*** INTRODUCTION TO SWITCHGEAR

CHAPTER - 01

* Switch Gear :-

The apparatus used for switching, controlling and protecting the electrical circuit and equipment is known as switch Gear.

* Essential Features of Switch Gear :-

The essential features of switch gear are

a) **Complete reliability :⇒**
Switch gear is added to the power system to improve the reliability i.e when fault occurs on any part of the power system. the switchgear must operate to isolate the faulty section from the remainder circuit.

b) **Absolutely certain discremination :⇒**
When fault occurs on any section of the power system the switchgear must be able to discreminate between the faulty section & the healthy section.

c) **Quick operation :⇒**
when fault occurs on any part of the power system, the switch gear must operate quickly so that no damage is done to generators, transformers and other equipment by the short ckt current.

d) **Provision for manual control :⇒**

e) Provission for Instruments :→

provission for instruments may be in the form of Ammeter or voltmeter on the unit itself or the necessary current or voltage transformer for connecting to the main switch board or a separate instrument panel.

* Switchgear Equipment :→

a) switch
b) Fuse
c) circuit breaker
d) Relay

a) Switch :→

⇒ A switch is a device which is used to open or closed an electrical circuit in a convient way and can be used under full load or no-load condition but it can not interrupt the fault current

⇒ It is three type

1) Air-break switch
2) Oil switch
3) Isolator / disconnecting switch

1: Air-break switch :-

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

⇒ In order to quench arc that occur on opening such a switch special arcing

⇒ Air-break switches are generally used outdoor for circuit of medium capacity such as lines supplying and industrial load from a main transmission line or feeder.

2: Oil switch :-

⇒ The contact of such switches are open under oil usually transformer oil.

⇒ The effect of oil is to cool & quench the arc that tends when the ckt is opened

⇒ These switches are used for ckt of high voltage and large current carrying capacity

3: Isolator / Disconnecting Switch :⇒

⇒ It is a knife switch and is designed to open a circuit under no-load whose main purpose is to isolate one portion of the circuit from the other and is not intended to be open while current is flowing in the line.

⇒ Such switches are generally used on both sides of the circuit breaker. In order that repairs and replacement of the ckt breaker can be made without any danger and never be opened until the ckt breaker in the same ckt has been opened and should always be closed before the ckt breaker is closed.

b> Fuse :⇒ (copper, lead)

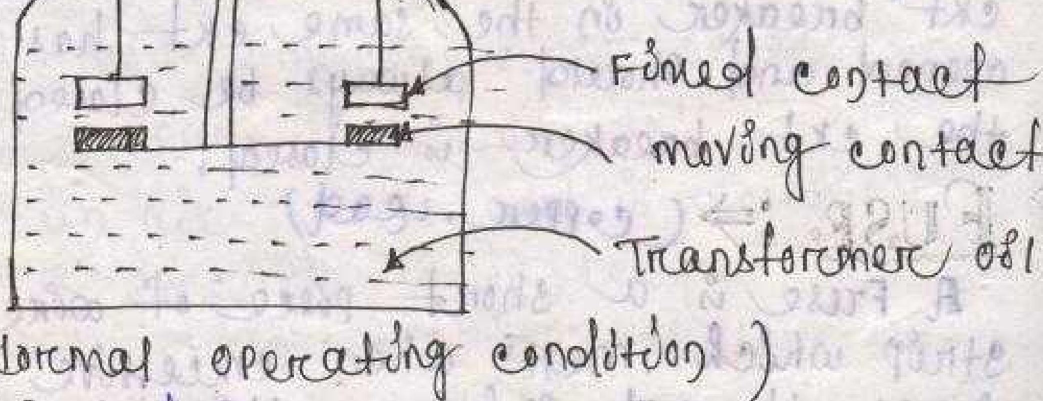
⇒ A Fuse is a short piece of wire or thin strip which melts when excessive current flows through it for sufficient time, below its melting point, so that it carries the normal load current without over heating.

→ When a short circuit or over load occurs the current through the fuse element increases beyond its rated capacity which raises the temp^r and the fuse element melts, disconnecting the circuit protected by heat.

c) Circuit breaker :→

A circuit breaker is an equipment which can open or closed a circuit under all condition such that no-load, full load & fault condition which is so designed that it can be operated manually (or by remote control) under normal condi and automatically under fault condition.

Fig :- 1



(Normal operating condition)

Fig - 2

⇒ In fig(i) under normal operating cond? the contact remain closed and the ckt breaker carries the full load current continuously.

⇒ So that the emf in the secondary winding of the current transformer is insufficient to operate the trip coil of the breaker, but the contacts can be open and hence the ckt can be open by manual or remote control

⇒ In fig(ii), when a fault occurs, the resulting over current in the C.T. primary wdg increases the secondary e.m.f, which energizes the trip coil of the breaker and moving contact are pulled down, thus opening the contacts and hence the ckt.

d> Relay :⇒

⇒ A Relay is a device which detects the fault and supplies information to the ckt breaker for circuit interruption.

⇒ Relay ckt can be divided into 3 part

a> primary wdg of a current t/F which is connected in series with the ckt to be protected.

b> Secondary ckt is the secondary wdg of the C.T connected to the relay operating coil.

⇒ under normal load condition the e.m.f of the secondary wdg of C.T is small and the current flowing in the relay operating coil is insufficient to close the relay contacts, which keeps the trip coil of the circuit breaker on unenergized

⇒ Consequently the contact of the ckt breaker remain closed and carries the normal load current.

⇒ When a fault occurs a large current flows through the primary of the C.T which increases the secondary emf and hence current through the relay operating coil.

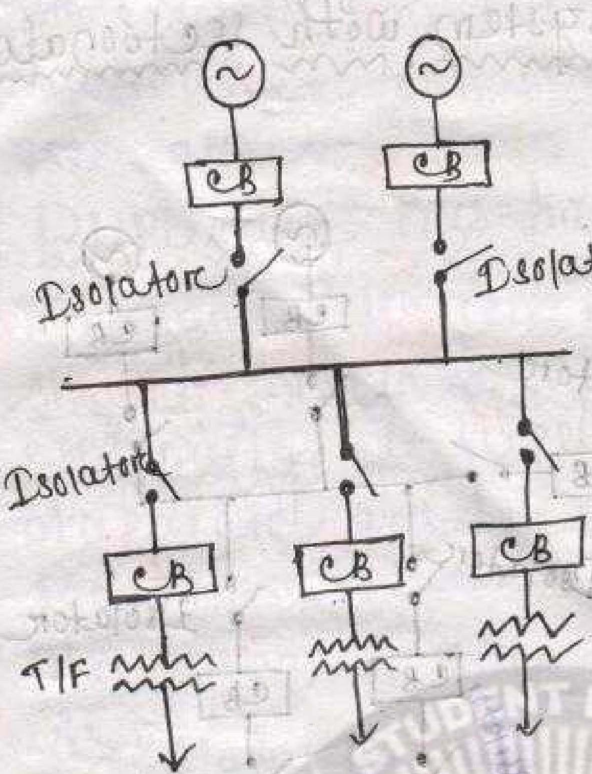
⇒ The relay contact are closed and the trip coil of the circuit breaker is energized to open the contact of the ckt breaker.

* BUSBAR ARRANGEMENT :⇒

⇒ When a no of generator or feeder operating at the same voltage have to be directly connected electrically, bus-bars are used as the common electrical component

⇒ These are copper rods or thin walled tubes and operate at constant voltage

1. Single Bus-bar system :⇒

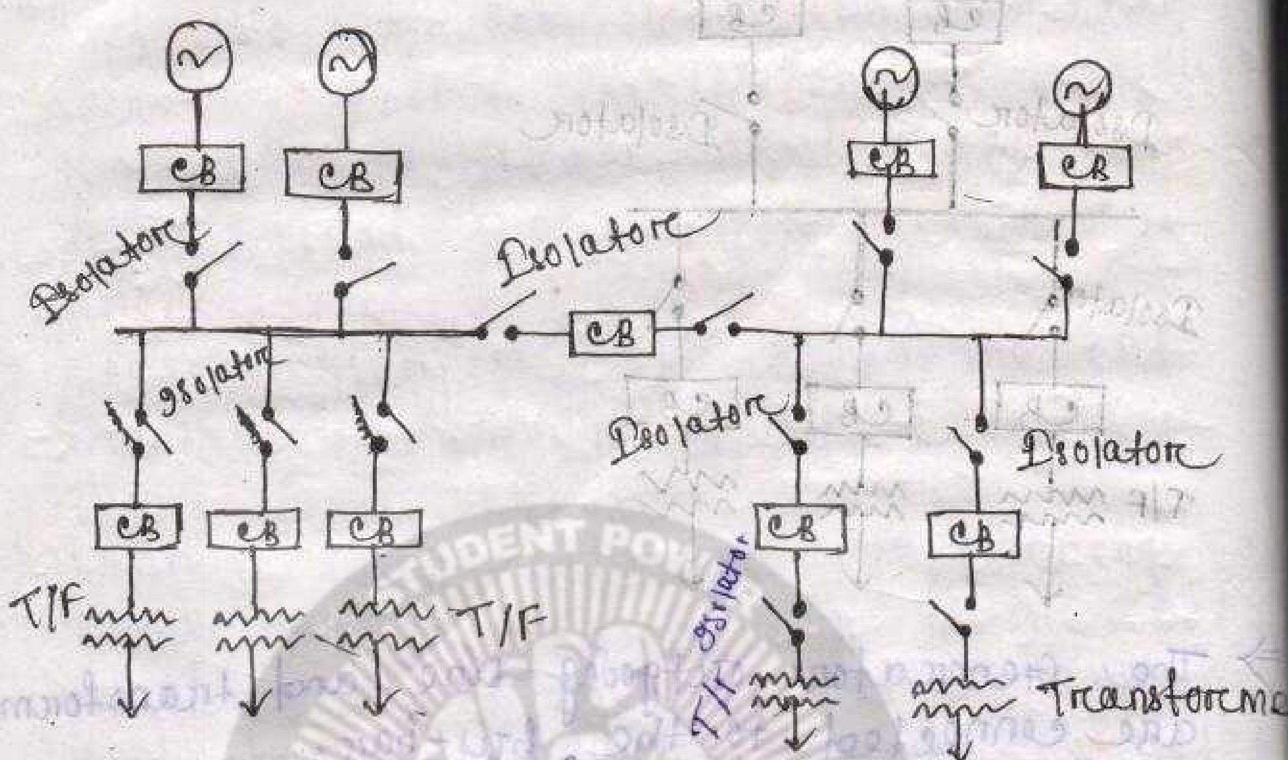


→ The Generators, outgoing line and transformer are connected to the bus-bar.
→ each generator & feeder is controlled by a circuit breaker, the Isolator permit to isolate generators, feeders and circuit breaker from the bus-bar for maintenance

Advantage :—
→ Low initial cost
→ Less maintenance
→ It has simple operation.

Disadvantage :→
→ If a fault occurs on the bus-bar itself there is complete interruption of supply
→ Any fault on the system is fed by the generating capacity, resulting is very large fault current.
→ The bus-bar can not be cleaned, repair

2. Single bus-bar system with sectionalization



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

→ Fig shows above the bus-bar is divided into two section connected by a circuit breaker & Isolator.

Advantages :—

→ If fault occurs on any section of the bus-bar that section can be isolated without affecting to the supply to other section.

Disadvantages :→

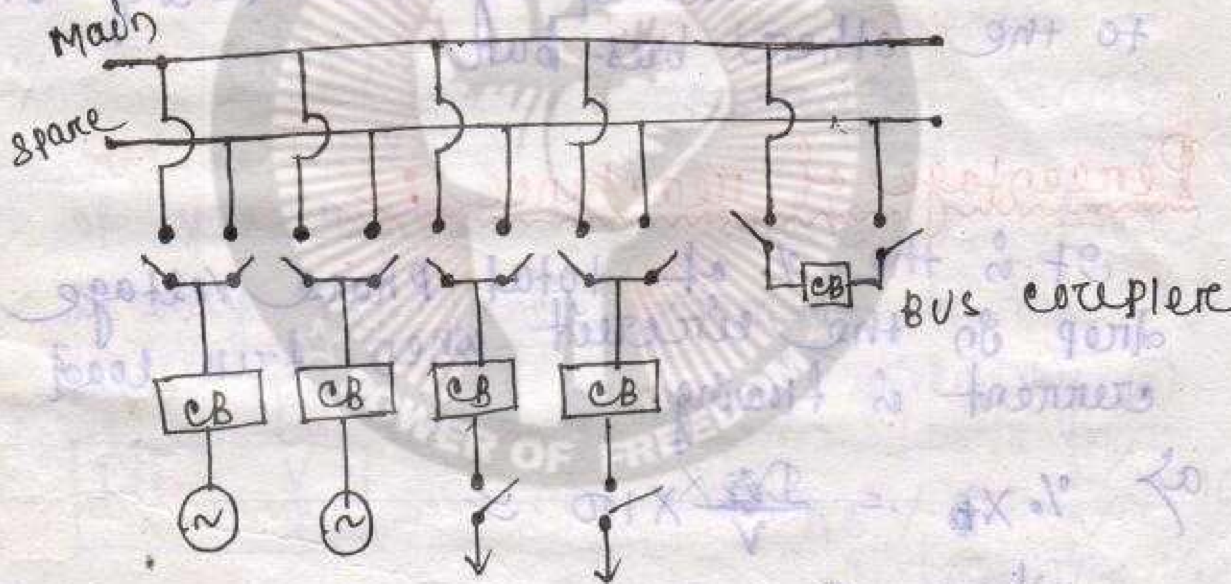
→ circuit breaker should be used as the

with isolate on both sides so that it's maintenance can be done while the bus-bar are alive.

3> Duplicate Bus-bar system :->

=> In large station breakdown & maintenance should interfere as little as possible with continuity of supply. So to acheive this duplicate Bus-bar system is used in important section.

=> This system consists of two bus-bars
a> Main bus-bar
b> spare bus-bar



=> Here each Generator and feeder may be connected to either bus-bar with the help of bus-coupler which consists of a circuit breaker and Isolator.

=> This service is interrupted during switch over from one bus to another

=> However, if it is desired to switch a

Advantages :-

- ⇒ If repaire and maintenance it to be carried on the main bus the supply need not be interrupted as the entire load can be transfere to the spare bus.
- ⇒ The testing of feeder circuit breaker can be done by putting them in spare bus-bar
- ⇒ Thus keeping the main bus-bar un-disturbed.
- ⇒ If a fault occures on the bus-bar the continuity supply to the circuit can be maintained by transfering it to the other bus-bar

* Percentage of reactance :⇒

It is the % of total phase voltage drop in the circuit when full load current is flowing

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

where I = Full load current
V = Phase voltage
X = Reactance in ohm/phase

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

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

$$= \frac{(KVA)_{n} \times 100}{\frac{V}{1000} \times V}$$

$$= \frac{(KVA)_{n} \times \frac{100}{100}}{\frac{V}{1000} \cdot \frac{V}{100}} = \frac{(KVA)_{n}}{\frac{V}{1000} \cdot \frac{V}{100} \cdot \frac{10}{10}}$$

$$= \frac{(KVA)_{n}}{10 \times \frac{V^2}{1000000}} = \frac{(KVA)_{n}}{10 \times \frac{V}{1000} \times \frac{V}{1000}}$$

$$= \frac{(KVA)_{n}}{10 \times KV \times KV}$$

$$\boxed{\% X = \frac{(KVA)_{n}}{10 KV^2}}$$ (proved).

→ If you neglect the resistance of n is only reactance element in the ckt then short ckt current given by ③

$$\boxed{I_{sc} = \frac{V}{X}}$$

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

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

④ $I_{sc} = \frac{I \times 100}{\% X}$

$$I_{sc} = \frac{V}{X}$$

$$\Rightarrow I_{sc} = \frac{V}{X} = \frac{V}{\left(\frac{V \times \% n}{I \times 100}\right)}$$

$$= \frac{I \times 100 \times \cancel{V}}{\cancel{V} \times \% n}$$

example :-

% of reactance = 20%

Full load current (I) = 50 Amp.

A:-

$I_{sc} = \frac{50 \times 100}{20} = \frac{50 \times \cancel{100}^{5}}{\cancel{20}}$

$= 250$ Amp.

* **Base KVA :⇒**

⇒ % of reactance of an equipment depend upon its KVA rating. Generally the various equipment used in power system have different KVA rating

⇒ Therefore it is necessary to find the % of reactance of all the elements on a common KVA rating

⇒ The common KVA rating is known as Base KVA.

* **Short circuit KVA :⇒**

④ The product of normal system voltage and short circuit current at the point of fault expressed in KVA is known as short ckt KVA.

V = Normal phase voltage in volts.

I = Full load current in amp at base KVA

%x = percentage of reactance of a system on base KVA upto the fault point.

⑤ Short ckt KVA for 3∅ circuit

$= \frac{3VI_{sc}}{1000}$

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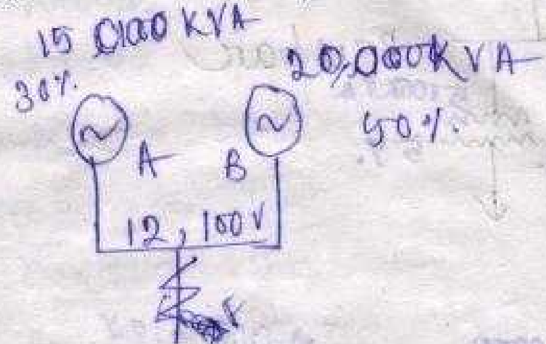
$$= \frac{3VI}{1000} \times \frac{100}{\%\, x}$$

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

$$\boxed{\text{Short ckt KVA} = \text{Base KVA} \times \frac{100}{\%\, x}}$$

Example 17·1 :⇒



Find the short ckt current that will flow in a complete 3ϕ short ckt at F = ?

Ans :-

Let Base KVA = 20000 + 15000 = 35 000 KVA.

Let generator = A

% x = 30%.

15 000 = 30%.

$$1 = \frac{30}{15\,000} \times 35\,000 = 70\%.$$

35 000

$$\%\, x_A = \frac{35{,}000}{15000} \times 30 = 70\%.$$

Generator B = 87·5 %.

$$\%\, x_B = \frac{35{,}000}{20{,}000} \times 50 = 87{\cdot}5\%.$$

Line current corresponding to 35000 KVA at 12 KV is

$$\frac{\sqrt{3} V_L I_L}{1000} \text{ KVA} = 35000 \text{ KVA}$$

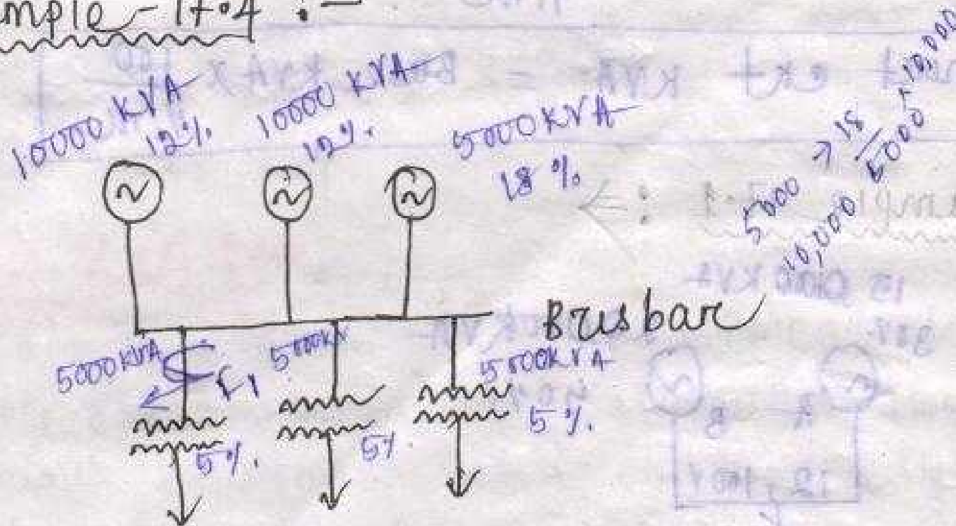
$$\Rightarrow \sqrt{3} \times 12000 \times I_L = 35000 \times 1000$$

$$\Rightarrow I_L = \frac{35\,000 \times 1000}{\sqrt{3} \times 12000} = \frac{35000}{\sqrt{3} \times 12} = 1684 \text{ Amp.}$$

$$I_{sc} = \frac{I \times 100}{\% x} = \frac{1684 \times 100}{38.8}$$

$$= 4340.2 \text{ (Ans.)}$$

Example - 17.4 :-



Let base KVA = 10000

% x of $G_1 = 12\%$ $X_{G_1} = 12 \times \frac{10,000}{10,000} = 12\%$

$G_2 = 12\%$ $X_{G_2} = \frac{12 \times 10000}{10000} = 12\%$

$G_3 = 36\%$ $X_{G_3} = 18 \times \frac{10000}{5000} = 36\%$

% x of $T_1 = 10\%$

$T_2 = 10\%$

$T_3 = 10\%$ $X_{T_1} = 5 \times \frac{10,000}{5,000} = 10\%$ $X_{T_3} = 5 \times \frac{10,000}{5,000} = 10\%$

% x up to fault F_1 $X_{T_2} = 5 \times \frac{10,000}{5,000} = 10\%$

$$\frac{1}{\frac{1}{12} + \frac{1}{12} + \frac{1}{36}} = \cancel{\ldots} = 5.14$$

Short ckt fault KVA at F1 $= \frac{10000 \times 100}{5.14}$ $\qquad \frac{\text{Base KVA} \times 100}{\% X}$

$= \cancel{68050.1 \text{ KVA}}$ 194.5 MVA

$= \cancel{66.05 \text{ MVA}}$

% x upto fault F_2 = $\cancel{15.14}$ 5.14 + 10 = 15.14 %

Short ckt KVA = $\frac{10000}{15.14} \times 100$ = 66 MVA

* Switchgear Accommodation :⇒

⇒ It is necessary to house the switchgear in power station & substations in such a way so as to safeguard personal during operation & maintenance & to ensure that the effect of fault on any sections of the switchgear are confined to a limited reason.

⇒ Depending upon the voltage to be handled switchgear may be broadly classified into two types.

i> outdoor type
ii> Indoor type

i> outdoor type :⇒

For voltage above 66kV, switchgear equipments is installed outdoor because such voltages, the clearance between conductors & the space required for switches, ckt breakers, transformer and other equipments becomes so great that it is not economical to install all such equipment indoor.

ii> In-door type :⇒

⇒ For voltages below 66kV, switchgear is generally installed indoor because of economic consideration.

⇒ In this type of construction all live parts are completely enclosed in an earthed metal casing.

* Short circuit :⇒

→ when a short ckt occures the voltage at fault point is reduce to zero & curr of abnormally high magnitude flows through the network to the point of fau

* causes of short ckt :→

short ckt may be caused due to intern or external effects.

i) Internal effects :→

→ Internal effects are caused by breakdo of equipments or transmission lines, fro deterioration of insulation in a generat transformer etc such troubles may be due to aging of insulation, in adequat design or improper installation.

ii) External effects :→

external effects causing short ckt includ insulation failure due to lightning surge over loading of equipment causing excessive heating, mechanical damage by public e

* Effects of short circuit :→

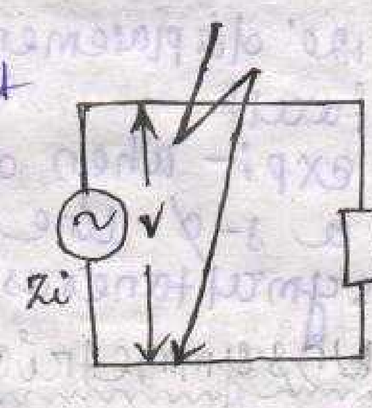
→ The heavy current due to short ckt causes excessive heating which may result in fire or explosion and someti short ckt takes the form of an arc & causes considerable damage to the system.

→ The low voltage created by ~~effect~~

be short down & generators on the power system may be become unstable

* Short ckt currents :-

→ when short ckt occures a heavy current called short ckt flows through the ckt



→ Figure shows a single phase generator of voltage 'v' & internal impedance 'zi' & supplying to a load z'

→ If the load terminal get shorted due to any region the ckt impedance is reduce to a very low value

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

→ The magnitude of short ckt current determines the size of the protective reactor which must be inshorted in the system so that the C.B is able to withstand the fault current.

* Faults in a power system :⇒

→ A fault occures when two or more conductors that normally operate with a potential difference come in contact with each other which may be caused by sudden failure of a piece of equipment, accidental damag or short ckt to overhead lines or by insulation failure resulting from lightening

→ Faults in a 3-ϕ system can be classified

a) **Symmetrical fault :—**

→ That fault which gives rise to symmetrical fault current (equal fault current with 120° displacement) is called a symmetrical fault.

→ exp:- when all the three conductors of a 3-ϕ line are brought together symultaneously into a short ckt condⁿ.

b) **Unsymmetrical fault :→**

→ That fault which gives rise to unsymmetrical fault current is called a unsymmetrical fault

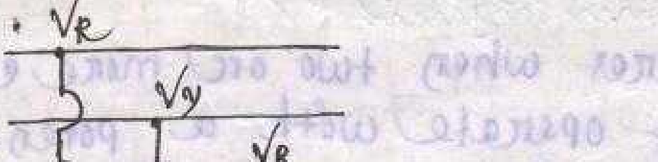
→ exp:- Single line to ground
Line to line
Double line to ground

—— oxox ——

*** FAULT CALCULATION

chapter-2

* Symmetrical fault on 3-ϕ system :→



symmetrical fault occurs when all the three conductors of a 3-ϕ line are brought together symmultaneously into a short ckt condition.

current is limited by the impedance of the system upto the point of fault.

* Percentage Reactance :-

→ The reactance of generators, transformers reactors etc is usually expressed in percentage reactance to permit rapid short ckt calculation.

→ percentage reactance is the percentage of total phase voltage dropped in the ckt when full load current is flowing.

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

where I = full load current

V = Phase voltage

X = Reactance in Ω per phase.

→ percentage reactance can also be express in terms of KVA & KV as under

$$\boxed{\%X = \frac{(KVA) \cdot X}{10 (KV)^2}}$$

where X = Reactance in Ω

If 'X' is the only reactance element in the ckt then short ckt current

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

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

$$\Rightarrow \frac{V}{X} = \left(\frac{I}{\%X}\right) \times 100$$

* Base KVA & percentage reactance :-

is known as base KVA.

→ The value of this base KVA may be

(i) equal to that of the largest plant.

(ii) equal to that of total plant capacity

(iii) Any arbitrary value.

percentage reactance at base KVA

$$= \frac{\text{Base KVA}}{\text{Rated KVA}} \times \text{Percentage reactance at rated KVA.}$$

* Short circuit KVA :→

The product of normal system voltage & short ckt current at that point of fault expressed in KVA is known as short ckt KVA.

Let V = normal phase voltage in volts.

I = full load current in Amp at base KVA

%X = percentage reactance of the system on base KVA upto the fault point.

So short ckt KVA for 3-Ø ckt $= \frac{3VI_{sc}}{1000}$

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

$$= \left(\frac{3VI}{1000}\right) \times \frac{100}{\%X}$$

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

* Reactor control of short ckt current

In order to limit the short ckt current to a value which the circuit points.

Advantages :—

→ Reactors limit the flow of short ckt current & thus protect the equipment from over rating as well as from failure.

→ Troubles are localized isolated are that point where they originate without communicating their disturbing effects to other points of the power system.

→ They permit the installation of circuit breakers of lower rating.

* Location / different type of Reactors :→

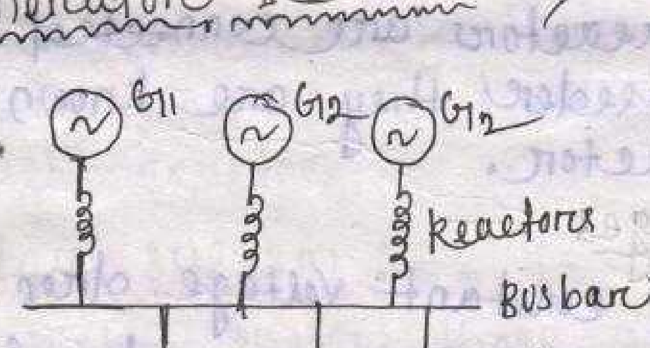
The short ckt current limiting reactor may be connected

a) In series with each generator

b) In series with each feeder.

c) In bus-bars.

(a) Generator Reactor :→



→ when the reactors are connected in series with each generator, they are known as generator reactor.

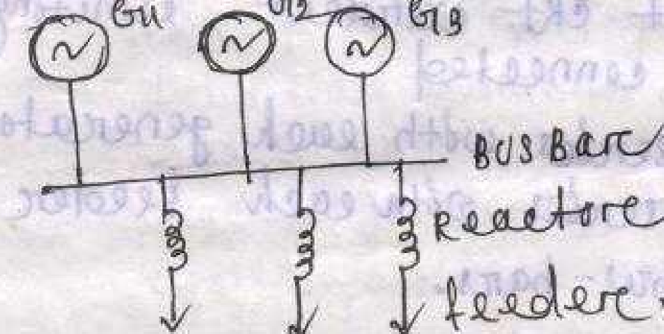
Disadvantages :—

→ If a bus-bar or feeder fault occurs close to the bus-bars the voltage at the bus-bar will be reduced to a low value thereby causing the generators to fall out of step.

→ If a fault occurs in any feeder, the continuity of supply to other is rightly to be affected

So modern power station generator has sufficiently large leakage reactance to protect them against short ckt.

b) Feeder Reactor :→



→ when the reactors are connected in series with each feeder they are known as feeder reactor.

· Disadvantages :—

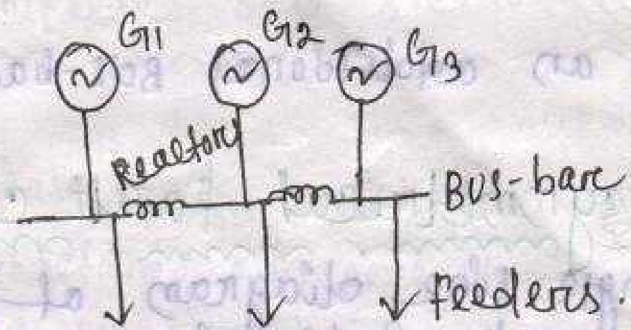
→ There is a constant voltage drop & power loss in the reactors even during normal operation.

→ If a short ckt occurs at the busbar no protection is provided to the generator

→ If the no. of generators is increased the size of feeder reactors will have to be increase to give the

(C) Busbar Reactor :⇒

The above two methods of locating reactors suffers from the disadvantage that there is considerable voltage drop & power loss in the reactors even during normal operation. So this can be overcome by locating the reactors in Busbar.



* BUS-BAR System :-

The are two system in BUS-BAR system
(1) Ring system
(2) Tie-bar system.

(1) Ring system :-

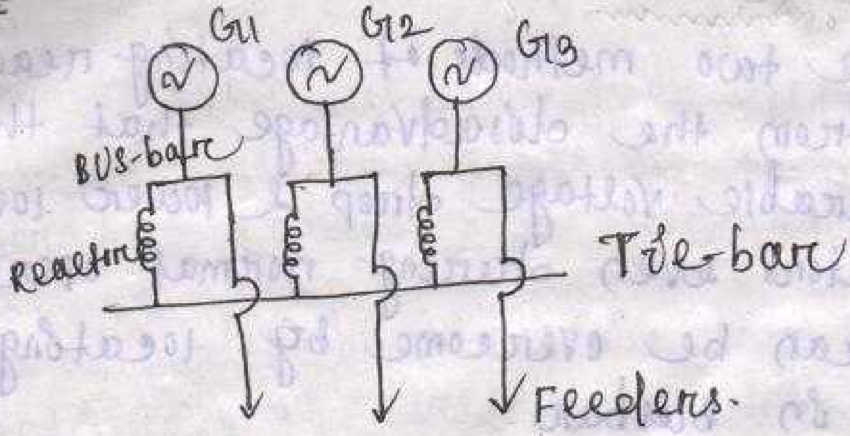
→ In this system Bus-bar are divided into sections and these sections are connected through reactor.

(2) Tie-bar system :-

→ In Tie-bar system these are effectively ~~two~~ Rector in series between sections, so that Reactors must have approximately half the reactance of used in a comparable ring system.

→ Another advantage of Tie bar system is

Dia :—



Advantage :—

This requires an additional BUS-bar i.e tie-bar

* Steps for symmetrical fault calculation

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

→ choose a numerical conveanent value of base KVA & convert all % reactance to this base value.

→ corresponding to the single line diagram of the network draw the reactance diagram showing the one phase of the system & the neutral, indicate the %age reactance on the base KVA in the reactance diagram.

→ Find the total %age reactance of the network upto point of fault. Let it be X %.

→ Find the full load current corresponding to the selected ~~kVA~~ base KVA & the normal system voltage at the fault point let it be 'I'.

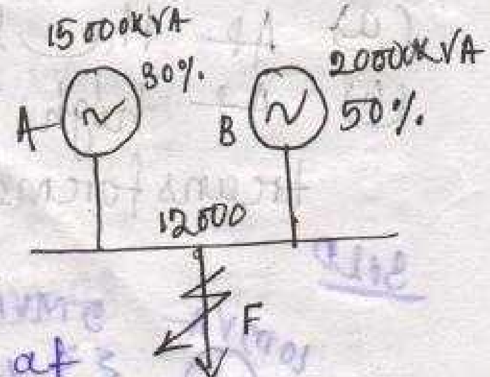
→ Then various short ckt calculation.

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

Problem

(Q-1) Fig. shows the single line diagram of a 3-ϕ system. The %age reactance of each alternator is based on it's base capacity. Find the s.c current that will flow into a complete 3-ϕ s.c at at 'F' point.

Soln



Let Base KVA = 35000 KVA

→ %age Reactance of generator A' (at base KVA).

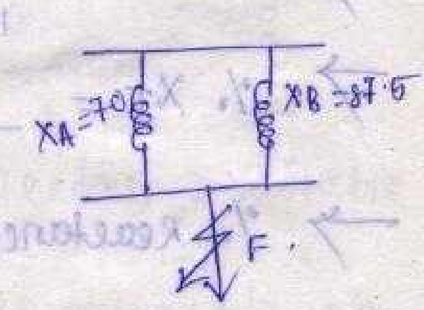
$$= \frac{Base\ KVA}{Rated\ KVA} \times \%\ Reactance\ at\ rated\ KVA$$

$$= \frac{35000}{15000} \times 30$$

$$= 70\ \%.$$

→ $\%age\ X_B = \frac{35000}{20000} \times 50 = 87.5\ \%.$

→ Total % Reactance :-



$$X_A \parallel X_B = \frac{70 \times 87.5}{70 + 87.5}$$

$$= 38.89\ \%.$$

→ Full load current $(I_L) = \frac{35000 \times 10^3}{\sqrt{3} \times 12000}$ $\qquad \frac{\sqrt{3} V_L I_L}{1000} = 35000$

$$= 1684\ Amp.$$

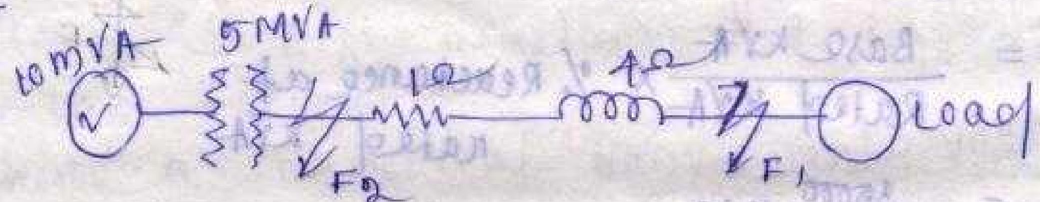
→ S.C $I_{sc} = I \times \frac{100}{\%X} = 1684 \times \frac{100}{38.89}$

(Q-2) A 3-ϕ transmission line operating at 10 KV & having a resistance of 1Ω and reactance of 4Ω is connected to the generating station bus-bar through 5 MVA step-up T/F having a reactance of 5% the bus-bar are supplied by a 10 MVA Alternator having 10% reactance calculate the S.C KVA fault to the symmetrical phase between of it occure.

(a) At the load end of the the transmission

(b) At high voltage terminal of the transformer.

Sol^n



Base KVA = 10000 KVA

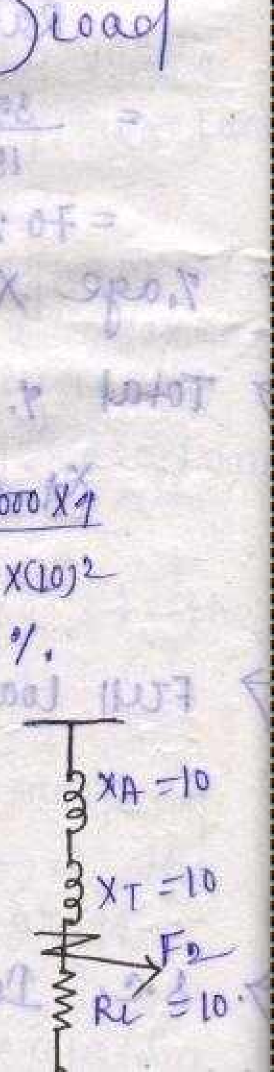
→ $\% X = \frac{10 \times 10^3}{10 \times 10^3} \times 10 = 10\%$

→ $\% X_T = \frac{10 \times 10^3}{5 \times 10^3} \times 5 = 10\%$

→ % Reactance transmission line $= \frac{10000 \times 4}{10 \times (10)^2}$

$= 40\%$.

→ % Reactance $= \frac{10000}{10 \times 10^2} = 10\%$.



Single line diagram :—

Total % Reactance

$= 40 + 10 + 10 = 60\%$.

% R_L = 10%

→ For F_1 fault % reactance is 60%.

So. S.C KVA = Base KVA × $\frac{100}{\%X}$

$= 10 \times 10^3 \times \frac{100}{60.83}$

$= 16439.25$

→ For F_2 fault

$\%X = 20\%$

$S.C\ KVA = 10 \times 10^3 \times \frac{100}{20}$

$= 50 \times 10^3$ KVA. (Ans.)

*** FUSES chapter-02

* Fuse:→

A fuse is a short piece of material inserted in the ckt which melts when excessive current flows through it & thus breaks the ckt.

* Advantages:→

→ It is the cheapest form of protection available.

→ It requires no maintenance.

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

* Disadvantages:—

→ considerable time is lost in rewiring or replacing a fuse after operation.

→ On heavy short ckt discrimination between fuses in series cannot be obtained unless there is sufficient difference in the fuse cannot always be corelated with that of the protected operators.

* Desirable characteristics of fuse element

→ The function of a fuse is to carry the normal current without over heating but when the current exceeds its normal value it rapidly heats upto the melting point & disconnected the ckt. protected by it.

→ The fuse element should have the following characteristics.

(i) Low melting point (tin, lead)
(ii) High conductivity (silver, cupper).
(iii) Free from deterioration due to oxidation (silver)
(iv) Low cost. (tin, lead, cupper).

* Fuse element Material :-

→ The most commonly used material for fuse element are lead, tin, cupper, zinc & silver.

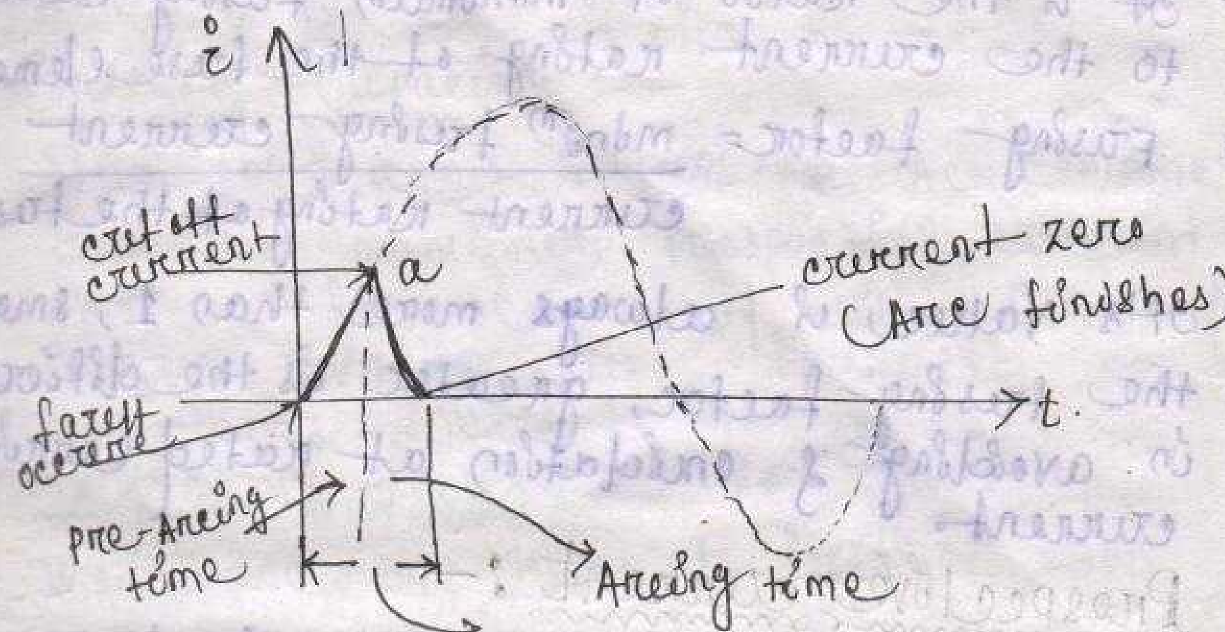
→ For small currents upto 10A; tin or an alloy of lead and tin (lead 37% & tin 63%) is used for making the fuse element.

→ For large current cupper or silver is employ.

→ zinc in strip form is good if a fuse with considerable time lag is required i.e one which does not melt very quick with a small overload.

→ The present trend it to used silver despite its high cost due to the follow

(ii) It doesnot deteriate when used in drywire.
(iii) The co-efficient of expansion of silver, is so small therefore the fuse element can carry the rated current continously for a long time.
(iv) The conductivity of silver is very high.



* Important terms :—

(a) current rating of fuse element :—
It is the current which the fuse element can normally carry without overheating or melting & it depends upon the temp rise of the contacts of the fuse holder, fuse material & the surrounding of the fuse.

(b) Fusing current :—
⇒ It is the minimum current at which the fuse elements melts & thus disconnects the ckt.
⇒ It depends upon.

current because a short fuse can easily conduct away all the heat.

(iii) The diameter $\boxed{I = Kd^{3/2}}$

(iv) size & location of terminals.

(v) Type of encloser used.

* **Fusing factor :-**

→ It is the ratio of minimum fusing current to the current rating of the fuse element.

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

→ It's value is always more than 1, smaller the fusing factor, greater is the difficulty in avoiding of oxidation at rated carrying current.

* **Prospective current :-**

It is the r.m.s value of the first loop of the fault current obtained, if the fuse is replaced by a ordinary conductor of negligible resistance.

* **Cut-off current :-**

→ It is the maximum value of fault current actually reached before the fuse melts.

→ It's value depend upon current rating of fuse, value of prospective current asymmetry of short ckt current.

* **Pre-Arcing time :-**

It is the time between the commencement

* **Arcing time :—**

This is the time between the end of pre-Arcing time and the instant, when the Arc is extinguished.

* **Total operating time :—**

It is the sum of pre-Arcing & Arcing times is taken as 0.002 sec.

* **Breaking capacity :—**

It is the r.m.s value of AC component ~~fuse~~ of maximum prospective current that a fuse can deal with at rated service voltage.

* **Types of fuses :—**

→ There are two types of fuses.
(a) Low voltage fuse.
(b) High voltage fuse.

→ There are also low voltage fuse can be subdivided into 2 types.
(1) semi-enclosed rewirable fuses.
(2) High rupturing capacity (HRC) cartridge fuses.

(1) **Semi-enclosed rewirable fuses :—**

→ Rewirable fuse is also known as kit-kat type (is used where low values) of fault current are to be interrupted.

→ It consist of a base and fuse carrier the base is of procelain & carrying the fixed contact to which the in coming &

⇒ The fuse carrier is also procelain and holds the fuse element (tilled current wires) between it's terminal and can be inserted in or taken out of the base when desired.

⇒ This fuses are made upto 500 Amp rated current and it's breaking capacity is about is 4000 Amp on 400 V. service line.

⇒ So it is used for domestic & lighting loads.

* Advantages :-

⇒ The detachable fuse carrier permit the replacement of fuse element without any danger of comming in contact with live parts.

⇒ The cost of replacement is negligible.

* Disadvantages :-

⇒ There is a possibility of renewal by the fuse wire of wrong size or by improper material.

⇒ This type of fuse has a low breaking capacity & hence can not be used in ckts of high fault level.

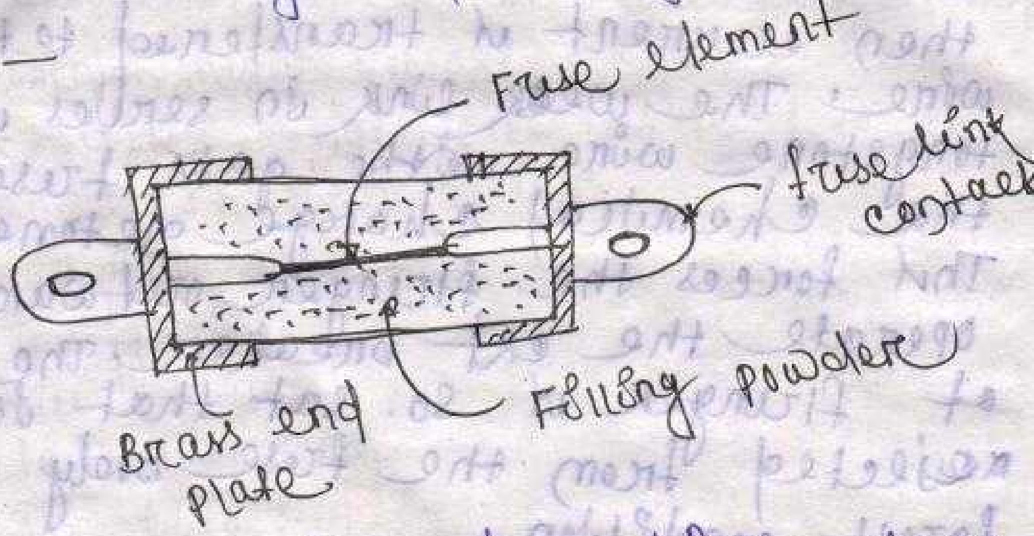
(2) High - rupturing capacity (HRC) catridge fuses :-

⇒ It consist of a heat resisting ceramic body having metal end caps to which is welded silver current carrying element.

⇒ The space within ...

of pyarish, marbol dust and acts as an Arc-quenching and cooling medium.

Dia:—



⇒ Under normal load condⁿ the fuse element is at tempʳ below it's melting point, but when fault occurres the current increases and fuse element melts before the fault current reaches in a 1st peak.

⇒ The heat produce in the process veporizes the melted silver element.

* The chemical reaction betⁿ the silver vepore and the filling powder results in the formation of a high resistance substances, which helps in quenching the Arc.

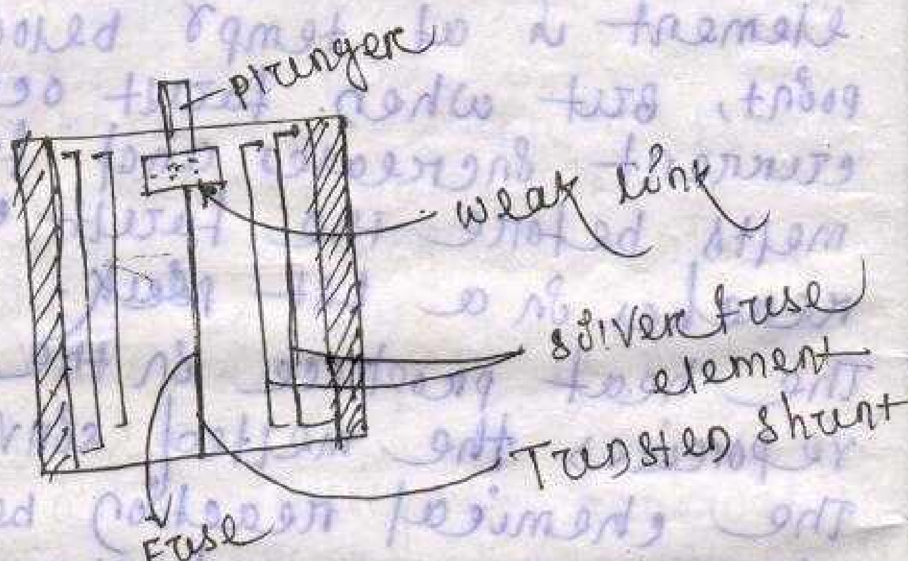
⇒ Low voltage (HRC) fuses breaking capacity of 16000 Amp to 3000 at 440 v. service line and used on L.V sg distribution system against over load & s.c condⁿ.

* HRC catredge fuses with tripping device

→ when a fault occures the silver fuse element are 1st are blown out and then current is transfered to the tongsten wire. The weak link in series with the tongstone wire gets fuses, cause the chemical charge detoned.

→ This forces the plunger outward to operate the ckt breaker. The travel of plunger is so sat that it is not rejected from the fuse body under fault condition.

Dia:-



Advantage:-

→ oncase of a single phase fault on a 3-ϕ system, the plunger operats the tripping mechanism the c.B to open all the 3 and thus prevents single phasing

→ The effects of full s.c current need not be consider in the choice of ckt breaker, which permits the use of a relatively inexpensive ckt breaker.

→ The fuse tripped c.B is generally capa of dealing with small fault cre,

(2) High voltage fuses :—

⇒ Low voltage fuses can be successfully used on modern high voltage ckt.

⇒ So the supply engineers has lead to the development of high voltage.

⇒ It is three type.

a) cartridge fuse.
b) Liquid fuse.
c) metal clad fuse.

a) cartridge fuse :—

⇒ This is similar in general construction to the low voltage cartridge type accept that special design feature are in corporate which employ fuse element, wound in the form of helix, so as to avoid corona effects at higher voltage.

⇒ On some design there are two fuses element in parallel one is low resistance (silver wire) and the other of high resistance.

⇒ Under normal load condition the low resistance element carries the normal current, But when a fault occurres the low resistance is blown out and the high resistance element reduces the short ckt current & finally breaks the ckt.

⇒ It is used upto 33KV with breaking capacity of about 8700 Amp.

⇒ At that voltage rating of the order of 200 Amp at 6.6KV & 11KV and 50 Amp at 33KV are also available.

(b) Liquid type fuse :—

⇒ These fuses are filled with carbon tetra cloride & have the wide range of high voltage, which may be used for ckt on systems upto 132 kV upto about 100 Amp rated current & breaking capacity of order of 6100 Amp.

⇒ It consist of a glass tube filled with carbon tetra cloride solution and sealed at both ends with brass caps.

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

⇒ When the current exceeds the prescribed fuse wire is blown out, as fuse melts the ~~fuse~~ spring retracts ~~reacts~~ a part of it through a liquid director ~~tone~~ & draws it well into the liquid.

⇒ The small quantity of gas generated at the point of fusion forces ~~sum~~ some part of liquid into the passage through the liquide director & there it effectively extinguishes Arc.

(c) Metal Clad ~~Fuse~~ :—

⇒ Metal clad oil immersed ~~immersed~~ fuses ~~having~~ have been dev ~~depend upon~~ with the object of providing ~~the~~ a substitute for the oil circuit breaker & can be used for very high voltage ckts & opera most satisfactorily under short ckt con approaching their ~~approximately~~ rated capacity.

* Current carrying capacity of fuse element :-

When the fuse element attains steady temperature

Heat produce per second = heat loss per sec by conversion, radiation, conduction.

$\therefore I^2R = K \times$ constant ~~reflective~~ surface ~~crosssectional~~ Area.

$\Rightarrow I^2R = K \times C\, l \times d$

$\Rightarrow I^2 \times \rho \frac{l}{A} = K \times l \times d$ d = diameter of fuse element, l = length of "

$\Rightarrow I^2 \times \frac{\rho}{\frac{\pi}{4} d^2} = K \times d$

$\Rightarrow I^2 \times \frac{\rho}{(\pi/4)} = K \cdot d^3$

$\Rightarrow I^2 = \left(\frac{K}{K'}\right) d^3$. $I^2 \propto d^3$ $\boxed{I = K' \cdot d^{3/2}}$

$\Rightarrow \boxed{I = K \cdot d^{3/2}}$

* Current carrying capacity of a fuse element mainly depends on the metal used & the cross sectional area but is affected also by the length, the state of surface & the surroundings of the fuse.

*** CIRCUIT BREAKERS

Chapter - 04

* Circuit Breaker :-

→ A circuit breaker is a piece of equipment which can -

i) Make or break the ckt either manually or by remote control under normal condition.

ii) Break a ckt automatically under fault cond

iii) Make a ckt either manually or by remote control under fault conditions.

* Operating Principle :-

→ A ckt breaker essentially consists of fixed & moving contacts called electrodes.

→ Under normal operating condition this contact remain closed & will not open automatically until & unless the system becomes faulty.

→ When a fault occurs on any part of the system, the trip coil of the C.B gets energize & the moving contacts are cooled apart by some mechanism thus opening the ckt.

* Arc Phenomenon :-

→ When a short ckt occurs a heavy current flows through the contacts of the C.B before they are opened by the protective system.

→ At that instant when the contacts begin to separate the contact area decreases rapidly & large fault current causes increased current density & hence rise temp r.

→ The heat produced in the medium (oil, ...

⇒ The potential difference betn the contacts is quite small & it just sufficient to maintain the arc, which provide a low resistance path & consequently the current in ckt remains uninterrupted so long as the arc persist.

⇒ During the arcing period the current flowing betn the contacts depend upon the arc resistance & which depends upon the following factor.

a) Degree of ionisation $\left(R \propto \frac{1}{\text{Degree of ionisation}}\right)$

b) length of the arc $(R \propto L)$

c) crossection of arc $\left(R \propto \frac{1}{A}\right)$.

⇒ The factor responsible for the maintainance of arc betn the contacts these are :

a) potential difference betn the contacts.

b) Ionise particle betn the contacts.

* Principle of Arc extinction :→

⇒ one way to estinguish the arc is to separate the contacts to such a distance that potential difference becomes inadequate to maintain the arc.

⇒ The ionise particle betn the contacts tend to maintain the arc.

If the arc path is deionised, the arc extinction will be facilitated which may be achieved by cooling the arc or by bodily removing the ionised particle from the ...

Method of Arc extinction :-

There are two methods of extinguishing the arc in C.B such that

(i) High resistance method.

(ii) Low resistance method or current zero method.

(i) High Resistance method :-

→ In this method arc resistance is made to increase which time, so that the current is reduced to a value insufficient to maintain the arc.

→ Consequently the current is interrupted or the arc is extinguish.

→ Disadvantage of this method is that enormous (high) energy is dissipated in the arc. Therefore it is employed only in d.c C.B to low capacity of A.C C.B.

→ The resistance of the arc can be increased by
(a) Lengthening the arc.
(b) cooling the arc.
(c) Reducing the X-section of Arc
(d) splitting of arc.

(ii) Low Resistance method or current zero meth

→ In this method arc resistance is kept lo until the current is zero where the arc extinguishes naturally & it prevented from restriking inspite of the rising volta across the contact.

→ In A.C system at every current zero th arc extinguishes betn the contacts conta ions & electrons so that it has small

⇒ If immediately after current zero the dielectric strength of the medium betn contacts is built at more rapidly than the voltage across the contact, the arc fails to restrike & the current will be interrupted.

⇒ In A.c arc interruption is to rapidly deionise the medium betn the contacts as soon as the current becomes zero so that the rising contact voltage or restriking voltage can't breakdown space betn the contacts.

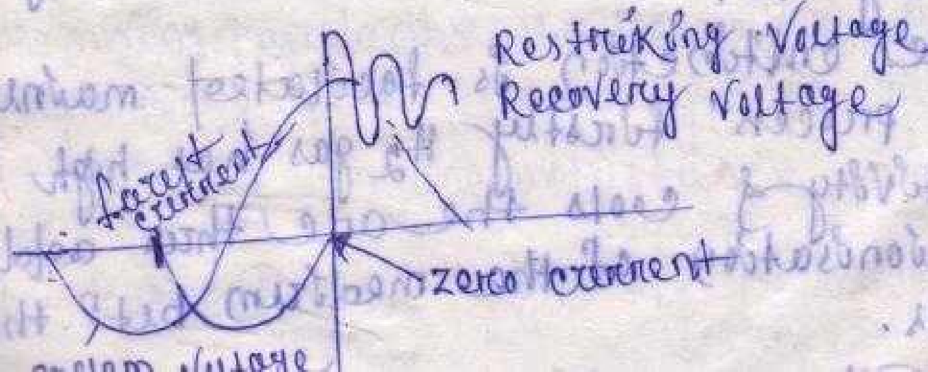
⇒ Deionisation of the medium can be achieved by.

ⓐ Lengthening of the gap.
ⓑ High pressure.
ⓒ cooling.

* Important terms :—

1) Arc Voltage :—
It is the voltage that appears across the contacts of the C.B during the arcing period.

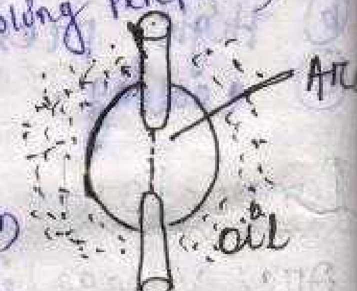
2) Restriking Voltage :—
It is the transient voltage that appears across the contacts at or near current zero during arcing period.



3) Recovery Voltage :-
It is the normal frequency R.m.s Voltage that appears across the contacts of the C.B after final arc extinction.

* Classification of circuit Breaker :-
There are four types C.B
i) Oil circuit breaker.
ii) Air blast C.B.
iii) SF_6 C.B.
iv) Vaccum C.B.

i) Oil circuit Breaker :-
⇒ In this C.B transfomer oil is used as an arc quenching (cooling perpose) medium.
⇒ The contacts are open under oil & arc is struck betn them.



⇒ The heat of arc evaporates the surrounding oil & dissociates in into a substantial volume of gasious hydro at high pressure.
⇒ The H_2 gas occupies a volume about 1000 times that the oil decomposed so that the oil is pushed away from the arc & expanding H_2 gas bubble surroundings the arc region.
⇒ The arc extinction is faciliated mainly by two process firstly H_2 gas has high conductivity & cools the arc thus adding the deionisation of the medium betn the contacts.

from the arc path.

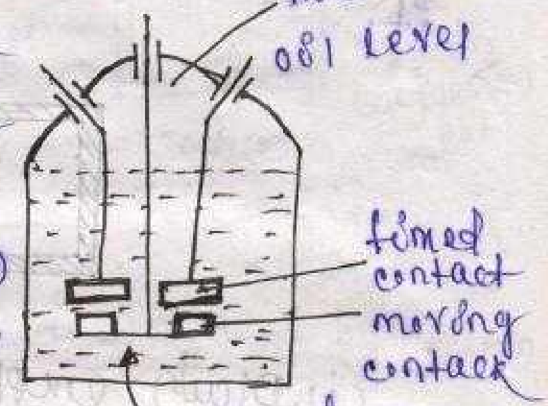
⇒ The result is that the arc is extinguished & the ckt current interrupted (zero/disconnected)

⇒ The oil circuit breaker is two type. such as

(1) Bulk ~~break~~ oil C.B.
(2) LOW ~~minimum~~ oil C.B

⇒ There are the Bulk ~~break~~ oil C.B is two type such as
(a) Plain break oil C.B
(b) Arc control oil C.B.

(a) Plain break oil circuit breaker :-



⇒ It consist of fixed & moving contacts enclosed in a strong weather tight earthed tank containing oil upto a certain level & air cushion above the oil level, which provides sufficient room to allow for the reception of ~~reacting~~ the arc ~~earth~~ gases without the generation of unsafe pressure in the dome of C.B.

Disadvantage :-

⇒ There is no special control over the arc other then the increasing length by separating the moving contacts therefore for successful interruption long arc length is necessary

⇒ It has long & inconsistance arcing time.

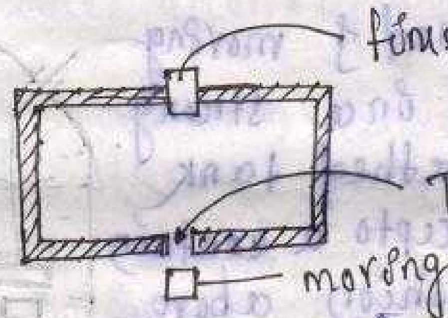
⇒ It donot permit high speed interruption.

* Arc control C.B :⇒

⇒ The arc control C.B is two type
a) Self blast oil C.B.
b) Forced blast oil C.B.

a) Self blast oil C.B :⇒

⇒ In this type the gases produced during arcing are confined to a small volume by the use of an insulating rigid pressure chamber or pot surrounding the contact.
⇒ Since the space available for the arc gases is restricted by the chamber a very high pressure is developed to force the oil & gas through or around the arc to extinguish it.

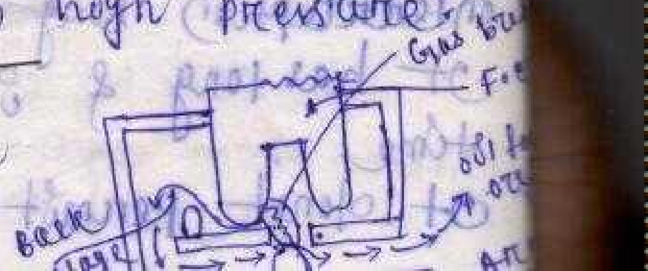


* The heat of the arc de... oil into a gas at very h... pressure in the pot. This h... pressure forces the ... & gas through & ... the arc to ex...

(i) Plain explosion pot :- It is a rigid cylinder of insulating material & encloses the fixed & moving contacts. When fault occurs, the contacts get separated & an arc is struck bet...

Disadvantage :-
⇒ It can't be used for very low & very high fault current.
⇒ With low fault current the pressure developed is small there by increasing the arcing time and with high fault current the gas is produced so rapidly that explosion pot is liable to burst due to high pressure.

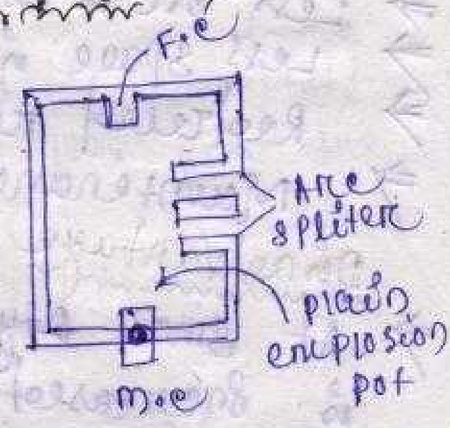
(ii) Cross jet explosion pot :-
⇒ When fault occurs the moving coil of the C.B ... separate ;



→ The gas generated by the arc, exert pressure on the oil in the back passage.
→ When the moving contact uncovers the arc splitter dust fresh oil is pushed across the arc path.
→ The arc is driven side ways into the arc splitter which increases the arc length causing arc extinguished & current is interrupted.
→ It is efficient for interrupting very fault current.

(iii) Self compensated explosion pot :→

→ It can interrupt low as well as heavy short ckt current with reasonable accuracy as this type of pot is combination of plain explosion pot & cross jet explosion pot



(B) Forced blast oil C.B :—

→ In this C.B the oil pressure is created by piston cylinder arrangement.
→ The moment of the piston is mechanically coupled to the moving contact, when fault occurs the contact get separated and an arc struck.
→ The piston forces a jet of oil towards the contacts gap to extinguish the arc.

Advantage :—

Since oil pressure develop is independent of the fault current to be interrupted the performance at low current is more consistance then with self blast oil C.B.

* **Low oil C.B :→**

→ In this C.B a small %age of oil is used for Arc extention, while the major part utilized for insulation purpose.

→ For this reason the quantity of oil in bulk oil C.B reaches a very high fig. as the system voltage increase. Also increase fire risk & maintanance problem.

Advantage :-

→ Less oil is used.
→ Less space is used.
→ Reduced risk of fire.
→ Maintenance are used.

Disadvantage :-

→ At small qty oil, so degree of carbonoxide is increased.
→ Difficulty of removing the gases from the contact space in time.

* **Air Blast C.B :→**

→ These C.B employ a high pressure Air blast as an Arc quenching medium & the contact are open in a flow of air blast established by the opening of blast valve.

→ The Air blast cools the arc & sweeps away the Arcing products to the atmosphere, which rapidly increases the dielectric strength of the medium betn contacts & prevents from re-establishing the Arc. concequently the arc is estinguish & the flow of current is interrupted.

Advantage :-

of regular replacement ...

⇒ Arcing time is very small due to replace buildup of di-electric strength.

⇒ Due to lesser Arc energy Air blast C.B are very suitable for cond where frequent operation is required.

Disadvantage :-

⇒ Air blast C.B is very sensitive to the variations in the rate of rise of risk striking voltage.

⇒ The air has relatively inferior Arc extinguishing property.

⇒ Depending upon the direction of Air blast in relation to the Arc Air blast C.B are classified as two types such as

(a) Axial blast ~~Air C.B~~ type

(b) cross blast ~~Air C.B.~~ "

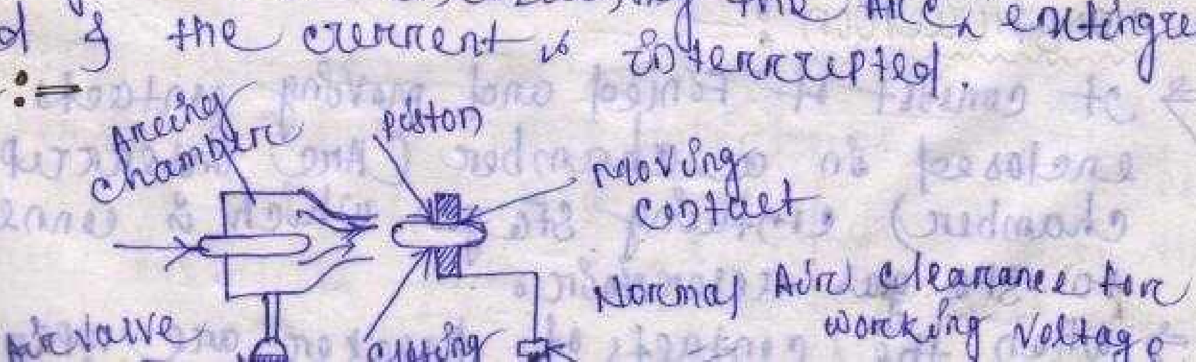
(a) Axial blast ~~Air C.B~~ type :→

⇒ When a fault occurs the tripping impulse causes opening of the Air valve, which connects the C.B reservoir to the Arcing chamber.

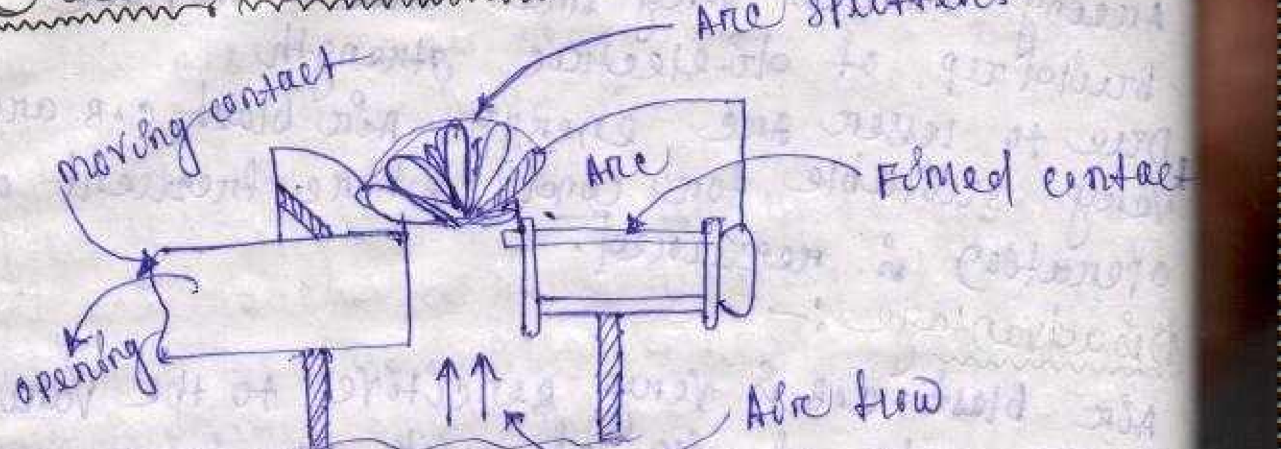
⇒ The high pressure Air entering the Arcing chamber pushes away the moving contact against spring pressure and the moving contact is separated an Arc struck

⇒ At the same time high pressure Air blast flow along the Arc & takes away the ionised gases along with ~~it~~ concequently the Arc is extinguished & the current is interrupted.

Fig :-



(b) Cross blast Air C.B :—



⇒ In this type C.B Air blast is directed at right angles to the Arc.

⇒ The cross blast lengthen the forces of Arc in the suitable place for Arc extention.

⇒ when the M.C is with drawn and the Arc is struck betn the Fixed and moving conta[ct] the high pressure cross blast forces the Ar[c] into to a place ~~consts~~ consisting of Arc splitters.

⇒ The splitter serve to increase the length [of] Arc & give improve cooling the result is that Arc is extinguished & flow of curren[t] is interrupted.

* Sulphur Hexa-fluoride (SF6) C.B :—

⇒ In this C.B SF6 gas is used as the Arc quenching medium which is a electro -ve gas has a strong tendency to absorve the electron.

Construction :—

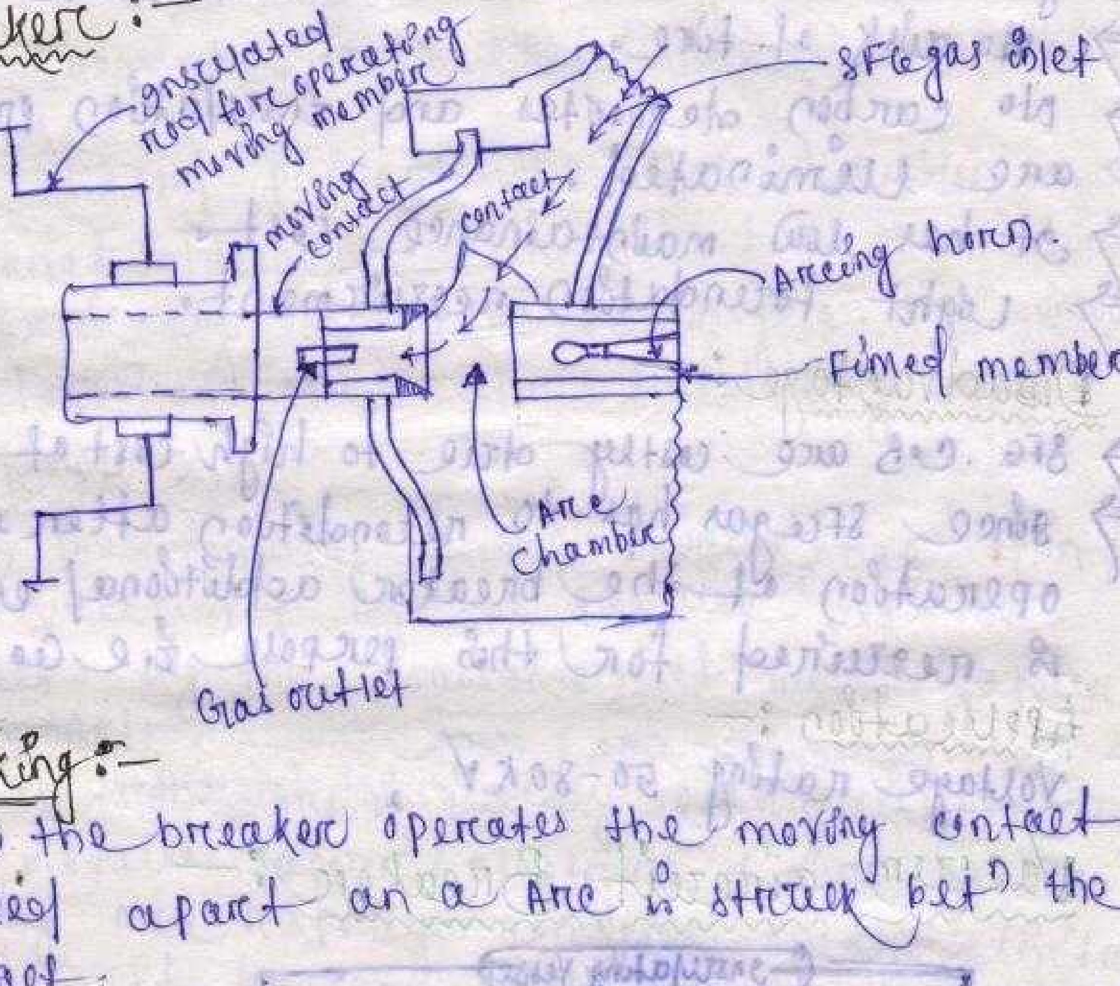
⇒ It consist of Fixed and moving contacts enclosed in a chamber (Arc interrupti[on] chamber) containg SF6 gas which is connect[ed] to SF6 gas reservoir.

interruption chamber

→ The Fixed contact is a hollow cylindrical current carrying contact fitted with an Arc horn, the moving contact is also a hollow cylindrical with rectangular holes in the sides to permit SF6 gas to let out through these holes after flowing along on the cross the Arc.

→ The tips of Fixed contact, & moving contact & Arcing horn are coated current tungsten Arc Resistant material.

Breaker :-



Working :-

→ when the breaker operates the moving contact pulled apart an a Arc is struck betⁿ the contact.

→ The moment of the moving contacts synchroniz with the opening of a valves which permits SF6 gas at 14 kg/cm² pressure from the reservoir to the Arc interruption chamber

→ The high flow of SF6 gas rapidly absorve the free electrons in the Arc path to from immobile strength & causes the extinction of the Arc at the breaker operation the valve is closed by the action of a set up strings.

Advantage :-

→ Due to supperiore Arc quenching property of SF6 this C.B has very short Arcing time.

→ Di-electric strength of SF6 gas is 2-3 times of Air, so this C.B can interrupt much large current.

→ It give noiseless operation due to its closed gas ckt and not adjust to atmosphere.

→ No risk of fire.

→ No carbon deposites and insulation problem are eliminated.

→ It has low maintainance cost.

→ Light foundation requirement.

Disadvantage :-

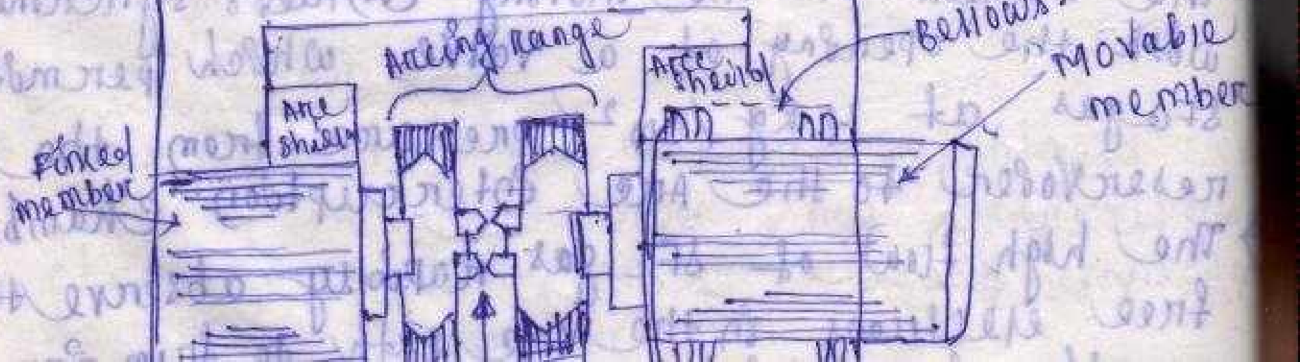
→ SF6 C.B are costly due to high cost of SF6

→ Since SF6 gas has to recondition after every operation of the breaker additional equipment is required for this purpose i.e 60 K Amp.

Application :-

Voltage rating 50-80KV

* Vaccum circuit Breaker :-



construction :-

→ In this ckt breaker vaccum is used as the arc quenching medium. As it offeres the highest insulating strength, it has far superior arc quenching properties than any other medium.
→ It consist of fixed chamber, moving chamber and arc shield mounted inside a vaccum chamber.
→ The moving member is connected to the control mechanizm by stenless steel bellows as which enable permanent shielding of the vaccum chamber, so as to eleminate the possibility of leak.
→ The shield prevents the deterioration of the internal dielectric strengths by preventing mechanically vapour falling on the inside surface of the outer insulating cover.

* principle :-

→ when the contacts of the breaker are opend in vaccum of arc is produce bet^n the contacts by the ionisation of metal vapours of contacts.
→ However the arc is quickly entinguish because the metalic vapour electrons & ions produce during arc rapidly condence on the surface of the ckt breaker contact resulting in quick recovery of dielectric strength.
→ As soon as the arc is produced in vaccum it is quickly entinguish due to fast rate of recovery of dielectric strength of vaccum

Working :-

→ when a breaker operates the moving contact

→ The production of Arc is due to ionisation of metal ions and depends very much upon material of contacts the Arc is quickly extinguish because the metalic vapours, electrons & ions produce during Arc is destroy in a short time and shield by the surface of moving and fixed members and shield.

* Advantage :—

→ It is compact, relayable & have longer life.
→ No fire agent
→ No generation of gas during & after operation
→ where require little maintainance quite in operation.
→ It has low Arc energy.

Application :—

→ It is used for outer Application ranging from 22kV to 66kV and with limited rating of 60-100 MVA.
→ It is suitable for a majority application rural Areas.

* Switchgear component :—

→ The following are some important component common to most of circuit breakers.

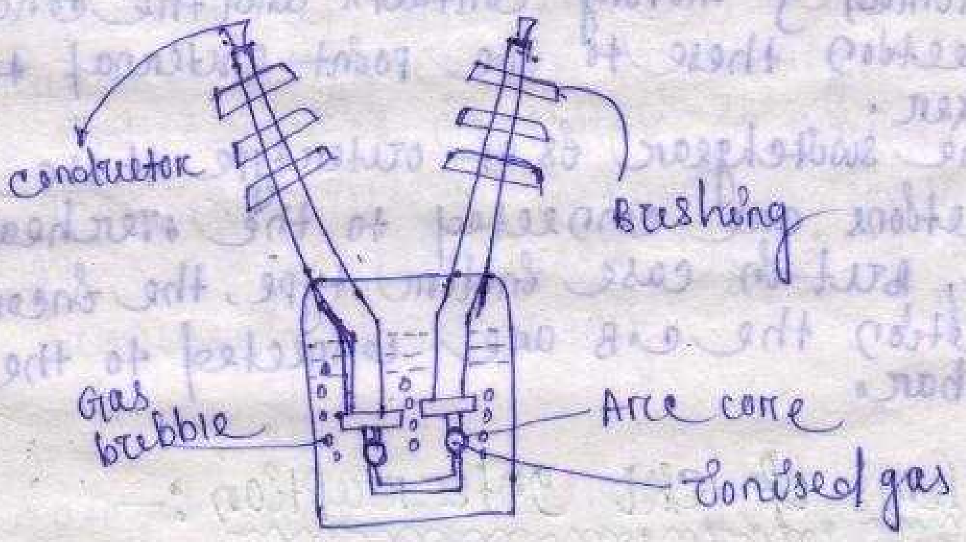
(a) Brushing
(b) C.B contacts
(c) Instrument transformer.
(d) Bus-bar and conductors.

(a) Brushing :—

→ When a high voltage conductor passes through a metal sheet or frames which is at earth potential, the necessary insulation conductor and the surrounding earth metal work.

⇒ The feature of bushing can occure into two ways firstly the breakdown may be cause by dielectric feature of the insulating material of bushing, 2ndly breakdown may occure in the form of a flashover between the exposed conductor at either end of the Bushing & the earthed metal.

⇒ So the Bushing are show designed that flasover takeplace before the dielectric feature, in the other hand a flashover may result in comparatively harmless burning on the surface of the Bushing, which can than ~~continue~~ continue to give adequate service.



(b) C.B. contacts :→

⇒ The circuit breakers are required to carry normal as well as short ckt current.

⇒ In carring the normal current it is desirable that the tempr should not rise above the specified limit and that there are should be low voltage drop at the point of contact.

⇒ In carring breaking & making the short ckt

→ There are 3 type C.B contacts.

(a) Tulip type
(b) Finger & wedge contact
(c) Butt contact.

(c) Instrument transformer :-

→ The function of instrument transformer is to transform voltage & current in the power lines to value, which are convineant for the operation of measuring instrument & relays

→ There are two type of instrument T/F :

(a) C.T (current transformer)
(b) P.T (potential transformer)

(d) Bus-bar & conductor :-

→ The current carrying member in a C.B consist of fixed & moving contacts and the conductor connection these to the point external to the breaker.

→ If the switchgear is of outer type these connections are connected to the overhead line, but in case indoor type, the incoming condition the C.B are connected to the bus-bar.

* Problems of ckt interruption :-

(i) Rate of rise of Restriking voltage :-

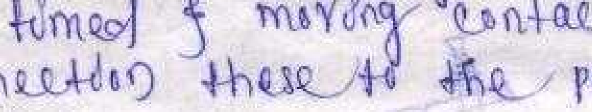
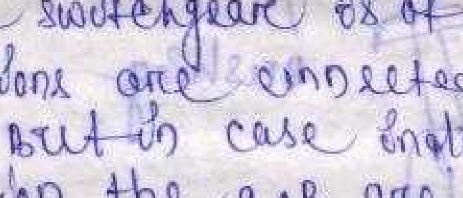


Fig-1



⇒ Fig-1 shows a s.c on transmission line and fig-2 it's equivalent ckt where inductance (L) per phase of the system upto the point of fault and c is the capacitance per phase of the system.

⇒ consider the opening the C.B. under fault conditions shown in fig-2.

⇒ Before current interruption the capacitance c' is s.c by the fault & the s.c current through the breaker is limited by inductance (L) of the system.

⇒ so the s.c cu will lag the voltage by 90° where (i) represent the s.c current.

e_0 = Arc voltage

⇒ when the contacts are opened & the Arc extinguished at some current zero.

⇒ Generator voltage (e) is suddenly applied to the inductance & capacitor in series.

⇒ This transient voltage is known a Restriking voltage & may reach upto $2E_m$ & produces a transient of frequency

$$f_n = \frac{1}{2\pi\sqrt{LC}}$$

⇒ so rate of rise of restriking voltage is the rate of increase of restriking voltage & is denoted as R.R.R.V.

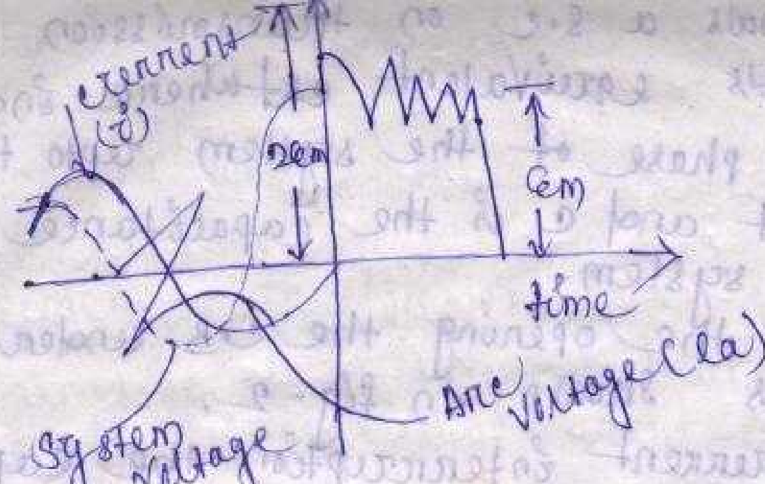
⇒ It's unit is (kV/μsec)

⇒ It decides wheather the Arc will restrik or not

⇒ If R.R.R.V is great than the rate of rise a dielectric strength betn the contact then the Arc will Restrik.

⇒ It depends upon recovery voltage & nature frequency of oscillations.

⇒ For a s.c occuring near the power statio value.

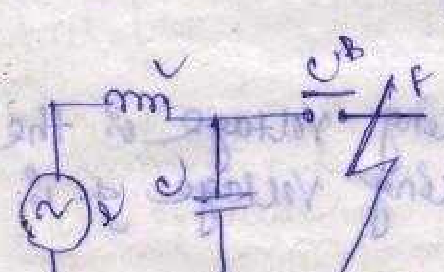


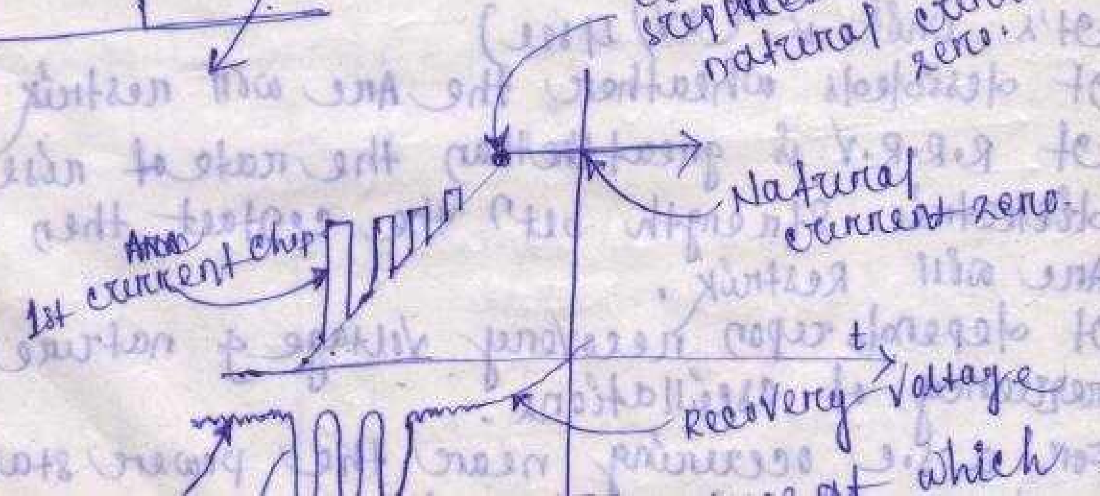
(ii) Current Chopping :—

⇒ It is the phenomenon of current interruption before the natural current zero is reached.

⇒ It mainly occures in Air blast c.B because they written the same extinguishing power irrespecting of the magnitude of the current to be interrupted.

⇒ when breaking low current (for exp transformer magnetizing current) with such breaker the powerful deionising effect of Air blast causes the current to fall abruptly to zero before the natural current zero is reached this phenomenon is known as current chopping.





which

⇒ suppose the Arc current is (i), when it is chopdown to zero value at as soon by a point A.

⇒ As the chop occurs at current (i), therefore energy stored in inductance is $\frac{1}{2}$.

⇒ This energy will be transferred to the capacitance (c) charging that to a prospective voltage (e) is given by:—

$$\frac{1}{2} L i^2 = \frac{1}{2} c e^2$$

$$\Rightarrow \boxed{e = \sqrt{\frac{L}{c}} \cdot i}$$

⇒ e is very high as compare to the dielectric strength gained by the gap so that the breaker is restrik which introduces a lower prospective voltage to re-ignite the Arc.

⇒ In fact several chops may occur until low enough current is interrupted which produces insufficient induce voltage to restrik across the breaker gap.

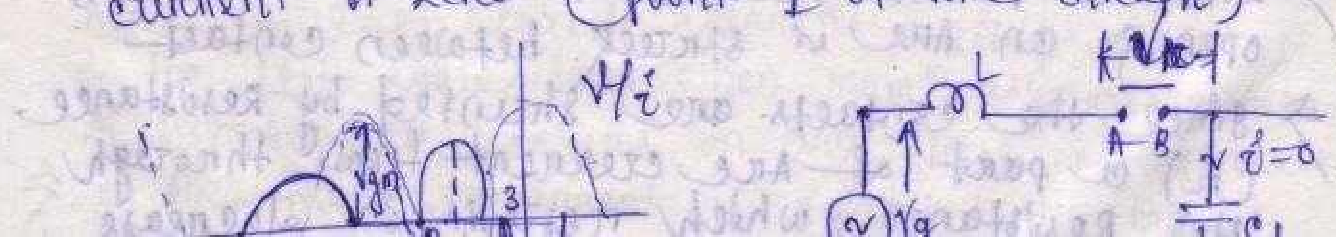
⇒ consequently the final interruption current take place.

(iii) Capacitive current Breaking :—

⇒ Another cause of excessive voltage source in the C.B is the interruption of capacitive current.

⇒ example of such a instance are opening of an on-loaded long transmission line disconnecting a capacitor Band used for power factor improvement.

⇒ Let us suppose that the line is open by the C.B at the instant when line capacitive current is zero (point 1 of the Graph)



⇒ At this instant Vg will be maxᵐ lagging behind the current by 90°.

⇒ The opening of the line leaves a standing charge on it (end B' of the line) & the capacitor (C1) is charge to Vgm.

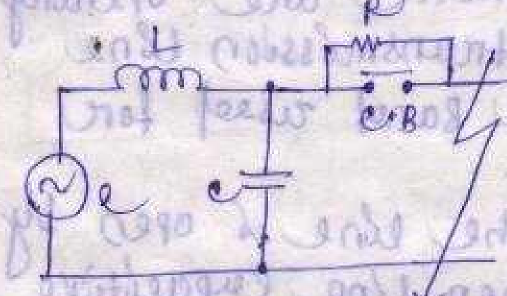
⇒ However the generator end of the line i.e point A' continues it's normal synosadal variation.

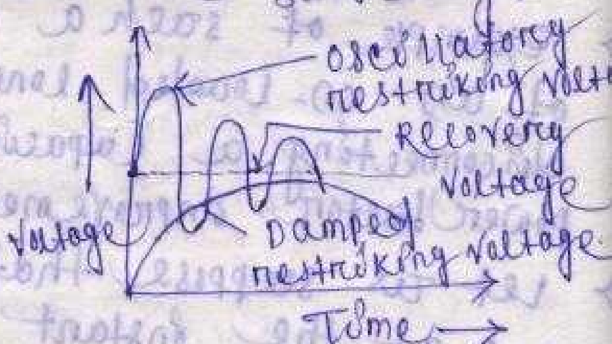
⇒ The voltage (Vr) across the C.B will be the difference between the voltage of the respective sides

⇒ It's initial value zero & increase slowly in the beginning. But after half of cycle potential of the C.B contact A' become maxᵐ -ve, which causes the voltage across the breaker to become to Vgm, which is sufficient to restrik the Arc.

* Resistance switching :-

⇒ current chopping, capacitive current breaking etc give rise to severe voltage oscillation, these excessive voltage surges during ckt interruption can be prevented by the use of shunt resistance (R) connected across the ckt breaker contacts which is known as Resistance switching.





⇒ When a fault occurs a contact of the C.B open & an Arc is struck between contact

⇒ Since the contacts are shunted by Resistance (R) a part of Arc current flows through

⇒ Consequently the Arc Resistance is increased which leads to a further increase in current through shunt resistance.

⇒ This process continues until the Arc current becomes so small that it fail maintain the Now the Arc extinguish & ckt current is interrupted.

⇒ Also shunt Resistance helps in limiting oscillatory growth of restriking voltage & cause it to grow exponentially upto recovery voltage.

* Circuit Breaker Rating :—

⇒ There are the C.B are three Rating

(i) Breaking capacity.
(ii) Making capacity.
(iii) Short time capacity.

(i) Breaking capacity :—

⇒ It is the current (r.m.s) that a C.B is capable of breaking at given recovery voltage and under specified condition (Exp - power factor & R.R.R.V)

⇒ If I rated breaking current in Amp & V is the rated service line voltage in volt then for 3-ϕ ckt breaking capacity in MVA $= \sqrt{3} \times V \times I \times 10^{-6}$ MVA

(ii) Making capacity :—

⇒ The peak value of current (including d.c component) during 1st cycle of current wave after the closer of C.B is known as making capacity.

⇒ From the defination with the 1st cycle of current wave unclosing the C.B which is because the maxm value of fault current possibly occurres in the 1st cycle only when maxm asymmetry ~~value~~ of ~~asymmetrical~~ occurs in any phase of the breaker.

⇒ So the making current is equal to the maxm

⇒ Making capacity = 2.55 x symmetrical breaking capacity.

Note :—

→ √2 is the covert this from r.m.s

→ 1.8 is include to symmetrical doubling effect of maxm asymmetry.

(iii) Short time Rating :—

⇒ It is the period for which the c.B is able to carry fault current while remaining close.

⇒ It depends upon this ability to withstand

(a) Electromagnetic force effects.

(b) the tempr rise.

*** PROTECTIVE RELAYS

* Defination of protective Relay :-

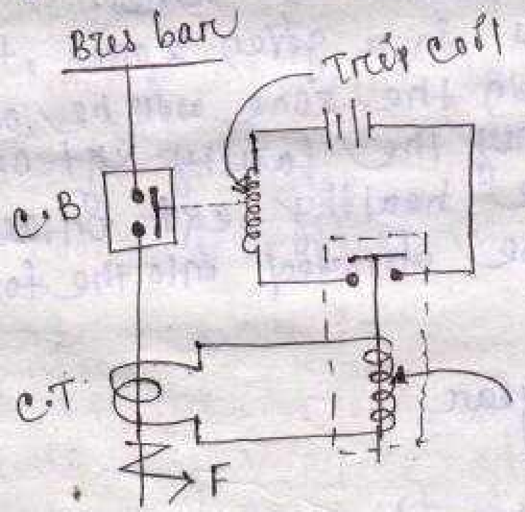
⇒ A protective relay is a device that detects the fault & initiates the operation of the ckt breaker to isolate the defective element from the rest of the system.

⇒ The relay ckt connections can be divided into 3 parts

i) 1st part is the primary winding of a CT which is connected in series with the line to be protected.

ii) 2nd part consists of 2ndary winding of C.T and the relay operating coil.

iii) 3rd part is the tripping ckt which may be either a.c or d.c which consist of a source of supply, the trip coil of the ckt breaker & the relay stationary contacts.



⇒ when a s.c occurs at point fault on the transmission line, the current flowing in the line increases to an enormous value which results in a heavy current flow through the relay coil, causing the relay to operate by closing its contacts.

⇒ which in turn closes the trip ckt of the breaker making the C.B open & isolating the faulty section from the rest of the system.

* Fundamental Requirements of protective Relay :

The protective relay system have the following qualities

a> Selectivity
b> speed
c> sensitivity
d> Reliability
e> simplicity
f> economy

(a) Selectivity :-

⇒ It is the ability of the protective system to select correctly that part of the system in trouble & disconnect the faulty part without disturbing the rest of the system

⇒ In order to provide selectivity to the system it is a usual practice to divided entire system into several protection zones.

⇒ when a fault occurs in a given zones, then only the C.B.s within the zone will be opened which will isolate only the faulty ckt or apparatus leaving the healthy ckt intact.

⇒ So, the system can be divided into the following protection zones. a

(a) Generator
(b) Low tension switchgear
(c) Transformers
(d) High tension switchgear
(e) Transmission lines.

(b) Speed :-

⇒ The relay system should disconnect the faulty section as fast as possible for the following reas

a> Electrical apparatus may be damaged at they are made to carry the fault current for long time

b> A failure on the system leads to a great

(iii) Sensitivity :-

⇒ It is the ability of the relay system to operate with low value of actuating quantity

⇒ sensitivity of a relay is a function of the volt amperes i/p to the coil of the relay necessary to cause its operation.

⇒ The smaller the VA i/p required to cause relay operation the more sensitivity is the relay.

(iv) Reliability :-

⇒ It is the ability of the relay system to operate under pre-determined conditions. without reliability the protection would be rendered largely ineffective & could even become a liability

(v) Simplicity :-

The relaying system should be simple so that it can be easily maintained.

(vi) Economy :-

⇒ The most important factor in the choice of a particular protection scheme is the economic aspect As a rule, the protective gear should not cost more than 5% of total cost.

* Basic Relay :-

⇒ Most of the relays used in the power system operate by virtue of the current or voltage supplied by current & voltage transformers connected in various combinations to the system element that is to be protected.

⇒ Having detected the fault the relay operates the trip ckt which results in the opening of the C.B and hence in the disconnection of the faulty ckt.

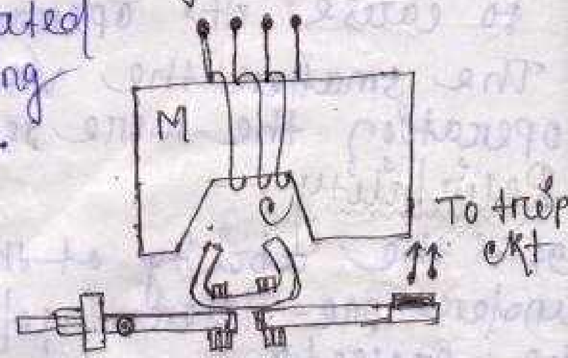
⇒ Most of the relays in service on electric power system today are of electromechanical

* Electromagnetic Attraction Relays :⇒

⇒ These relays operate by virtue of an armature being attracted to the poles of an electromagnet or a plunger being drawn into a solenoid.

a) Attracted armature type relay :—

⇒ It consists of a laminated electromagnet M' carrying a coil C & a pivoted laminated Armature.



⇒ Under the normal operating condition the current through the relay coil C is such that counter weight holds the armature in the position shown.

⇒ When S.C occurs the current through the relay coil increase sufficiently & the relay armature is attracted upwards.

⇒ The contacts on the relay armature bridge a pair of stationary contacts attached to the relay frame which completes the trip ckt which results in the opening of the C.B & therefore in the disconnection of the faulty ckt.

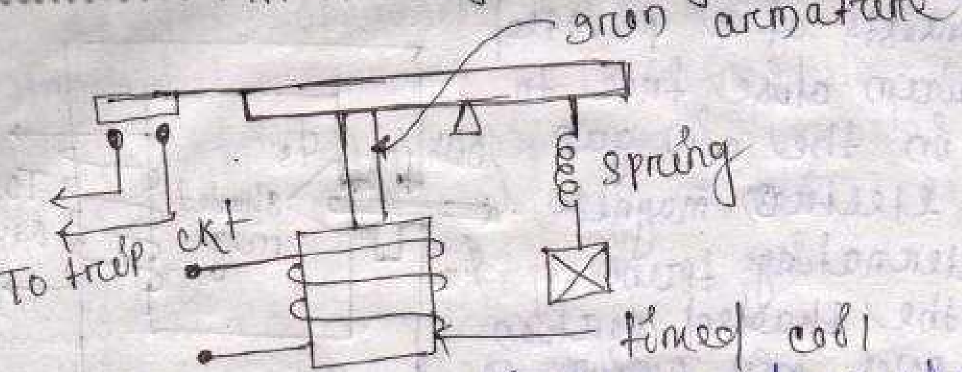
b) Solenoid type relay :—

⇒ It consists of a solenoid & moveable iron plunger arranged as shown under normal operating cond^n, the normal through the relay coil C is such that it holds the plunger by gravity or spring in the position.

⇒ But in the occurrance of a fault, the current through the relay coil becomes more than the pick up value, causing the plunger to the attracted to the solenoid.

⇒ The upward movement of the plunger closes the trip ckt, thus opening the C.B & disconnecting the faulty ckt.

(iii) Balanced beam type relay:—



- It consists of an iron armature fastened to a balance beam.
- Under normal operating cond's, the current through the relay coil such that the beam is held in the horizontal position by the spring.
- When fault occurs the current through the relay coil becomes greater than the pick up value & the beam is attracted to close the trip ckt which cause the opening of the CB to isolate the faulty ckt.

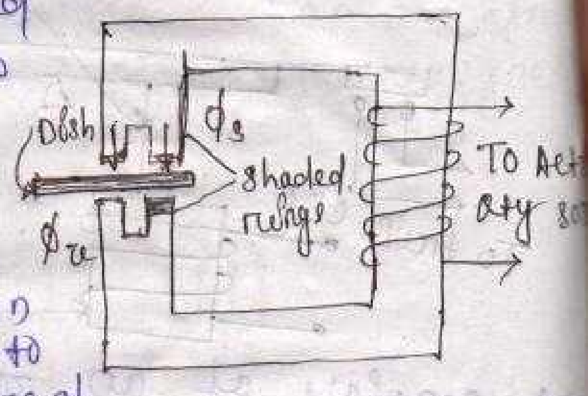
* Induction Relays:—

- This type of relays operate on the principle of I.M winding used for protecting relaying purposes involving a.c quantities which are not used with d.c quantities.
- It consists of a pivoted Aluminium disc placed in two alternating magnetic fields of the same frequency but displaced in time & space.
- The torque is produced in the disc by the interaction of one of the magnetic field with the currents induced in the disc by the other.
- The following 3 types of structures are commonly used for obtaining the phase difference in the fluxes & hence the operating torque in induction relays.

1) Shaded pole structure

i) Shaded pole structure :→

→ It consists of a pivoted Aluminium disc free to rotate in the air gap of an electro magnet



→ The alternating flux ϕ_s in the shaded portion of the pole will owing to the reaction of the current induced in the ring lag behind the flux ϕ_u in the unshaded portion by an angle α.

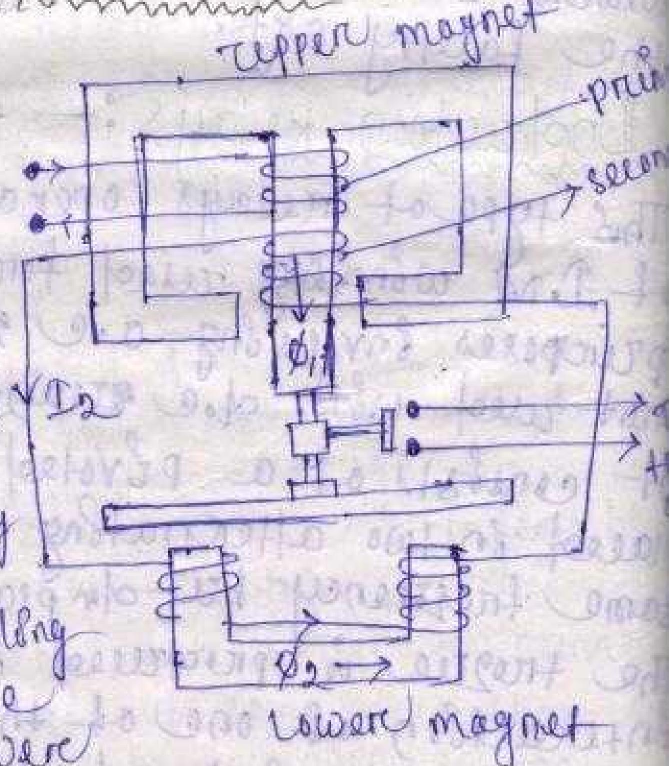
→ These two A.c fluxes differing in phase will produce the necessary torque to rotate the disc.

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

$T \propto I^2 \sin\alpha$ [As ϕ_s & $\phi_u \propto I$)

ii) Watthour- meter structure :—

→ It consist of a pivoted aluminium arranged to rotate freely between the poles of two electro-magnets.

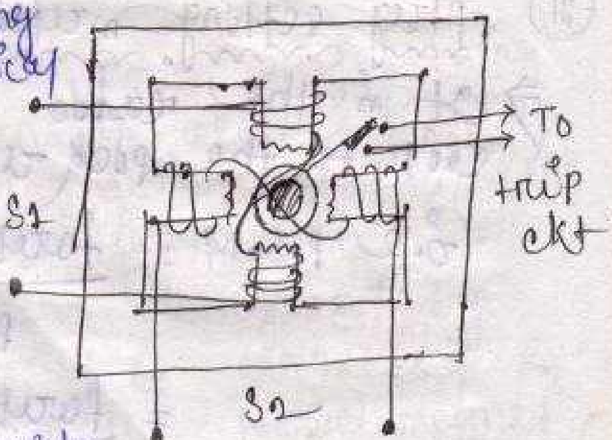


→ The primary winding of upper electro-magnet carries relay current I_1 which the secondary winding is connected to the winding of the lower magnet

→ The primary current induces emf and circulates a current I_2 in the secondary, the flux ϕ_2 induced in the lower magnet by the current also proportional to $\phi_1 \phi_2 \sin\alpha$.

So, the operation of this type relay be controlled by opening or closing the secondary winding ckt. The relay can be made in operative by opening in secondary winding ckt.

iii) Induction cup structure :→



⇒ In this structure the moving element is a hollow cylindrical rotor which turns on its axis, the rotating field is produced by two pairs of coils wound on four poles.

⇒ The rotating field induced current in the cup to provide the necessary driving torque

⇒ If ϕ_1 & ϕ_2 represent the fluxes produced by the respective pairs of poles, then torque produced is proportional to $\phi_1 \phi_2 \sin\alpha$ where α is the phase difference between the two fluxes.

⇒ A control spring & the back stop for closing of the contacts carried on an arm are attached to the spindle of the cup to prevent the continuous rotation

* Important terms :—

i) pick-up current :—

It is the minimum current in the relay coil at which the relay starts to operate when the relay coil current is equal to or greater than the pick up value, the relay operates to energise the trip coil which opens the ckt breaker.

ii) current setting :—

To adjust the pick up current to any required in terms of %age full load rotating of C.T with which the relay is associated & represent the value above which the disc commences to rotate & finally closes the trip ckt.

∴ pick-up current = Rated 2ndary cu. of C.T × current setting.

(iii) Plug-setting multiplier :—

⇒ It is the ratio of fault current in relay coil to the pick-up current

i.e P.S.M = $\frac{\text{fault current in relay coil}}{\text{pick-up current}}$

= $\frac{\text{fault current in relay coil}}{\text{Rated secondary current of C.T} \times \text{current setting}}$

(iv) Time setting multiplier :—

A relay is generally provided with control to adjust the time of operation. This adjustment is known as time setting multiplier

* Classification of functional Relay :—

There are various type of functional relay which are

i) Induction type overcurrent relays.

ii) " " overcurrent power relays.

iii) Distance relays

iv) Differential relays

v) Translay scheme

* Induction type overcurrent Relay (Non-d

⇒ This type of relay works on the induction principle. The actuating source is a current in the ckt supplied to the relay from
facilitates corrective measures when current in the ckt exceeds

a current transformer.

flow in either direction.

Construction :—

⇒ It consists of a metallic (Al) disc which is free to rotate in between the poles of two electromagnets. The primary winding of the upper electromagnet is connected to the secondary of C.T in the line to be protected & is tapped at intervals.

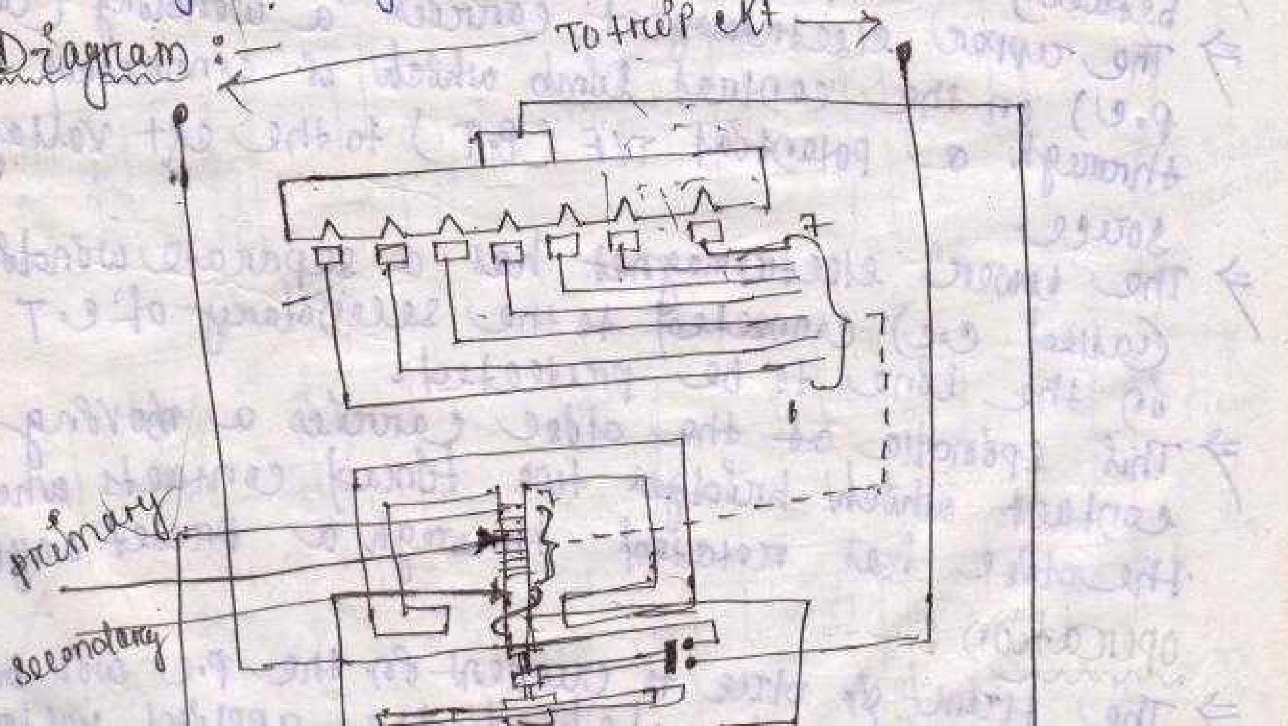
⇒ The tappings are connected to a plug setting bridge by which the no' of active turns on the relay operating coil can be varied, thereby giving the desired current setting.

⇒ The secondary winding is energised by induction from primary & is connected in series with the winding on the lower magnet & the controlling torque is provided by a spiral spring.

⇒ The spindle of the disc carries a moving contact which bridges two fixed contacts when the disc rotates through a preset angle, which can be adjusted to any value bet^n 0° & 360°

⇒ By adjusting this angle, the travel of the moving contact can be adjusted & hence the relay can be given any desired time setting.

Diagram :—



Operation :-

→ The driving torque on the Al disc set up due to which is opposed by the restraining torque provided by the spring.

→ Under normal operating conditions, the restraining torque is greater than the driving torque produced by the relay coil current, so the Al disc remains stationary.

→ If the current in the protected ckt exceeds the preset value the driving torque becomes greater than the restraining torque, the disc rotates & the moving contact bridges the fixed contacts, so the trip ckt operates the C.B which isolates the faulty section.

* Induction type directional power relay :-

This type of relay operates when power in the ckt flows in a specific direction, so it is essentially a wattmeter & the direction of the torque set up in the relay depends upon the direction of the current relative to the voltage with which it is associated.

Construction :-

→ It consists of an Al disc which is free to rotate between the poles of two electromagnets.

→ The upper electromagnet carries a winding (called P.C) on the central limb which is connected through a potential T/F (P.T) to the ckt voltage source.

→ The lower electromagnet has a separate winding (called C.C) connected to the secondary of C.T in the line to be protected.

→ The spindle of the disc carries a moving contact which bridges two fixed contacts when the disc has rotated through a preset angle.

Operation :-

in phase with the operating current I'

⇒ The interaction of fluxes ϕ_1 & ϕ_2 with the eddy currents induced in the disc produces a driving torque

$$T \propto \phi_1 \phi_2 \sin \alpha$$

As $\phi_1 \propto V$, $\phi_2 \propto I$ & $\alpha = (90° - \phi)$

$$T \propto VI \sin(90 - \phi)$$

$$\propto VI \cos \phi$$

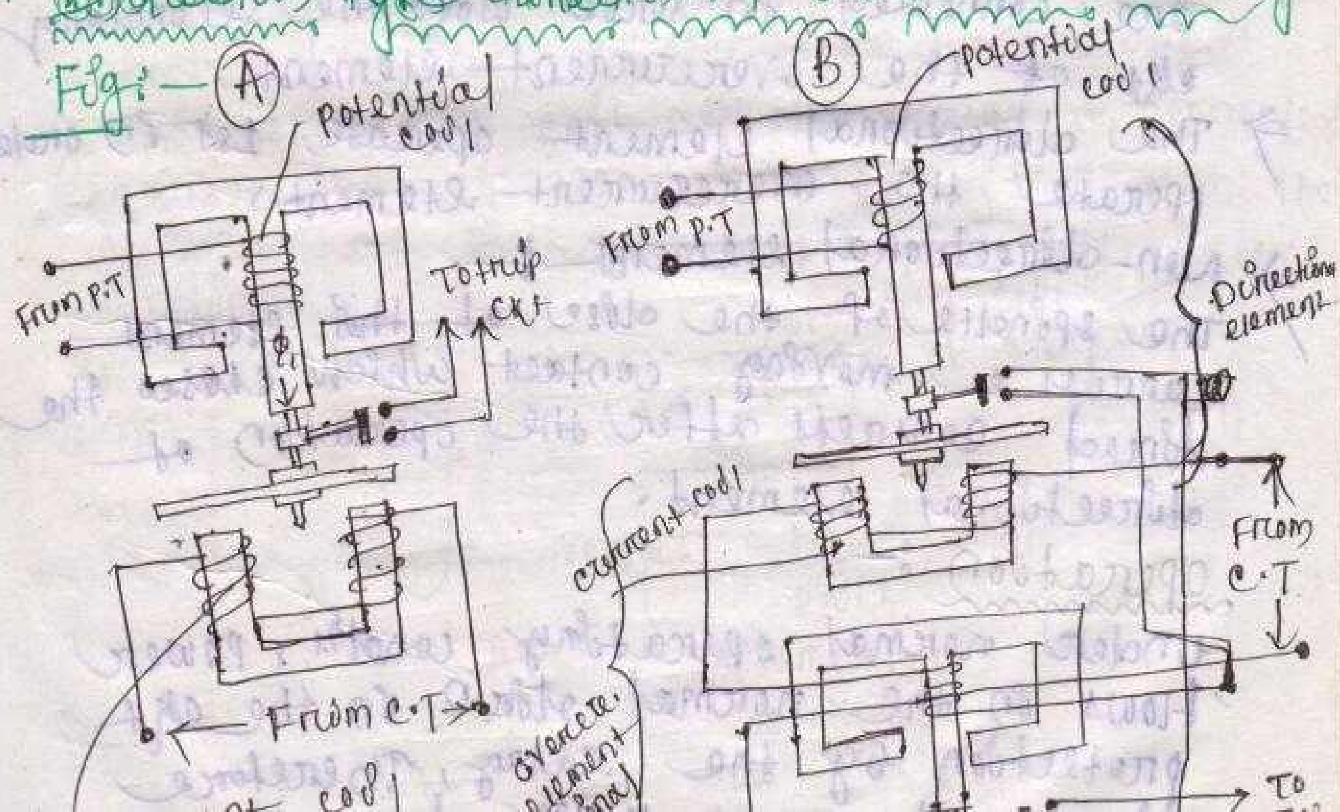
$\propto$ power in the ckt.

⇒ When the power in the ckt flows in the normal direction the driving torque & the restraining torque help each other to turn away the moving contact from the fixed contacts.

⇒ So, relay remains in operative, But when the reversed driving torque is large enough the disc rotates in the reverse direction & the moving contact closes the trip ckt which cause the operation of the C.B which disconnects the faulty section.

* ~~Induction type directional overcurrent Relay~~

Fig:— (A) (B)



* Induction type directional overcurrent relay

when s.c occures, the system voltage falls to a low value & there may be insufficient torque developed in the relay to cause its operation which is overcome in the directional overcurrent relay which is designed to be almost independent of system voltage & power factor.

Construction :-

→ It consists of two relay element mounted on a common case such that
  a) Directional element
  b) Non-directional element.

→ It is a directional power relay which operates when power flows in a specific directional.

→ The p.c of this element is connected through a P.T to the system voltage & the c.c of the element is energised through a C.T by the ckt element.

→ The trip contacts of the directional element are connected in series with the secondary ckt of the overcurrent element.

→ The directional element operate, 1st in order operate the overcurrent element.

→ Non-directional element :-
The spindle of the disc of this element carries a moving contact which closes the timed contacts after the operation of directional element.

Operation :-

Under normal operating condn, power flows in the normal direcn in the ckt protection by the relay, Therefore

⇒ when a s.c occures, there is a tendency for the current or power to flow in the reverse direction. The disc of the non-directional element rotates & moving contact attached to it closes the trip ckt. faulty section.

* Differential Relay :→

⇒ A differential relay is one that operates when the phasor difference of two or more similar electrical quantities exceeds a pre-determined value.

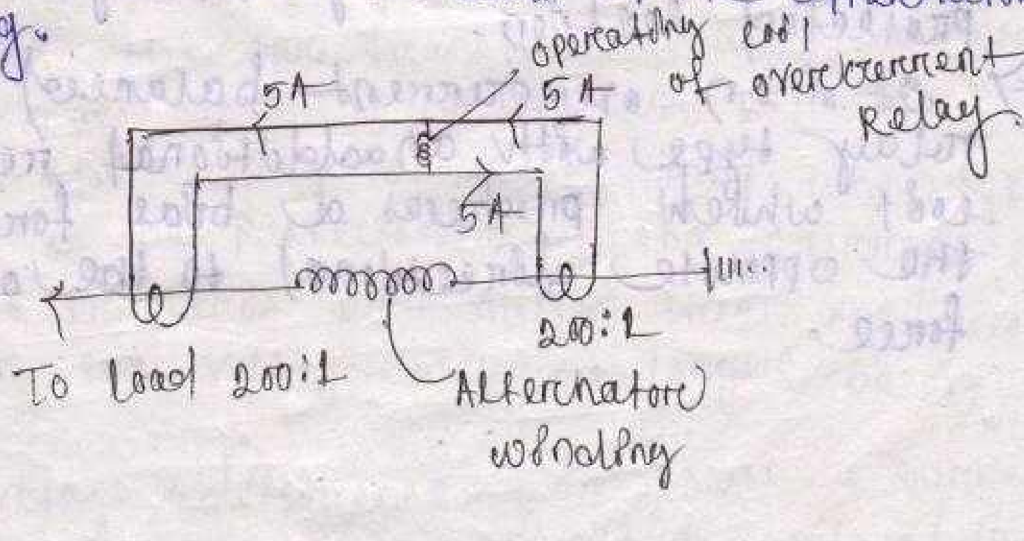
⇒ There are two types of differential relay
i) current differential relay
ii) Voltage balance differential relay.

i) current differential relay :—

⇒ In this type of relay a pair of identical C.T.s are fitted on either end of the section to be protected (alternator winding).

⇒ The secondaries of CT's are connected in series in such a way that they carry the induced current in the same direction.

⇒ The operating coil of this relay is connected across the CT secondary ckt & compare the current at the two ends of the alternator winding.



Working :-

⇒ under normal operating cond^n, the alternator winding carries a normal current which circulates bet^n two CTs & no current will flow through the differential relay. so relay remains inoperative

⇒ If a ground fault occurs on the alternator winding the two secondary current will not be equal & the current flows through the operating coil of the relay causing the relay to operate

Disadvantage :-

⇒ The impedance of the pilot cables generally causes a slight diff. bet^n the currents at the two ends of the section to be protected

⇒ If the relay is very sensitive, then the small differential current flowing through the relay may cause it to operate even under no fault cond^n.

⇒ Accurate matching of CT can't be achieved due to pilot ckt impedance

Percentage differential Relay

It is designed to respond to the diff. current in terms of its fractional relation to be current flowing through the protected section.

⇒ It is an overcurrent balanced beam relay type with an additional restraining coil which produces a bias force in the opposite directional to the operating force.

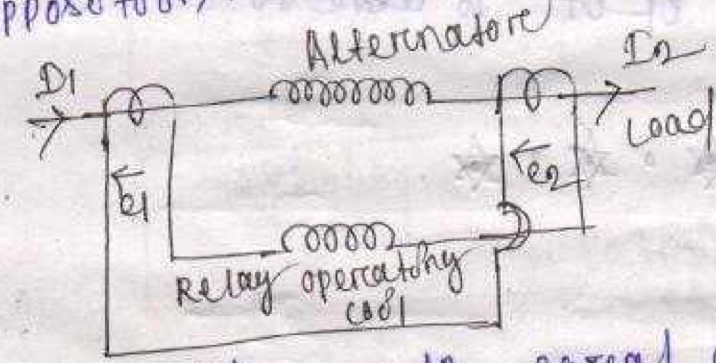
⇒ Under normal and through load cond's the bias force due to restraining coil is greater than the operating force

⇒ Therefore, the relay ~~a~~ remains in operation. when internal fault occurs, the operating force exceeds the bias force, consequently the trip contacts are closed to open the C.B & the bias force can be adjusted by varying the no. of turns on the restraining coil.

* Voltage Balance differential Relay :⇒

⇒ In this type relay two similar CTs are connected at either end ~~of~~ the element to be protected by means of pilot wires.

⇒ The secondary winding of CT are connected in series with a relay in such a way that under normal cond's, their induced emf are in opposition.



⇒ Under healthy cond's, equal current ($I_1 = I_2$) flow in both p-windings. Therefore, the secondary voltage at the two transformer are balanced against each other & no current will flow through the relay operating coil, when fault occurs in the protected ~~zero~~ zone, the current in the two primaries will differ from one another & their sec-voltage will no longer be in blance.

⇒ This voltage difference will cause a current

* Types of Protection :-

The protection sheme is divided into the classes

i> primary protection.

ii> back-up protection.

* primary protection :→

It is designed to protect the component parts of the power system.

* Back-up protection :→

It is the second line of defence in case of failure of the primary protection f designed to operate with sufficient time delay so the primary relaying will be given enough time to function if it is able to.

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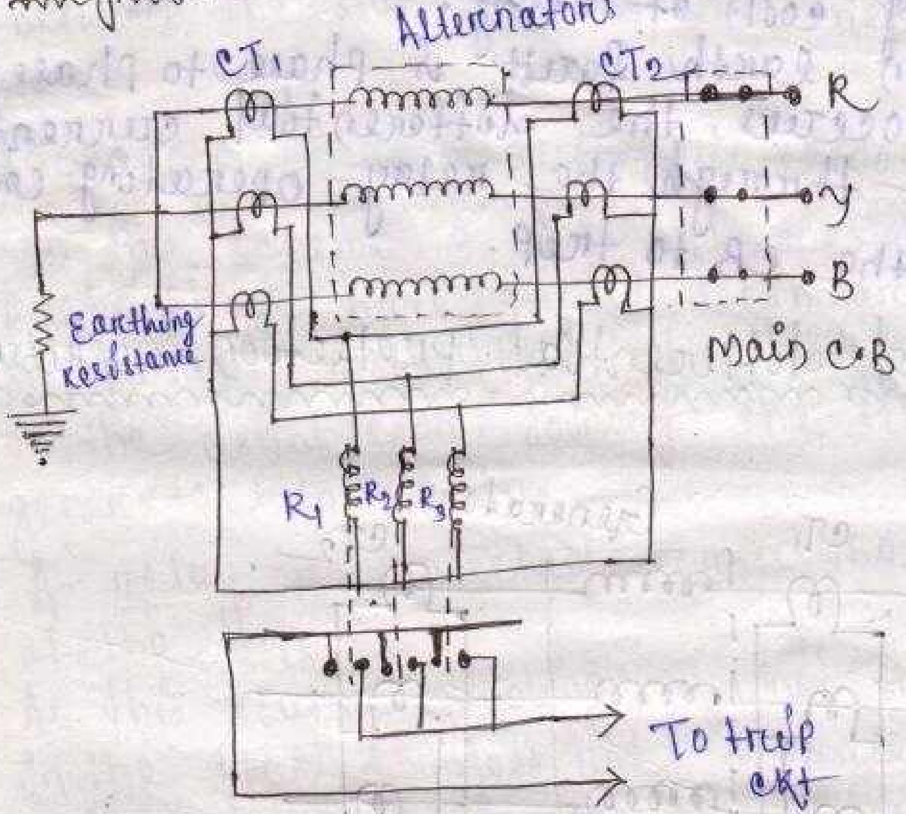
*** PROTECTION OF ELECTRICAL POWER EQUIPMENT AND LINES

Chapter-06

* Differential Protection for Alternators :→

In this scheme of protection, currents at the two ends of the protected section are compared & such a protective scheme is called a Merz-Price circulating current system.

Diagram :—



→ In this protection scheme, two sets of identical CTs, each set is mounted on either side of the stator phase winding.

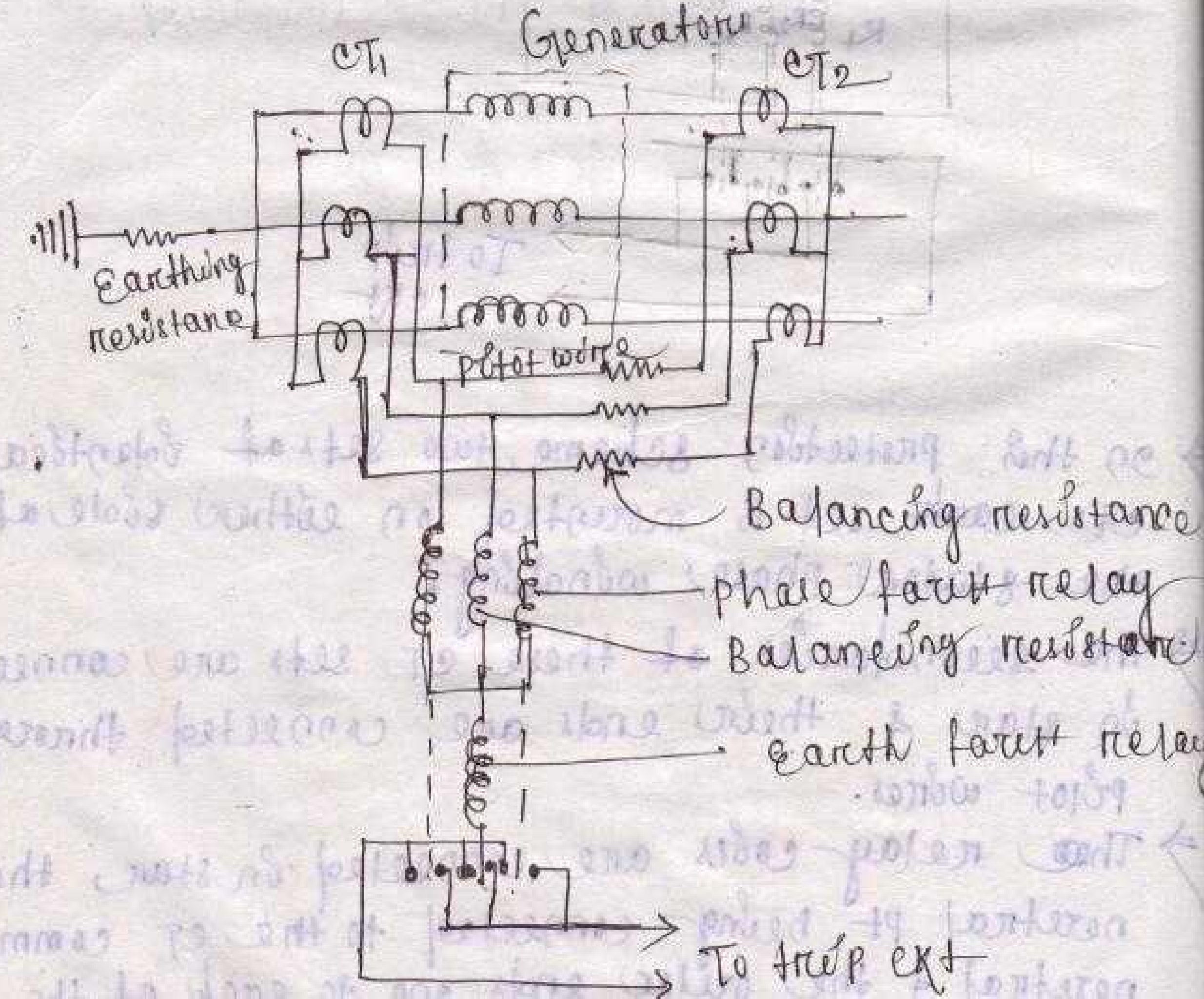
→ The secondaries of these CT sets are connected in star & their ends are connected through pilot wires.

→ The relay coils are connected in star, the neutral pt being connected to the CT common neutral & the outer ends are to each of the can be accomplished by inserting balancing resistances in series with the pilot wires to make equipotential pts located near the main CB which are adjustable in order to obtain the exact balance.

⇒ Under healthy condition, the currents at both ends of each winding will be equal, emfs induced in secondaries of CTs will be equal & so no current will flow through operating coils of relay.

⇒ When an earth fault is phase to phase fault occurs, the differential current flowing through the relay operating coil makes the CB to trip.

* Modified differential protection for Altern



⇒ In the modified form of differential protection the setting of earth fault is reduced without imparing stability.

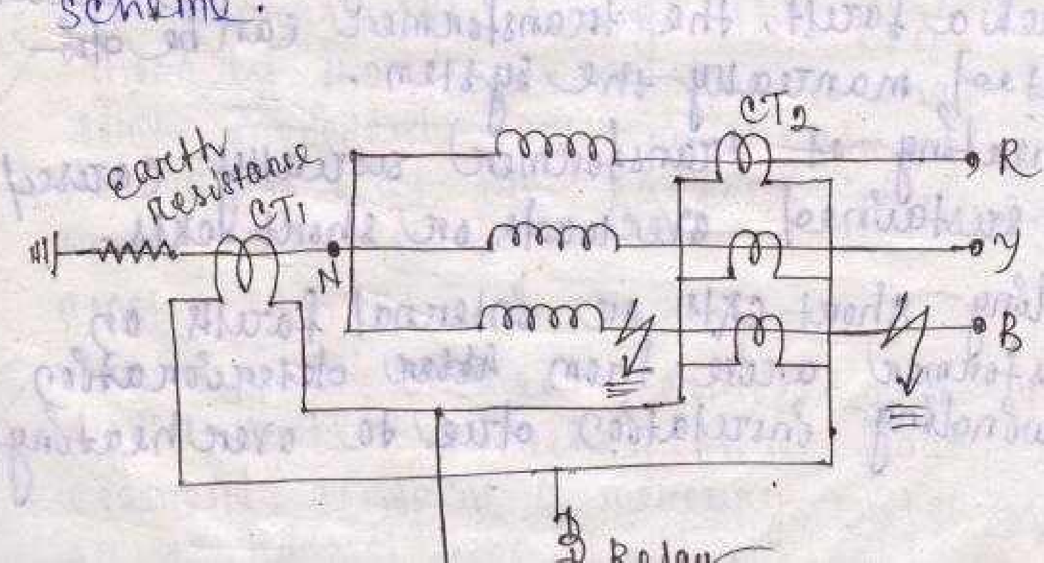
⇒ In this scheme two elements are arranged for phase fault protection & the third for earth fault protection the two phase elements together with a balancing resistor are connected in star & the earth fault relay is connected between the star pt and the neutral pilot wire.

* Balanced earth fault protection :→

⇒ In this scheme, 3 line CTs, one mounted in each phase have their secondaries connected in parallel with that of a single CT mounted on the conductor joining the star pt of the generator to earth.

⇒ A relay is connected across the secondaries of the CTs.

⇒ As this stator winding against the earth fault in the star & does not operate in case of external earth fault, so this scheme is called restricted earth fault protection scheme.



⇒ Under normal working conditions, the current flowing in the secondaries of the line CTs sum up to zero and current flowing in the secondary of neutral CT is also zero. Thus the relay remains de-energized.

⇒ When an earth fault occurs left of the line CTs, the fault current flows through the primary of neutral CT and the corresponding secondary current flows through the relay which trips the C.B.

⇒ In case the earth fault develops external of the line CTs, the sum of the currents at the terminals of the generator is exactly equal to the current in the neutral connection & as such no current flows through the relay operating coil.

* Protection systems of transformer :→

Transformer faults :–

i) open ckts fault
ii) over heating
iii) winding short-ckt.

⇒ open ckt in one phase of a 3-ϕ transformer may cause undesirable heating. so on occur of such a fault, the transformer can be dis-connected manually the system.

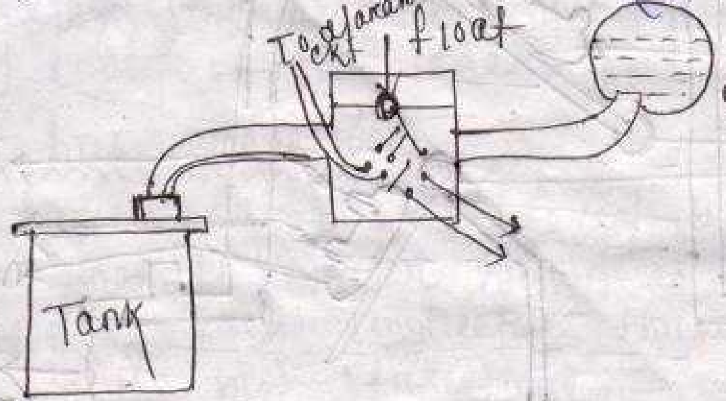
⇒ overheating of transformer usually caused by sustained overloads or short ckts.

⇒ winding short ckts or internal faults on transformer arise from ~~ddd~~ deterioration of winding insulation due to over heating.

* Buchholz - Relay :-

⇒ It is a gas actuated relay & used on all oil immersed transformer having rating more than 750 KVA.

⇒ This relay is fitted to the transformer equipped with conservator tanks as it is installed in between the conservator tank & the main tank.



Operation :-

⇒ when a minor fault occurs, heat is produced due to current leakage, some of the oil in the transformer tank evaporates & some vapour collect in the top of the chamber while passing to the conservator tank.

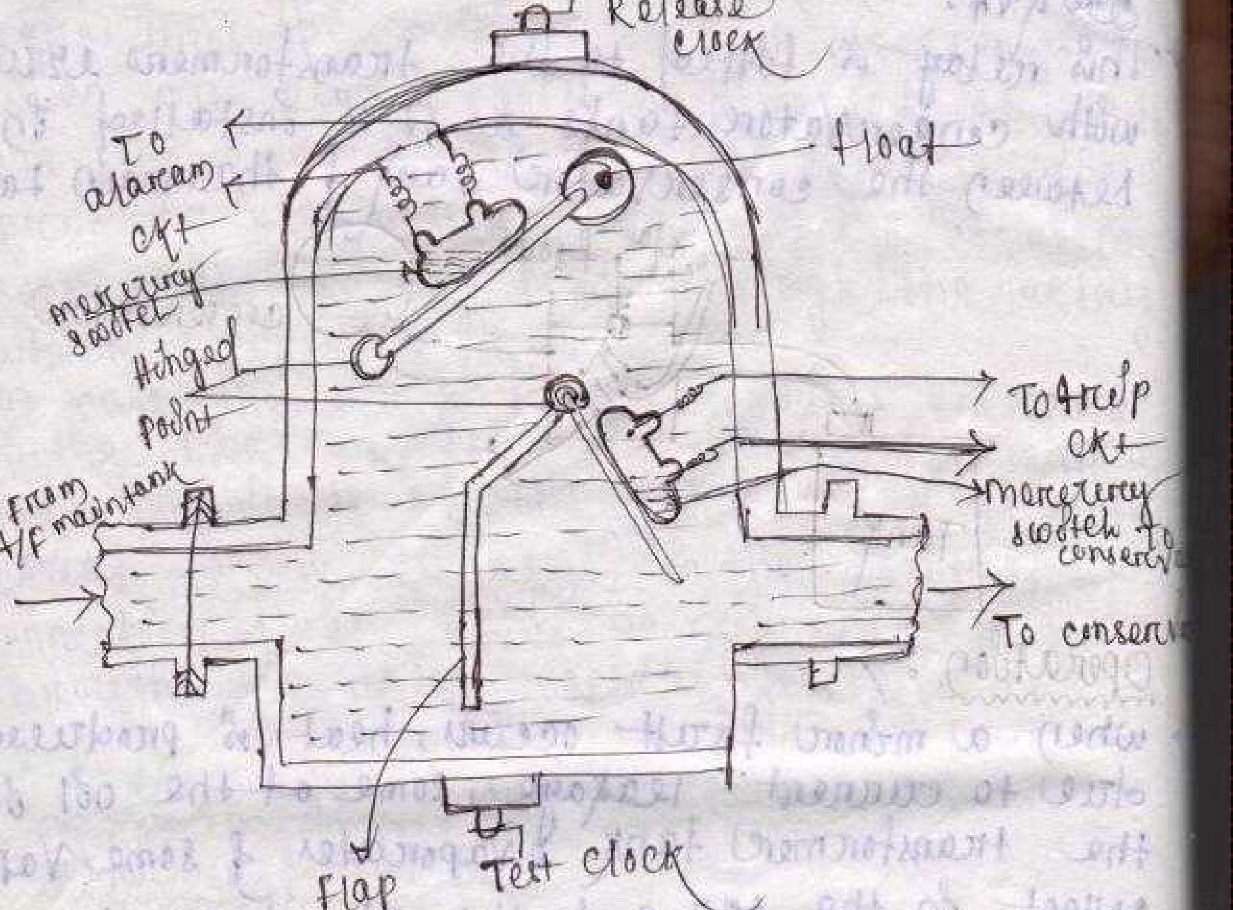
⇒ when a predetermined amount of vapour accumulate in the top of the chamber, the oil level falls, the mercury type switch attached to the float is fitted & so closes the alaram ckt & rings the bell.

⇒ There by the operator knows that there is some incipient fault in the transformers & is disconnected at the earliest possible & the gas sample is tested.

Construction :-

⇒ The upper element consists of a mercury type switch attached to a float. The lower element contains a mercury switch mounted

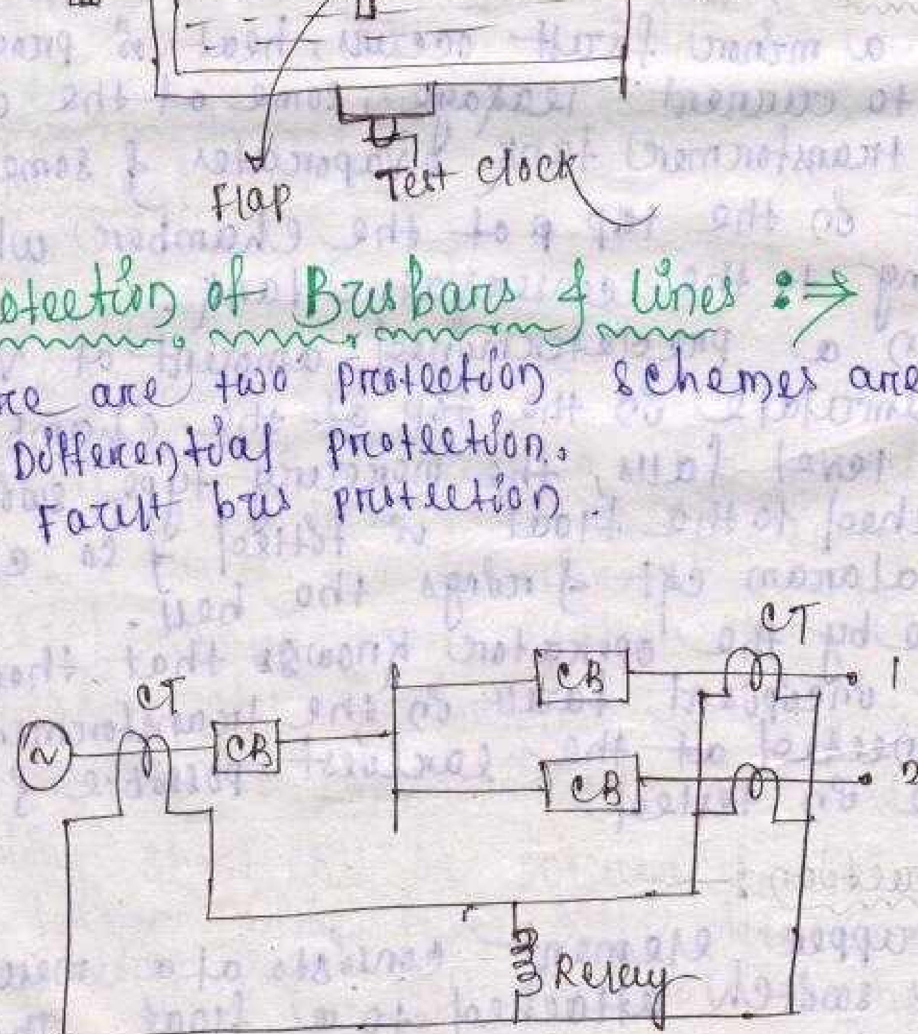
→ The upper element closes on alaram ckt during faults where as the lower element is arranged to trip the C.B in case of severe internal faults.



* Protection of Busbars & lines :→

There are two protection schemes are used
i> Differential protection.
ii> Fault bus protection.

(i)



→ The bus-bar is fed by a generator & supplies

⇒ Under normal load cond^n or external fault cond^n, the sum of the currents entering the bus is equal to those leaving it & no current flows through the relay.

⇒ If a fault occurs within protected zone, the current entering the bus will no longer be equal to those leaving it.

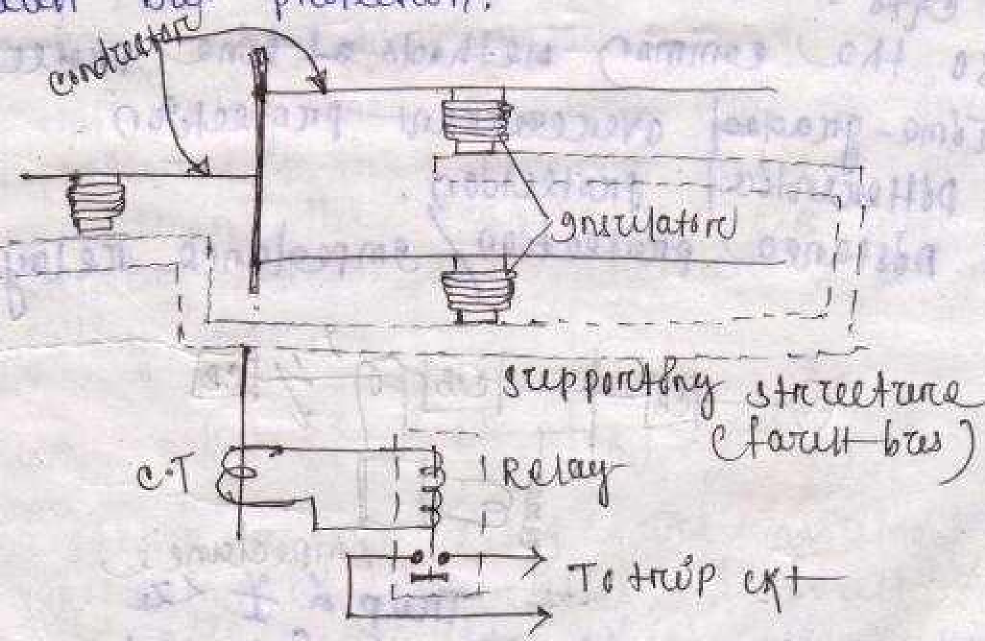
⇒ The difference of these currents will flow through the relay & cause the opening of the generator C.B & each of the line C.Bs.

(ii) Fault bus protection :⇒

⇒ Earth faults can be achieved by providing earthed metal barrier known as fault bus surrounding each conductor through its entire length in the bus structure.

⇒ With it arrangement every fault that might occur must involve a connection bet^n a conductor & an earthed metal part.

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



⇒ From the fig. the metal supporting structure

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

→ A fault involving a connection betⁿ a conductor & earthed supporting structure will result in current flow to ground through the fault bus, causing the relay to operate the operation of relay will trip all breakers connecting equipment to the bus.

* Protection of Lines :→

→ The requirements of line protection are

i> In the event of a s.c the C.B closest to the fault should open, all other C.Bs remain in a closed position.

ii> In case the nearest breaker to the fault fails to open, back up protection should be provided by the adjacent C.Bs.

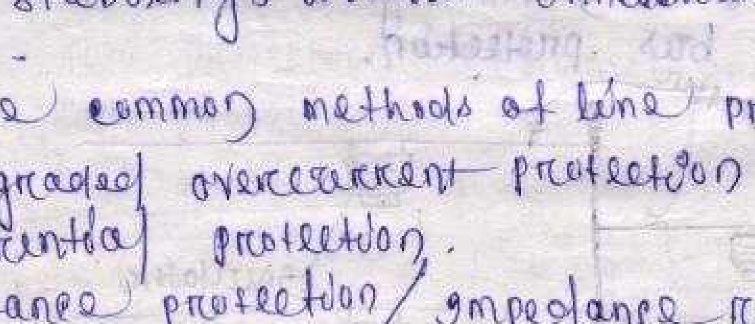
iii> The relay operating time should be just as short as possible in order to preserve system stability, without unnecessary tripping of ckts.

so the common methods of line protection:

i> Time-graded overcurrent protection.

ii> Differential protection.

iii> Distance protection / impedance relay.



→ overcurrent non-directional (⟷)

→ Directional (⟶)

(I) Time graded overcurrent protection :—

(1) Radial feeder :—

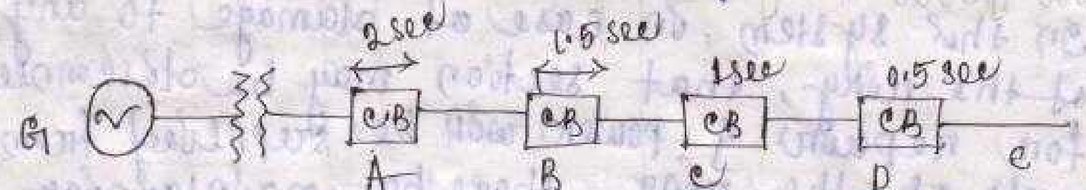
Time graded protection of a radial feeder can be achieved by using

i> definite time relay

ii> inverse time relay

(i) Definite time Relay :—

In this relay the time of operation of each relay is fixed & is independent of the operating current. This relay has an operating time of 0.5 sec while for other relays, time delay is successively increased by 0.5 sec.



⇒ If a fault occurs in the section DE, will be cleared in 0.5 sec by the relay & CB at D because all other relay have highest operating time.

⇒ If the relay at 'D' fails to trip, the relay at 'C' will operate after a time delay of 0.5 sec i.e after 1 sec from the occurance of fault.

ii> Using Inverse time Relay :—

⇒ In this relay, the operating time is inversely proportional to the operating current with this arrangement, the farther the C.B from the generating station, the shorter is its relay operating time.

⇒ The three relays A, B & C are assumed to have inverse time characteristics. A fault in section BC will give relay times which will allow breaker at B to trip out before the breaker

(2) Parallel feeder :→

⇒ If a fault occurs on one feeder it can be disconnected from the system & continuity of supply can be maintained from the other feeder & it can be protected by non-directional over current relays only.

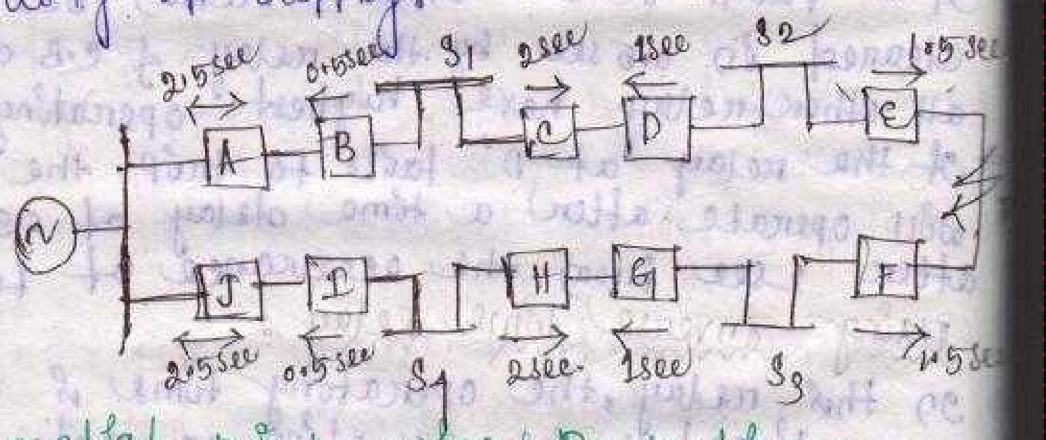
→ protection of this system requires that

i) each ~~generator~~ feeder has a non-directional overcurrent relay at the generator end which have inverse time characteristic.

ii) each feeder has a reverse power or directional relay at the substation end.

Ring main system :→

⇒ In this system, in case of damage to any section of the ring, that section may be disconnected for repairs & power will be supplied from both ends of the ring, thereby maintaining continuity of supply.



* Differential pilot-wire Protection :—

principle :—

⇒ Under normal cond^{n}s, the current entering one end of a line equal to that leaving the other end.

⇒ when fault occurs bet^n the two ends, the difference of incoming & outgoing current is arranged to flow through a relay which operates the C.B to isolate the faulty line.

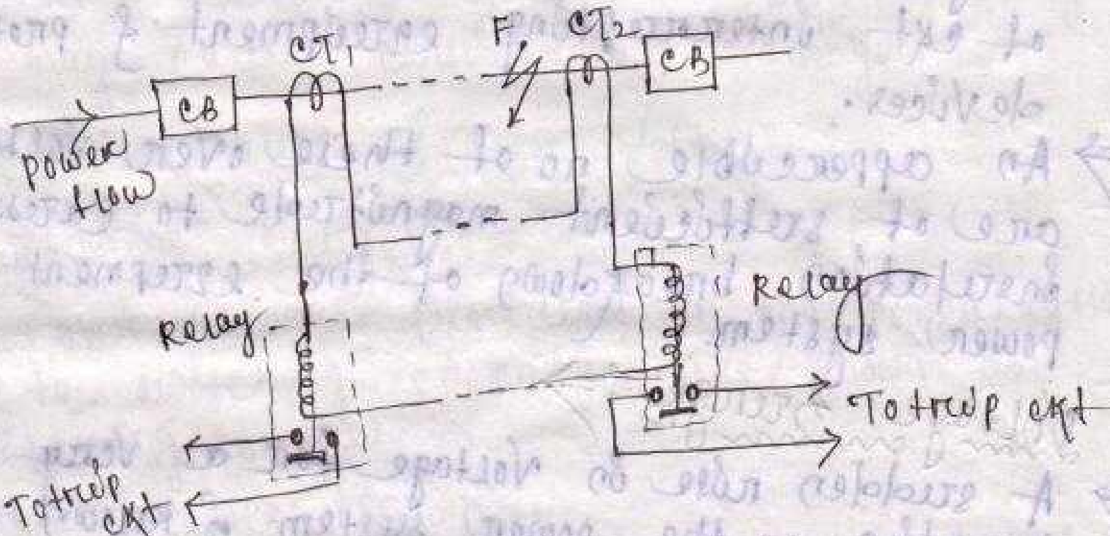
Two schemes used for pilot wire

* Merz-price voltage balance system :→

⇒ In this system, identical CTs are placed in each phase at both ends of the line.

⇒ suppose a fault occurs at pt. fault on the line which will cause a greater current to flow through CT_1, then through CT_2 consequently their secondary or voltage becomes unequal & circulating current flows through pilot wire & relay.

⇒ The CBs at both ends of the line will trip out & the faulty line will be isolated.



*** PROTECTION AGAINST OVER VOLTAGE AND LIGHTING

chapter-07

* Protection against over voltage :⇒

⇒ The over voltage i.e voltages greater than the normal value.

⇒ The over voltage on the power system may be caused due to lighting, the opening of a C.B the grounding of a conductor etc.

⇒ Most of the over voltage are not of large magnitude but their effect on the performance of ckt interrupting equipment & protective devices.

⇒ An appreciable no of these over voltage are of sufficient magnitude to cause insulation breakdown of the equipment in power system.

Voltage Surge :⇒

⇒ A sudden rise in voltage for a very short duration on the power system is known as a voltage surge in transient voltage.

⇒ It originate from switching and lighting when lighting strikes a line, the surge rushes along the line and may cause the line ~~and may~~ insulator to flash over and may also damage the near by transformer generators or other equipment connected to the line if the equipment is not suitably protected.

Cause of over Voltage :—

⇒ There are two cause in the over voltage

(1) Internal Cause :—

iv) Resonance.

→ These donot produce surges of large magnitude and hardly increase the system voltage to twice the normal value surges due to internal causes are takecare of providing proper insulation to the equipment in the power system.

(2) External cause :—

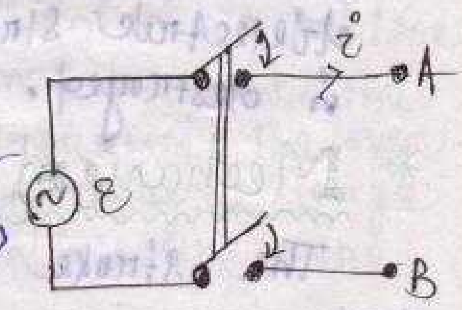
Surge due to lighting are very several and may increase the system voltage to several times to normal value of the equpt. in the power system is not protected against lighting surges, it may cause considerable damage.

* Internal causes of over voltage :—

(1) Switching surges :—

The over voltages produced on the power system due to switching operations are known as switching surges.

i) case of open line :—



when unloaded line is connected to the voltage sources which cause voltage doubling i.e. voltage on the line becomes twice the normal value & also in switching condition.

ii) case of loaded line :—

when a loaded line is suddenly interrupted which will set up a voltage of $2 Z_n i$ across the switch.

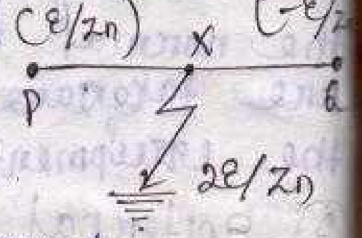
iii) current chopping :—

It results in the production of high voltage transients across the contacts of the air blast C.B.

system is the grounding of conductor which may cause over voltage in the system.

(3) Arcing ground :—

The phenomenon of intermitted are taking place in line to ground fault of a 3-ø system with consequent production of transients is known as Arcing ground.



(4) Resonance :—

Under resonance, the impedance of the ckt is equal to resistance of the ckt & p.f is unity which cause high voltage in the electrical system.

* External cause of over voltage (lightning) :—

⇒ An electric discharge between cloud & earth bet clouds or between clouds or between charge centers of the same cloud is known as lightning.

⇒ It is a huge spark & takes place when clouds are charged to such a high potential (+ve or -ve) w.r.t earth or a neighbouring cloud that the dielectric strength of neighbouring medium (air) is destroyed.

* Mechanism of lightning discharge :—

• The stroke mechanism is as under :—

i> As soon as the Air near the cloud breaks down a streamer called leader streamer to pilot streamer starts from the cloud towards the earth & carries charge with it. The leader streamer will continue its journey towards earth as long as the cloud from which it originates feeds enough charge to it to maintain gradient at the tip of leader streamer above the dissipated without the formation of a complete stroke.

* Mechanism :—

When a charged cloud passes over the earth which induces equal & opposite charge on the earth As the charge acquired by the cloud increase the potential betⁿ cloud & earth increase & therefore, gradient in the air increase when the potential gradient is sufficient to break down the surrounding air, the lighting stroke starts.

* Types of Lighting strokes :—

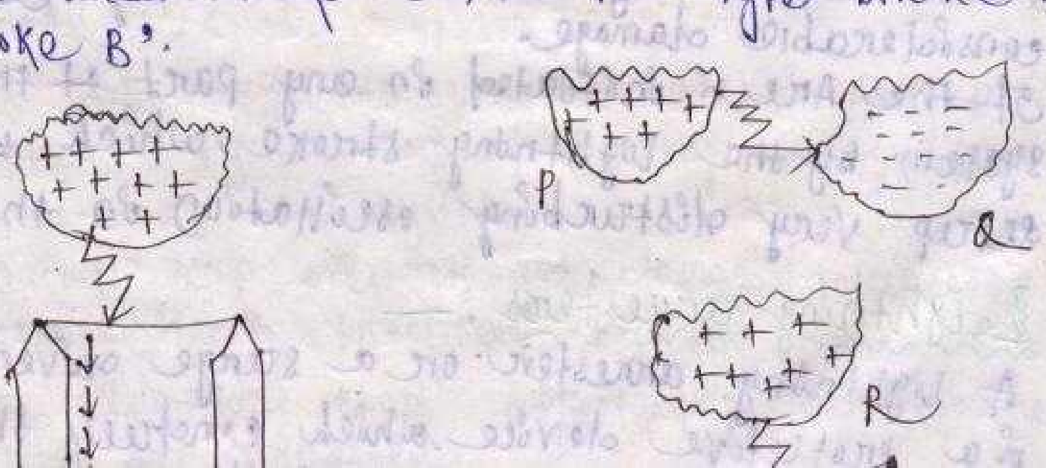
There are two main ways in which a lighting may strike the power system used (over head lines towers, substations etc) normally

1> Direct stroke
2> Indirect stroke.

(1) Direct stroke :—

In the direct stroke, the lightning discharge
→ is directly from the cloude to an over head line from which the current path may be over the insulators down the pole to the ground. The over voltages set up due to the stroke may be large enough to flash over this path directly to the ground.

→ The direct strokes can be two types stroke A' stroke B'.



→ On stroke 'A' cloud will induce a charge of +ve sign on tall object when the potential between the cloud & line exceeds the breakdown value of Air the lighting discharge occurs bet^n the cloud and the line.

→ In stroke 'B' the charge on cloude Q is bound by the cloud R' & the cloud P' shifts too near the cloud Q' then lighting discharge will occurs between them & charges on both these clouds disappear quickly, result is that charge on cloud R' suddenly becomes free & discharge rapidly to earth.

Diagram 

(2) Indirect Stroke :—

It result from the electrostatically induced charges on the conductors due to the presence of ~~conductors~~ due to the charged clouds.

→ A +vely charged cloud is above the line & induced a -ve charge on the line by electrostatic in induction. The induced +ve charge leaks slowly to earth via the insulators.

→ When the cloud discharges to earth or to another cloud the -ve charge rushes along the line is both direction in the form of travelling wave.

* Harmful effects of Lightning :—

→ The travelling waves produced due to lighting surge will shatter the insulators.

→ If the travelling waves hit the winding of a transformer or generator which may cause considerable damage.

→ If the Arc is initiated in any part of the power system by the lightning stroke, which will setup very disturbing oscillation in the line

* Lightning arresters :—

A lightning arrester or a surge diverter i> Under normal operation the lightning arrester is off the line i.e it conducts no current to earth or the gap is non conducting.

ii> On the occurrence of overvoltage, the air insulation across the gap breaks down & an arc is formed providing a low resistance path for the surge to the ground.

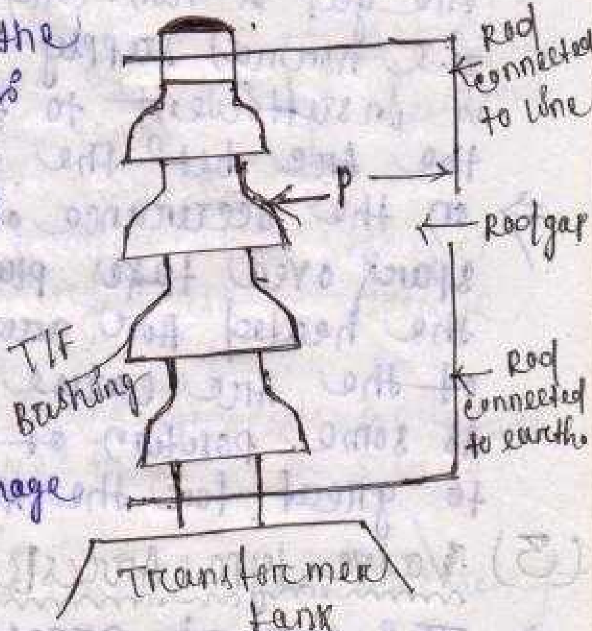
* Types of lightning arresters :—

(1) Rod Gap Arrester :—

⇒ It is a very simple type of diverter & consist of two 1.5 cm rods which are bent at right angle with a gap in between as shown in fig.

⇒ One rod is connected to the line ckt & the other rod is connected to earth.

⇒ The distance between gap & insulator (i.e distance P) must not be less than one-third of the gap length, so that the arc may not reach the insulator & damage its.



⇒ Under normal operating condition the gap remains non conducting on the occurrence of a high voltage surge on the line the gap sparks over surge current is conducted to earth.

Limitation :—

i> After the surge is over the Arc in the gap is maintained by the normal supply voltage leading to a l.c on the system.

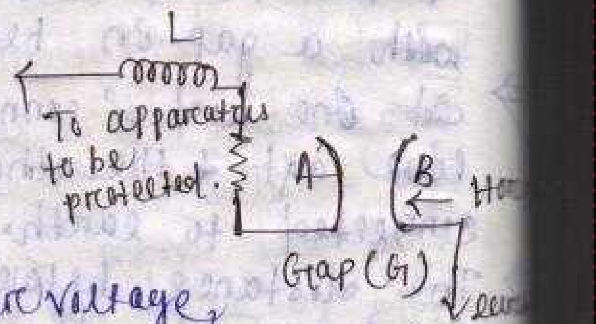
ii> The rods may melt or get damaged due to excessive heat produced by the Arc

iii> The climatic cond^n affect the performance

(2) Horn gap arrester :-

⇒ It consists of two horn shaped metal rods A & B separated by a small air gap. The horns are mounted on porcelain insulators one end of horn is connected to the line through a resistance R and choke coil L while the other end is effectively grounded. The choke does not allow the transients to enter the apparatus to be protected & the gap betn horns is so adjusted that normal supply voltage is not enough to cause an Arc across the gap

⇒ Under normal condition the gap is non-conducting i.e normal supply voltage is insufficient to initiate the Arc betn the gap.



⇒ On the occurrance of an over voltage, spark over takes place across the small gap G, the heated Air around the arc & magnetic effect of the Arc cause the arc to travel up the gap. At some position of the arc, the distance may be to great for the Voltage to maintain the Arc.

(3) Valve type Arrester :-

⇒ This type of arrester incorporate non-linear resistor & are extensively used on systems.

⇒ It consists of two assemblies.

i) series spark gaps.

ii) Non-linear low resistor discs in series.

⇒ The non linear elements are connected in series with the spark gap.

Working :-

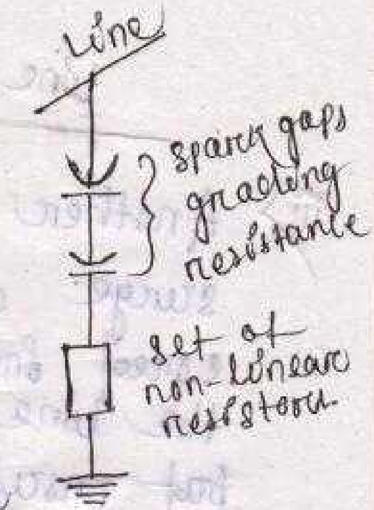
⇒ Under normal condition, the normal system voltage is insufficient to cause the breakdown of air gap assembly.

non-linear resistors.

⇒ since the magnitude of surge current is very long the non-linear elements will offer a very ~~long~~ low resistance to the passage of surge which results the surge will rapidly go to earth instead of being sent back over the line

* Surge Absorber :—

⇒ The travelling waves set up on the transmission lines, by the surges may reach the terminals oparatus & cause damage to it & the amount of damage caused not only depends upon the magnitude of the surge but also upon the steepness of its wave front, steeper the wave form of the surge, the more the damage caused to the eqpt, so to reduce the steeper of the wave front of a surge use a surge absorber.



⇒ So A surge absorber is a protective device which reduces the steepness of wave front of a surge by absorbing surge energy.

⇒ A few causes of surge absorption are discussed below.

i> A condenser connected between the line and earth can act as a surge absorber, Here capacitor acts as surge absorber to protect the transformer winding the reactance of a condenser is inversely proportional to frequency, since the surges are of high frequency, the capacitor acts as a s.c &