's of the 2 side of the t/f are connc in star this compensate for the φ diffr beth the power t/f primary & secondary.

→ The CT's on the 2 sides are connc by pilot wires & one relay is use for each pair of CT. During the normal ope. condn the secondary of CT's carry identical current.

∴ The current entering & leaving the pilot wire at both end are same & no.

current flow through the relay.

→ If a ground & ϕ to ϕ fault occure the current in the secondary side of CT will not same and differential current flowing through the relay ckt.

* Protection of alternator:-

→ It is desirable & necessary to provide the protection against the wide range of fault which may occur in the modern generating plant. Some of the imp. fault which may occure on the alternator are:-

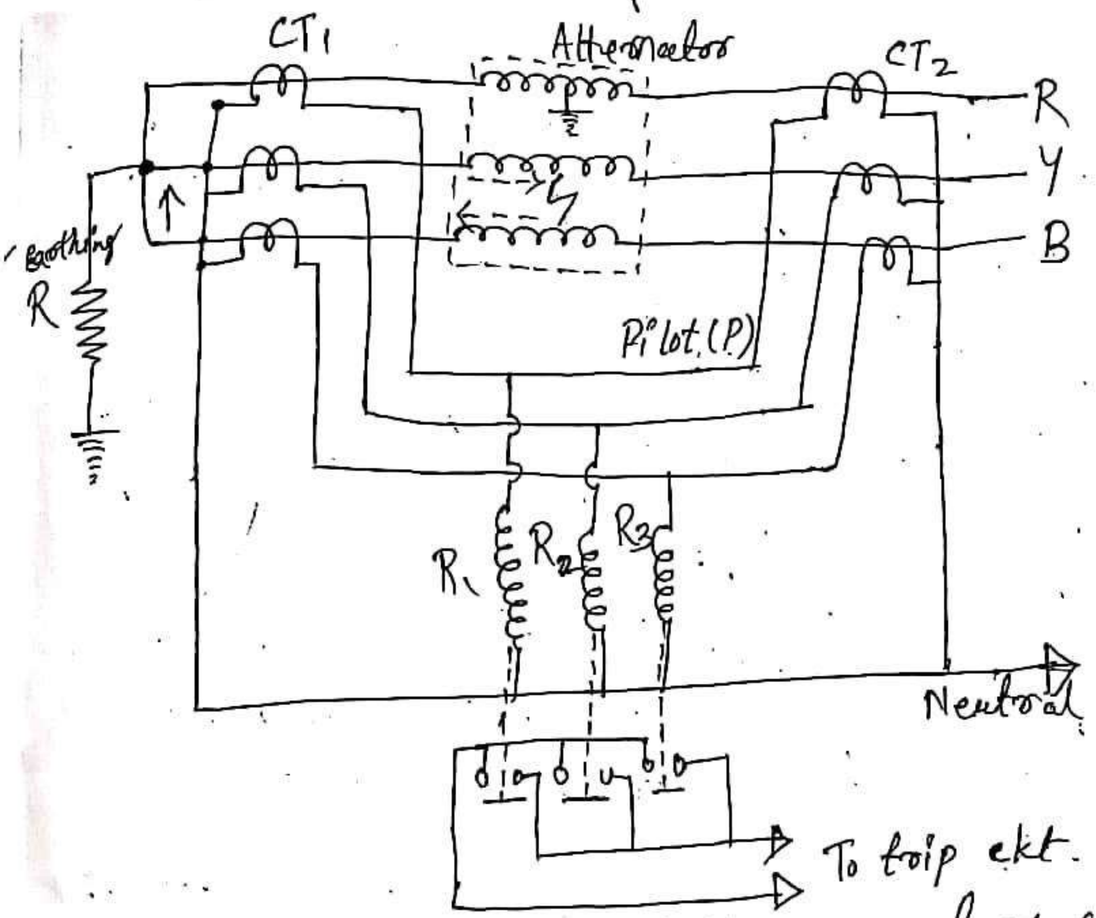
i) Failure of Prime-mover
ii) Failure of field winding
iii) Over current
iv) Over speed
v) over voltage
vi) Unbalanced loading
vii) Stator wnd fault.

→ The stator wnd faults are the most dangerous which may cause damage to the expensive m/c. ∴ automatic protection necessary to clear such fault in order to minimize the damage.

→ For the protection of alternator against such fault, differential protection also known as merz-price system is most commonly employed.

→ Differential protection of Alternator:- Dt-13/03/2

→ The most common system used for the protection of stator wnd fault employed circulating current principle.



→ In this scheme current at the two end of the protected section are compared.

→ Under normal ope. condn these currents are equal but in case of faults there may be difference in currents & this resulting / differential current pass through the operating coil of the relay. Then the relay close its contact to isolate protected section from the system.

→ This form of protection is also known as <u>merz-price</u> <u>circulating</u> <u>current</u> <u>scheme</u>.

<u>schematic</u> arrangement :-

The fig. <u>shows</u> the schematic arrangement of differential I protection for a 3ϕ alternator.

→ Here the identical current t/f pairs CT1 & CT2 are placed on either side of each phase of the stator winding.

→ The secondary wnd of each set of CT are connc in star and the two neutral point & the corresponding terminal of the 2 star group being connected together by means of 4 core pilot wire.

→ Thus there is an independent path for the I. circulating in each pair of the CT & the corresponding pilot wire

→ The relay coils are connc in star the neutral point being connc to the CT common neutral & the outer ends are connected each of the 3 pilot wire. *

→ The relays are connc across the equip-potential point of the 3 pilot wire & these points are naturally located at the middle of the pilot wire.

* Operation:— Under the normal operating condn the current at both end of each wnd will be equal & hence the I at secondary of 2-CTs connected in any phase will also be equal.

∴ there is a balanced circulating current in the pilote wire & no current flow through the relay coil.

→ When an earth fault or phase to phase fault occur the diff current flowing through the relay ckt & then the relay operates to trip the ckt breaker.

→ Suppose an earth fault occur on phase

'R' due to break down of its insulation to earth as shown in fig. the I in the effected phase (R) will flow through the core & frame of the m/c to earth.

→ Then the ckt being competed through the neutral earthing R. The I in the secondary of the two CT in phase R will becomes un-equal and the difference of the 2 current will flow through the corresponding relay coil (R_1) & then the relay operated to trip the ckt breakers.

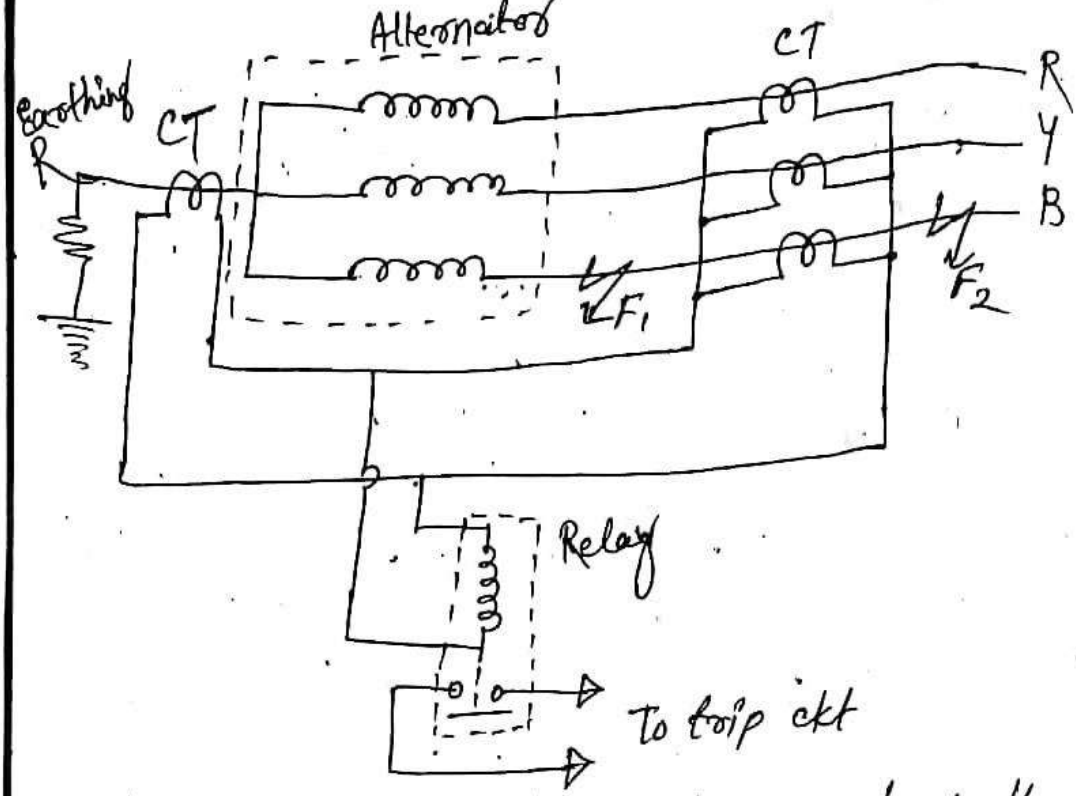
* suppose now a short ckt fault occurs both the phase Y & B as shown in fig. The Isc circulate through the neutral end of the 2 wind and through the fault as shown by the dotted arrow. of the CTs in each

→ The I in the secondary will becomes unequal effected phase (Y & B) will flow through the operating & the diffr I will flow through the operating coils of the relays (R_2 & R_3) connc in these phase. Then relay close the contact of trip coil to close the ckt breaker.

* **Balanced earth fault protection system:-**

In small size alternator the neutral & the 3ϕ windg are connc internally to a single terminal, ∴ it is not possible to use the circulating I system, becz there are no facilities to accomodate the necessary CTs in each phase cond.

merz-price



* Schematic arrangement :- The fig. shows the schematic arrangement of balanced earth fault protection for a 3ϕ alternator.

* It consist of 3 line CT, one mounted in each phase having their secondary connc in llel with the single CT in the conductor joining the star point of the alternator to earth.

→ A relay is connc across the CT secondary.

→ Operation :- Under normal operating condn the I flowing in the alternator leads & hence the I flowing in the secondary of the line CT add to zero and no I flows through the relay coil.

→ Under this condn the I in the neutral wire is also zero.

→ If the earth fault develope at F_2 which is external to the protected zone the sum of the I at the terminal of the alternator is exactly equal to the I in the neutral conne & hence no current flows through the relay.

→ When a earth fault occur in F_1 or with in the protected zone, these current will no longer equal & the differential I flows through the operating coil of the relay & the relay then close its contact to disconnect the alternator from the system.

* **Protection of busbar :-**

The busbar & transmission line are the imp. element of the ele. power system & reqr the immediate protection against the possible fault occuring on them.

→ The busbar in the generating station & substation form an imp. link beth the incoming and outgoing ckt.

→ If the fault occur in a busbar it can damage the incoming & outgoing section.

→ The busbar zone for the purpose of protection include not only the busbar themself but also the isolating s/w, ckt breakers are used. In the event of fault on any section of the busbar all the ckts equipement conne to that section must be trip to give the complete isolation.

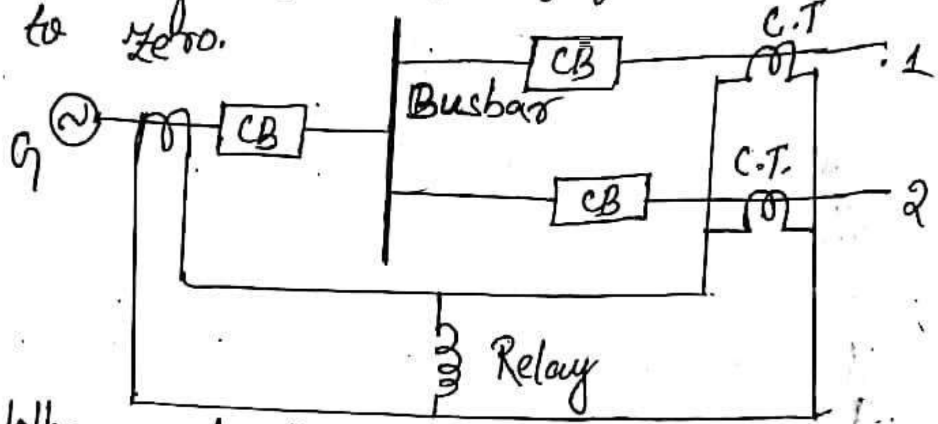
→ There are 2 must commonly used methods for the busbar protection are :-

(a) Differential protection

(b) Fault bus ″

a) Differential protection :- The basic method for busbar protection is the differential scheme of protection.

- In this scheme the current entering & leaving the bus are totalised.
- During normal operating condition the sum of incoming current & outgoing currents is equal to zero.



- When a fault occurs, the fault current produces a differential current to operate a relay.
- The fig. shows the single line diagram of differential protection scheme.
- The busbar is fed by the generator and supplies load to two lines.
- The secondaries of CT in generator load, line 1 & line 2 are conn^c in parallel.
- The protective relay is connected across this parallel connection.
- Under normal cond^n the sum of the current entering the bus is equal to the sum of the current leaving from bus and no current flows through the relay.
- If a fault occurs within the protected zone the current entering the bus will not equal to the current leaving the bus.
- The difference of these currents will flow through the relay & cause opening of Generator, Ckt breaker & each of the line ckt breaker.

* Fault bus protection :-

→ This is design to provide the protection against the earth fault.

→ This can be achived by providing earthed metal barrier surrounding each conductor, throughout its entire length in the bus structure

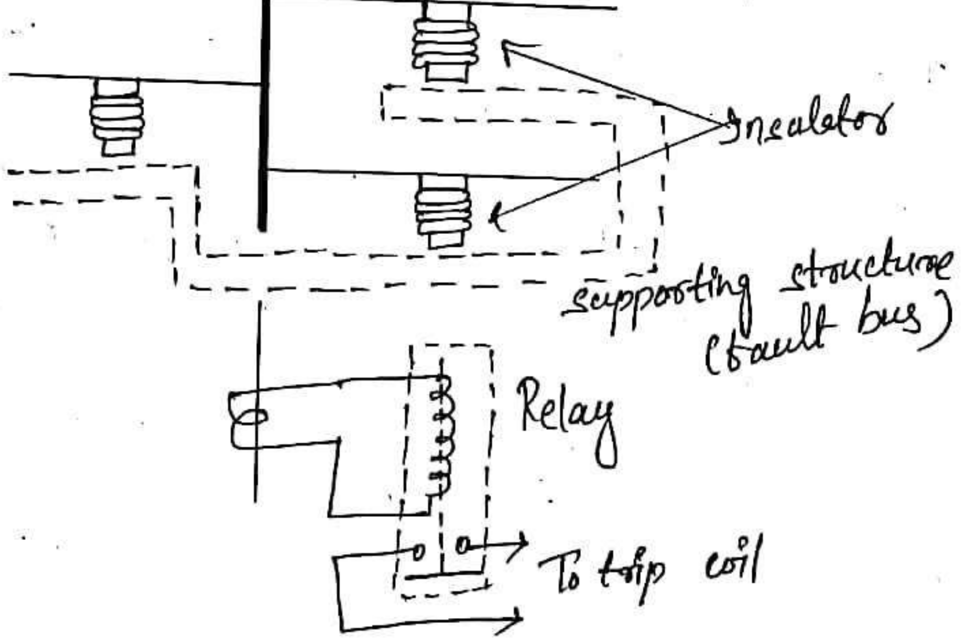
→ In this arrangement, By directing the flow of earth fault current, it is possible to detect the faults & determine their location this type of protection is known as fault bus protection.

→ The metal supporting structure or fault bus is earthed through a CT. A relay is connected across the secondary of CT.

→ Under normal operating condn. there is no current flow from fault bus to ground so the relay remain inoperative.

→ When a fault occur a connection betn a conductor & earthed supporting structure will result in current flow to ground through the fault bus which causes the relay to operate.

→ The ope. of relay will trip all breakers connecting equipment to the bus.



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* Differential pilot wire protection :-

→ The differential pilot wire protection is based on the principle that under normal condn the curre entering one end of a line is equal to that leaving the other.

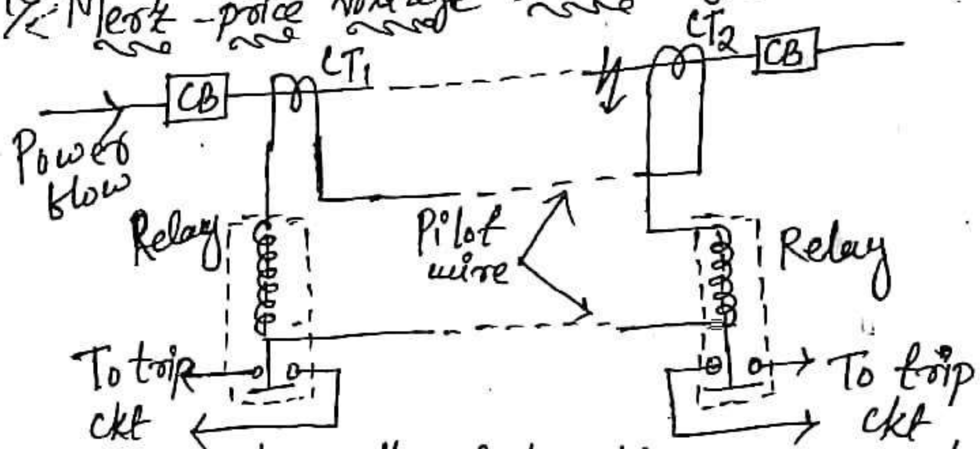
→ But when fault occurs betn the 2 ends, the diff betn incoming & outgoing current flow through the relay which operate the ckt breaker to isolate the faulty line.

→ There are 2 types of differential protection scheme

1) Merz- price voltage balance system.

2) Transly scheme.

1) Merz -price voltage balance system :-



→ The fig. shows the single line diagram of merz- price voltage balance system for the protection of a 3ϕ line.

→ Identical current t/fs are placed in each phase at both ends of the line.

→ The pair of CTs in each line is connected in series with a relay in such a way that under normal condn their secondary voltage are equal and in opposite direction.

→ Under normal condition current entering the line at one end is equal to that leaving it at the other end. Therefore equal & opposite voltage are induced in the secondaries of the CTs at the 2 end of line so that no current flows through the relay.

→ If the fault occurs at point F on the line this will cause a greater current to flow through CT_1 than CT_2

→ ∴ secondary voltage become unequal & circulating current flows through the pilot wire & relay.

→ The ckt breakers at both ends of the line will trip out and the faulty line will be isolated.

* <u>Advantage</u>:-

i) This system can be used for ring main as well as parallel feeder.

ii) This system provide instaneous protection for ground fault.

* <u>Disadvantage</u>:-

i) Accurate matching of current t/f is very essential.

ii) If there is a break is the pilot wire ckt the system will not operate.

iii) This system is very expensive.

iv) This system can't be used for line voltage beyond 33KV because of constructional difficulties in matching the current transformer.

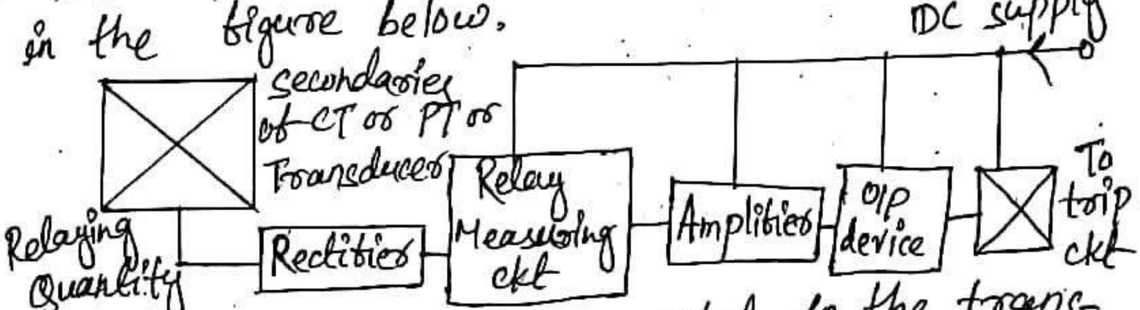
ch-8 Static Relay

* Defn:- The relay which does not contain any moving parts is known as static relay.

→ In such type of relays the o/p is obtain by the static component like magnetic & electronic ckt.

→ The relay which consist static & electromagnetic relay also called as static relay because the static unit obtain the response & the electromagnetic relay is only used for switching ope..

→ The component of the static relay is shown in the figure below.



→ The i/p of the CT is connected to the transmission line and their o/p is given to the rectifier.

→ The rectifier was rectifing the i/p signal & pass it to the relaying measuring unit.

→ The rectifying measuring unit has the comparates level detector & logic circuit.

→ The o/p signal from relaying unit obtains only when the signal reaches the threshold value.

→ The o/p of the relaying measuring unit acts as i/p to the amplifier.

→ The amplifier amplifies the signal & gives the o/p to the o/p device.

→ The o/p device activate the trip coil only when the relay operates.

→ The output device is activated & gives the tripping command to the trip coil.

→ The static relay only gives the response to the electrical signal.

→ The other physical quantity like heat, tempr. etc. is first converted into the analogue and digital electrical signal & then act as an input for the relay.

* <u>Advantage</u> <u>of</u> <u>static</u> <u>relay</u> :-

→ The static relay consumes very less power.

→ The static relay gives quick response, long life, high reliability & accuracy.

→ The reset time of the relay is very less.

→ The relay amplifies the i/p signal which increase their sensitivity.

→ The change of unwanted tripping is less in this relay.

* <u>Limitations</u> <u>of</u> <u>static</u> <u>relay</u> :-

→ Special maintenance is provided to the component

→ The relay is easily affected by the high voltage surge.

→ The working of the relay depends on the electric component.

→ The relay has less over-loading capacity.

→ The static relay is more costly.

→ The construction of the relay is easily affected by the surrounding interference.

* **Instantaneous Over-current relay:-**

→ This relay is one in which no intentional time delay is provided for operation.

→ In such relay, the relay contact close immediately after the current in the relay coil exceeds.

→ In this relay a magnetic core is wound by a current coil.

→ A piece of iron is so fitted by hinge support & restraining spring in the relay

→ When there is not sufficient current in the coil, the no contact remain open.

→ When the current in the coil crosses a preset value, the attractive force becomes enough to pull the iron piece toward the magnetic core & therefore no contact get closed.

→ This relay is referred as instantaneous over. The current in the coil gets higher than the preset current.

9th CHAPTER

1 PROTECTION AGAINST OVER VOLTAGE AND LIGHTENING

Voltage surge :-

-> The sudden rise in voltage for very short duration on the power system is known as voltage surge or transient voltage.

-> The transient or surge are of temporary nature & exist for a very short period of time but they cause over voltage on the power system.

-> The most important transient are cause by lightening striking to a transmission line.

Cause of over voltage :-

The cause of over voltage of a power system may be devided into main categories.

i> Internal cause
ii> External cause.

i> Internal cause :-

-> The internal cause do not produce surge of large magnetude.

-> The surge due to internal cause increase the system voltage to twice normal voltage.

-> The internal cause of over voltage on the power system can be produce by the suddenly change in ckt condition.

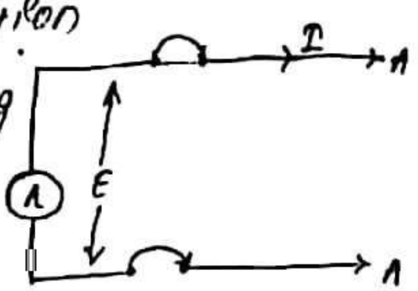
Switching surge :-

The over voltage produce on the power system due to switching operating are known as switching surge.

a) In case of unload line :-

-> During the switch operation of unloaded line travelling wave are set up which produce over voltage on the line.

dia



-> Consider a unloaded line connect the voltage source when the unloaded line connected to the voltage wave is set up which travel along the line.

-> on reaching the terminal point 'A' it is reflected back to the supply with out change of its sign this cause voltage doubled i.e on the line becomes twice the normal value.

b) In case of loaded line :-

-> The over voltage will be also produce during the switching operation of loaded line.

-> Suppose a loaded line is interrupted this will be set up the high voltage.

Current chopping :-

-> when the breaking low current with air blast ckt breaker, the powerful deionization effect of air blast cause the current to fall to 'zero' before the nature current 'zero'. This phenomenon is called current chopping & produce transient voltage across the breaker contact.

-> The over voltage due to current chopping are prevented by the resistance switching.

Insulation failure :-

-> The most common case of insulation failure is the grounding of conductor, which may cause over voltage in the system.

Resonance :-

-> Resonance of electrical system occurs when inductive reactance of the ckt equal to capacitive reactance.

-> under resonance condⁿ the impedance of the ckt is equal resistance of the ckt & power factor is unity so the resonance cause high voltage in electrical system.

ii) External cause :-

Lightning :-

An electric discharge betⁿ cloud and earth betⁿ cloude or betⁿ the charge centres of the same cloud is known as lightning.

-> Lightning is a huge spark and takes place when clouds are charged to such a high potential, with respect to earth or a neighbouring cloud thus the dielectric strength of neighbouring medium (air) is destroyed.

-> There are several theories exist to explain how the cloude acquire charge the most accepted one is that during the up rush of warm moist air from earth, The friction betⁿ the air and the tiny particles of water causes building up of charges.

→ when drop of water formed, the larger drop becomes positively charged & the smaller drops becomes negatively charged.

→ when the drops of water accumulate, they form clouds, & hence cloud may possess either a positive or a negative charge, depending upon the charge of drop of water they contain.

→ The charge on a cloud may become so large that it may discharge to another cloud or to earth & we call this discharge as lightning

Mechanism of lightning discharge :-

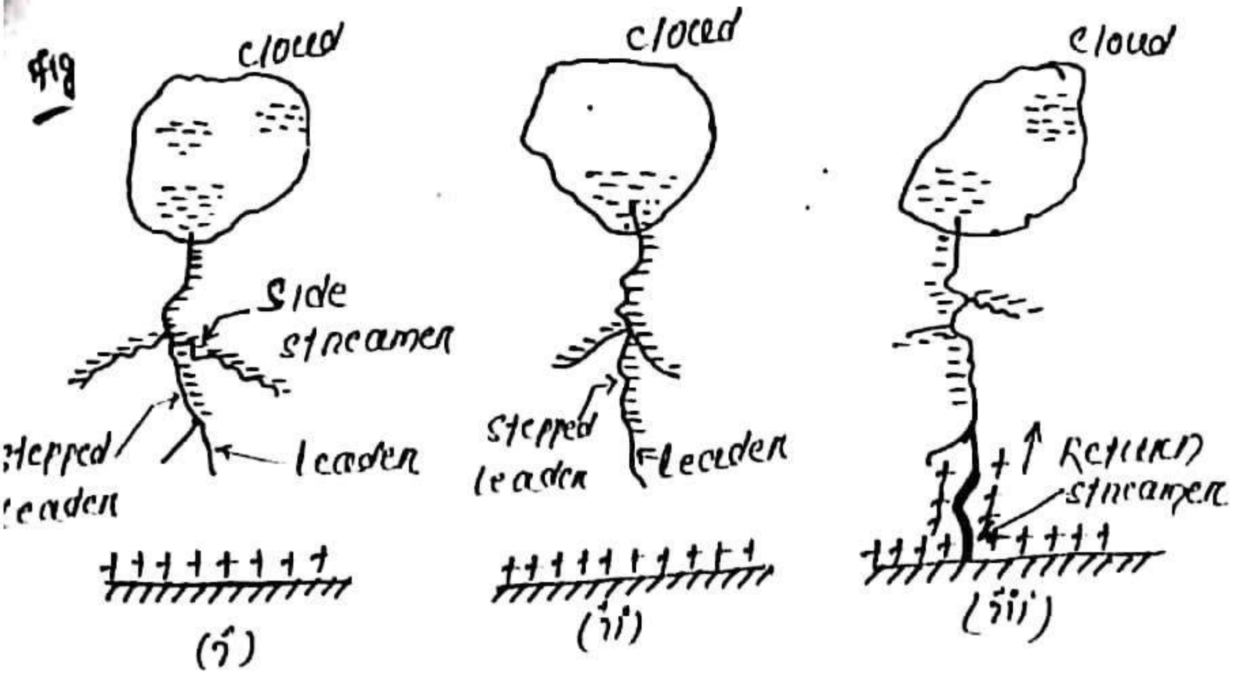
→ when a charged cloud passes over the earth, it induces equal & opposite charge on the earth.

→ The figure shows a negatively charged cloud induces a positive charge on earth.

→ As the charge acquired by the cloud increases, the potential difference betn cloud & earth increases and therefore potential gradient in the air increases.

→ when the potential gradient is sufficient (5 kV/cm to 10 kV/cm) to break down the surrounding air the lightning stroke starts.

fig



Types of lightning stroke :-

There are two main ways in which a lightning strike the power system. these are

(i) Direct stroke
(ii) Indirect stroke

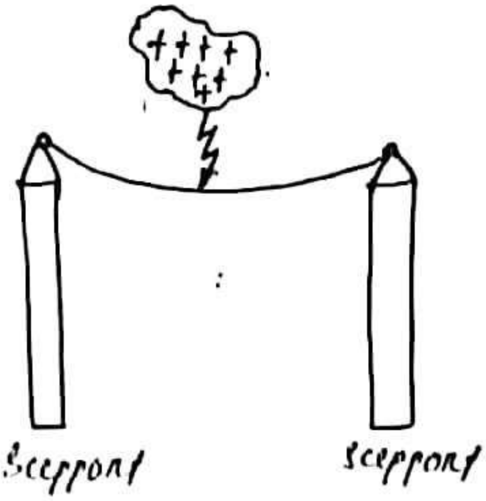
Direct stroke

In the direct lightning strokes, the cloud attains a large amount of charge and induces an opposite. charge on taller objects such as temples, churches etc.

-> when the intensity of electrostatic field becomes sufficiently great to ionise the neighbouring air, the air break down and discharge takes place. betn the cloud and the object.

-> Such types of discharge take a long time to produce and it strikes the highest and the most sharply pointed building.

fig



Indirect strokes :-

Indirect strokes result from the electrostatically induced charges on the conductors ? due to the presence of charged clouds.

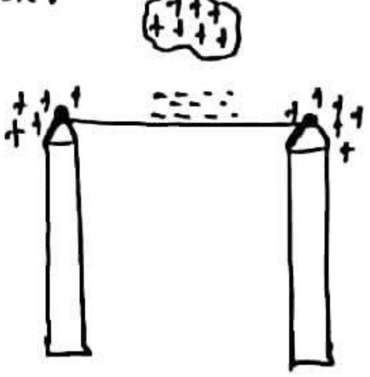
-> A positively charged cloud is above the line and induces a negative charge on the line by electrostatic induction.

-> This negative charge will be present only on the portion of the line right under the cloud and portion of line away from it will be positively charged as shown in fig.

-> The induced +ve charges leak slowly to earth via the insulator.

-> When the cloud discharge to earth or to another cloud, the -ve charge on the wire is isolated as it cannot flow quickly to earth over the insulator.

fig



Harmful effect of lightning :- 7

A direct or indirect lightning stroke on a transmission line produces a steep-fronted (rise & fall sharply) voltage wave on the line

-> The voltage of this wave may rise from zero to peak value (about 2000KV) in 1μs & decay to half the peak value in 5 μs.

-> This steep fronted voltage wave will initiate travelling waves along the line in both direction.

(i) The travelling wave produced due to lightning surges will damage the insulators, and may also damage the poles

(ii) If the travelling wave produced due to lightning hit the windings of a transformer or generator it may damage the equipments.

(iii) If the arc is initiated in any part of the power system by the lightning stroke, this arc will set up very disturbing oscillations in the line, this may damage other equipment connected to the line.

Lightening Arrester :-

-> A lightening arrester or a switch device is a protective device which conduct the high voltage surge on power switch to ground

> It consist of spark gap in Series with a non-linear resistor. one end of the diverter is connected to the terminal of equipment which is to be protected & the other end is connected to the ground.

-> The length of the gap so set the normal line voltage can't enough to cause an arc.

-> The property of the non-linear resistance is that its resistance decrease & voltage increase vice versa.

-> Under normal cond^n operating the lightning arrester is off & it conduct no current to earth providing the low resistance path to the ground in this way the excess charge on the line due to the surge is harmlessly conducted to the arrester to the ground.

Types of Lightening Arrester :-

There are several types of lightening arrester there are

i> Rod-gap Arrester
ii> Horn-gap arrester
iii> multi-gap arrester
iv> Expression type arrester
v> Valve type arrester

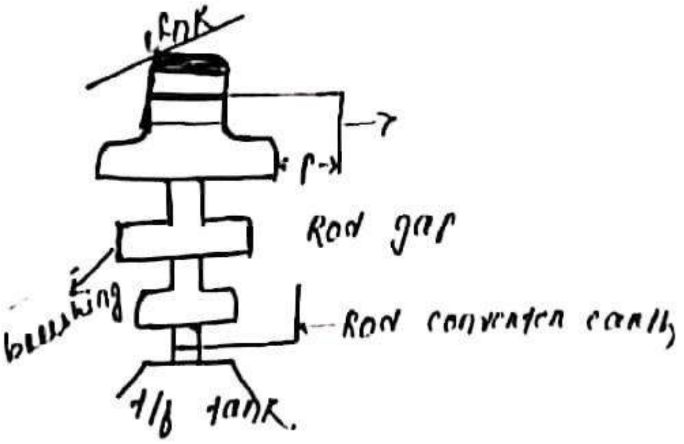
i> Rod-gap Arrester

-> It is very simple type of diverter & it consist of two 1.5 cm rod which are send at right angle with a gap in betn them.

-> one rod is connected to the line ckt & the other rod is connected to earth.

-> under normal operating condition the gap remain non-conducting, on the occurance of a high voltage on arc is produce & leads to the surge current is conducting to the earth in its way the excess charge on the line harmlessly conducted to the earth.

fig



limitation :-

-> After the surge is over the arc in the gap of main tripped by normal supply voltage which is large to short CKT on system.

-> The rod may melt or get damaged due to excessive heat produced by the arc.

-> The climating condn effect the pherformance of rod gap lightning arrester.

-> Due to the above limitation the rod gap arrester is only used as a backup protection in case of main arrester.

ii) Horn gap Arrester :-

it consist of two horn shape metal rod A & B seperated by a small air gap.

-> The horns are so constructed that the distance betn the two horns gradually increased toward the top as shown in fig.

-> The horns are mounted on the porcelein insulator

-> One end of the horn is connected to the line through a resistance 'R' & a choke coil 'L' ~~bon~~ the other end is grounded.

-> under normal operating condn the gap is non-conducting i.e the normal

IC insufficient to produce the gap betn horns.

-> on the occurance of over voltage an arc is produced betn the horns.

-> The arc moves progressively into the position 1, 2, & 3.

-> At the position 3 the distance betn the horns too large for the voltage to maintain the earth so the arc is extinguish.

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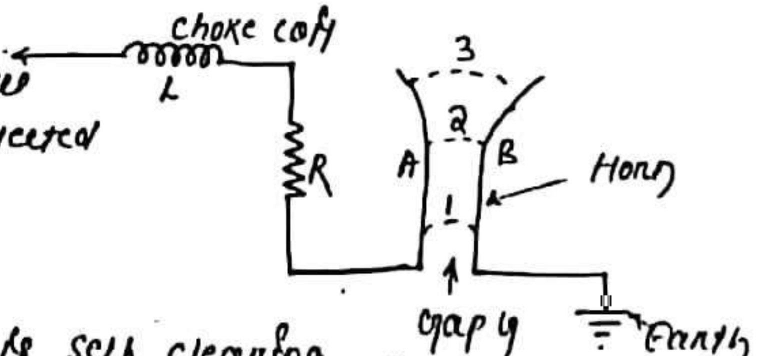


Advantage :-

-> The arc is self clearing therefore this type of arrester does'not cause short ckt after the surge is

-> The series resistance helps in limiting the current to a small value.

-> The bridging of gap by some external agency or cause can render the device useless

-> The time of operation is comparatively long.

iii) Multigap Arrester :-

-> It consist of a series of metallic cylinders insulated from one another & separated by small interval of air gap.

-> The 1st cylindere i.e (A) is connected to the line & the other connected to the ground through a series resistance.

-> under normal condn the normal supply voltage is unable to breakdown the gaps.

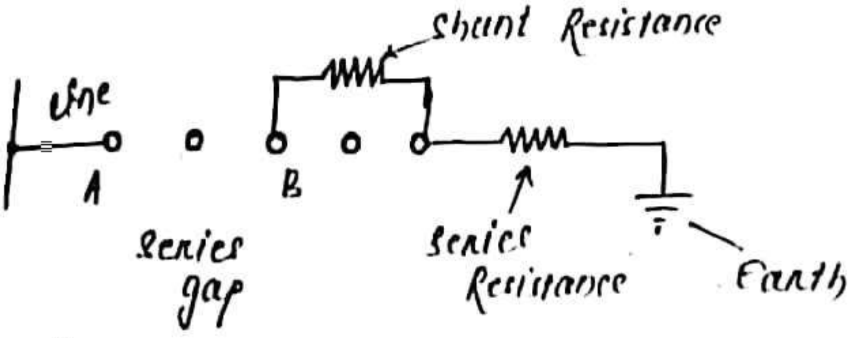
-> on the occurance of over voltage the breakdown of the gaps betn 'A & B' occurs.

-> The heavy current after breakdown will flowe to the earth through the gap betn 'B & C'

-> when the surge is over the arc betn the 'B to C' goes out & any current flowing throw the circuit can be limited by the two resistance.

-> This arrester can be employed where the system voltage does not exceeds 33 KV.

Dia



v) Valve type Arrester :-

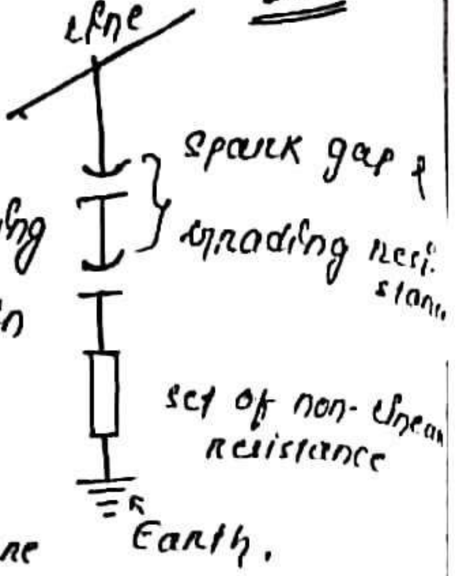
-> Valve type arrester use the non-linear resistor

-> It consist of two parts one is series spark gap & second one is non-linear resistance disc on series

-> The non-linear elements are connected in series with the spark gap

-> The spark gap ~~consting~~ concisting a no. of identical spark gap in series each gap consist of two electrode with a fixed gap.

Dia



-> The non-linear resisten disc are connected in series.

-> The non-linear resisten have the property of offering a high resistance to the current flow when normal system voltage is applied

-> But provide a low resistance to flow of high surge current.

-> Under normal cond^n the system voltage is in sufficient to cause the breakdown of airgap

-> On occurance of over voltage an arc is produced & the surge current conducted to earth through the non-linear resistance.

-> When the surge is over the non-linear resistan ~~no~~ provide high resistance to stop the flow of current.

Advantage :-

-> It provide very effective protection against the surge

-> It operate very rappidly taking less than 1sec.

Dis - Advantages :-

-> There performance is adversly effected by the entry of moisture into the encloser.

Application :-

-> This type of arrester are generally use for the protection of importance equipment in power station operating on the voltage upto 220 KV or higher.

Surge Absorber.

→ The travelling waves set up on the transmission lines by the surge may reach the terminals of the apparatus and cause damage to it.

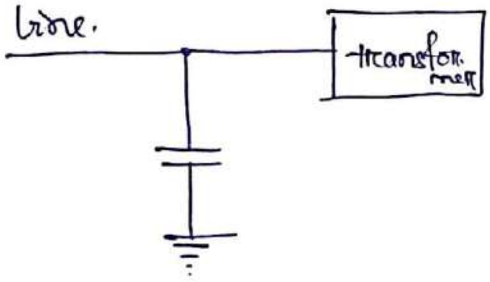
→ To reduce it we use surge absorber.

→ A surge absorber is a protective device which reduce the steepness of wave front of a surge. by absorbing surge energy.

→ A conductor connected between the line and earth can act as a surge absorber.

→ The figure shows a capacitor act as a surge. absorber. to Protect the transformer winding.

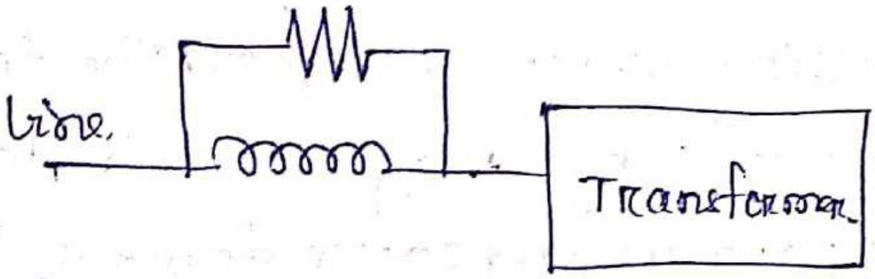
→



→ Since The reactance of a condenser is inversely Proportional to frequency, it will be low at high frequency and ~~to~~ high at low frequency.

→ Since the surge are of high frequency, the capacitor act as a short circuit and passes them directly to earth.

→ Another. type of surge absorber consist of a parallel combination of choke and resistance connected in Series with the line. as shown in fig.



The choke offers high reactance to surge frequency ($x_L = 2\pi f L$) the surges are therefore, forced to flow through the Resistance R where they are dissipated.

Thank You…. End of the Chapter