Class Note of Switch Gear and protective device

Class Note

Switch Gear and protective device

For 6Th Semester

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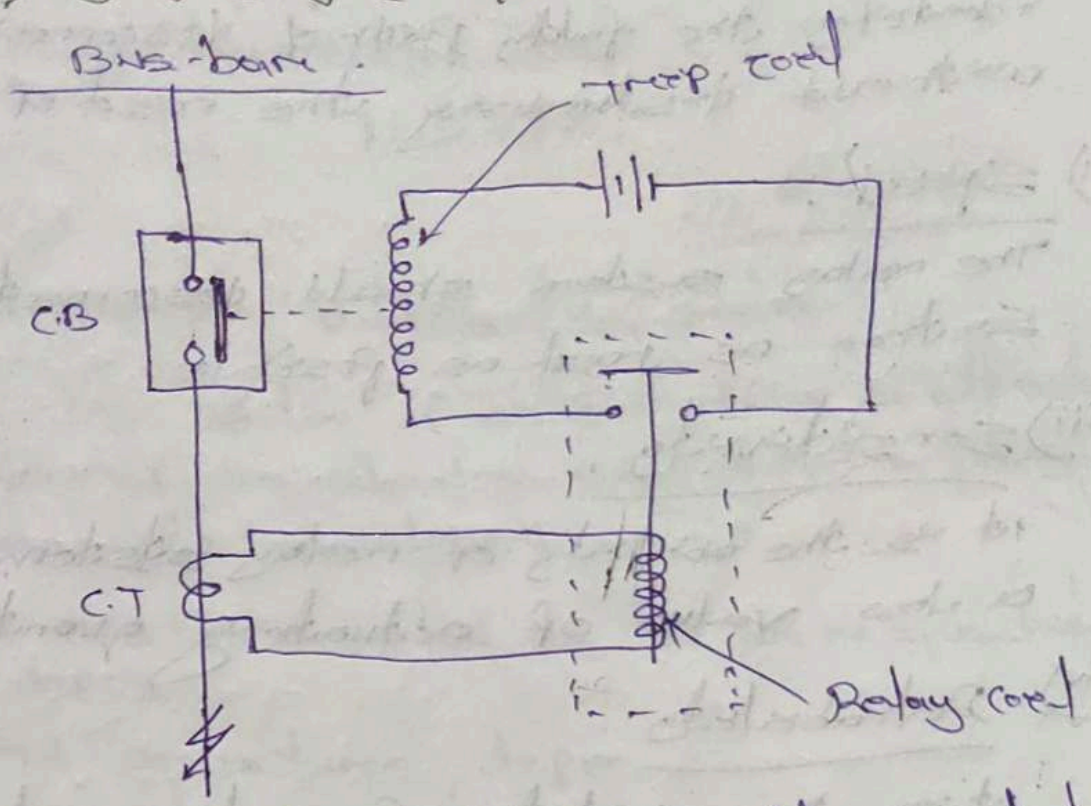
Department: Electrical Engineering

new chapter

PROTECTIVE RELAY



It is a device that detects the fault & initiates the operation of the CB to isolate the defective element from the rest of the system.

fundamental requirement of protective relay

i) Selectivity
ii) Speed -
iii) Sensitivity
iv) Reliability
v) Simplicity
vi) Economy

1) Selectivity

It is the ability of the protective system to identify the faulty path & disconnect the faulty part without disturbing the rest of the system.

ii) Speed:

The relay system should disconnect the faulty section as fast as possible.

iii) Sensitivity:

It is the ability of relay system to operate a low value of activating quantity.

iv) Reliability

It is the ability of relay system to operate under the pre-determine cond^n

v) Simplicity:

The relay system should be simple; so that it can easily maintain.

vi) Economy

The total system of relay should be design its economy aspect.

→ as a rule the protective gear of total system should not cost more 5% of the total cost

Basic relay

The two main operating principle
i) Electro magnetic attraction.
ii) " " Induction.

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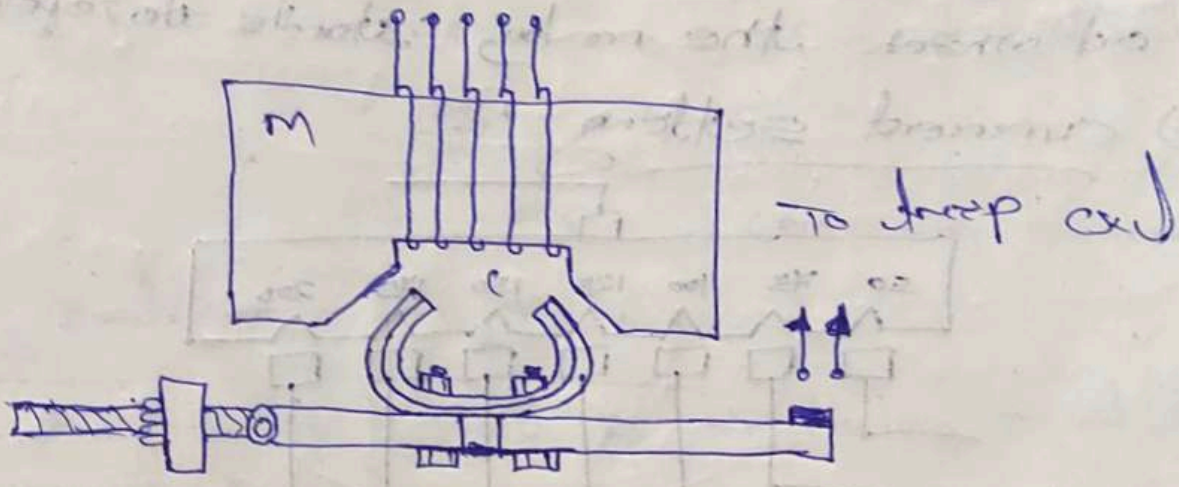
i) Electro magnetic attraction relay :

It operates by virtue of an armature be attracted to the pole of an electro magnet or a plunger being drawn into a solenoid.

- Such relay may be acquated by DC or AC quantities
- It is 3 types
  i) Attracted armature type
  ii) Solenoid type
  iii) Defi

i) Attracted armature type relay



It consist of a laminated electro magnet carrying coil "c" & a pivoted laminated armature,

- Armature is balanced by a counter weight & carries a pair of spring contact at a free end.

Working

Under normal operating cond^n the I through the relay coil 'C' is such that the counter weight poles the armature in the position

→ when fault occurs I through the coil ↑ sufficiently, hence it produces sufficient force of attraction to the armature,

→ Hence the armature is attracted upward & contact's on the relay complete the trip ckt

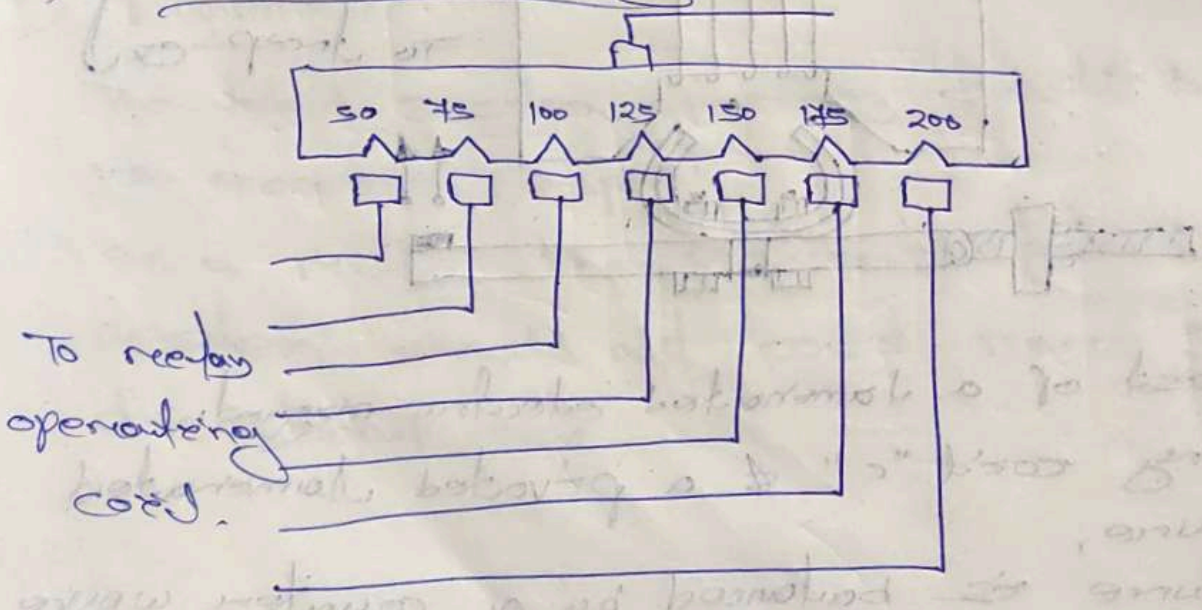
→ Hence it test to opening the CB & disconnect the faulty ckt.

Importance terms:

1) pick up current

It is the minimum I in the relay coil at which the relay starts to operate

2) current setting :-



⇒ pick-up I can be changed
⇒ it is achieved by the use of tappings on the relay operating coil.
⇒ The taps are brought out a plug bridge

Plug bridge:

⇒ It permits to change the no. of turns in relay coil.
⇒ The value assign to each term are expressed % of full load rating of CT with which relay is associated

> pick-up current = rated secondary I of CT × current setting

⇒ Let an over I relay current setting of 125% is connected to a supply ckt. to a CT of 400/5

⇒ rated secondary current of CT = 5 Amp.
⇒ pick-up I = rated secondary I of CT × current setting
= 5 × 125/100
= 6.25 Amp (minimum current)

⇒ Plug setting multiplier:

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

$$PSM = \frac{\text{fault current in relay coil}}{\text{pick-up I}}$$

$$PSM = \frac{\text{fault current in relay coil}}{\text{rated secondary current of CT} \times \text{current setting}}$$

Q1 A relay is connected to a 400/5 CT & set at 150% with the primary fault is 2400 Amp, Calculate PSM.

given: fault = 2400 Amp

rated secondary current of CT = 5

current setting = 150

pick-up I = rated sec current of CT × current setting

$= 5 \times \frac{150}{100}$

$= 7.5$ Amp.

fault current in relay coil $= 2400 \times \frac{5}{400}$

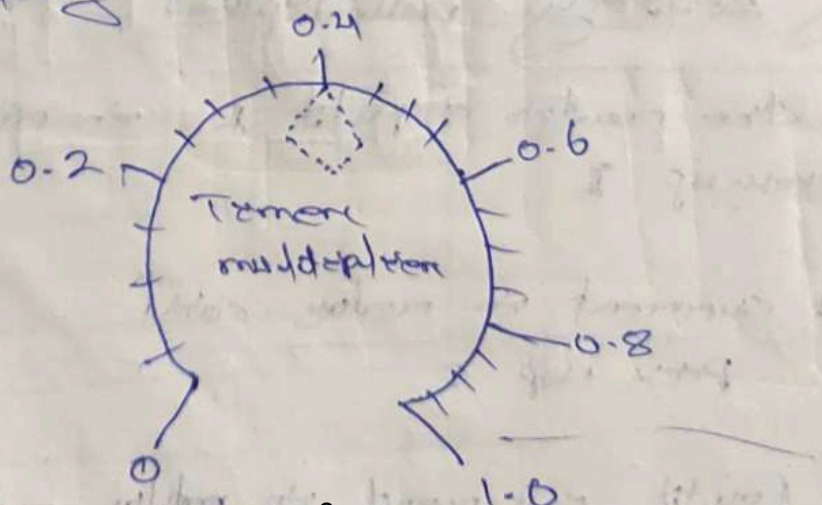
$= 30$ Amp

$PSM = \frac{\text{fault current}}{\text{pick-up I}} = \frac{30}{7.5} = 4$

TSM :-

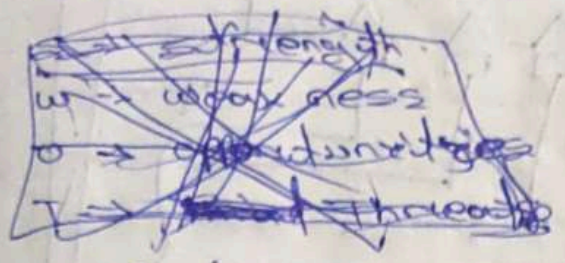
It is a relay which is provided with the control to adjust the time this adjust.

⇒ Time setting is calibrated with 0-1 in steps of 0.05%



It is use convert the time derived from the graph (Time) PSM into actual operating time.

SWOT ANALYSIS



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functional relay types:

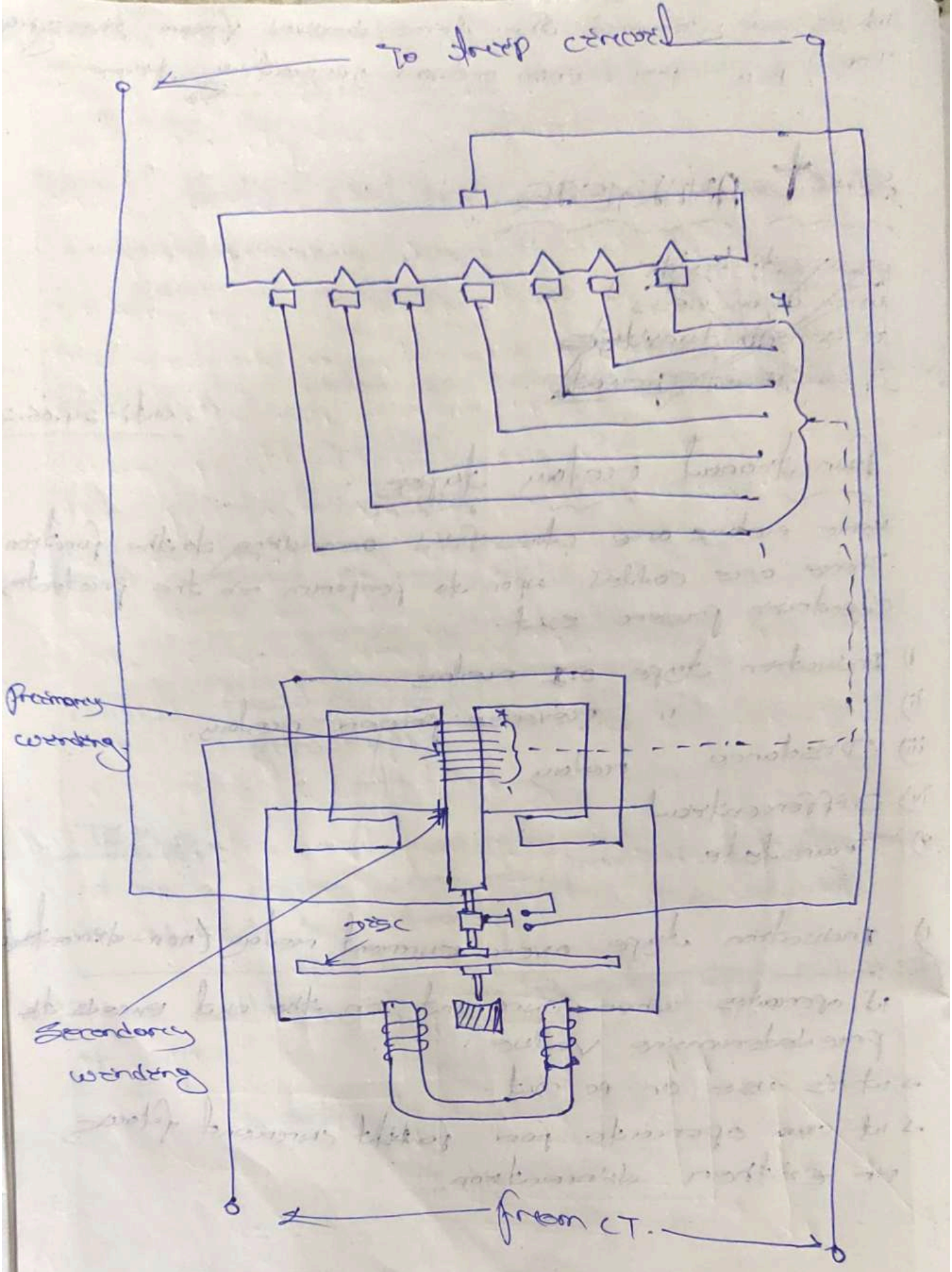
Here relays are classified according to the function. There are called upon to perform in the protection electrical power syst.

i) Induction type O:I relay
ii) " " reverse power relay.
iii) Distance relay
iv) Differential
v) Translate.

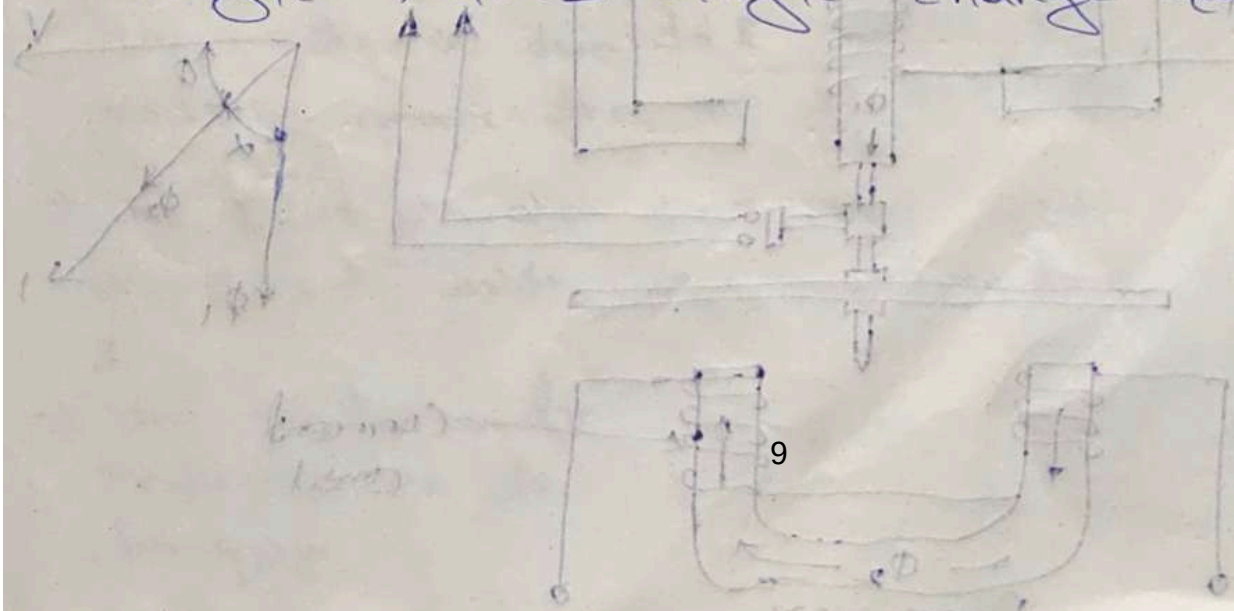
i) Induction type over current relay (non-directional)

It operates when current in the circuit exceeds the predetermine value.

→ It is use on AC circuit.
→ It can operate for fault current flows in either direction.


To trip circuit
Primary winding
Secondary winding
from CT.

→ It consist of metallic (Aluminium disc)
→ It is free to rotate in betⁿ the poles of two electromagnet.
→ The upper ∴ has a primary & secondary coil
→ The p. winding is connected to s. of CT.
→ It is tapped at intervals.
→ Tappings are connected plug setting bridge.
→ Here the active turn on the relay operating coil can be varied.
→ Hence desire I can be set.
→ The s. winding is energise by induction from primary.
→ It is connected in series with winding on lower magnet.
→ The controlling torque is provided by the spring.
→ spindle of the disc carries a moving contact which bridges two fixed contact.
→ The two fixed contact is connected with the circuit
→ The disc rotate through a preset angle, this angle change bet° 0° & 360°



Working:

The driving torque on the aluminium disc is set due to induction principle.

→ This driving torque is oppose by the controlling torque provide by the spring.

→ Under normal operating condn

→ The controlling torque > than the driving torque

→ hence the aluminium disc is at rest.

→ When fault occurs one the current exceeds the preset value, the driving torque > the controlling torque.

→ The disc rotates.

→ The moving contact bridges the fixed contact.

→ The trip ckt operates the CB which isolate the faulty section.

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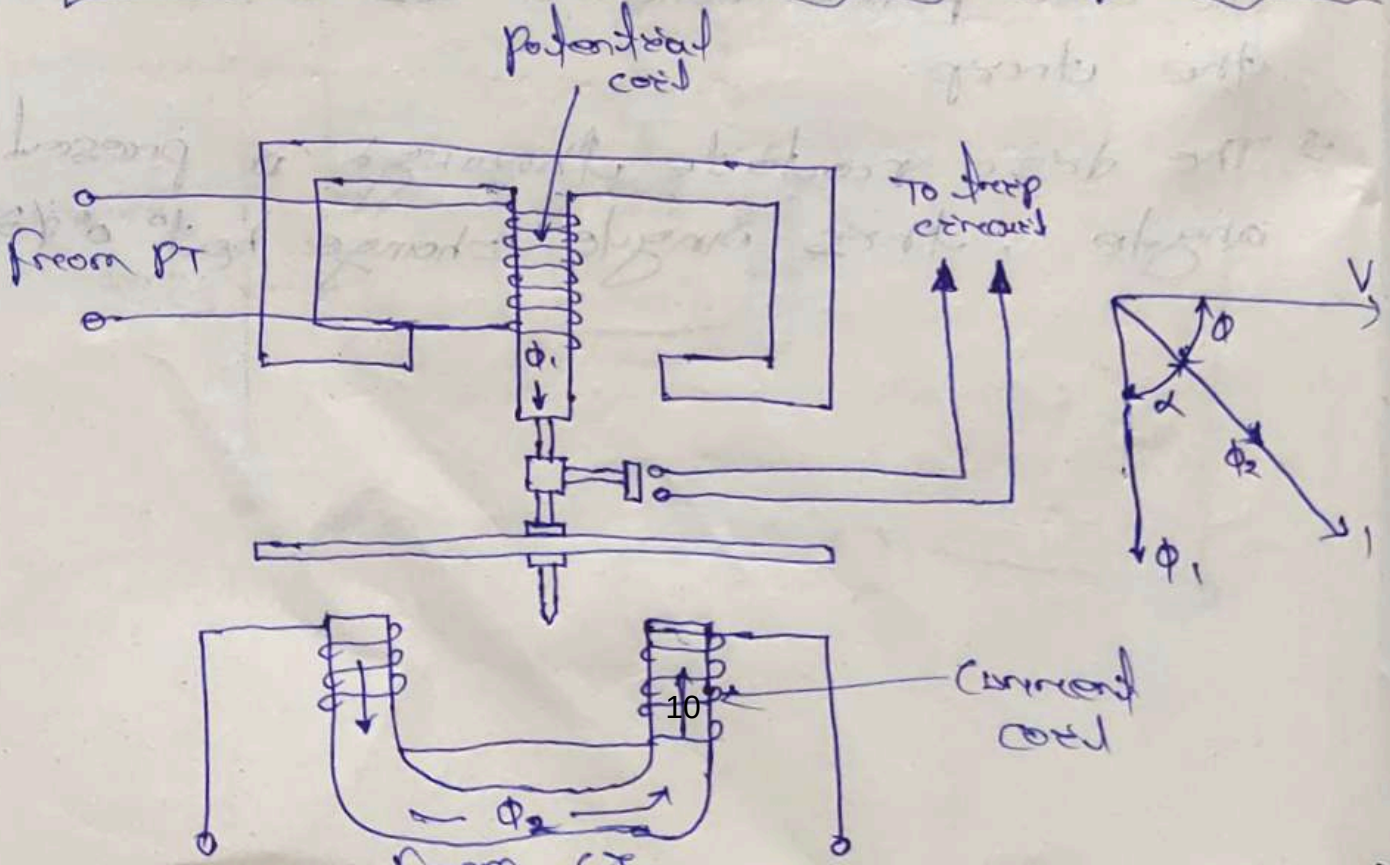
ii) Induction type directional power relay



it is essentialy a wattmeter direction of the power setup in relay depends upon the direction of I.

Construction:

- it consist aluminium disc.
- it is free to rotate in betn the poles of 2 electromagnet.
- upper " carries a winding called potential coil.
- PT is connected to the ext voltage source, the lower electron consist of separate magnet
- it is connected to the secondary of CT of line to be protected.
- The current coil provide the no. of tapping connect to the plug setting bridge
- this permit to have any desired I setting
- The restraining or controlling torque is provided by a spiral spring
- The spindle of disc simple carries the moving contact

Working:

The flux ϕ_1 due to I in the potential coil could be near the eddy behind the.

- The flux ϕ_2 due to I coil would be nearly in phase with the operating current I.
- The interaction of ϕ_1 & ϕ_2 with eddy I induced in the disc produces a driving torque

$T \propto \Phi_1 \Phi_2 \sin\alpha$

Since $\Phi_1 \propto B$

$\Phi_2 \propto I$

$\alpha = 90 - \theta$

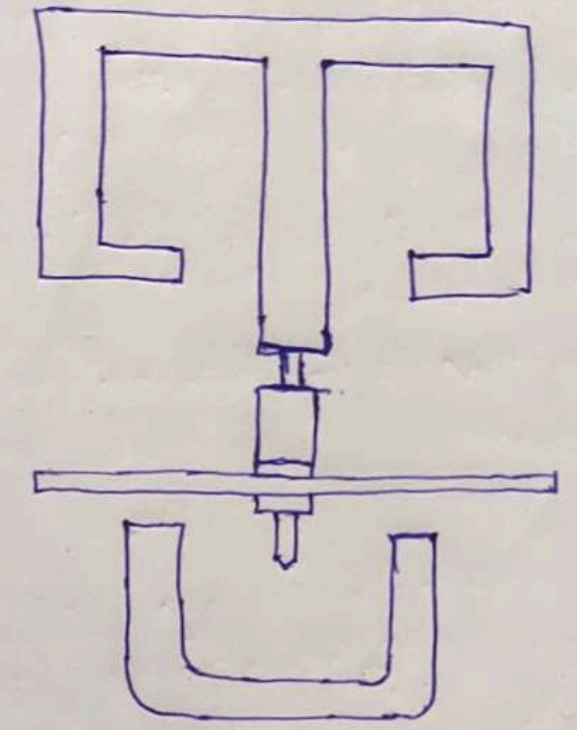
$\Rightarrow T \propto BI \sin(90-\theta)$

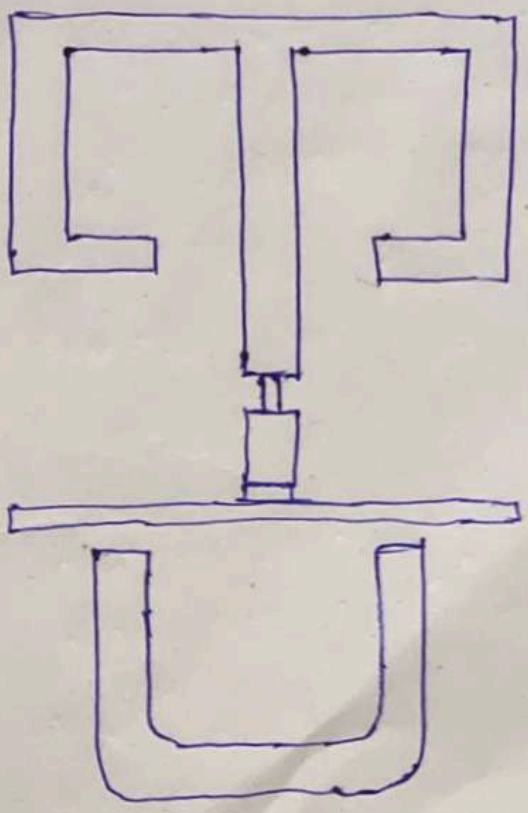
$\Rightarrow T \propto BI \cos\theta$ (power in the cct),

- Hence direction of driving torque on the depend upon the power flow in the which relay is associate.
- If power flow is normal driving torque when each other to turn away the moving contact to fixed cont. hence relay is operated
- when there is change the direct of driving torque direction changes
- when the reverse driving torque is very large this operates in the reverse direction

this causes operation of the CB that's connect the faulty section

Induction type direction over current relay





CHAPTER-1 Dt:- 24.03.2022

INTRODUCTION TO SWITCHGEAR

* What is switchgear ?

Ans :- The apparatus used for switching, controlling and protecting the electrical circuits an equipments is known as switchgear.

* Essential Features Of switchgear :—

The essential features of switchgear are,

(1)>- Complete Reliability :—

- Switchgear is added to the power system to improve the reliability.
- When fault occurs, switchgear must operate to isolate the faulty section from the remainder circuit.

(2)>- Absolutely Certain Discrimination :—

When fault occurs on any section of the power system, the switchgear must be able to discriminate between the faulty section & the healthy section.

(3)>- Quick Operation :—

When fault occurs on any part of the power system the switchgear must operate quickly, so that no damage is done to generator, transformer and other equipments by the short circuit currents.

(4)>- Provision For Manual Control :—

A switchgear must have provision for manual control.

- If automatic or electronic control fails necessary operation can be carried out by manual control.

(5)>- Provision For Instruments :—

There must be provision for instruments like ammeter or voltmeter to the main switch board.

* SWITHGEAR EQUIPMENTS :—

I.M.P

(1)>- Switches

(2)>- Fuses

(3)>- Circuit Breakers

(4)>- Relays

(1)>- Switches :—

→ A switch is a device used to open or close an electrical circuit in a convenient way.

→ It can be used under full-load or no-load condition.

→ But it can't interrupt the fault current.

→ When contacts of a switch are opened arc is produced in the air between the contacts.

→ Switches are of two types,

(i)>- Air switch

(ii)>- Oil switch

(2)- Fuses :—

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

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

Working :—

→ Under normal operating condition the fuse element is at a temperature below its melting point.

→ 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, hence its temperature increases, the fuse blows-out, disconnecting the circuit protected by it.

→ Fuse detects and interrupts.

(3)- Circuit Breakers :—

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

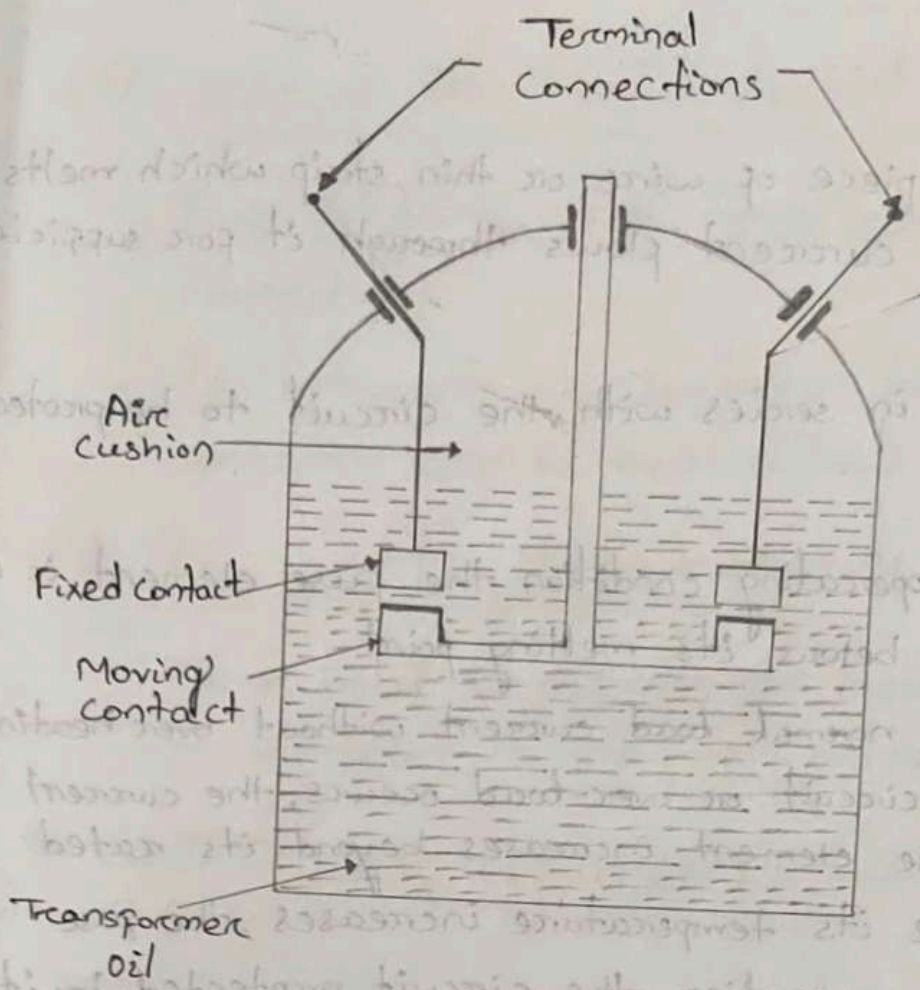
→ It can operate manually or by remote control.

→ The circuit breaker consists of,

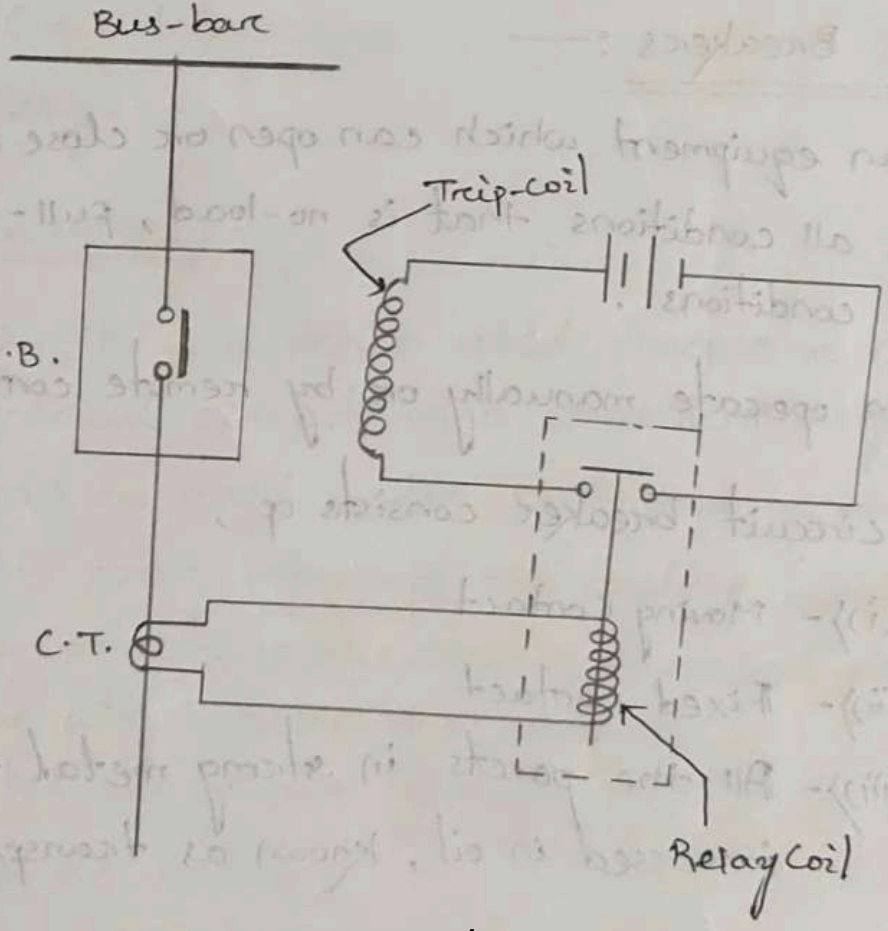
(i)- Moving contact

(ii)- Fixed contact

(iii)- All the parts in strong metal tank immersed in oil, known as transformer oil.


Terminal Connections
Air Cushion
Fixed contact
Moving contact
Transformer Oil

(i)


Bus-bar
Trip-coil
C.B.
C.T.
Relay Coil

(ii)

Case-I

Under Normal Operating Condition :—

- The contacts remain closed & the circuit breaker carries the full load current continously.
- EMF in the secondary winding of the CT (Current Transformer) is insufficient to operate the trip coil of the breaker.

Case-II

When Fault Occurs :—

The resulting over current in the C.T. primary winding increases the secondary emf.

- This energises the trip coil of the CB & moving contacts are pulled down, thus opening the contacts and hence the circuit.
- The arc produced during the opening operation is quenched by the oil, hence relay detects the fault.
- Circuit breaker does the actual circuit interruption.

(4)- Relays :—

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

→ It can be devided into 3 parts,

(i)- Primary winding of a current transformer (C.T.) is connected in series with the circuit to be protected. Primary winding is the main conductor itself.

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

(iii)- The third circuit is the tripping circuit consists of source of supply, trip coil of C.B. & relay stationary contacts.

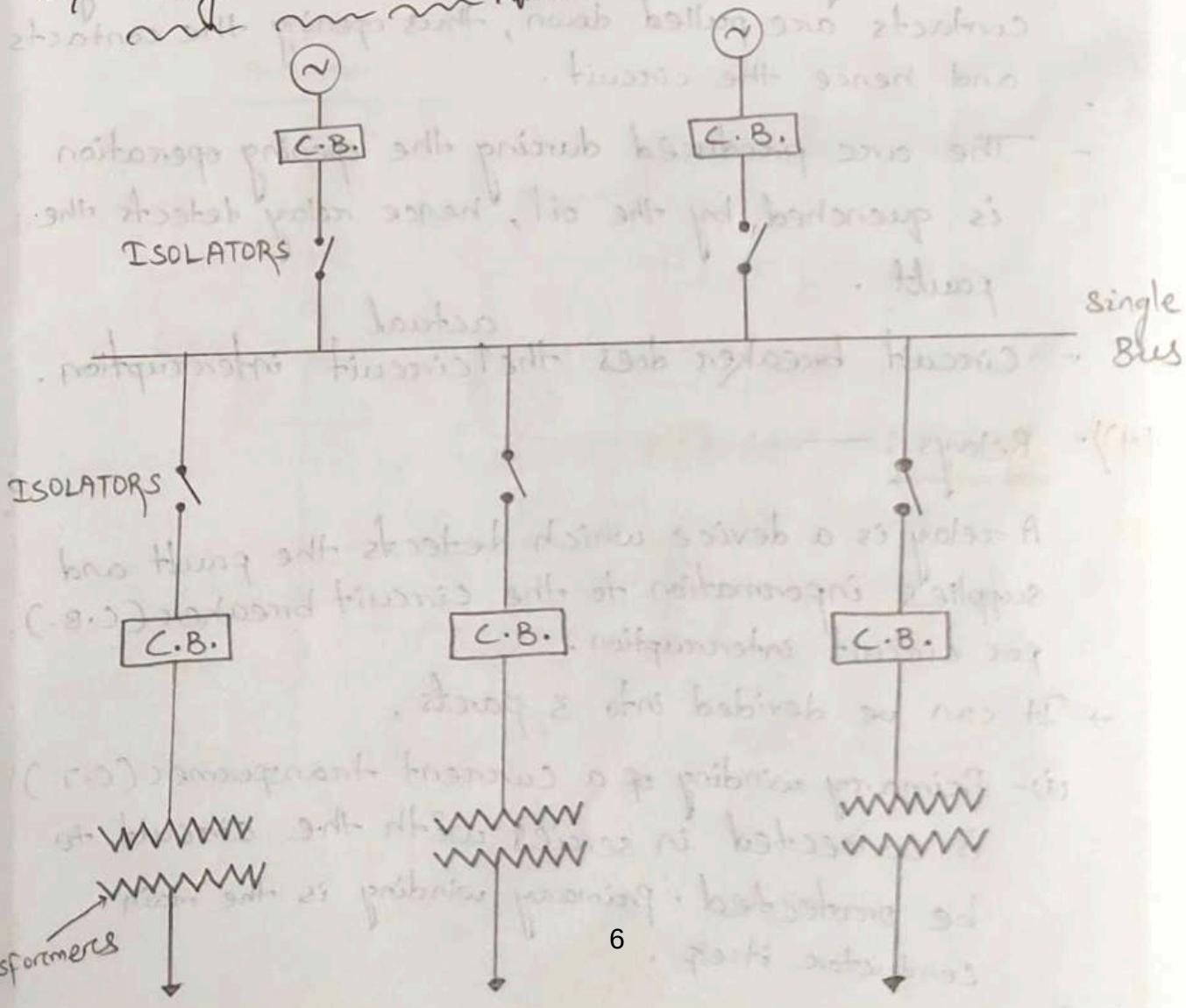
* BUS-BAR ARRANGEMENTS :—

(i)- Single Bus-Bar system.

(ii)- Single Bus-Bar system with ~~secto~~ sectionalisation.

(iii)- Duplicate Bus-Bar system.

(i)- Single Bus-Bar system :—



- It has the simplest design.
- It is used for power stations.
- It is also used in small out-door stations having few out-going or incoming feeders & lines.
- The generators out-going lines & transformers are connected to the bus-bar.
- Each generator & feeder is controlled by a circuit breaker.
- The isolators permit to isolate generators, feeders, circuit breakers from the bus-bar for maintainance.

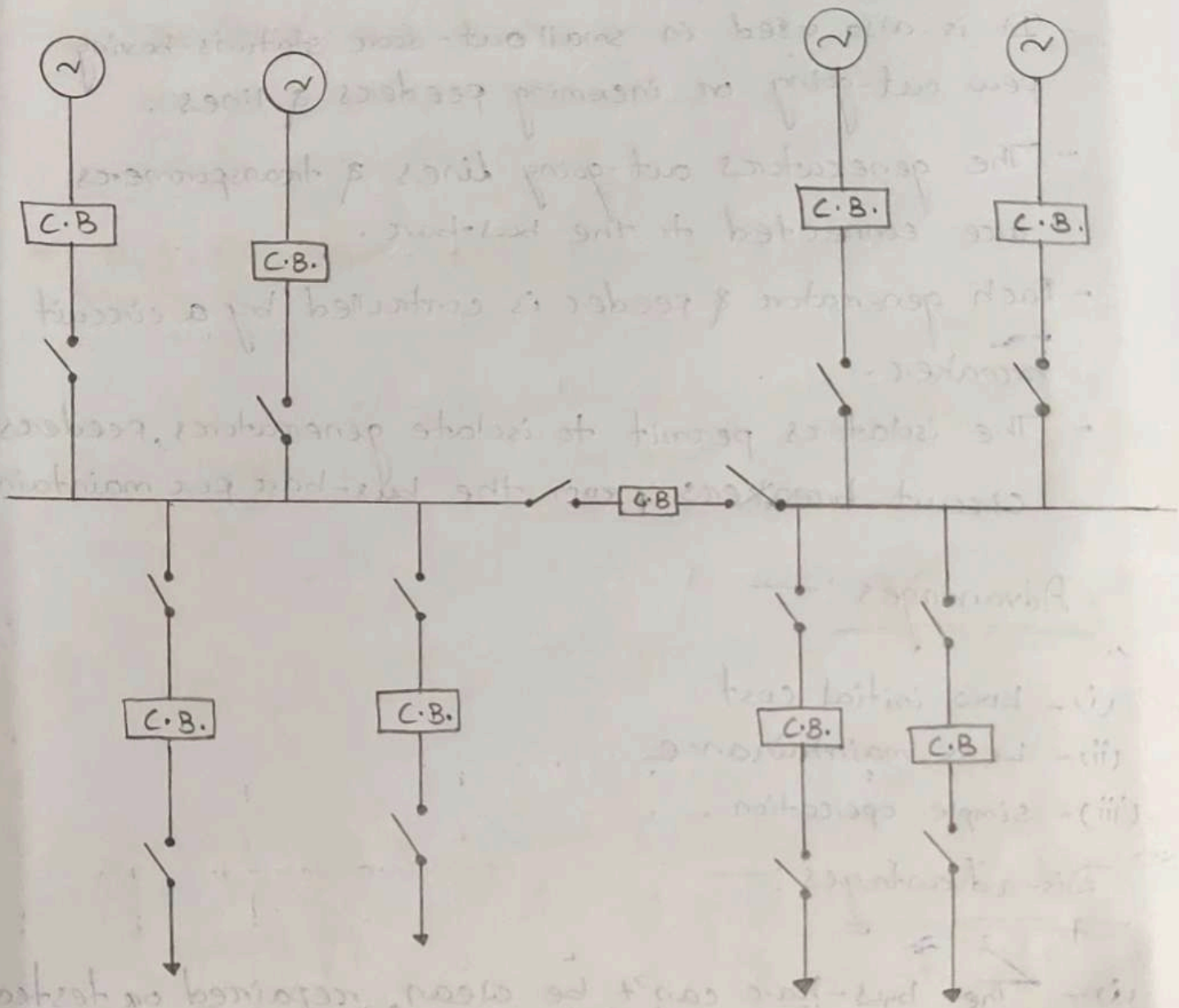
Advantages :—

(i) - Low initial cost.
(ii) - Less maintainance.
(iii) - simple operation.

Dis-advantages :—

(i) - The bus-bar can't be clean, repaired or tested without de-energising the whole system.
(ii) - If a fault occurs on the bus-bar itself, there is complete interruption of supply.
(iii) - Any fault on the system is fed by all the generating capacity, resulting in very large fault currents.

(ii)- Single Bus-Bar System With Sectionalisation :—



→ In large generating stations, where several units are installed, there the bus-bar is sectionalised, so that complete shut down can be avoided.

→ In the diagram, the bus-bar is devided into two sections connected by a circuit breaker and isolators.

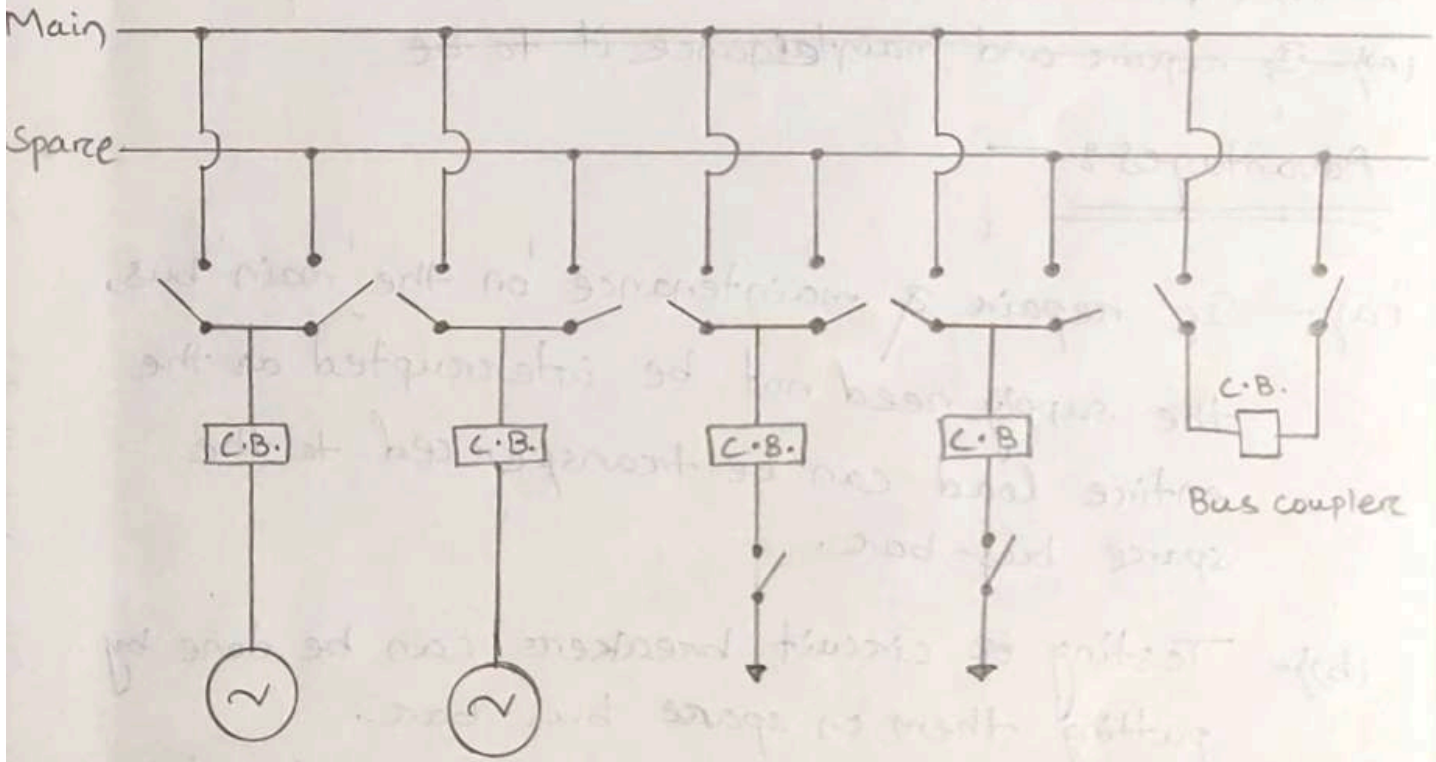
Advantages :—

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

(ii)>- If a fault occurs on any feeder, the current is much lower than with unsectionalised bus-bar.

(iii)>- Repairs & maintenance of any section of the bus-bar can be carried out by de-energising that section only.

(iiii)>- Duplicate Bus-Bar System :— Dt:- 25.03.22



- It is important that breakdown and maintenance should interfere as little as possible with continuity supply.
- In order to achieve this duplicate bus-bar system is used in important station.

- In this system there are 2 bus-bars.

(a)- Main Bus-Bar

(b)- Spare Bus-Bar

- Each generator & feeder may be connected to either bus-bar with the help of bus coupler.
- Bus coupler consists of circuit breaker & isolators.
- If it is desired to switch a circuit from one bus to another without interruption of service, there would have to be two circuit breakers for circuit.
- Such as arrangement is very expensive.

~~Advantages~~ :—

~~(a)- If repair and maintenance it to be~~

Advantages :—

(a)- If repair & maintenance on the main bus, the supply need not be interrupted as the entire load can be transferred to the spare bus-bar.

(b)- Testing of circuit breakers can be done by putting them on spare bus-bar.

(c)- If fault occurs on the bus-bar, continuity of supply to the circuit can be maintained by transferring it to other bus-bar.

* SWITCHGEAR ACCOMMODATION :—

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

- It is of two types,

(i) - Out-door Type

(ii) - In-door Type.

(i) - Outdoor Type :—

For voltages beyond 66 KV, switch-gear equipment is installed outdoor because for such voltages, the clearances between the conductor and the space required for switches, circuit breakers, transformers & other equipments, ~~become~~ hence it is not economical all such equipment indoor.

(ii) - Indoor Type :—

For voltages below 66 KV, switch gear is installed indoor because of economical considerations.

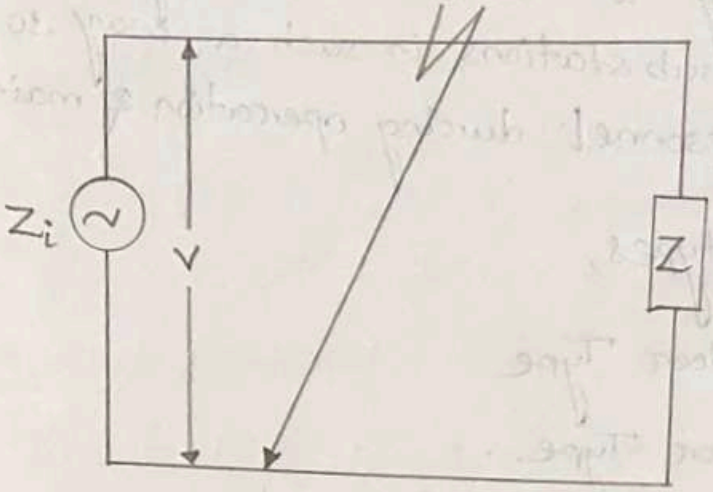
- The indoor switchgear is of metal type.

* SHORT CIRCUIT :—

When a fault occurs on a network such that a large current flows in one or more phase, a short circuit is said to have occurred.

Q.1

What is the difference between circuit & overload?



- In the fig. a single phase generator of voltage V and internal impedance 'Z_i' is supplying to a load Z.
- If load terminal get shorted due to any reason, the circuit impedance is reduced to a very low value.
- As 'Z_i' is very small, a large current flows through the circuit and this is called short circuit current.
- When a short circuit occurs, the voltage at fault point is reduced to 0 and current increases abnormally to high magnitude.
- An over-load means that loads greater than the designed values have been imposed to the system.
- Here the voltage at the over load point is low but not zero and the current is very high but less than that of short circuit case.

* Causes of short circuit :—

(i)- Internal Effects

(ii)- External Effects.

(i)- Internal Effects :—

- Breakdown of equipment or transmission lines.
- Deterioration of insulation in a generator, transformer etc.
- Inadequate design.
- Improper installation.

(ii)- External Effects :—

- Insulation failure due to lightning surges.
- Overload of equipment causing excessive heating.
- Mechanical damage by public.

* EFFECTS OF SHORT CIRCUIT :—

(a)- The heavy current due to short circuit causes excessive heating which may result in fire or explosion.

(b)- The low voltage due to short circuit may shut down consumers motors & generators on the power system & become unstable.

I.M.P Q.2 :- Why calculation of short circuit current is important?

Ans :- (i) Short circuit on the power system is cleared by a circuit breaker or a fuse.

(ii)- So it is necessary to know the maximum value of short circuit current. so that switchgear of suitable rating may be installed to interrupt them.

(iii)- Magnitude of short circuit current determines the setting, types & location of protective system.

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

(iv)- It enables us to make proper selection of the associated apparatus, so that they can withstand the forces that arise due to occurance of short circuits.

* Faults In a Power System :—

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

- Faults in a three phase system can be classified into,

(i)- Symmetrical Fault.

(ii)- Unsymmetrical Fault.

(i)- Symmetrical Fault :—

- That fault which give rise to symmetrical fault currents i.e., equal fault currents with 120° displacements is called symmetrical fault.

(ii)- Unsymmetrical Fault :—

- The faults which give rise to unsymmetrical current i.e., unequal line currents with unequal displacements are called unsymmetrical fault.

- It is of 3 types,

(i)- Single line to ground Fault.

(ii)- Line to Line Fault.

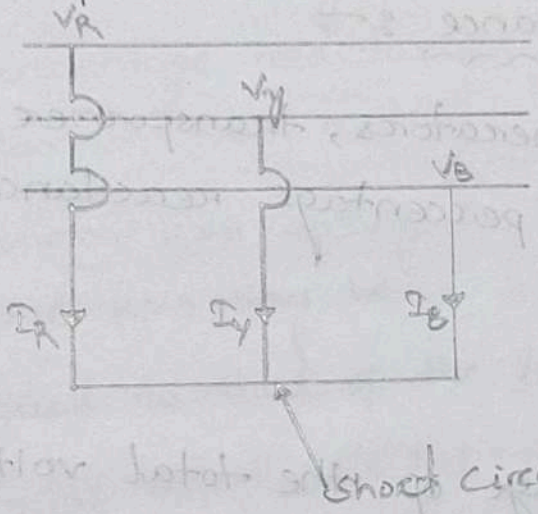
(iii)- Double line to ground Fault.

CHAPTER-2 Dt:- 25.03.2022

SYMMETRICAL FAULT CALCULATIONS

* INTRODUCTION :—

That fault on the power system which gives rise to symmetrical fault currents (i.e. equal fault currents in the lines with 120° displacement) is called a symmetrical fault.

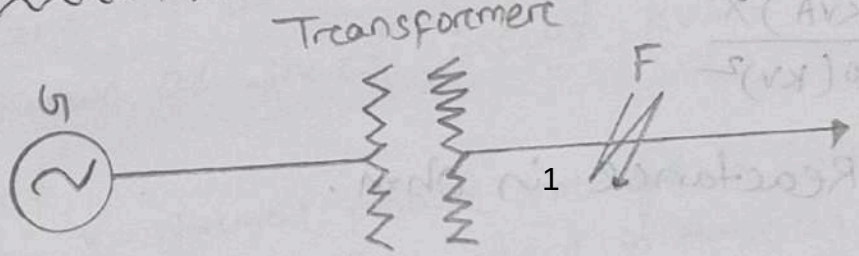


→ Symmetrical fault occurs when all the three conductors of a three phase line are brought together simultaneously into a short circuit condition. This type of fault gives rise to symmetrical currents i.e., equal fault current with 120° displacements.

→ Fault currents I_R, I_Y & I_B will be equal in magnitud with 120° displacement with each other.

→ Only one phase will be taken for calculation.

* Limitation Of Fault Current :—



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

→ If a fault occurs on the feeders at point 'F', then the short circuit current from the generating point to the fault point will be limited by the impedance of generator & transformer and the impedance of the line between the generator and the point of fault.

* Percentage Reactance :—

Reactance of generators, transformer, reactors etc. is expressed in percentage reactance for easy calculation.

Def^n :—

It is the percentage of the total voltage dropped in the circuit, when full-load current is flowing

i.e.,

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

Where, I = Full-load current

V = Phase voltage

X = Reactance in Ohms/phase

In terms of KVA,

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

Where, X = Reactance in Ohm.

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

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

$$\boxed{I_{se} = I\left(\frac{100}{\%X}\right)}$$

* Percentage Reactance & Base KVA :—

Various equipments used in power systems have different KVA ratings. So it is necessary to find percentage reactances of all the elements on a common KVA rating.

- This common KVA rating is known as base KVA.
- The base KVA may be,

(i)>- Equal to that of the largest plant.

(ii)>- Equal to the total plant capacity.

(iii)>- Any arbitary value.

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

* Short-Circuit KVA :—

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

Let,

V = Normal phase voltage in volts.

I = Full-load current in Amperes at Base KVA.

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

Short circuit KVA For 3-ϕ circuit,

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

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

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

Dt:- 26.03.2022

* REACTOR CONTROL OF SHORT-CIRCUIT CURRENTS :-

- In order to limit the short circuit currents to a value which the circuit breakers can handle, additional reactances known as reactors are connected in series with the system at suitable points.
- Reactors is a coil of number of turns designed to have a large inductance as compared to its ohmic resistance.

Advantages :—

(i)- Reactors limit the flows of short-circuit current & thus protect the equipment from over-heating as well as from failure due to destructive mechanical forces.

(ii)- Troubles are localised or isolated at the point where they originate without disturbing other parts of the power system. Hence it increases continuity of supply.

(iii)- It permits the installation of circuit breakers of lower rating.

* LOCATION OF REACTORS :—

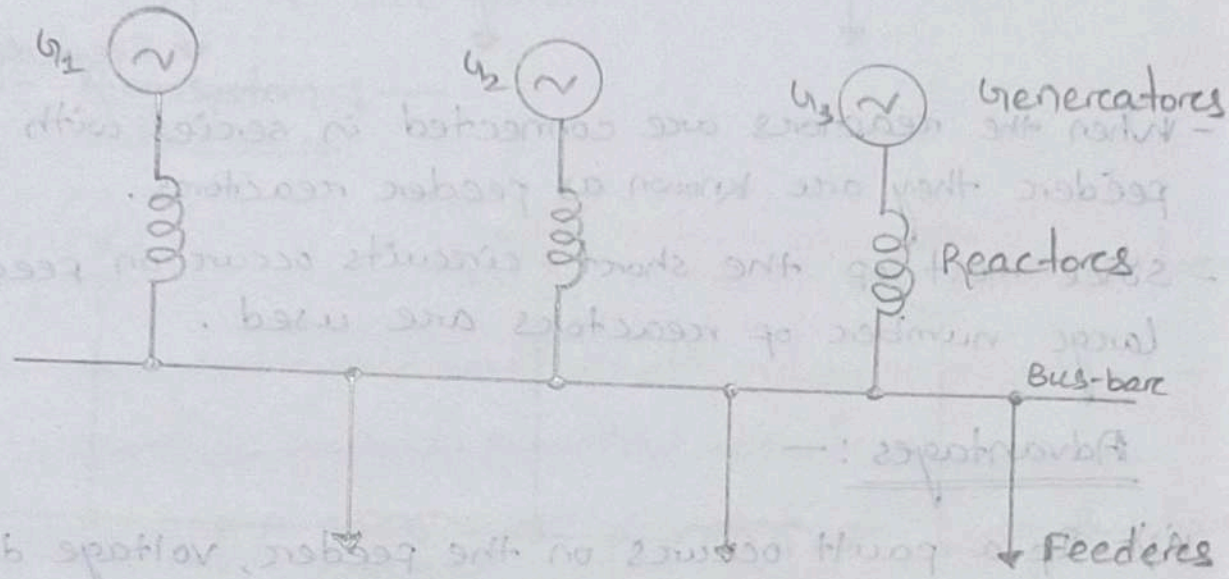
Reactors may be connected,

(i)- In series with each generator.

(ii)- In series with Feeder.

(iii)- In Bus-Bars.

(i)- Generator Reactors :—



- When the reactors are connected in series with each generator, they are known as generator reactors.
- It protects the generator in case of short-circuit.

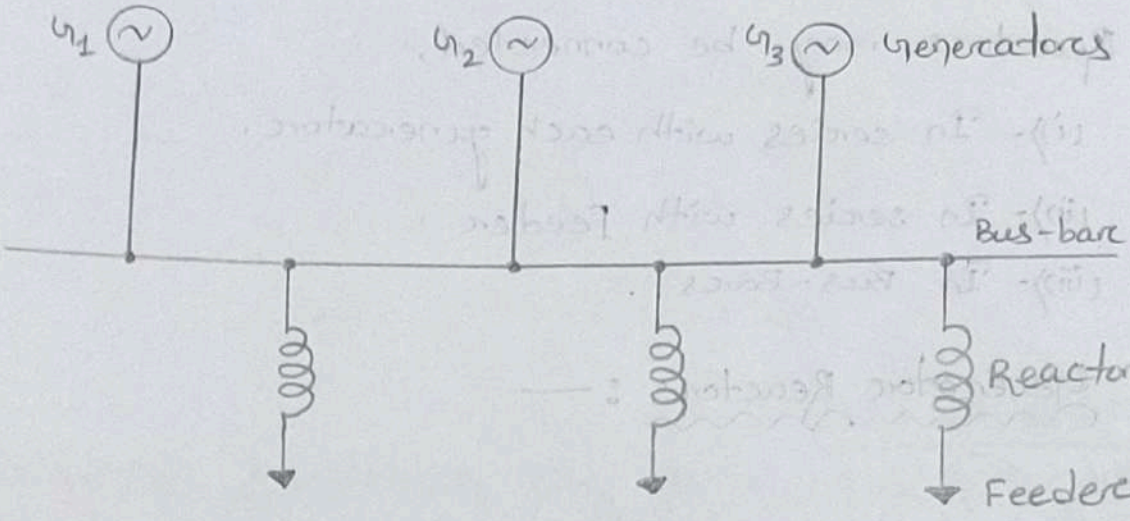
Disadvantages :—

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

(b)- If a bus-bar or feeder fault occurs close to the bus-bar, the voltage at the bus-bar will be reduced to a low value, hence it causes the generators to fault out of step

(c)- If a fault occurs on any feeder, continuity of supply is likely to be affected.

(ii)- Feeder Reactors :—



- When the reactors are connected in series with each feeder they are known as feeder reactors.
- Since most of the short-circuits occur on feeders large number of reactors are used.

Advantages :—

(a)- If a fault occurs on the feeder, voltage drop in its reactor will not affect the bus-bar voltage so that there is a little tendency for the generator to lose synchronism.

(b)- Fault on the feeder will not affect other feeders, hence each fault is localised.

Disadvantages :—

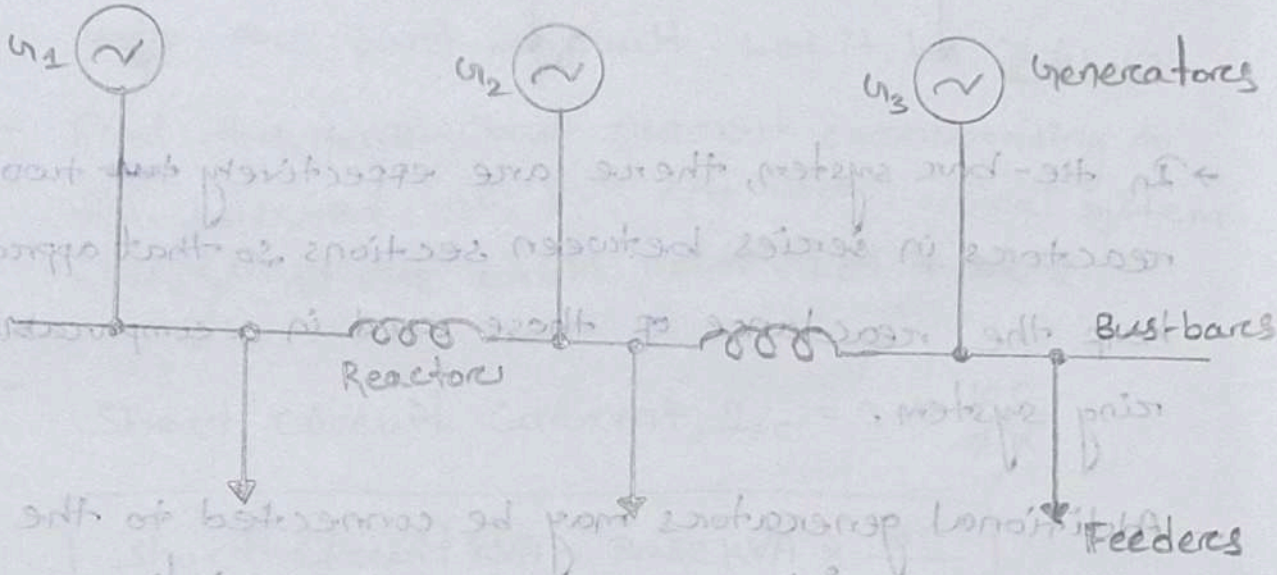
(a)- There is a constant power loss & voltage drop in the reactors even during normal operation.

(b)- If number of generators is increased, the size of feeder reactors will have to be increased to keep the short circuit currents with in the ratings of the feeder circuit-breakers.

(iii)- Bus-Bar Reactors :—

- There is a constant voltage drop & power loss in the above reactors even during normal operation, this disadvantage is overcome by locating the reactors in the bus-bars.
- There are two methods,
  - (a)- Ring System
  - (b)- Tie-Bar System

(a)- Ring system :—



→ Bus-bar is devided into sections & these sections are connected through reactors.

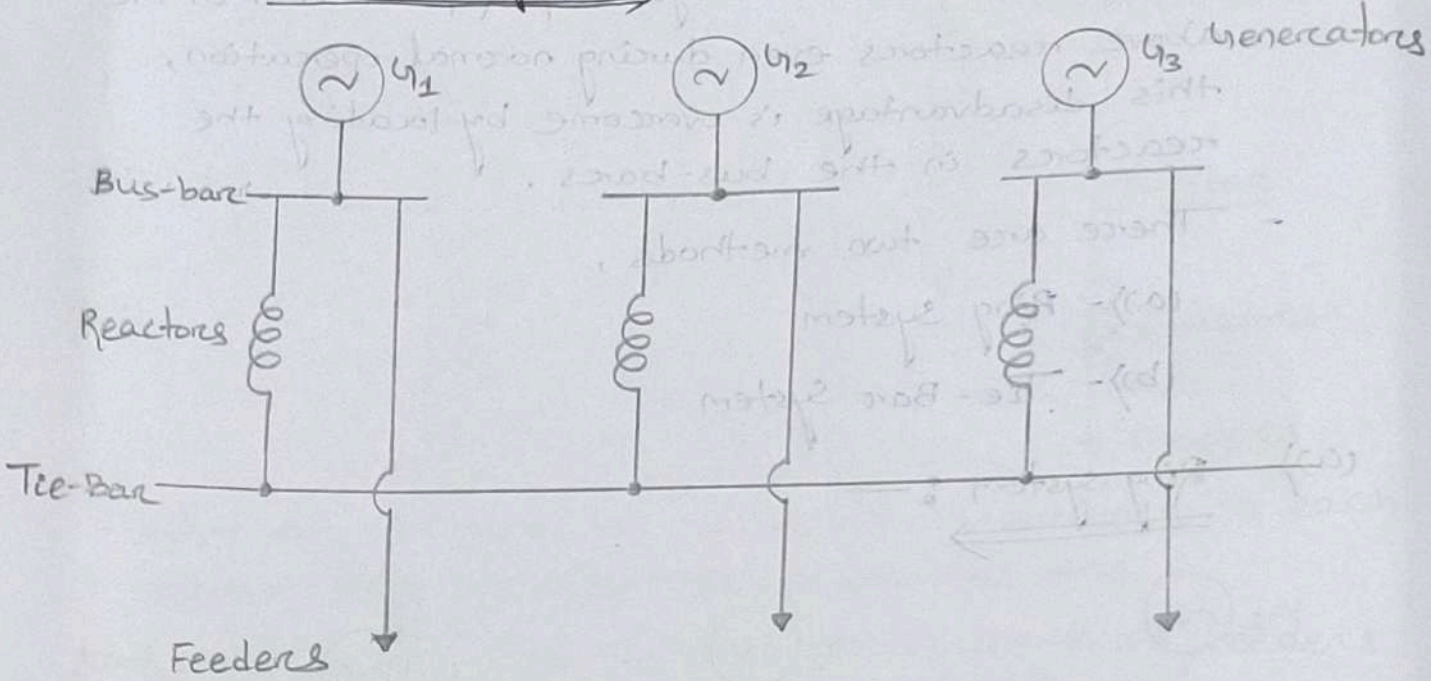
→ One feeder is fed from one generator only.

→ Under normal operating conditions, each generator will supply its own section of the load and very little power will be fed by other generators, hence it results in low power loss & voltage drop in the reactors.

→ If a fault occurs on any feeder only one generator mainly feeds the fault current & current from other generators is small due to the reactors, hence only that section of the bus-bar is affected to which the feeder is connected, the other section being able to continue in normal section.

Dt:- 28.03.22

(b)>- Tie-Bar system :—



→ In tie-bar system, there are effectively ~~two~~ two reactors in series between sections so that approximately half the reactance of those used in a comparable ring system.

- Additional generators may be connected to the system without requiring changes in the existing reactors.

Disadvantage :—

It requires an additional bus-bar i.e., tie-Bar.

* Steps For Symmetrical Fault Calculations :—

(i)>- Draw a single line diagram of the complete network indicating the rating, voltage & percentage reactance of each element of the network.

(ii)- Choose a numerically convenient value of base KVA & convert all percentage reactances to this base value.

(iii)- Corresponding to the single line diagram of the network, draw the reactance diagram showing one phase of the system and the neutral. Indicate the percentage reactances on the base KVA in the reactance diagram. The transformer in the system should be represented by a reactance in series.

(iv)- Find the total % reactance of the network upto the point of fault. Let it be X%.

(v)- Find the full-load current corresponding to the selected base KVA and the normal system voltage at the fault point. Let it be I.

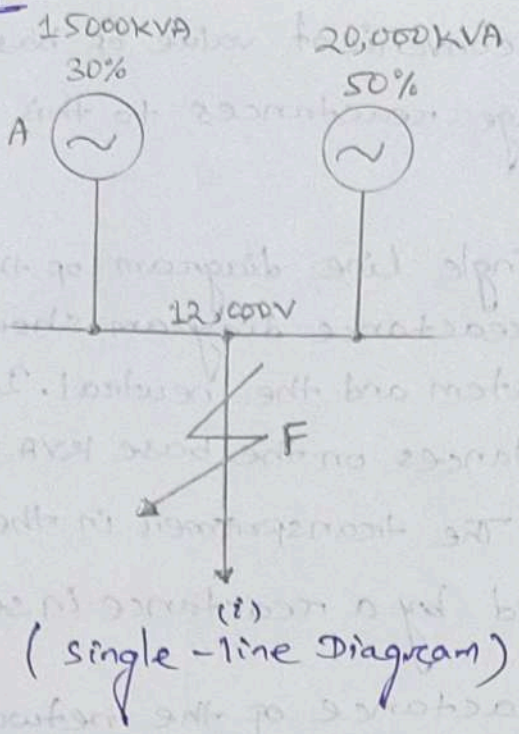
(vi)- Short circuit current, $I_{sc} = I \times \frac{100}{\%X}$

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

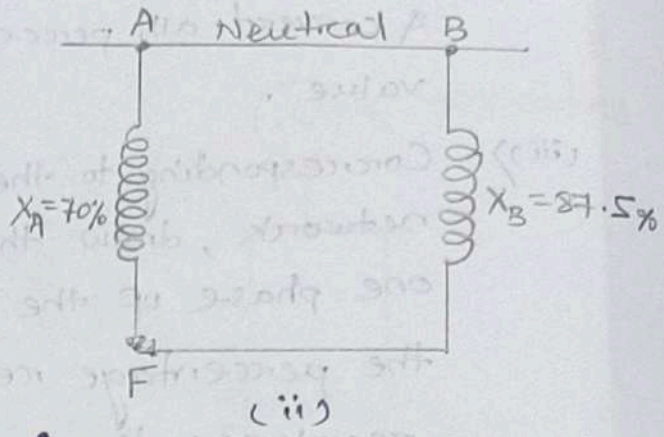
NUMERICAL :—

(1)- In the given fig. the single line diagram of a 3-ϕ system. The percentage reactance of each alternator is based on it own capacity. Find the short circuit current that will flow into a complete 3-ϕ short circuit at F.

Step-1



(single-line Diagram)



[Reactance diagram at 35,000KVA]

Step-2

Let, the base KVA be 35,000 KVA.

% Reactance of alternator A at the base KVA is,

$$\%X_A = \frac{\text{Base KVA}}{\text{Rated KVA}} \times \%\text{ age reactance at the rated KVA}$$

$$= \frac{35,000}{15,000} \times 30$$

$$= 70\ \%$$

% Reactance of alternator B at the Base KVA is,

$$\%X_B = \frac{\text{Base KVA}}{\text{Rated KVA}} \times \%\text{ Age reactance at the rated KV}$$

$$= \frac{35,000}{20,000} \times 50$$

$$= 87.5\%$$

Line current corresponding to 35,000 KVA at 12 KV,

$$I = \frac{35,000 \times 10^3}{\sqrt{3} \times 12000} = 1684\ A.$$

Total percentage reactance from generator neutral upto fault point is,

$$\% X = X_A \,||\, X_B$$

$$= \frac{X_A \cdot X_B}{X_A + X_B} = \frac{70 \times 87.5}{70 + 87.5} = 38.9\,\%$$

Isc (short ckt current), $= I \times \frac{100}{\% X}$

$$= 1684 \times \frac{100}{38.9}$$

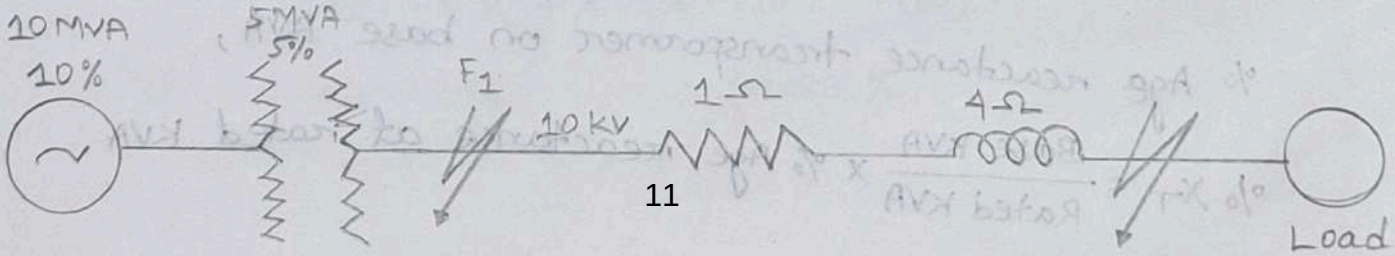
$$= 4329.04\ A$$

Dt:- 31.03.22

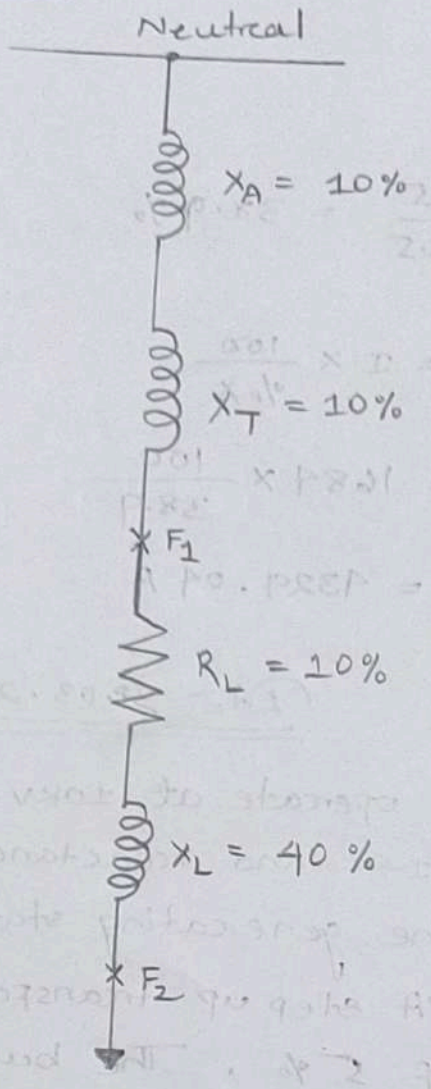
(2)}- A 3-ϕ Transmission line operate at 10kV and having a resistance of 1Ω and reactance of 4Ω is connected to the generating stations bus-bars through 5MVA step up transformer having a reactance of 5%. The bus bars are supplied by a 10MVA alternator having 10% reactance. Calculate the short circuit KVA fed to symmetrical fault between phases if it occurs,

(i)}- At the load end of transmission line.

(ii)}- At the high voltage terminals of the transformer.



Step-1



1 MVA = 1000 KVA
5 MVA = 5000 KVA
10 MVA = 10,000 KVA

Step-2

Let, the base KVA be 10 MVA = 10,000 KVA

% Age reactance of alternator on base KVA,

$$\% X_A = \frac{\text{Base KVA}}{\text{Rated KVA}} \times \% \text{ Age reactance at rated KVA.}$$

$$= \frac{10,000}{10,000} \times 10\%$$

$$= 10\%$$

% Age reactance transformer on base KVA,

$$\% X_T = \frac{\text{Base KVA}}{\text{Rated KVA}} \times \% \text{ Age reactance at rated KVA}$$

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

The line impedance is given ohms, it can be converted into % Impedance,

% reactance of transmission line,

$$\% X_L = \frac{(\text{Base KVA}) \times \text{reactance in } \Omega}{10(\text{KV})^2}$$

$$= \frac{10,000 \times 4\Omega}{10 \times (10)^2} = 40\%$$

% Resistance of transmission line,

$$\% R_L = \frac{\text{Base KVA} \times \text{Resistance in } \Omega}{10\,(10)^2}$$

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

(ii) - For a fault at the end of a transmission line i.e., at point F_2,

Total % reactance $= X_A + X_T + X_L$

$= 10\% + 10\% + 40\%$

$= 60\%$

Total % resistance $= R_L = 10\%$

% impedance from generator neutral upto fault point F_2,

$$Z = R + jX$$

$$|Z| = \sqrt{R^2 + X^2} = \sqrt{(10)^2 + (60)^2}$$

$$= 60.83\%$$

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

$= 10,000 \times \frac{100}{60.83}$

$= 16439.25$ KVA

(ii)}- For the fault at the high voltage terminals of the transformer i.e., at point F_1,

Total % reactance from generator neutral up to fault point F_1,

$= X_A + X_T$

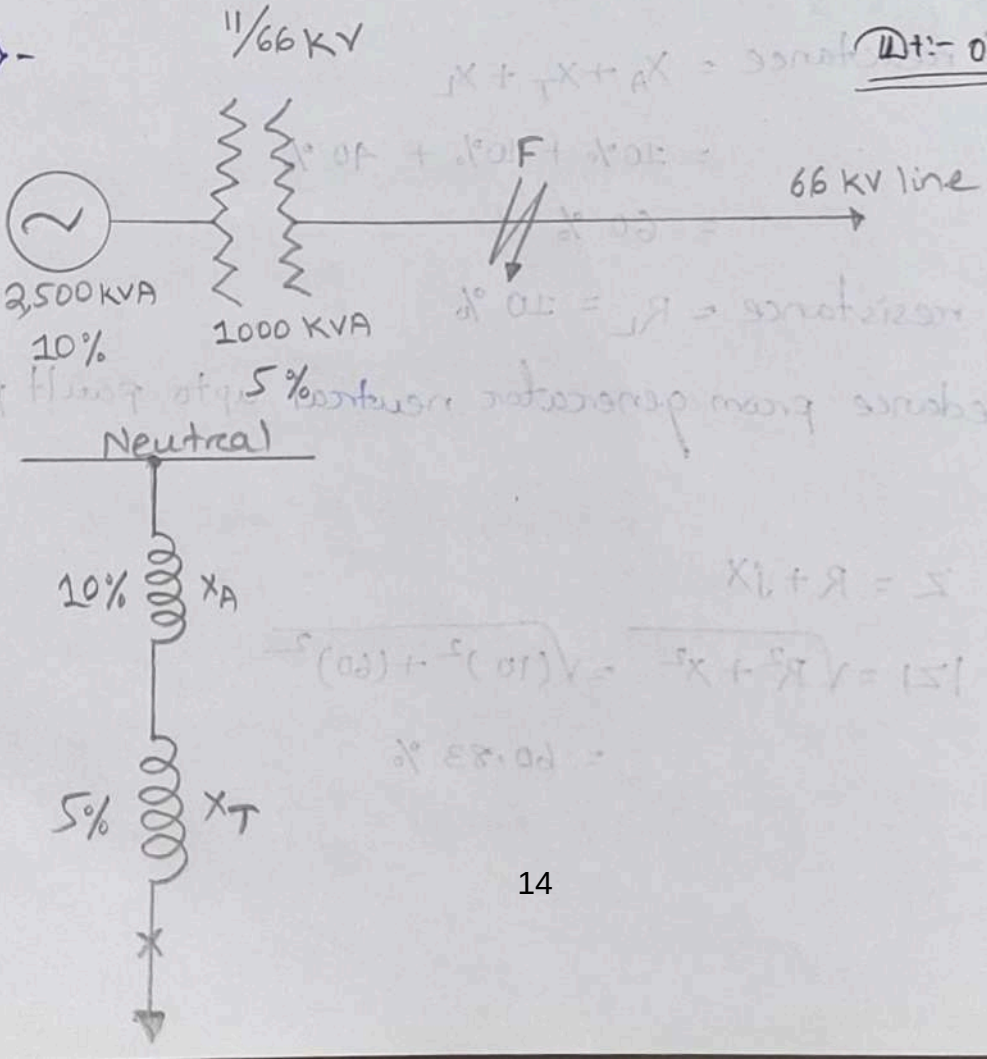
$= 10 + 10 = 20\%$

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

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

$= 50,000$ KVA.

(3)}-



Dt:- 02.04.22

Let the fault occurs at the high voltage terminals of transformer,

Case-1

Let, the base KVA be 2,500 KVA

Reactance of alternator at base KVA,

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

$$= 10\%$$

Reactance of transformer at base KVA,

$$\% X_T = \frac{2500}{1,000} \times 5$$

$$= 12.5\%$$

Total % reactance up to the fault point,

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

$$= 10 + 12.5$$

$$= 22.5\%$$

Full-load current corresponding to base KVA at 66 KV is given by,

$$I = \frac{2500 \times 1000}{\sqrt{3} \times 66 \times 1000} = 21.869$$

$$= 21.87 \text{ A}$$

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

$$= 21.87 \times \frac{100}{22.5\%}$$

$$= 97.2 \text{ A}$$

Case-2

Let, the base KVA be 5000 KVA

$$\% X_A = \frac{5000}{2500} \times 10\%$$

$$= 20\%$$

$$\% X_T = \frac{5000}{1000} \times 5\%$$

$$= 25\%$$

Total % reactance up to the fault point,

~~$\% X_T = \frac{5000}{1000} \times 5\%$~~

$$\% X = X_A + X_T$$

$$= 20 + 25$$

$$= 45\%$$

Full-load current corresponding to base KVA at 66KV is given by,

$$I = \frac{5000 \times 1000}{\sqrt{3} \times 66 \times 1000} = 43.74 \text{ A}$$

$$I_{sc} = I \times \frac{100}{\% X} = 43.74 \times \frac{100}{45\%}$$

$$= 97.2\%$$

Note

Hence, whatever the value of base KVA, the value of I_{sc} will be same.

)\- A 3-ϕ, 20MVA, 10KV alternater has internal reactance of 5% and negligible resistance. Find the external reactance per phase to be connected in series with the alternater, so that steady current on short circuit, doesn't exceed 8 times the full-load current.

Ans

$$I = \frac{20 \times 10^6}{\sqrt{3} \times 10 \times 10^3} = 1154.7 \text{ A}$$

$$\text{Voltage/phase} = \frac{10 \times 10^3}{\sqrt{3}} = 5773.5 \text{ volt}.$$

As the short circuit current is to 8 times the full-load current.

$$I_{sc} = 8I \Rightarrow \frac{1}{8} = \frac{I}{I_{sc}}$$

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

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

$$= \frac{1}{8} \times 100$$

$$= 12.5\ \%$$

External % reactance required, $= 12.5\% - 5\%$

$$= 7.5\ \%$$

Let 'X-Ω' be the per phase external reactance required,

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

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

$$= \frac{5773.5 \times 7.5\%}{1154.7 \times 100}$$

$$= 0.375\ \Omega \quad \underline{\text{Ans}}$$

CHAPTER:-3 Dt:- 23.04.22

FUSES

* FUSE :—

Fuse is a short piece of metal, inserted in the circuit, which melts when excessive current flows through it and thus breaks the circuit.

- It is made of materials having low melting point.
- It should have high conductivity.
- Least deterioration due to oxidation eg:- silver, Copper etc.
- It is connected in series with the circuit to be protected.
- Under normal operating condition, the fuse element is at a temperature below its melting point.
- It carries the normal current without overheating.
- When a short circuit or overload occurs, the current through the fuse increases beyond its rated value.
- It ~~rises~~ raises the temperature & fuse element melts hence it disconnected the circuit protected by it.
- In this way fuse protects the machines & equipment from damage due to excessive currents.

Advantages :—

(i)- Cheapest form of protection.
(ii)- It requires no maintenance.
(iii)- Its operation is inherently automatic.
(iv)- It can break heavy short circuit currents without noise or smoke.
(v)- Smaller sizes of fuse elements impose a current limiting effect.

Disadvantages :—

(i)- Time is lost in rewiring or replacing a fuse after operation.

(ii)- On heavy short circuits, discrimination between fuses in series can't be obtained unless there is sufficient differences in the sizes of the fuses concerned.

* Desirable Characteristics Of Fuse Element :—

(i)- Low melting point e.g., tin, lead.

(ii)- High conductivity e.g., silver, copper.

(iii)- Free from deterioration due to oxidation e.g., silver.

(iv)- Low cost e.g., Lead, tin, copper.

For example,

(i)- **Lead :—**

It has low melting point but it has high specific resistance.

- It is liable to oxidation.

(ii)- **Copper :—**

- It has high conductivity.
- It oxidises rapidly.

IMP Note

A compromise is made in the selection of material for a fuse.

* Fuse Element Materials :—

(i) - Lead
(ii) - Tin
(iii) - Copper
(iv) - Zinc
(v) - Silver

- Present trend is to use silver despite its high cost, because,

(i) - It is free from oxidation.
(ii) - It doesn't deteriorate when used in dry air.
(iii) - Its conductivity is very high.
(iv) - Resistance of the silver increaseds abruptly as the melting temperature is reached.

* Difference between a Fuse & Circuit Breaker :—

S.No.	Particular	Fuse	Circuit Breaker
1	Function	It performs both detection & interruption functions.	It performs interruption function only. The detection of fault is made by relay system.
2	Operation	Inherently completely automatic.	Requires elaborate equipment (i.e., relays) for automatic action.
3	Breaking capacity	small.	very large.
4	Operating time	very small (0.002 sec or so)	comparatively large (0.1 to 0.2 sec)
5	Replacement	Requires replacement after every operation.	No replacement after operation.

Date:- 23.04.22

* IMPORTANT TERMS RELATED TO FUSE :—

(1)- Current Rating of Fuse Element :—

It is the current which the fuse element can normally carry without overheating or melting.

- It depends upon,
  - (a)- Fuse material.
  - (b)- Surrounding of the fuse.
  - (c)- Temperature rise of the contacts of the fuse holder.

(2)- Fusing Current :—

- It is the minimum current at which the fuse element melts & disconnects the circuit protected by it.
- Its value will be more than the current rating of the fuse element.
- Fusing current depends upon;
  - (a)- Material of fuse element.
  - (b)- Length of the fuse element (smaller the length greater the current)
  - (c)- Diameter
  - (d)- Size & location of terminals.
  - (e)- Type of ~~enclosed~~ enclosure used.

$$I = Kd^{3/2}$$

where, K = Fuse constant

d = Diameter of the wire

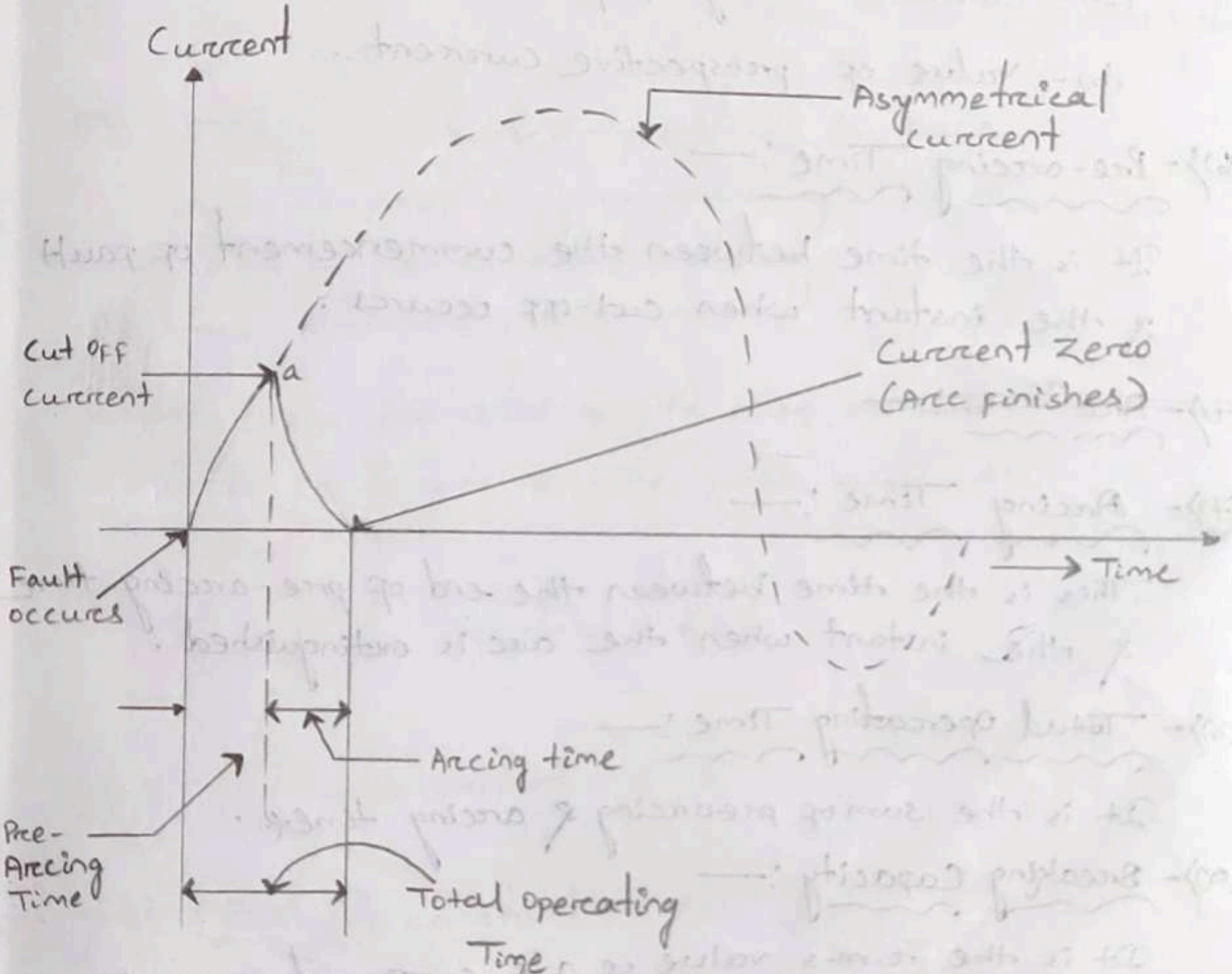
I = Fusing Constant.

(3) - Fusing Factor :—

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

$$\text{Fusing Factor} = \frac{\text{Minimum Fusing Current}}{\text{Current rating of the fuse}}$$

- Its value always more than 1.



(4)}- Prospective Current :—

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

(5)}- Cut-off Current :—

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

- It depends upon,

(a)- Current rating of fuse.

(b)- Value of prospective current.

(6)}- Pre-arcing Time :—

It is the time between the commencement of fault & the instant when cut-off occurs.

~~(7)}- Arc Time :—~~

(7)}- Arcing Time :—

This is the time between the end of pre-arcing time & the instant when the arc is extinguished.

(8)}- Total Operating Time :—

It is the sum of prearcing & arcing times.

(9)}- Breaking Capacity :—

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

* Current Carrying Capacity Of Fuse Element :—

It depends upon,

(i) - Cross-sectional area.

(ii) - Type of metal used.

- It is affected by the length, surrounding of the fuse, surface of the fuse.

- Heat produced per second = Heat lost per second by convection, radiation & conduction.

or, I^2R = constant × Effective Surface.

$$\Rightarrow \boxed{I^2\left(\rho\frac{l}{a}\right) = \text{constant} \times d \times l}$$

Where, d = diameter of the fuse element

l = length of the fuse element

or, $$I^2 \rho \frac{l}{\pi r^2} = \text{constant} \times d \times l$$

$$\Rightarrow I^2 \rho \frac{l}{\pi \frac{d^2}{4}} = \text{constant} \times d \times l$$

$$\Rightarrow I^2 4\rho \frac{l}{\pi d^2} = \text{constant} \times d \times l$$

$$\Rightarrow I^2 = \frac{\text{constant} \times \pi \times d^3 \times k}{4\rho k} = \frac{\text{constant} \times \pi}{4\rho} \times d^3$$

$$\Rightarrow \boxed{I^2 = d^3} \quad \Rightarrow \boxed{I^2 = \text{Constant} \cdot d^3}$$

∴ This is called ordinary fuse law.

Q.

A fuse wire of circular cross-section has a radius of 0.8mm. The wire blows off at a current of 8A. Calculate the radius of the wire that will blow off at a current of 1A.

Ans

From the fuse law,

given, $I^2 \propto r^3$ $\quad \left[\because I^2 = d^3 \rightarrow I^2 = (2r)^3\right.$

$I_1 = 8\,Amp$

$r_1 = 0.8mm$

$I_2 = 1A$

$r_2 = ?$

then,

$$\frac{I_1^2}{I_2^2} = \frac{r_1^3}{r_2^3}$$

$$\Rightarrow r_2^3 = \frac{I_2^2}{I_1^2} \times r_1^3$$

$$\Rightarrow r_2^3 = \frac{(1)^2}{(8)^2} \times (0.8)^3$$

$$\Rightarrow r_2 = \sqrt[3]{0.008}\ mm$$

$$\Rightarrow r_2 = 0.2\ mm \quad \text{Ans}$$

Dt:- 05.05.22

* TYPES OF FUSES :—

(i)- Low voltages fusses.

(ii)- High voltages fuses.

(i)- Low Voltage Fuses :—

It is of two types,

(a)- Semi-enclosed rewireable Fuse.

(b)- High rupturing capacity (H.R.C.) cartridge Fuse.

(a)- Semi-enclosed Rewireable Fuse :—

- It is kit-kat type fuse.
- It is used at low values of fault currcent are to be interrupted.
- It consists of,
  - (i)- A base
  - (ii)- A fuse carrier

(ii)- Base :—

- It is made up of porcelain.
- It carrcies the fixed contacts to which incoming & outgoing phase wire are connected.

(iii)- Fuse Carrier :—

- It is also of porcelain.
- It holds the fuse element between its terminals.
- The fuse element is tinned copper wire.
- Fuse carrier can be inserted in or taken out of the base when desired.

Working

- When fault occurs, fuse element is blown out & the circuit is interrupted.
- The fuse carrier is taken out and the blown out fuse element is replaced by the new one.
- The fuse carrier is then re-inserted in the base to restore the supply.

Advantages

(i)- Detachable fuse carrier permits the replacement of fuse element without any danger of coming in contact with live parts.

(ii)- Cost of replacement is negligible.

Disadvantages :—

(i)- There is a possibility of renewal by the fuse wire of wrong size or by improper material.

(ii)- It has a low breaking capacity, hence it can't be used in high fault level.

(iii)- The protective capacity of such a fuse is uncertain as it is affected by the ambient conditions.

(iv)- The fuse element is subjected to deterioration due to oxidation through the continuous heating up of the element.

Rating -

- It is made up to 500A rated current.
- It is used in domestic & lighting loads.

Dt:- 06.05.22

(b)- High-Rupturing capacity (H.R.C.) Cartridge Fuse :-

The low & uncertain breaking capacity of semi-enclosed rewireable fuses is overcome in H.R.C. cartridge fuse.

Construction :-

- It consists of a heat resisting ceramic body.
- It has metal end-caps.
- The silver current-carrying element is welded to the metal end-caps.
- The space within the body surrounding the element is packed with a filling powder.
- The filling powder may be chalk, plaster of paris, quartz or marble dust.
- The filling material acts as an arc quenching & cooling medium.
- Hence it carries the normal current without over heating.

Working Operation :—

- When a fault occurs, the current increases and the fuse element melts before the fault current reaches its first peak.
- Heat produced in the process vapourises the melted silver element.
- The chemical reaction between the silver vapour and the filling powder results in the formation of high resistance substance.
- It helps in quenching the arc.

Advantages :—

(i)- It is capable of clearing high as well as low fault currents.

(ii)- It doesn't deteriorate with age.

(iii)- They have a high speed of operation.

(iv)- They provide reliable discrimination.

(v)- They require no maintenance.

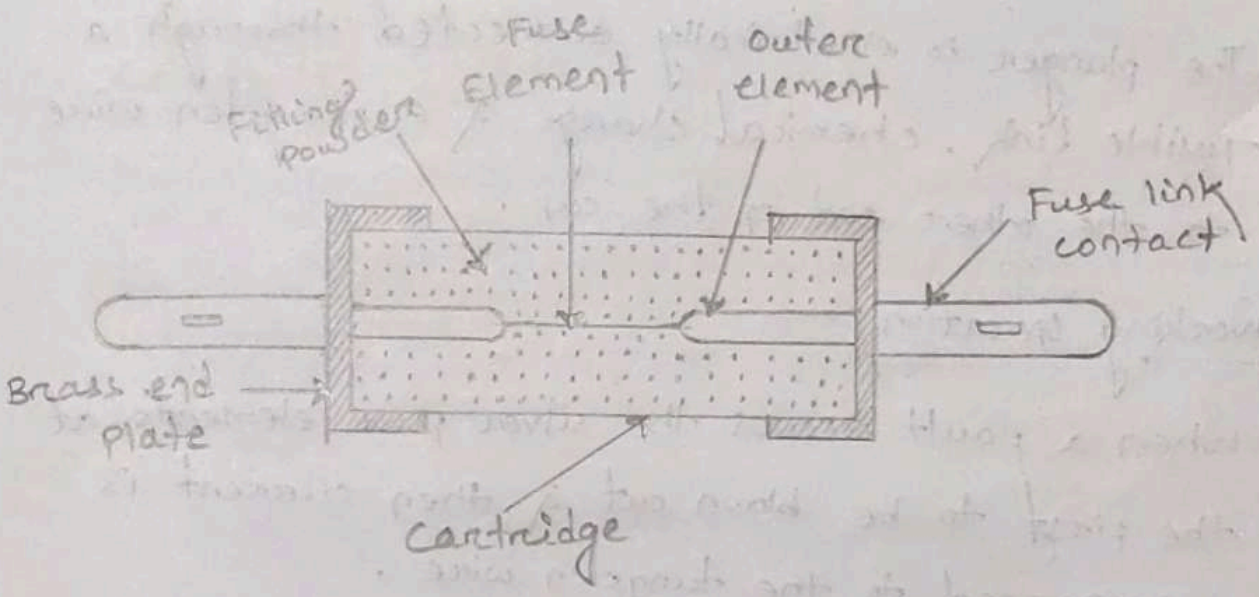
(vi)- They are cheaper than other circuit interrupting devices.

(vii)- They permit consistent performance.

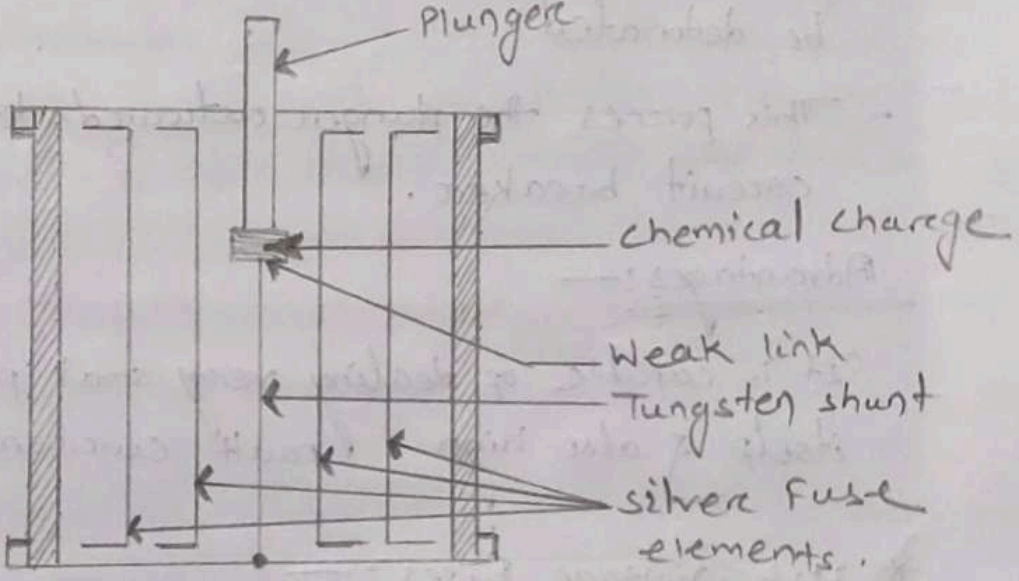
Disadvantages :—

(i)- They have to be replaced after each operation.

(ii)- Heat produced by the arc may affect the associated switches.



(c)) - H.R.C. Fuse With Tripping Device :—



- Here, H.R.C. cartridge fuse is provided with a tripping device.

Construction :—

- The body of the fuse is of ceramic material with a metallic cap rigidly fixed at each end.
- These are connected by a number of silver fuse elements.
- At one end is a plunger under fault conditions hits the tripping mechanism of the circuit breaker & causes it to operate.

- The plunger is electrically connected through a fusible link, chemical charge & a tungsten wire to the other end of the cap.

Working operation :—

- When a fault occures the silver fuse elements at the first to be blown out & then current is transperred to the tungsten wire.
- The weak link in series with the tungsten wire gets fused and causes the chemical charge to be detonated.
- This forces the plunger outward to operate the circuit breaker.

Advantages :—

It is capable of dealing very small fault current itself & also high fault current.

* High Voltage Fuses :—

(i)- cartridge type fuse.

(ii)- Liquid type fuse.

(iii)- Metal clad fuses.

(i)- Cartridge Type :—

Some fuse designs employ fuse elements wound in the form of a helix to avoid corona effects at higher voltages.

- So there are two fuse elements in parallel.
  - (a)- One of low resistance (silver wire)
  - (b)- One of high resistance (Tungsten wire)
- Under normal load condition the low resistance element carries the normal current.
- When fault occurs low resistance element is blown out & the high resistance element reduces the short circuit current and breaks the circuit.

Dt:- 11.05-22

(ii)- Liquid Type :—

- These fuses are filled with carbon tetrachloride.
- It has wide applications in H.V. systems.
- It consists of a glass tube filled with carbon tetrachloride solution.
- It is sealed at both ends with brass caps.
- The fuse wire is sealed at one end of the tube and the other end of the wire is held by a strong phosphor bronze spiral spring fixed at the other end of the ~~wire~~ glass tube.
- When the current exceeds the prescribed limit, the fuse wire is blown-out.

- As the fuse melts, the spring retracts part of it through a baffel or liquid director, it draws well into the liquid.
- The small quantity of the gas generated at the point of fusion forces some part of liquid into the passage & there extinguishes the arc.

CHAPTER-6

Dt:- 11.05.22

PROTECTION OF ALTERNATORS & TRANSFORMERS :—

* PROTECTION OF ALTERNATORS :—

Important faults that occur on an alternator,

(i)}- Failure of prime-mover.

(ii)}- Failure of field.

(iii)}- Over current.

(iv)}- over speed.

(v)}- Over voltage.

(vi)}- Unbalanced loading.

(vii)}- Stator winding faults.

(1)}- Failure of Prime-Mover :—

When input to prime-mover fails, the alternator runs as a synchronous motor.

- It draws current from the supply system.

(2)}- Failure of Field :—

- This fault is very rare.
- If it occurs, no immediate damage will be caused ~~by~~ the alternator is permitted to run without a field for a short-period.

(3)}- Overcurrent :—

It occures due to partial breakdown of winding insulation or due to over load on the system.

(4)- Overspeed :—

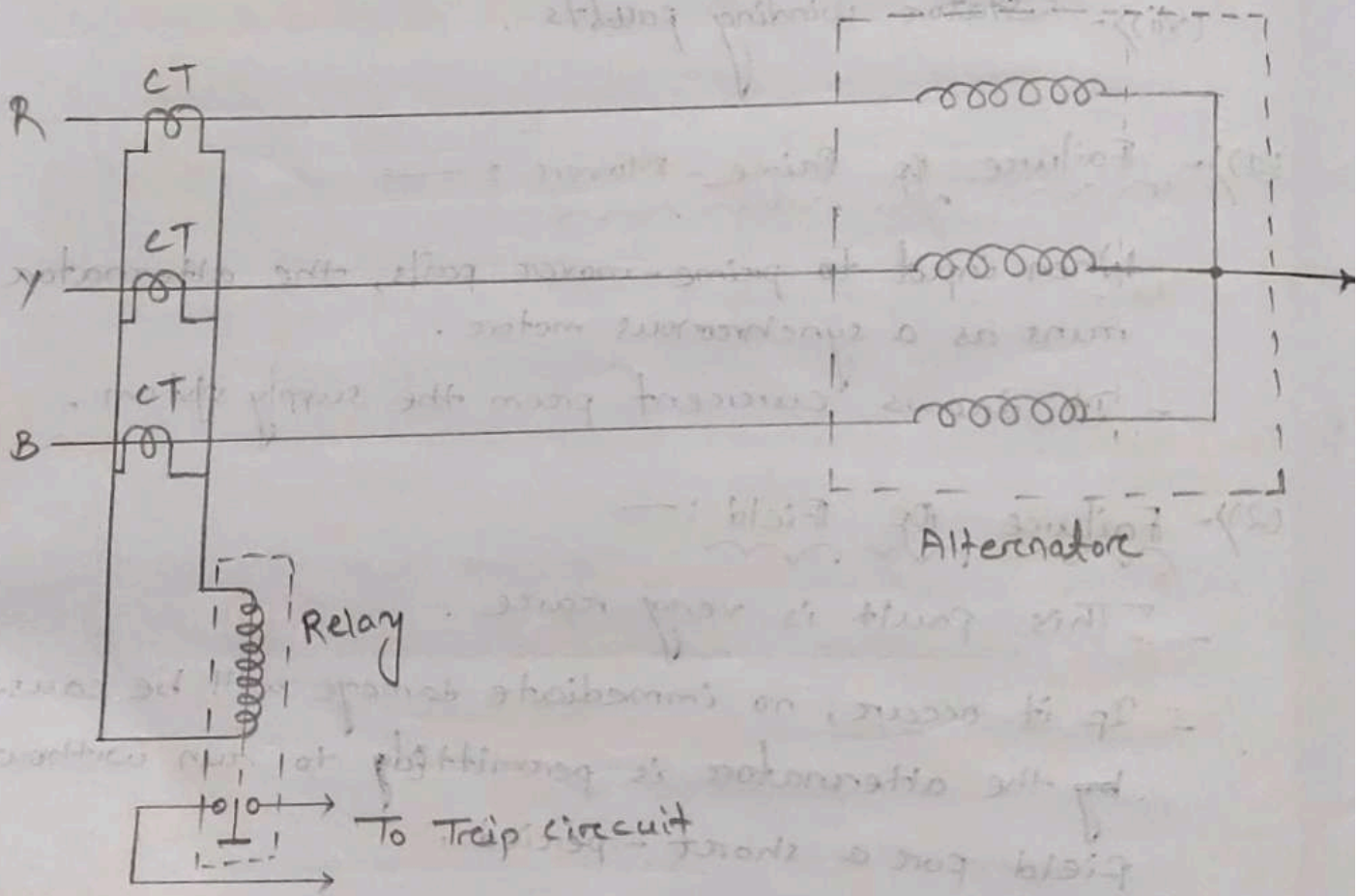
It occures due to sudden loss of all or the major part of load on the alternator.

(5)- Overvoltage :—

Overvoltage in an alternator occures when speed of the prime-mover increases due to sudden loss of the alternator load.

(6)- Unbalanced Loading :—

- It means there are different phase currents in the alternator.
- It occures from faults to earth or faults between phases.



- Under normal operating conditions, equal currents flow through the different phases of the alternator and their algebric sum is equal to zero.
- Hence no current flows through the operating coil of the relay.
- Hence fault occurs currents induced in the secondaries will be different & the resultant of these currents will flow through the relay.
- The operation of the relay will trip the circuit breaker to disconnect the alternator from the system.

Dt:- 12-05-22

(7)- Stator Winding Faults :—

It occurs due to insulation failure of the stator winding like,

(i)- Fault between phase & ground.

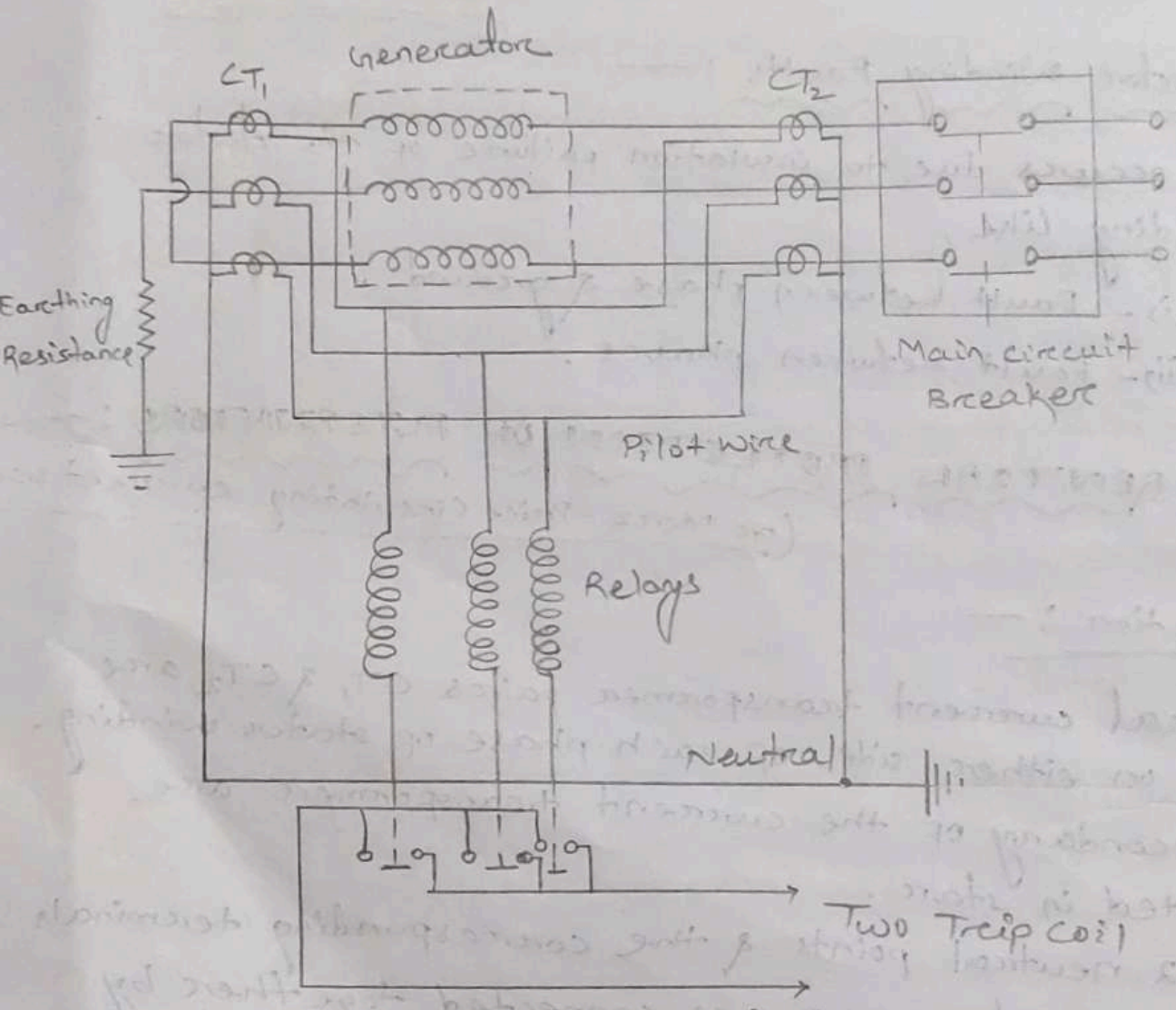
(ii)- Fault between phases.

* DIFFERENTIAL PROTECTION OF ALTERNATORS :—
(or Merz-Price Circulating current scheme)

Construction :—

- Identical current transformer pairs CT_1 & CT_2 are placed on either side of each phase of stator winding.
- The secondary of the current transformer are connected in star.
- The 2 neutral points & the corresponding terminals of the two star group are connected together by means of four-core pilot cable.
- There is an independent path for the currents circulating in each pair of current transformers & corresponding pilot 'p'.

- The relay coils are connected in star, the neutral point being connected to the current-transformer common neutral & the outer ends each relay coil is connected to other three pilot.
- Relays connected across equipotential points of 3 pilot wires.
- These equipotential point are located near the middle of the pilot wires.
- Relays are electromagnetic type ~~and~~, it acts instantaneously when the fault occures.



Working Operation :—

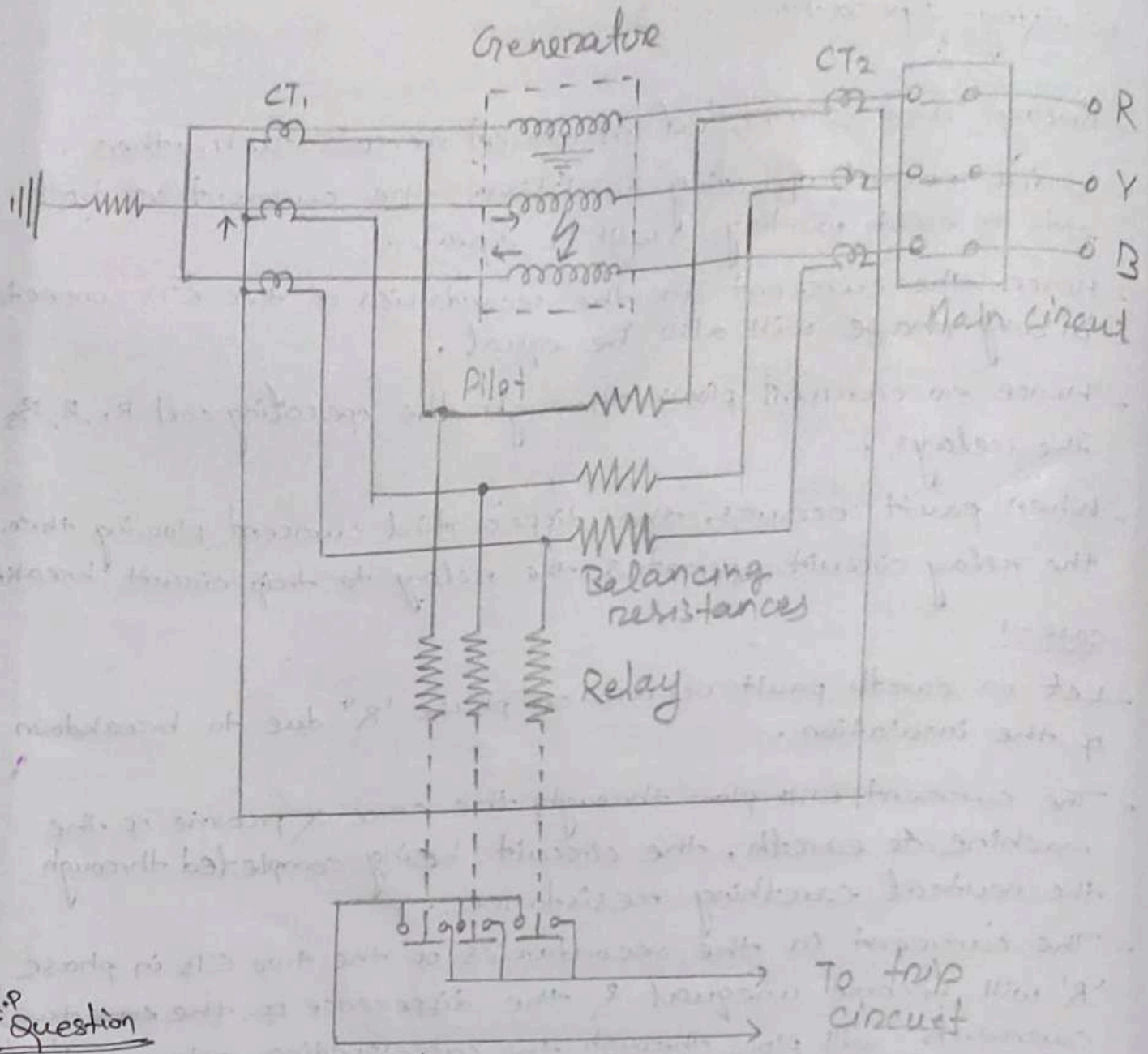
- Relays are connected in shunt across each other.
- Under normal operating conditions, the current at both ends of each winding will be equal.
- Hence the current in the secondaries of two CTs connected in any phase will also be equal.
- Hence no current flows through the operating coil R_1, R_2, R_3 of the relays.
- When fault occurs, the differential current flowing through the relay circuit operates the relay to trip circuit breaker.

case-1

- Let on earth fault occurs on phase 'R' due to breakdown of the insulation.
- The current will flow through the core & frame of the machine to earth, the circuit being completed through the neutral earthing resistance.
- The current in the secondaries of the two CTs in phase 'R' will become unequal & the difference of the two currents will flow through the corresponding relay coil 'R_1' returning through the neutral pilot.
- Relay operates to trip the circuit breaker.

case-11

- short circuit fault occurs between Y & B phase.
- The short circuit current circulates via the neutral end connection through the two windings & through the fault.
- The fault is shown by dotted line.
- The current in the secondaries of two CTs will become unequal & the differential current will flow through the operating coil of the relay that i.e, R_2 & R_3.
- The relay is closes its contact to closed the circuit breaker.



W.I.M.P Question

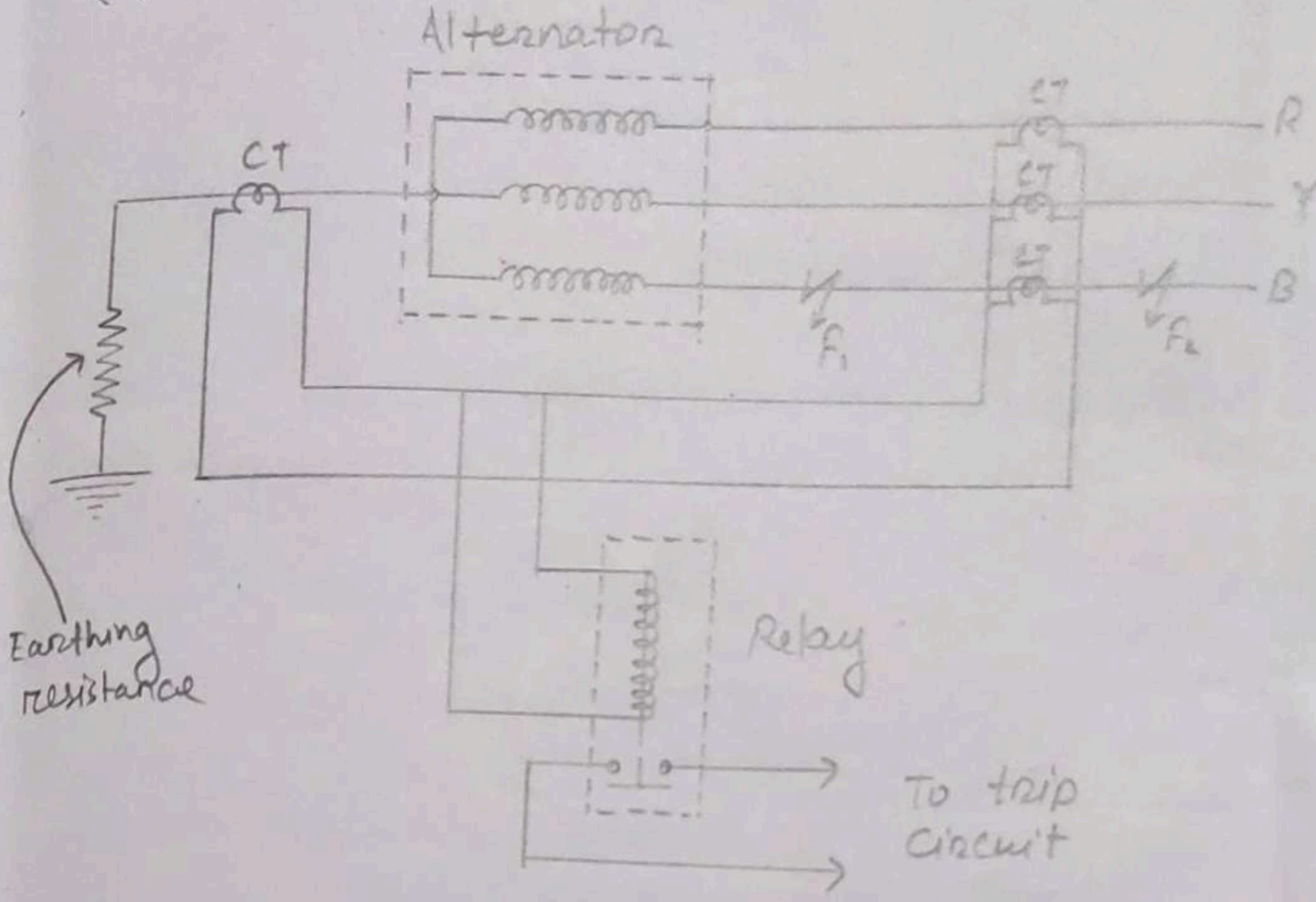
Why balancing resistor are used Merz-Price circulating current scheme / Differential protection of alternator?

Ans :-

- In some cases, the alternator is located at a considerable distance from the switchgear.
- As the relays are located closed the circuit breaker & therefore, it is not convenient to connect the relay coils to the actual physical mid-points of pilot wire.
- Under the situation, balancing resistances are inserted in the shorter length of the pilot so that the relay tapping points devide the whole secondary impedance of two sets of CTs into equal portions.

- These resistances are adjustable in the nature.

* Balanced Earth Fault Protection :—



Dt:- 19.05.22

in small size alternators, neutral end of the 3-ϕ winding are connected internally to a single terminal of the.

⇒ It is not possible to use merz-price circulating current principle because there are no facilities for accommodating the necessary C.T of the in the neutral connection of each phase winding.

⇒ Hence to provide protection against earth fault it can only be used for balanced earth fault protective scheme.

⇒ It provides no protection against ph-to-ph faults until they developed into earth fault

Schematic arrangement;

It consist of 3 identical current T/F, one mounted in each phase having three secondary connected in parallel with that of a single current T/F in the conductor joining the star point of alternator to earth.

⇒ A relay is connected across the T/F secondaries

⇒ The protection against of earth fault is provided by the relay both the neutral & the line current T/F

operation:

under normal condn the I flowing through diff. leads

⇒ The current flowing in the secondaries of of the the current T/F add to zero

⇒ Hence no current flows through the relay

⇒ current in the neutral wire zero

⇒ I secondaries of neutral T/F

⇒ under fault cond^n, if an earth fault occures at f_2 external to the protected zone.

⇒ If the sum of the I at the terminals of the diff. enact equal to the I in the neutral connector.

⇒ Hence no I flow through, the relay

⇒ when an earth fault occures at f, or within the protected zone; then I are no longer equal & the differential I flows through the operating coil of the relay

⇒ Hence relay closed its contact to disconnect the alternator from system

Protection of Transformers:

Common TIF fault :-

- ⇒ open circuit.
- ⇒ over heating.
- ⇒ winding short-circuit.
- ⇒ earth fault, phase-to phase fault & interturn fault

Protection system for transformer :

1) Buchholz Devices :

it provide protection against all kinds of incipient fault i.e. slow developing fault such as insulation failure of winding, core heating

⇒ fault of oil level due to leaky joints.

* Rec fault relay

it provides protection against earth fault only

2) over current relay

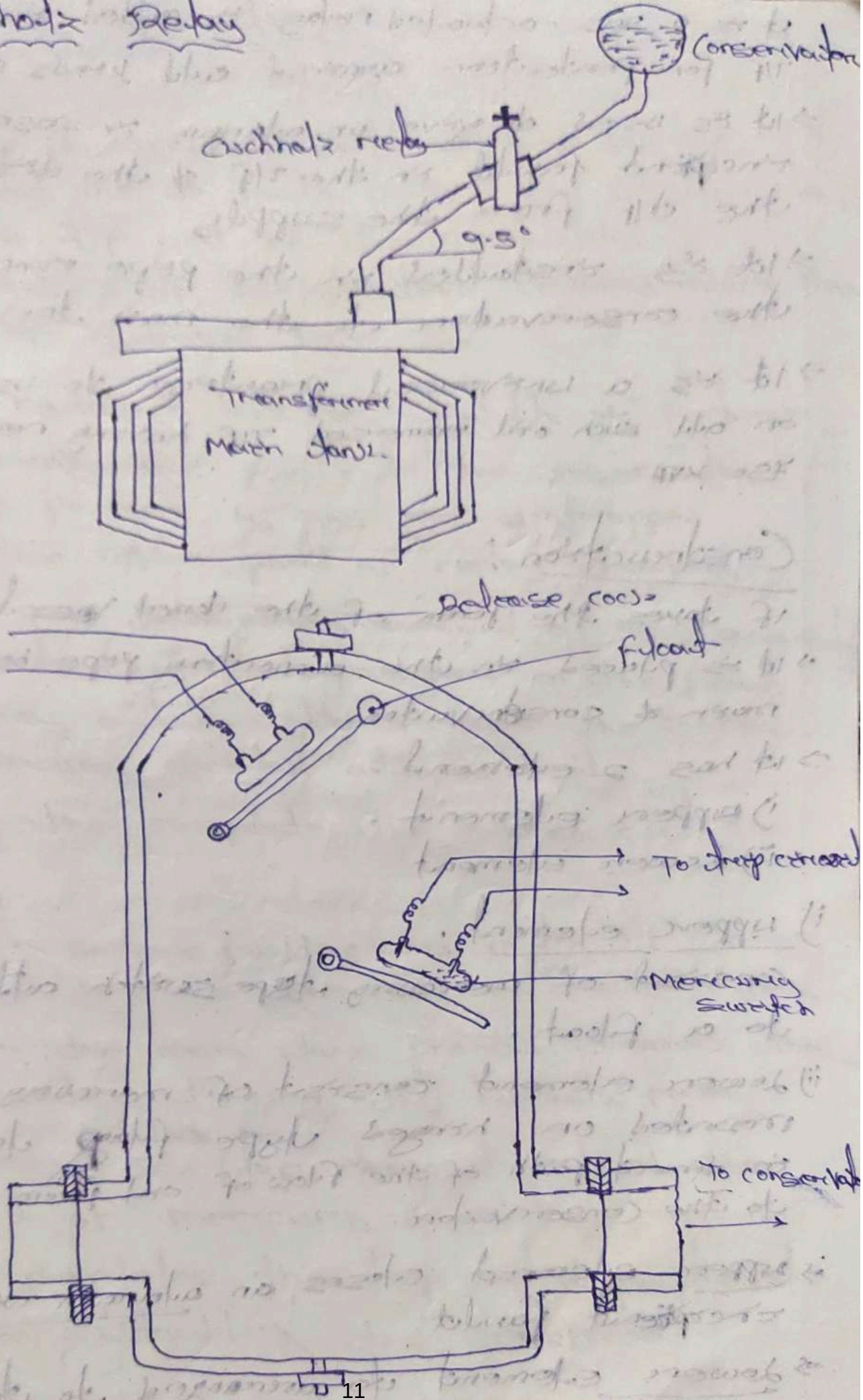
it provide protection against :

phase to phase fault & overloading.

3) Differential system or circulating

it provide protection against both earth & phase faults.

Buchholz Relay

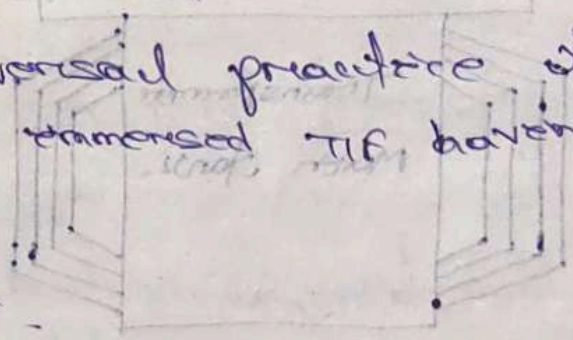


It is a gas actuated relay is called Buchholz relay for protection against all kinds of faults.

⇒ It is used to give an alarm in case of incipient fault in the T/f & the disconnect the T/f from the supply

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

⇒ It is a universal practice to use Buchholz on all such oil immersed T/f having rating 750 KVA



Construction:-

It takes the form of the domed vessel.

⇒ It is placed in the connecting pipe between the main & conservator

⇒ It has 2 elements.

i) Upper element.

ii) Lower element

i) Upper element.

Consist of mercury type switch attached to a float.

ii) Lower element consist of mercury switch mounted on hinged type flap located in direct path of the flow of oil from the T/f to the conservator.

⇒ Upper element closes an alarm circuit during incipient fault.

⇒ Lower element is arranged to trip the CB in case of severe internal fault

Working operation:

Case:-1

In case of incipient fault with in the TIF. The heat due to fault causes the decomposition of the oil in the main tank.

→ The product of decomposition contains more than 70 % of hydrogen gas.

→ The hydrogen gas is lightly in nature.

→ It hydrogen gas goes into the conservator

→ In this process H_2 gas gets entrapped in the upper part of relay chamber

→ when pre determined amount of gas accumulated it exerts sufficient pressure on the float.

- to cause it to tilted & closed the contact of mercury switch attached to it.

→ Hence the completes the alarm circuit

Case:-2

When a severe fault occures in the TIF, large amount of gas is generated in the main tank

→ oil in the main tank process towards the conservator through the buchholz relay

→ In doing so flap tilts the to closed the contact of mercury switch.

→ this completes the trip ckt to open the ckt. breaker controlling the transformer.

Advantages:

→ It is simplest form of TIF.
→ It detects the incipient fault at a very early stage

Dis advantages:

→ It is use only with the oil ~~transformer~~ TIF equiped with the conservator tank.

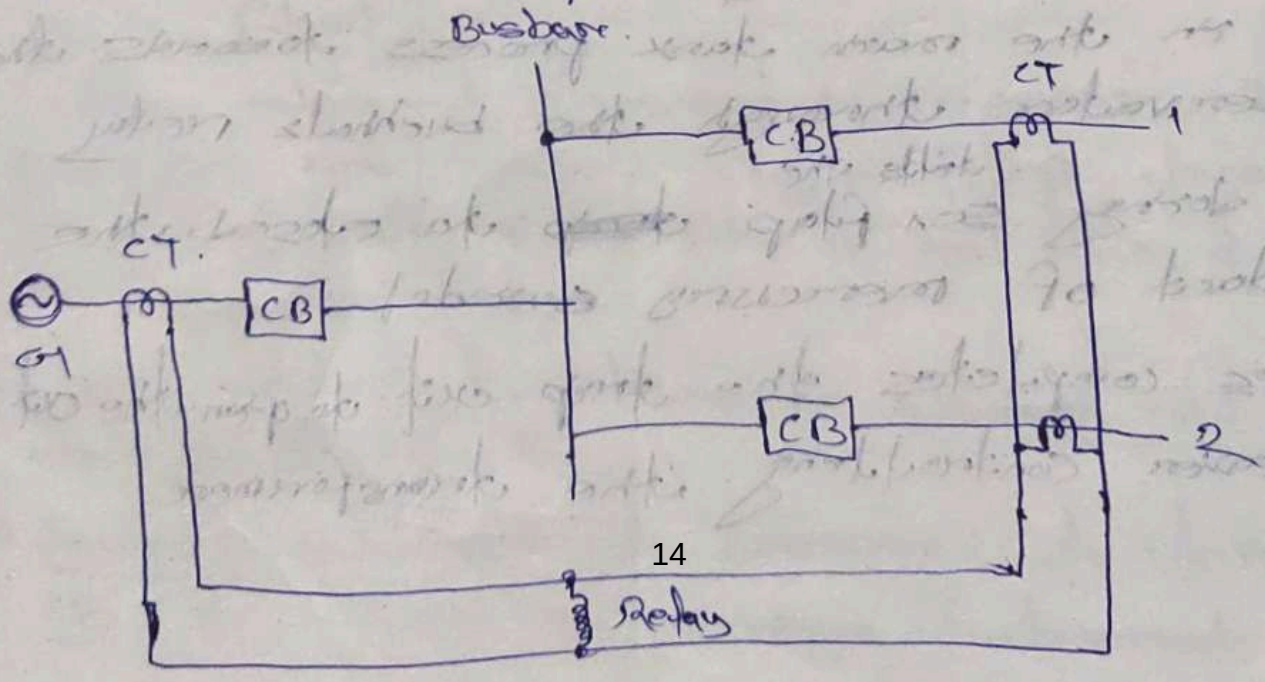
dt:-20.05.22

Busbar protection:

Busbar is the important link bet^n incoming & outgoing ckt.

→ If fault occures on busbar there would be plot of damage disruption of supply.
→ So it needs quick action on protection.
→ The most commonly ~~used~~ used busbar protection are: 1) differential
2) fault bus protection.

1) Differential protection.



in this scheme currents entering & leaving the bus totalled

→ During normal operation, sum of this current is equal to zero.

→ When fault occurs, fault current disturbs the balance & produces a difference current to operate relay

→ In the diagram bus bar is fed by a generator & supply load to two lines.

→ The secondaries CT transformer in the generator lead, in λ_1 & in λ_2 are all connected in Hall.

→ The protective relay is connected across this Hall connection.

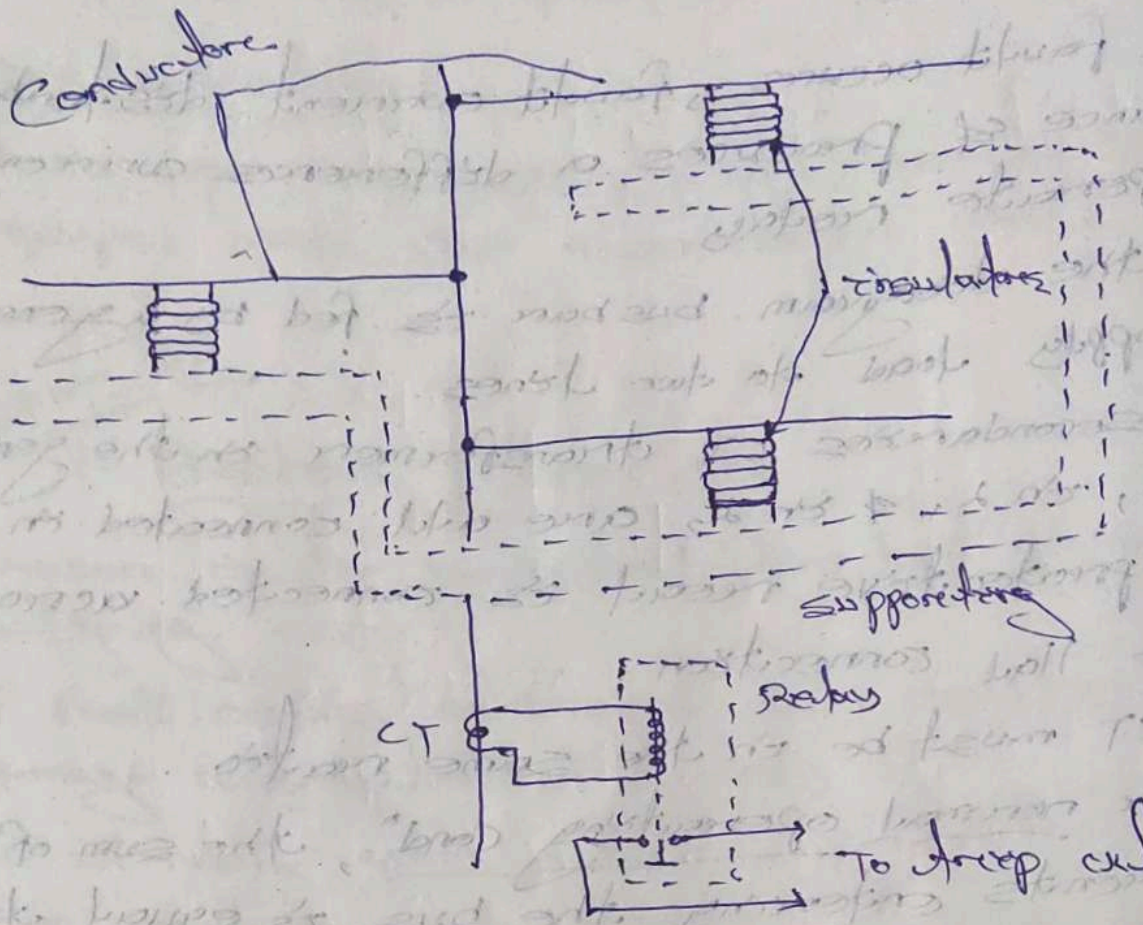
→ All CT must be in the same ratio.

→ Under normal operating cond", the sum of the currents entering the bus is equal to the sum of currents leaving the bus. hence there is no current difference to flow through the relays.

→ When fault occurs protected zone the I entering the bus will not be equal to those leaving the bus.

→ The difference this current will flow through the relay hence it causes the opening the generator CB & each of the line C.B.

* Fault bus protection:



- this protection is achieved by providing earthed metal barrier surrounding each conductor throughout it's entire length or the bus structure
- Here every fault that might occurs must involve a connection betn a conductor & earthed metal part.
- by detecting the flow of current, it is possible to detecting fault between
- the metal supporting structure is earth through a CT
- A relay is connected across the secondary of the CT.

→ under normal operating cond^n no I flow from fault bus to ground hence relay is inactive

→ when fault occures bet^n a conductor & earth supporting structure will result in I flow to ground through the fault by

When relay is operate when relay will trip all breaker connecting bus.

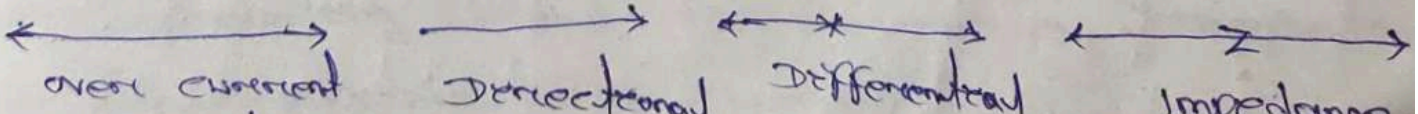
✱ Protection of lines:

Requirement line protection:-

1) when short ckt occures, the CB closed to the fault should open, all other CB remaining in closed position.
2) In case nearest CB to the fault fails to open, back up protection should be provided by the adjacent CB.
3) The relay operating time should be short as possible as

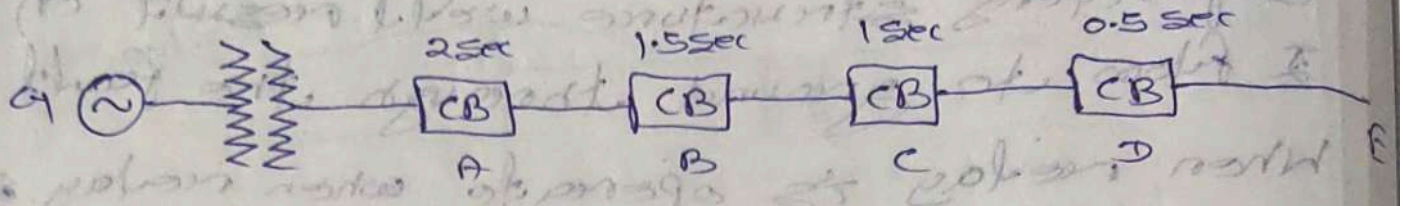
✱ Common methods of line protections:-

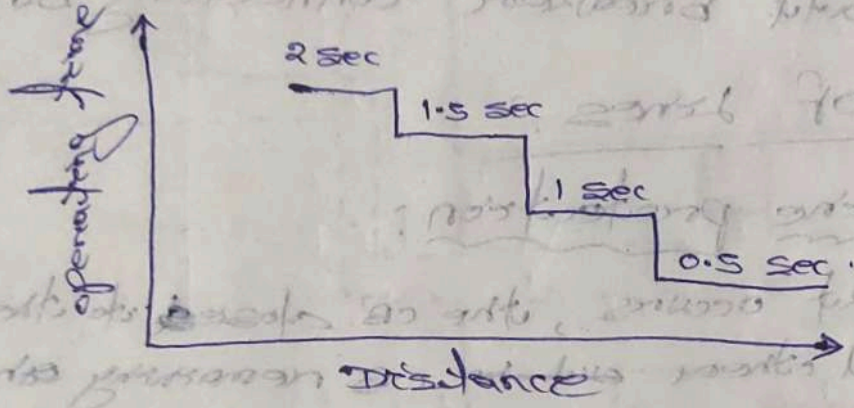
1) Time graded over I protection.
2) Differential protection
3) Distance protection



Time Graded over-current protection :-

* Radial feeder :-





→ Here power flows only in one direction i.e. generator or supply to the load.

DES - advantage

Continuity of supply cannot be maintained.

→ Time graded protection is of two types

i) Definate time relay

ii) Inverse time relay

Dt: 21.05.22.

① Definate time relay:

Time of operation in each relay is fixed.

⇒ It is independent of fault current.

⇒ Relay 'D' has an operating time of 0.5 sec.

⇒ Time relay is successively increase by 0.5 sec.

⇒ If a fault current occurs in the section DE.

⇒ It would be ~~3 order~~ cleared 0.5 sec by the relay & CB at point D.

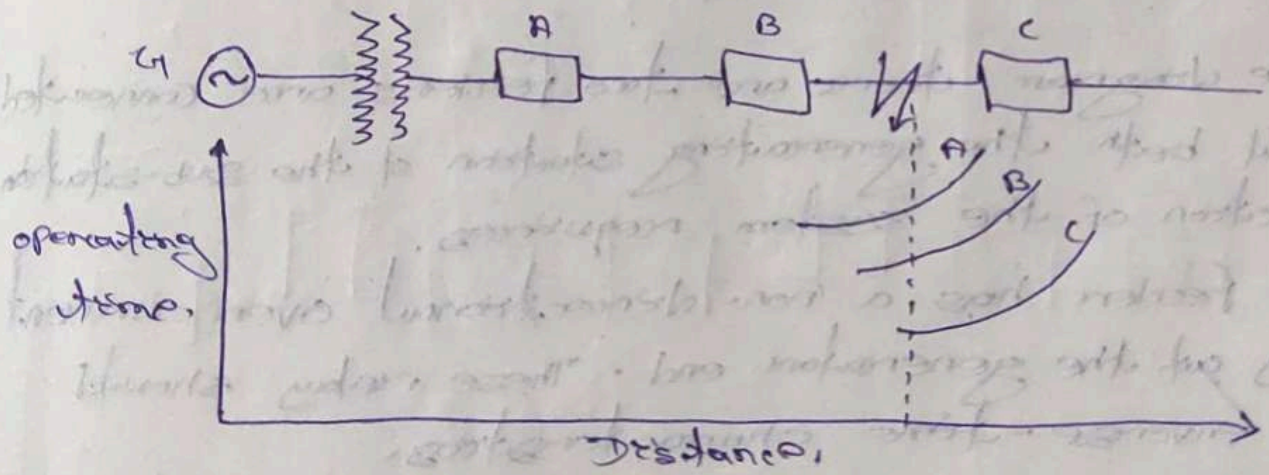
⇒ If the relay at D, phase to trip, relay at CB will operate after the time relay of 0.5 sec.

DTs - Advantages:

⇒ If there are a no. of feeders in series, the tripping time for fault near the supply ends becomes high i.e 2 sec.

⇒ This disadvantages by overcome inverse time relay.

② Inverse time relay:



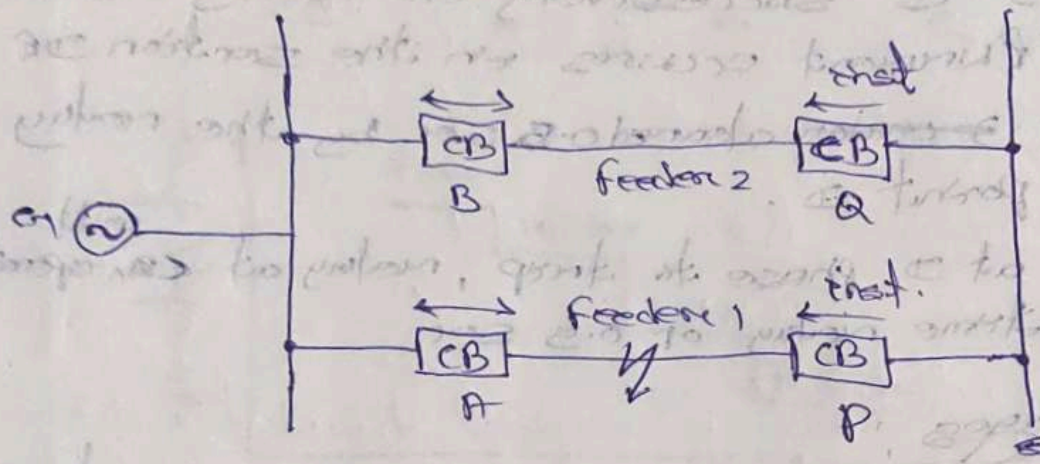
Here operating time is inversely proportional to the operating current.

⇒ Here farther the CB from generating station more is it's relay operating time.

⇒ A fault in BC which given relay trip which would delay to trip out before the breaker act a.

*

Parallel feeder:



It is installed where continuous supply is necessary
⇒ if a fault occurs one one feeder it is disconnected from the system & continuity of the supply from other system.
⇒ Here non-directional over I relay & Directional over I relay is used.

Dt:-26.05.22

⇒ In the diagram there are two feeders are connected in load both the generating station & the sub-station Protection of the system requires.

i) Each feeder has a non-directional over current relay at the generator end. These relay should have inverse-time characteristics.

ii) Each feeder has a reverse power or directional relay at the sub-station end. it should be instantaneous type.

It should operate only when power flows in the reverse direction of arrows

Let earth fault occurs in feeder one

⇒ only CB at A & B should open to clear the fault

⇒ feeder 2 should remain intact to maintain the continuity of supply.

⇒ The shown fault is fed via 2 path.

i) Directly from feeder one via the relay

ii) From feeder on via B, Q & substation

⇒ power flows in relay Q in normal direction

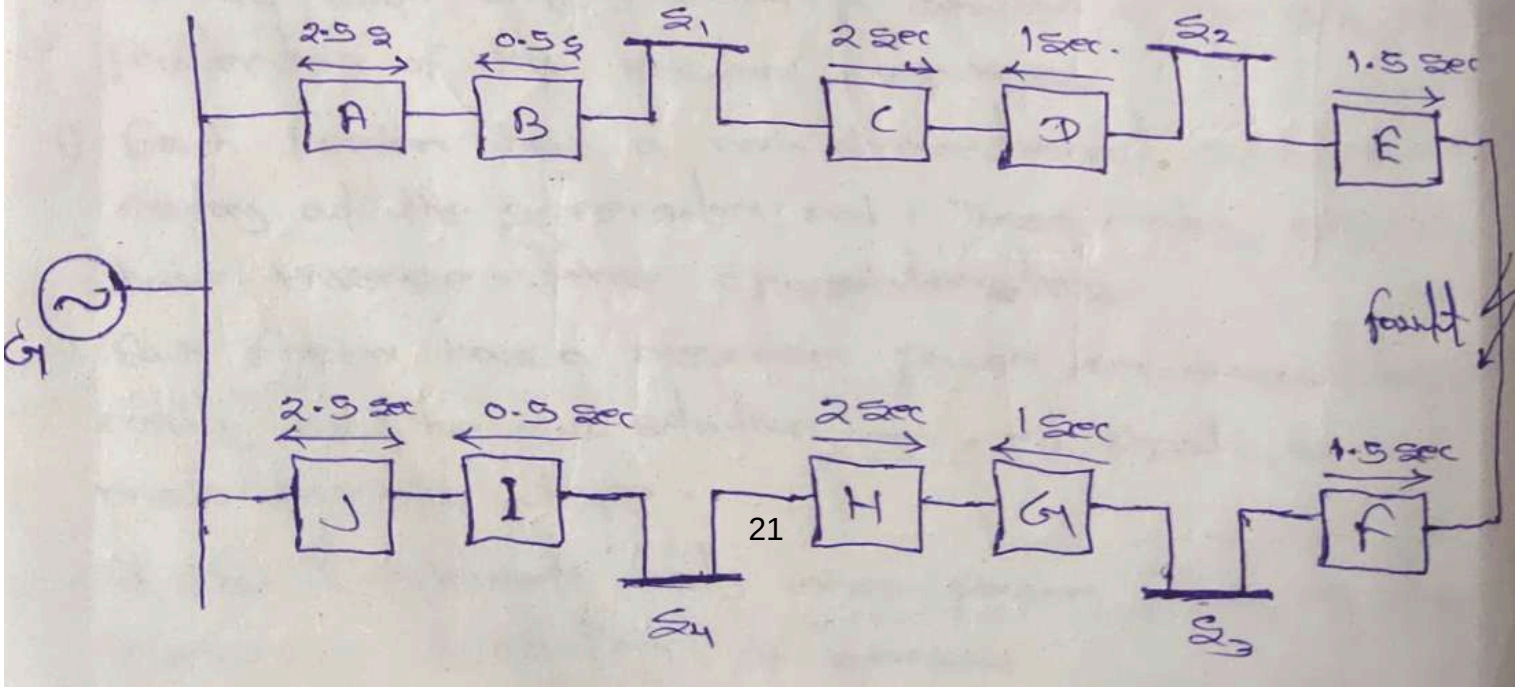
⇒ The power flow is reversed in P.

⇒ This causes the opening of the CB & P.

⇒ Also the relay A will operate, by relay B remains operating.

⇒ because the relay are inverse time characteristic & flowing in relay A is in excess of that flowing relay B, in this way only the faulty feeder is isolated

Ring main system:

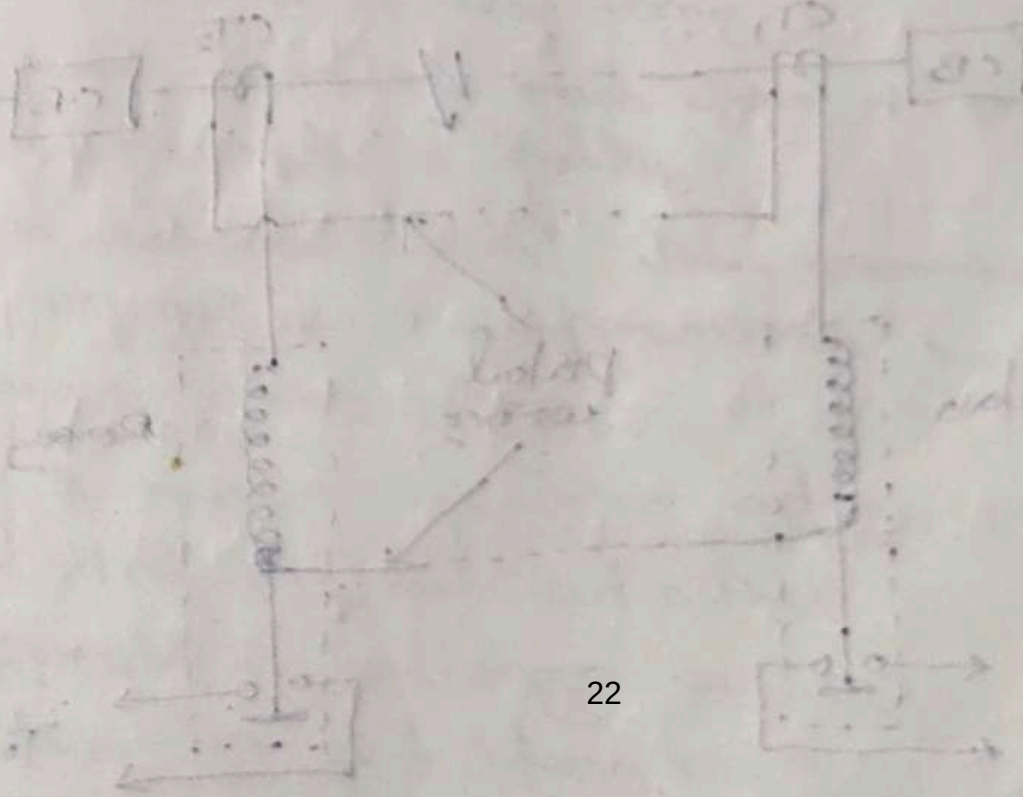


various power station & substation are interconnected by alternation used,

forming a closed relay.

→ In this of the damage any section of the ring that section may be disconnected may be repaired.

→ power will be supply both the ends of relay hence continuity supply is maintain.



Differential pilot wire protection:

Working

Under normal operating cond^n the I entering one end of line that equal to leaving.

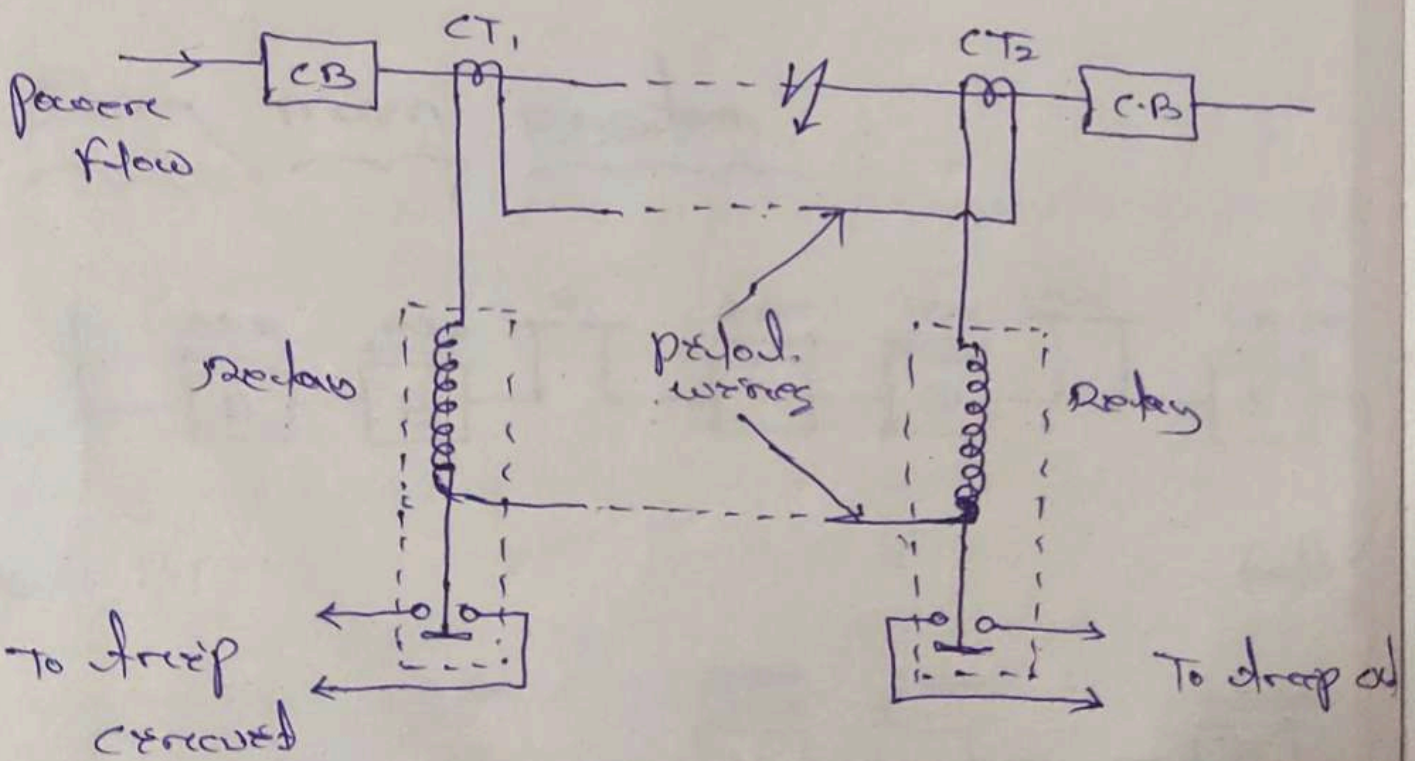
When fault occurs, the difference of incoming & outgoing I is directed flows through the relay, hence operate CB to isolate the faulty

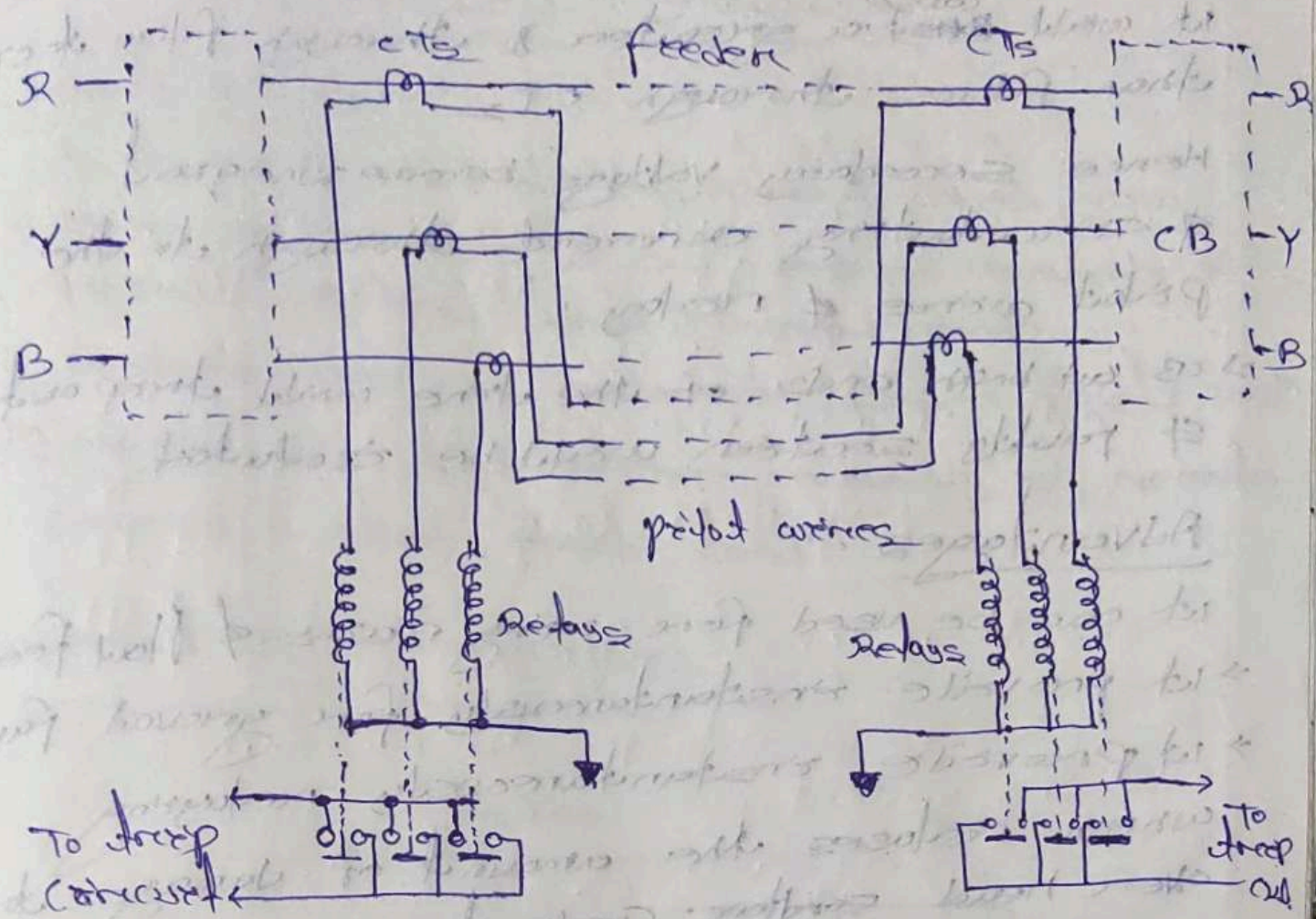
There are 2 schems.

i) Merz-price voltage balance system.

ii) Translate scheme.

i) Merz-price voltage balance system:





→ Identify current T/P are placed in each phase at both ends of the line.

→ The pair of CT is each line is connected in series with a relay.

→ Under normal cond^n the secondary voltages are equal & in opposition hence the balance each other.

→ Hence I entering line at one end is equal to that leaving at at other end hence equal & opposite voltage induced. Secondaries of the CT at two end of line.

hence no I flows through the relay

when fault occurs at point f on the line
it will cause a greater I through flow to CT,
than flows through CT2
Hence secondary voltage become unequal
& circulating current through to the
pilot wire & relay.
⇒ CB at both ends of the line will trip out
& faulty section will be isolated

Advantages:

It can be used for ring mains & flat feeder
⇒ It provide instantaneously for ground fault
⇒ It provide instantaneously relaying
which reduces the amount of damage to
over head conductors.

Its advantages:

Accurate matching of very essential
⇒ Is there is the break in the pilot
wire circuit the system will not operate
⇒ The system very expensive due to the
greater length of pilot wire
⇒ It can not be used for line voltage beyond
33 kV.

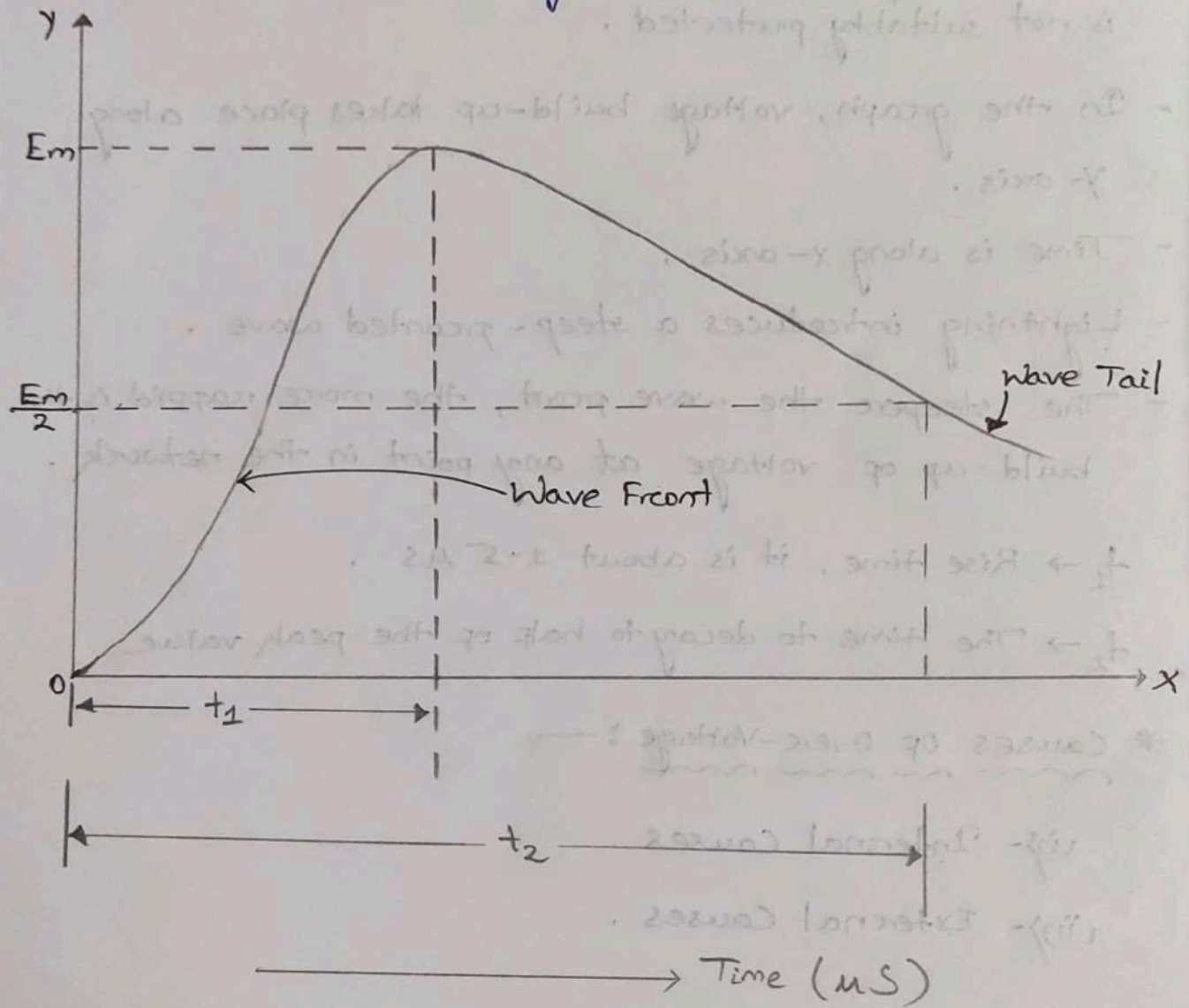
CHAPTER-7

Dt:- 31.03.22

PROTECTION AGAINST OVERVOLTAGES

* VOLTAGE SURGE :—

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



- Transient or surge are of temporary in nature.
- It exists for a very short duration.
- It causes over voltage on the power system.
- When lightning strikes a line, surge rushes along the line.
- Surge causes the line insulator to flashover.
- It damages the near by transformers, generators or other equipment connected to the line if the equipment is not suitably protected.
- In the graph, voltage build-up takes place along y-axis.
- Time is along x-axis.
- Lightning introduces a steep-fronted wave.
- The steeper the wave front, the more rappid is the build-up of voltage at any point in the network.

$t_1 \rightarrow$ Rise time, it is about 1-5 μs.

$t_2 \rightarrow$ The time to decay to half of the peak value

* Causes of Over-Voltage :—

(i)- Internal Causes.

(ii)- External Causes.

(i)- Internal Causes :—

(a)- Switching Surges.

(b)- Insulation Failure.

(c)- Arcing ground.

(d)- Resonance

(ii)- External Causes :—

Lightning.

Dt:- 07.04.22

* LIGHTNING :—

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

- It is a huge spark.
- It takes place when clouds are charged to such a high potential (+ve or -ve) w.r.t earth or neighbour cloud.

Q-1 How Clouds acquire charge ?

During the upsush of warm moist air from earth, the friction between the air and the tiny particles of the water causes the buiding up of charges.

- When drops of water are formed, larger drops become positively charged.
- Smaller drops become negatively charged.
- When the drops of water accumulate, they form clouds.
- Cloud may possess either a positive or negative charge.
- When the charge on the cloud becomes so great that it may discharge to another cloud or to earth.

Q-2 Why thunder accompanies lightning ?

Ans :- Lightning suddenly heats up the air, there by causing the air to expand.

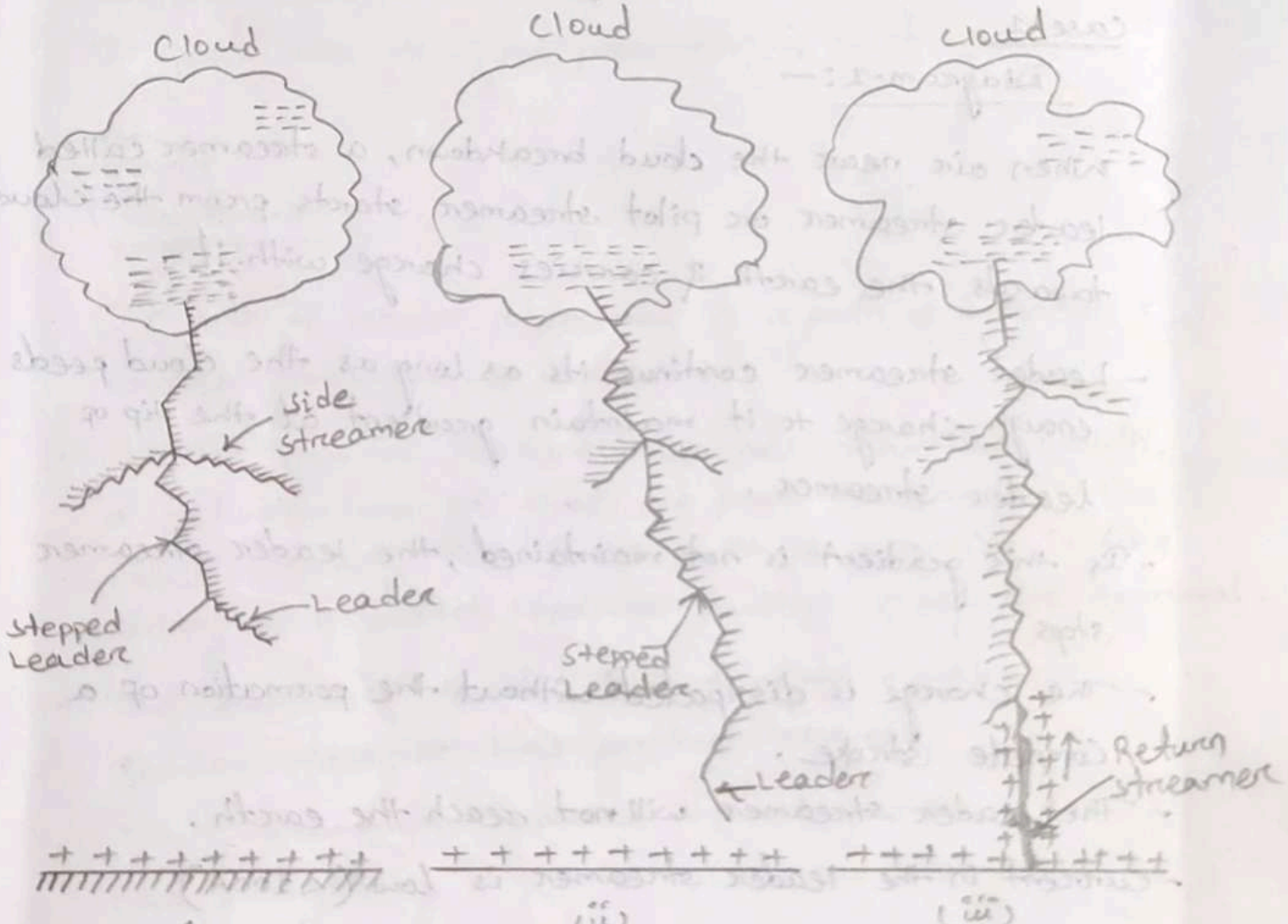
- The surrounding air pushes the expanded air back and forth causing the wave motion of air which is called thunder.

Q-3 Which occures first thunder or lightning & Why ?

Ans :- Lightning occures first because velocity of light is greater than velocity of sound.

3×10^8 m/sec

* MECHANISM OF LIGHTNING DISCHARGE :—



- When a charge cloud passes over the earth, it induces equal and opposite charge on the earth below.
- In the diagram negatively charged cloud inducing a positive charge on the earth below it.
- As the charge acquired by the cloud increases, the potential between cloud & earth increases, hence voltage gradient increases.
- When the potential gradient is sufficient (5KV/c.m to 10KV/c.m) to breakdown the surrounding air, hence lightning stroke starts.
- The stroke mechanism is given under,

Case-1

Diagram-1:-

When air near the cloud breakdown, a streamer called leader streamer or pilot streamer starts from the cloud towards the earth & carries charge with it.

- Leader streamer continue its as long as the cloud feeds enough charge to it maintain gradient at the tip of leader streamer.
- If this gradient is not maintained, the leader streamer stops.
- The charge is dissipated without the formation of a complete stroke.
- The leader streamer will not reach the earth.
- Current in the leader streamer is low (< 100A)
- Luminosity is leader very low.

case-2

Diagram-2

If the leader streamer continues its journey towards earth until it makes contact with earth or any object on the earth.

- As the leader streamer moves towards earth, it is accompanied by points of luminescence which travel in jumps giving raise to stepped leaders.
- Velocity of stepped leader exceeds one-sixth of that of light.
- Distance travelled in one step is about 50m.
- Stepped leaders have sufficient luminosity.
- It gives rise to visual phenomenon of discharge.

case-3

Diagram-3

- The path of leader streamer is a path of ionisation & complete breakdown of insulation.
- As the leader streamer reaches near the earth, a return streamer shoots up from the earth to the cloud, following the same path, this action is like closing of a switch between positive & negative terminal.
- The downward leader having negative charge.
- Return streamer has positive charge.
- This phenomenon causes a sudden spark which is called lightning.

* Notes About Lightning Discharge :—

(a)- Lightning discharge appears to the eye as a single flash, this single flash is made up no. of strokes.

(b)- 87% of all lightning strokes result from negatively charged cloud & 13% originate from positively charged clouds.

(c)- 100 lightning strokes occur per second.

(d)- Lightning discharge may have currents in the range of 10KA to 90KA.

Dt:- 08.04.22

* Types Of Lightning strokes :—

It is of 2 types,

(i)- Direct stroke

(ii)- Indirect stroke

(i)- Direct stroke :-

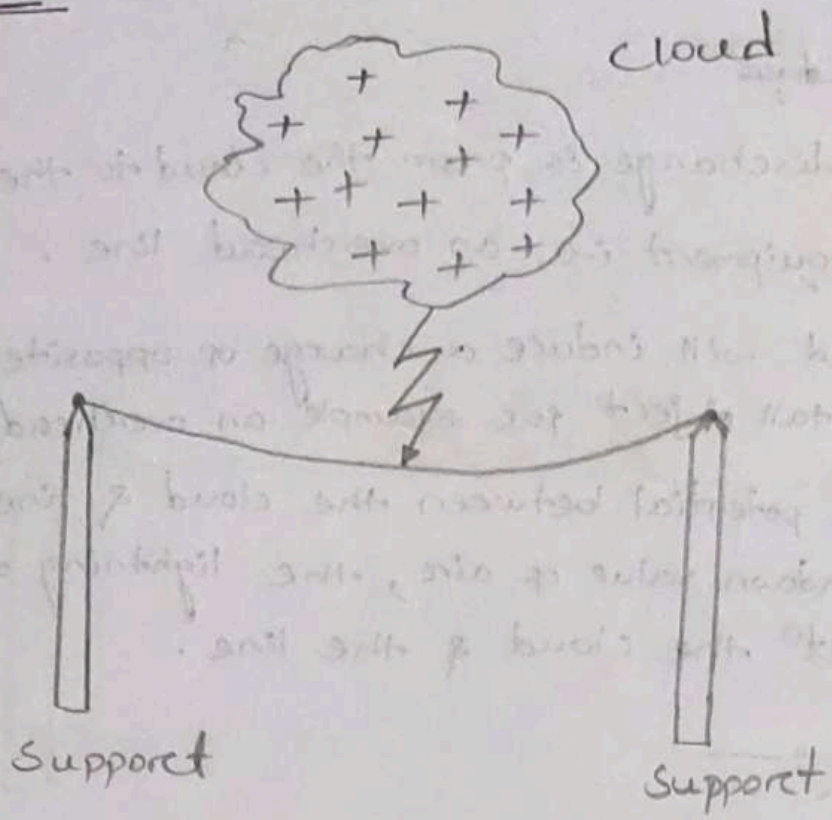
Here, the lightning discharge i.e., current path is directly from the cloud to the subject equipment, for example, an overhead line.

- From the line, the current path may be over the insulators down the pole to the ground.
- Over voltages setup due to stroke may be large enough to flash-over, this path directly to the ground.
- Direct strokes are of 2 types,

(a)- Stroke A.

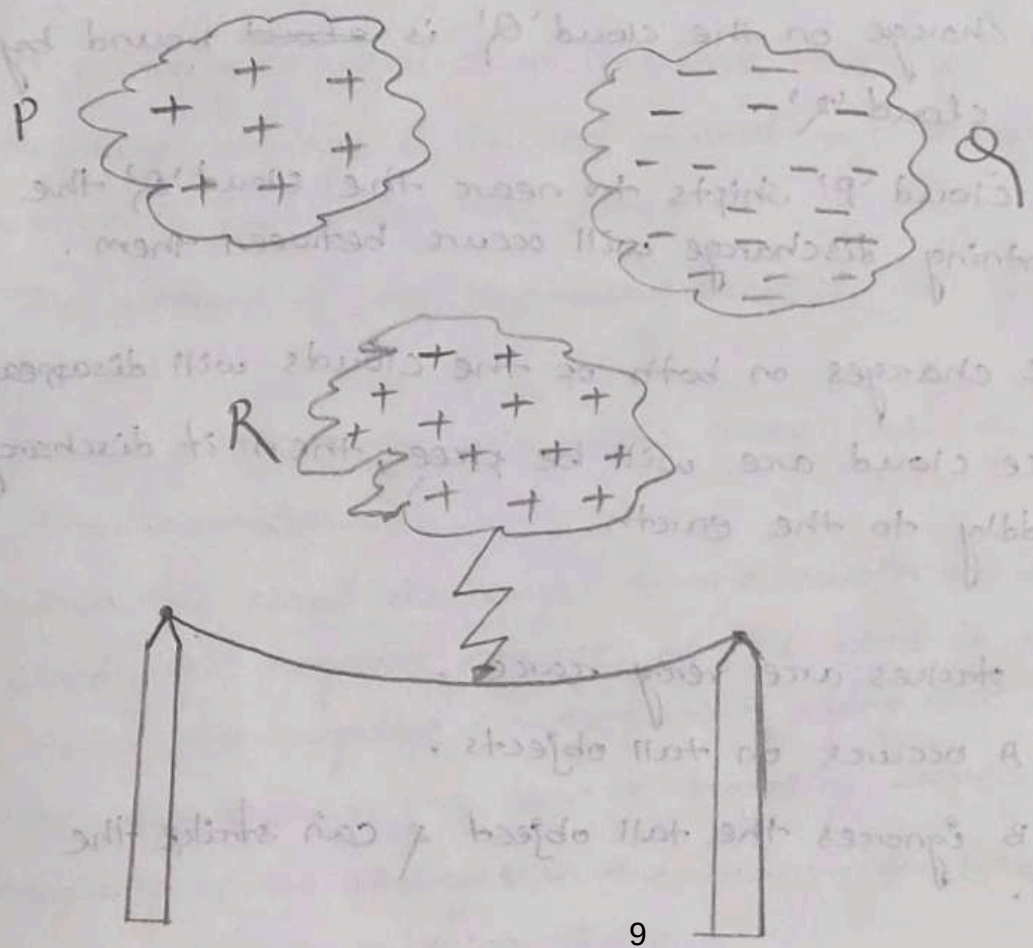
(b)- Stroke B.

Case-1



(i)

Case-2



(ii)

(a)- Stroke A :—

~~Lightning is of~~

Lightning discharge is from the cloud to the subject equipment i-e, an overhead line.

- The cloud will induce a charge of opposite sign on the tall object for example an overhead line.
- When the potential between the cloud & line exceeds the breakdown value of air, the lightning discharge occurs bet^n the cloud & the line.

(b)- Stroke B :—

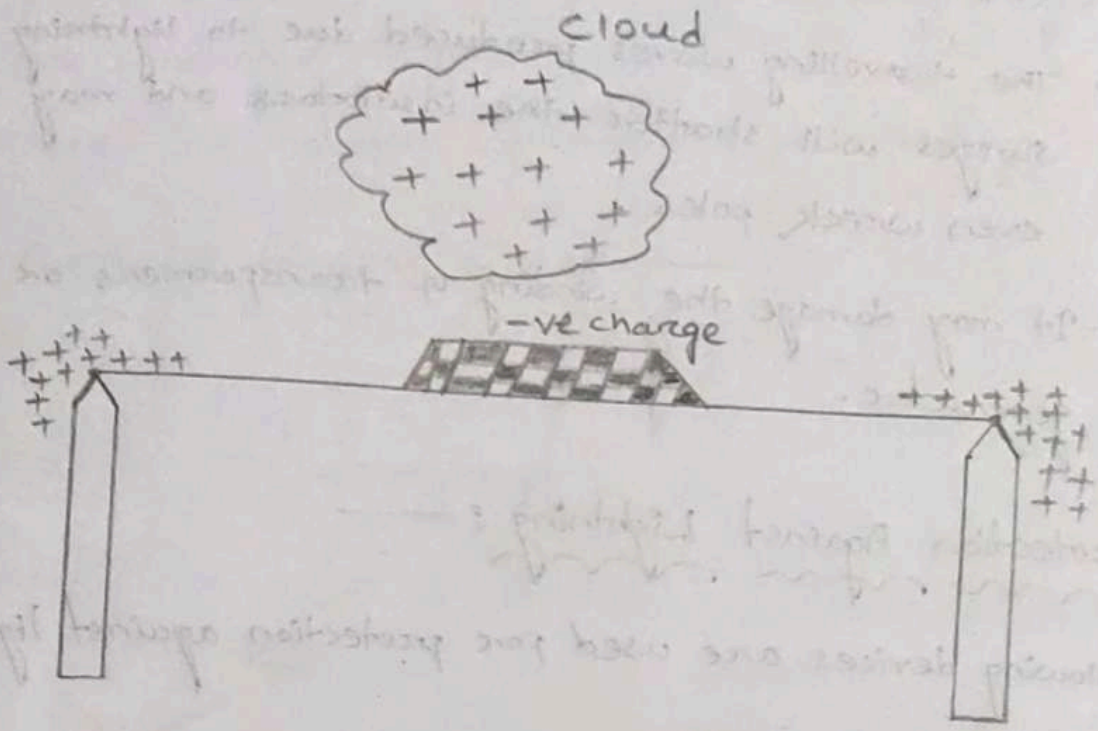
There are 3 clouds P, Q & R having +ve, -ve & +ve charge respectively.

- The charge on the cloud 'Q' is ~~about~~ bound by the cloud 'R'.
- If, cloud 'P' shifts too near the cloud 'Q' the lightning discharge will occur between them.
- Hence charges on both of the clouds will disappear.
- Hence cloud are will be free, then it discharges rapiddly to the earth.

Notes :-

* Direct strokes are very rare.
* Stroke A occurs on tall objects.
* stroke B ignores the tall object & can strike the ground.

(ii)- Indirect stroke :—



- It results from the electrostatically induced charges on the conductors due to the presence of charged clouds.
- A positively charged cloud is above the line.
- Negative charge is induced on that portion of the line which is just under the cloud.
- The portions of the line away from it, will be positively charged.
- This +ve charge will leaks slowly into the earth via the insulators.
- When the cloud discharges to the earth or to another cloud, the negative charge on the wire is isolated. Hence the negative charges rush along the line in both the directions in the form of travelling waves.
- Majority of the charges in the transmission line are caused by indirect lightning stroke.

* Harmful Effects Of Lightning :—

(i)- The travelling waves produced due to lightning surges will shatter the insulators and may even wreck poles.

(ii)- It may damage the winding of transformers or generators.

* Protection Against Lightning :—

Following devices are used for protection against lightning surges,

(i)- Earthing screen.

(ii)- Overhead ground Wires.

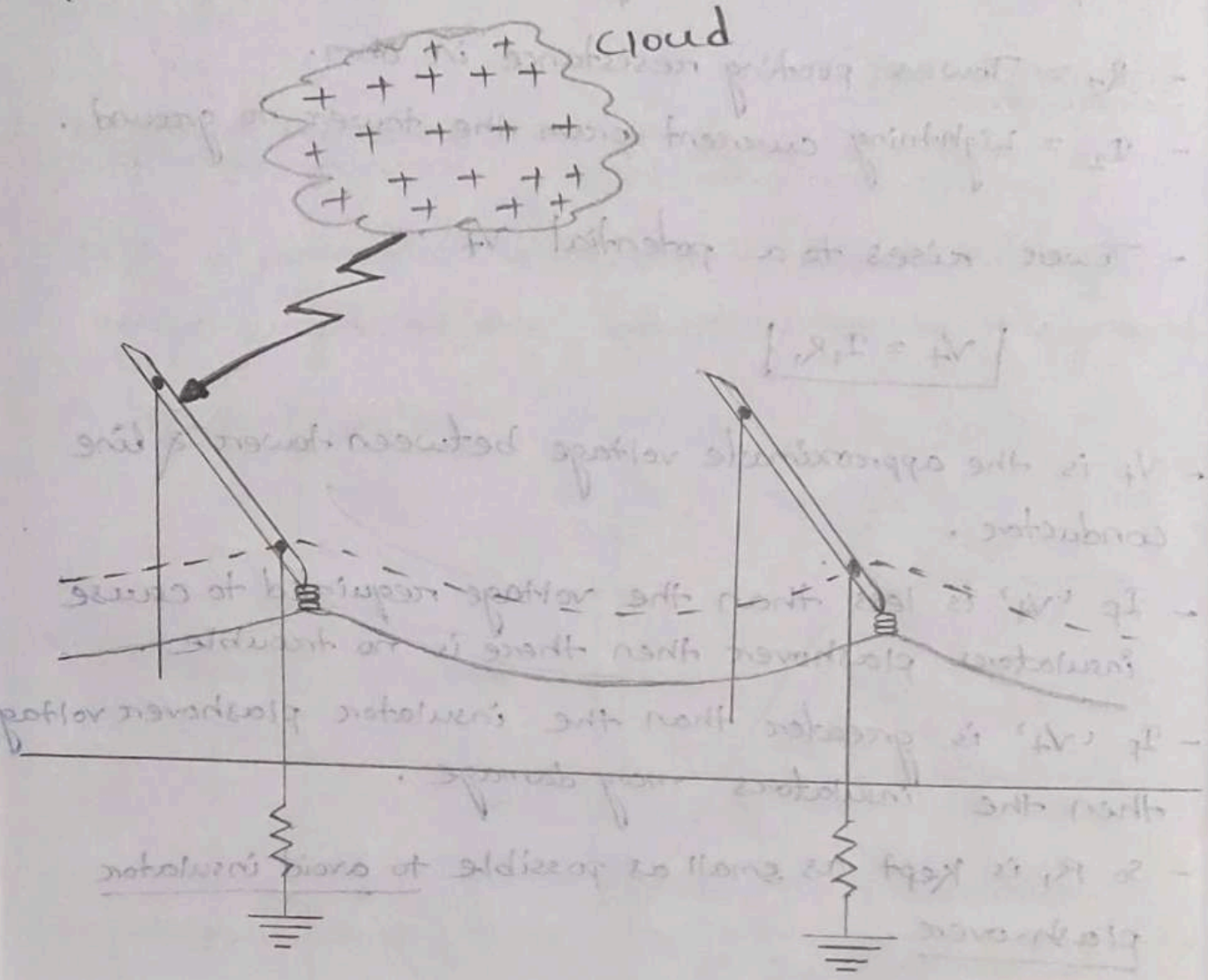
(iii)- Lightning arresters or surge diverters.

* Earthing Screen :—

- The power station & substation houses expensive equipments.
- These stations can be protected against direct lightning strokes by providing earthing screen.
- It consists of a network of copper conductors mounted all over the electrical equipment in the substations or power station.
- This shield is properly connected to earth on at least two points through a low impedance.

- On the occurance of direct stroke on the station, screen provides a low resistance path by which lightning surges are conducted to ground.
- Hence the station equipment is protected against damage.

* Overhead Ground Wires :—



- In the diagram, the ground wire is placed above the line conductors at such position that all lightning strokes intercepted by the ground wires.
- The ground wires are grounded at each tower or pole through low resistance.

- Due to their proper location, the ground wires will take up all the lightning strokes instead of allowing them to the line conductors.

- Degree of protection provided by the ground wires depends upon the footing resistance of the tower.

- R_1 = Tower footing resistance in ohm.
- I_1 = Lightning current from the tower to ground.
- Tower rises to a potential V_t.

$$V_t = I_1 R_1$$

- V_t is the approximate voltage between tower & line conductor.
- If 'V_t' is less than the voltage required to cause insulators flashover then there is no trouble.
- If 'V_t' is greater than the insulator flashover voltage then the insulators may damage.
- So R_1 is kept as small as possible to avoid insulator flash-over.

Advantages :—

(i)- It protects against direct lightning strokes on transmission lines.

(ii)- It provides electrostatic shielding against external fields.

- In the diagram, lightning arrester consists of a spark gap in series with a non-linear resistor.
- One end of the diverter is connected to the terminal of the equipment to be protected.
- Other end is grounded.
- Length of the gap is so set that normal line voltage is not enough to cause an arc across the gap, but a dengerously high voltage will break-down the air insulation and form an arc.

Property Of Non-linear Resistance :—

Its resistance will decrease with increase in voltage or current & vice-versa.

Action :—

(i)- Under normal condition, the lightning arrester is off the line i.e, it conducts no current to earth or the gap is non-conducting.

(ii)- When the fault occurs air insulation breaks-down and an arc is formed, providing a low resistance path for the surge to the ground.

(iii)- As the gap sparcks over due to over voltage, the arc will be short-circuit on the power system. It may cause power flow current in the arrester.

(iv)- Non-linear resistor offers low resistance to high voltage it prevents the effect of short circuit.

(v)- When the surge is over, the resistor offers high resistance to make the gap non-conducting.

* TYPES OF LIGHTNING ARRESTERS :—

(1)- Rod Gap Arrester.

(2)- Horn Gap Arrester.

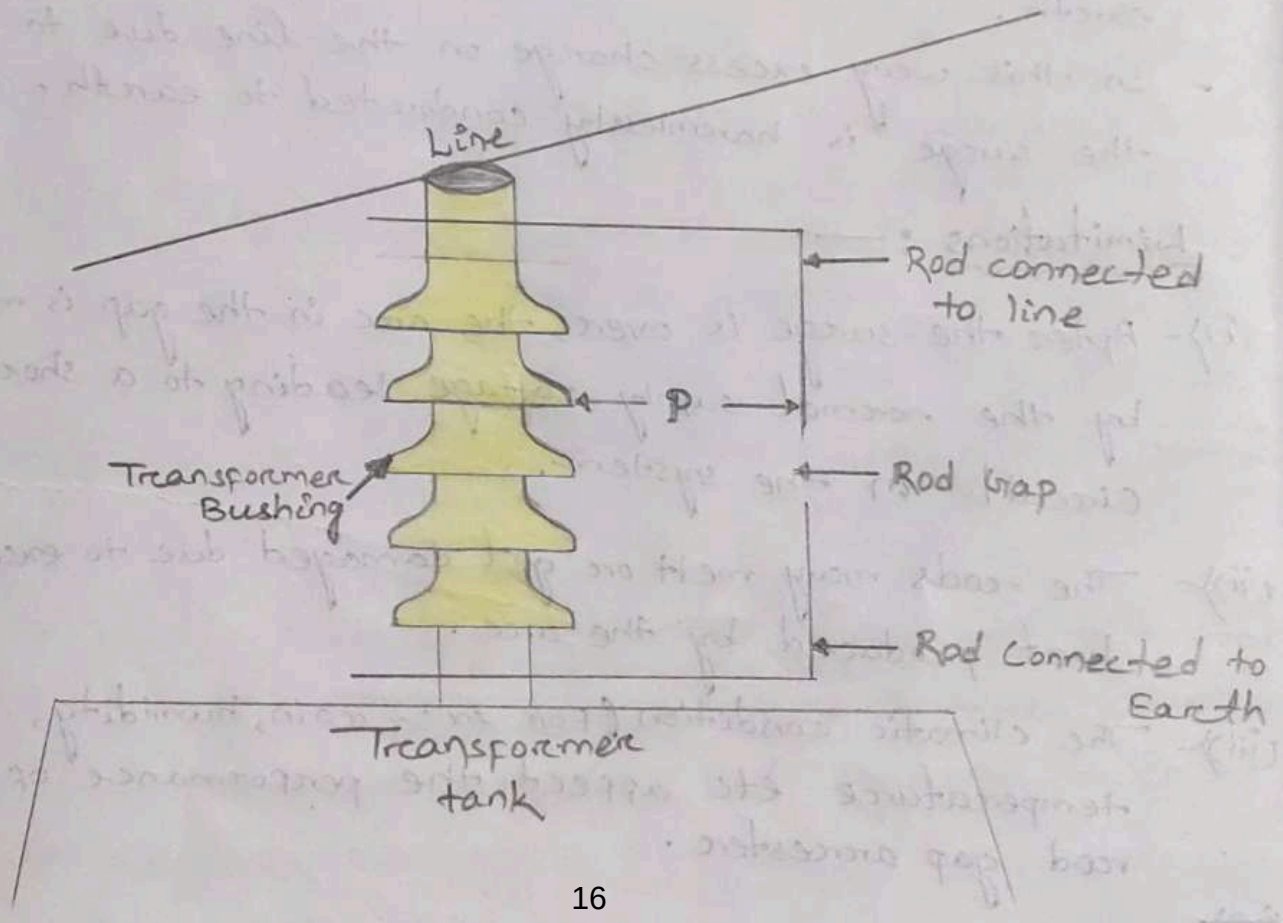
(3)- Multi Gap Arrester.

(4)- Expulsion Type Lightning Arrester.

(5)- Valve Type Lightning Arrester.

Dt:- 21.04.22

(1)- Rod Gap Arrester :—



- It is a very simple type of diverter.
- It consists of two 1.5 c.m rods.
- These rods are between at right angles with a gap in between.
- One rod is connected to the line circuit and the other rod is connected to earth.
- The distance between the gap & insulator i.e., distance P must be less than one-third of the gap length, so that the arc may not reach the insulator & damage it.
- Under normal operating condition gap remains non-conducting.
- When high voltage occurs on the line, the gap sparks over & the surge current is conducted to earth.
- In this way excess charge on the line due to the surge is harmlessly conducted to earth.

Limitations :—

(i)- After the surge is over, the arc in the gap is maintained by the normal supply voltage leading to a short-circuit on the system.

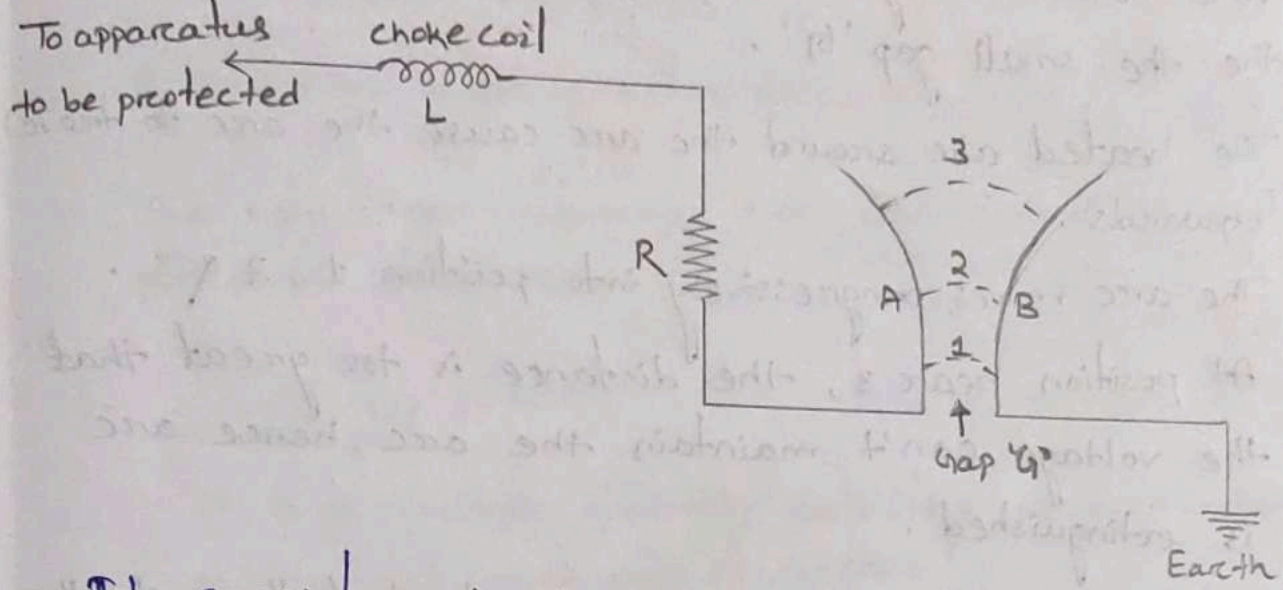
(ii)- The rods may melt or get damaged due to excessive heat produced by the arc.

(iii)- The climatic condition (For ex :- rain, humidity, temperature etc affect the performance of rod gap arrester.

Note :—

Rod gap arrester is used as back-up protection.

(2)- Horn Gap Arrester :—



- It consist of two horn shaped metal rods A & B, separated by a small air gap.
- The horns are so constructed that distance between them gradually increases towards the top.
- The horns are mounted on porcelain insulators.
- One end of horn is connected to the line through a resistance 'R' & choke coil 'L', other end is effectively grounded.
- 'R' helps in limiting the flow of current to a small value.
- The choke coil is so designed that it offers small reactance at normal power frequency but high reactance at high ~~for~~ frequency.

- The gap between horns is so adjusted that the normal supply voltage is not enough to cause an arc cross the gap.
- Under normal condition the gap is non-conducting.
- When over voltage occurs spark over takes place across the the small gap 'G'.
- The heated air around the arc cause the arc to travel upwards.
- The arc moves progressively into position 1, 2 & 3.
- At position near 3, the distance is too great that the voltage can't maintain the arc, hence arc is extinguished.
- Excess charge on the line is conducted through the arrester to the ground.

Advantages

(i)- The arc is self clearing.

(ii)- Resistance helps in limiting the current to a small value.

Disadvantages :-

(i) - The bridging of gap by some external agency like birds can make the device useless.

(ii)- The setting of horn gap is ~~tightly~~ likely to change due to corrosion or pitting.

(iii)- It adversly affects the performance of arresters.

(3)- Valve Type Arrester :—

- It incorporate non-linear resistors and used on systems operating at high voltages.
- It consists of two assemblies,
  (i)- Series spark gaps.
  & (ii)- Non-linear resistor discs in series.
- The non-linear elements are connected in tight porcelain container.

(i)- Spark Gap :—

- It is a multiple assembly consisting of a number of identical spark gaps in series.
- Each gap consists of two electrodes with a fixed gap spacing.
- The voltage distribution across the gap is linearised by means of additional resistance elements called grading resistor across the gap.
- The spacing is such that it will withstand the normal circuit voltage.
- Hence an over voltage will cause the gap to break-down causing the surge current to the ground, through non-linear resistors.

(ii) - Non-linear Resistors :—

- It is made up of an inorganic compound like metrosil or thyrite.
- These discs are connected in series.
- It offers high resistance to the current flow under normal system.
- It offers low resistance to the flow of high surge currents.

Working :—

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

- When over voltage occurs, the breakdown of the series gap takes place.
- Surge current is conducted to earth.

Advantages :—

(i) - It provides effective protection against surges.

(ii) - It operate very rapidly less than a second.

Disadvantage :—

Its performance is adversly affected by the entry of moisture into ~~enclosure~~ enclosure.

Applications :—

Two type applications, •

(i)- Station type

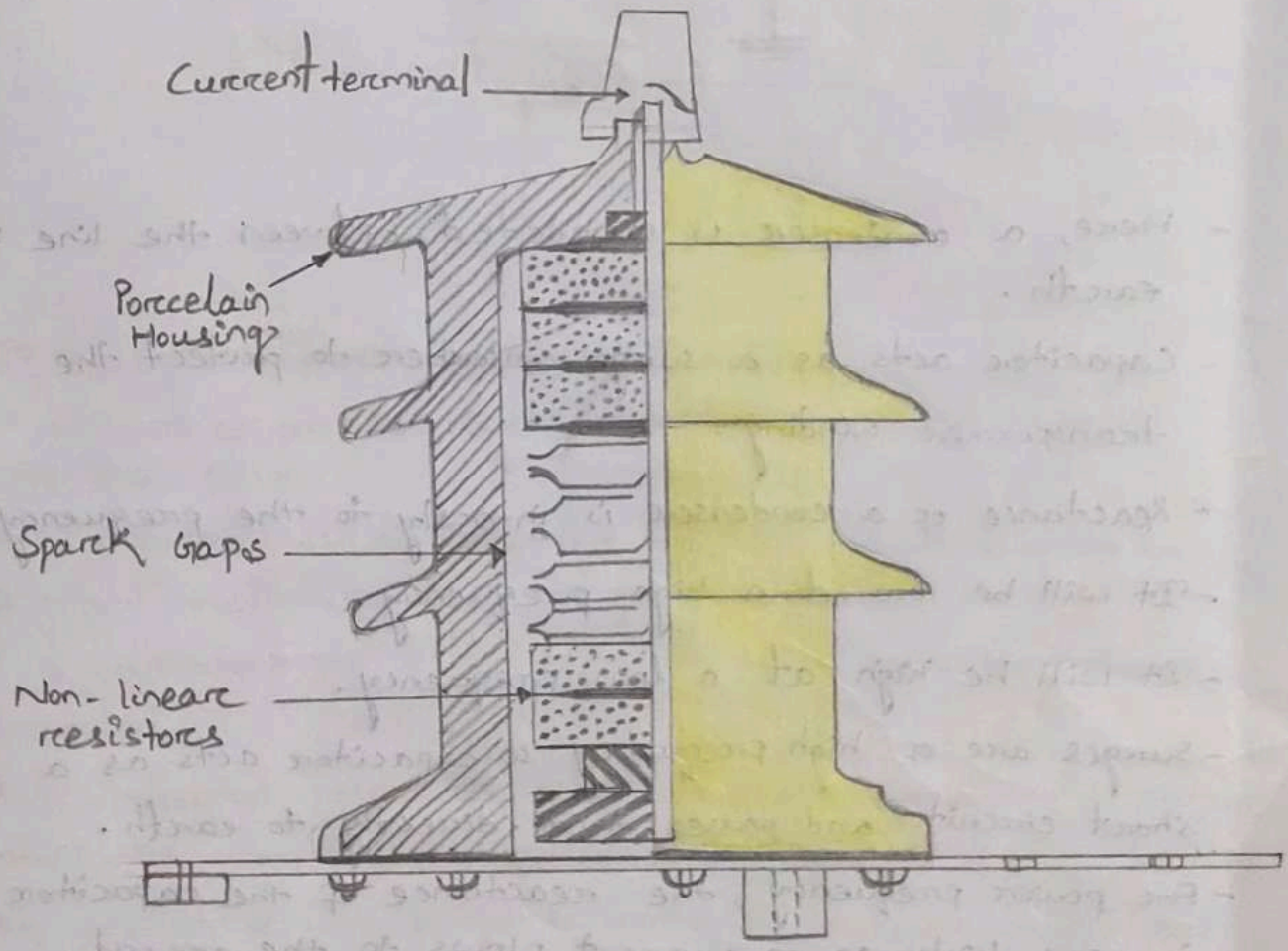
(ii)- Line type.

(i)- **station type :—**

Protection of equipments operating on voltage upto 220 KV or higher.

(ii)- **Line type :—**

It is used of stations handling of 66 KV.



[VALVE TYPE ARRESTER]

Dt:- 22.04.22

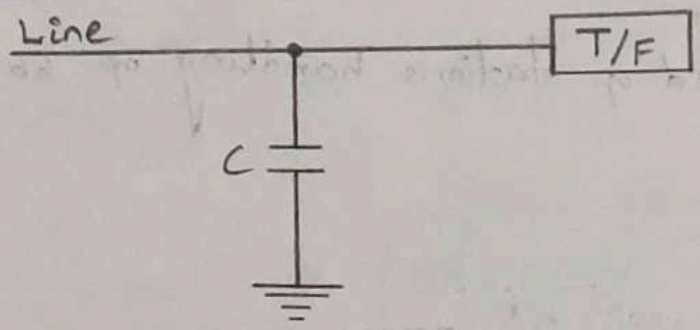
* SURGE ABSORBER :—

It is a protective device which reduces the steepness of wave front of a surge by absorbing surge energy.

- Surge diverter diverts the surge to earth but the surge absorber absorbs the energy.

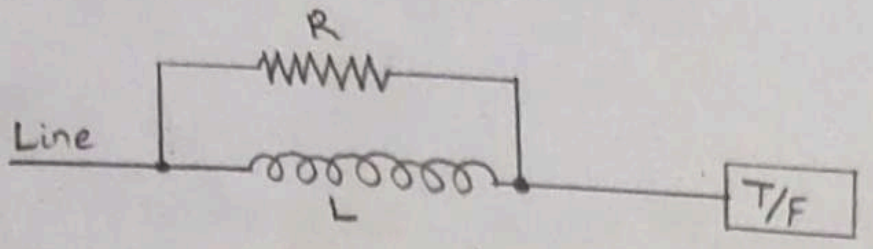
Few Examples,

Ex-1



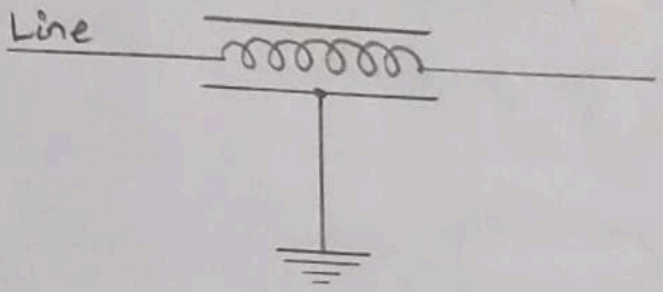
- Here, a condenser is connected between the line & earth.
- Capacitor acts as a surge absorber to protect the transformer winding.
- Reactance of a condenser is inversly to the frequency.
- It will be low at a high frequency.
- It will be high at a low frequency.
- Surges are of high frequency so capacitor acts as a short circuit and passes them directly to earth.
- For power frequency, the reactance of the capacitor is very high so no current flows to the ground.

Ex-2



- It consists of a parallel combination of choke and resistance connected in series with the line.
- The choke offers high reactance to surge frequencies ($X_L = 2\pi FL$) so the surges are forced to flow through the resistance 'R', where they are dissipated.

Ex-3



- It is called Ferranti surge absorber.
- It consists of an air cored inductor connected in series with the line.
- The inductor is surrounded by but insulated from an earthed metallic sheet called dissipator.
- It is equivalent to a transformer with secondary short circuited.
- The inductor forms the primary & the ~~secondary~~ dissipator forms the short circuited secondary.
- The energy of the surge is used of in the form of heat generated in the dissipator due to the transformer action.

- This type of surge absorber is used for the protection of transformers.

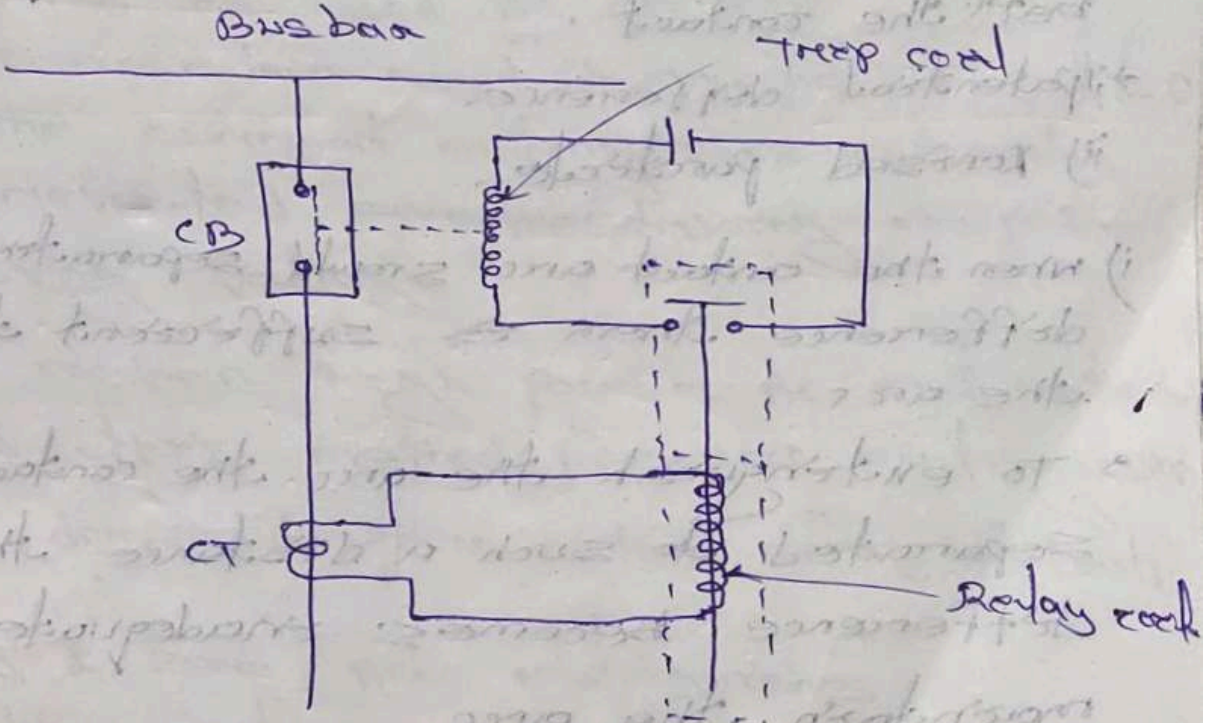
chapter

Circuit Breakers

What is CB

It is a piece of equipment which can
i) Make or breake a ckt either manually / remote control under normal cond^n.
ii) Breake the ckt automatic under fault cond^n
iii) Make the ckt either manually & remote control under fault cond^n

operating principle:



Arc phenomenon.

dt:- 27.05.22

During the working period, the I flowing beth the contact depends upon the arc resista greater the arc resistance, smaller the I Arc resistance depends upon the following factor

i) Degree of ionisation
ii) Length of the arc
iii) Cross-section of arc

$R = \rho \frac{l}{a}$

R ↑ l ↑

R ↑ a ↓

Prenciple of arc extinction:

Two factors responsible for the maintanance of arc beth the contact.

i) potential difference
ii) Ionised particle.

) when the contact are small separation, potential difference there is sufficient to maintain the arc

To extinguish the arc the contact are separated to such a distance that potential difference becomes inadequate to maintain the arc.

Ionised particle tend to maintain the arc here arc is extinguished by deionisation of the arcing pared

Methods of Arc extinction:

i) High resistance method.
ii) Low resistance or current zero method

i) High resistance method:

- Lengthening the arc
- Pulling the arc
- Reducing cross section of the arc.
- Splitting the arc.

ii) Low resistance or current zero method

- This method is used AC circuit
- Here arc resistance kept low until current is 0
- Where the current extinguishes naturally & is prevented restriking inspite of rising voltage.
- All the modern high power AC ckt method employed this method for arc extinction
- Current drops to zero after every half cycle.
- At every I zero, Arc extinguishes.
- Now medium contains ions & electrons, so that it has small dielectric strength.
- It can be easily broken down restriking voltage is known as re-striking voltage.
- If such a breakdown occurs arc would persist for another cycle. So after I zero, the dielectric strength of the medium has

contacts it build of more than the voltage across the contacts.

* When arc fails to restrike, current is interrupted.

* Dielectric strength can be increased:

i) causing the ionizing particle to recombine into neutral molecules.

ii) keeping the ionizing particle away of them by an ionizing particle.

iii) The de-ionisation of medium can be achieved by

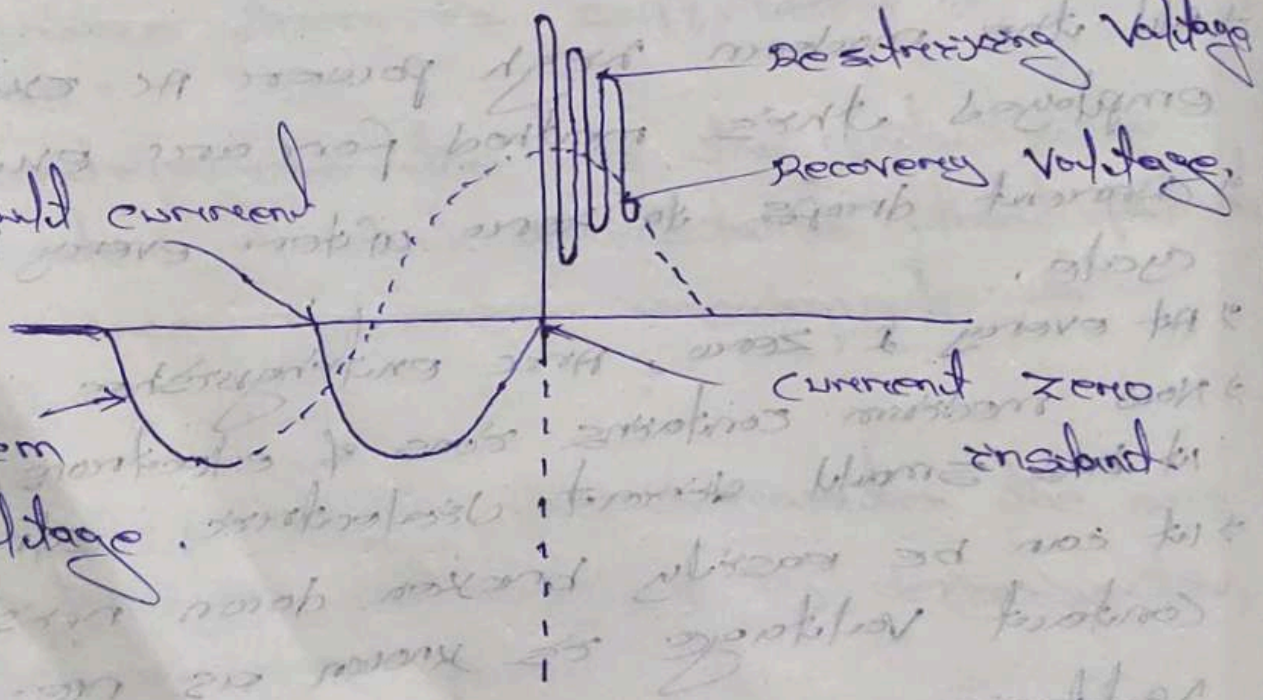
* lengthening of the gap.

ii) High pressure

iii) Cooling.

iv) Blast effect.

* Importance term:



Arc Voltage:

It is the voltage that appears across the contacts of the CB during arcing period

→ Restriking

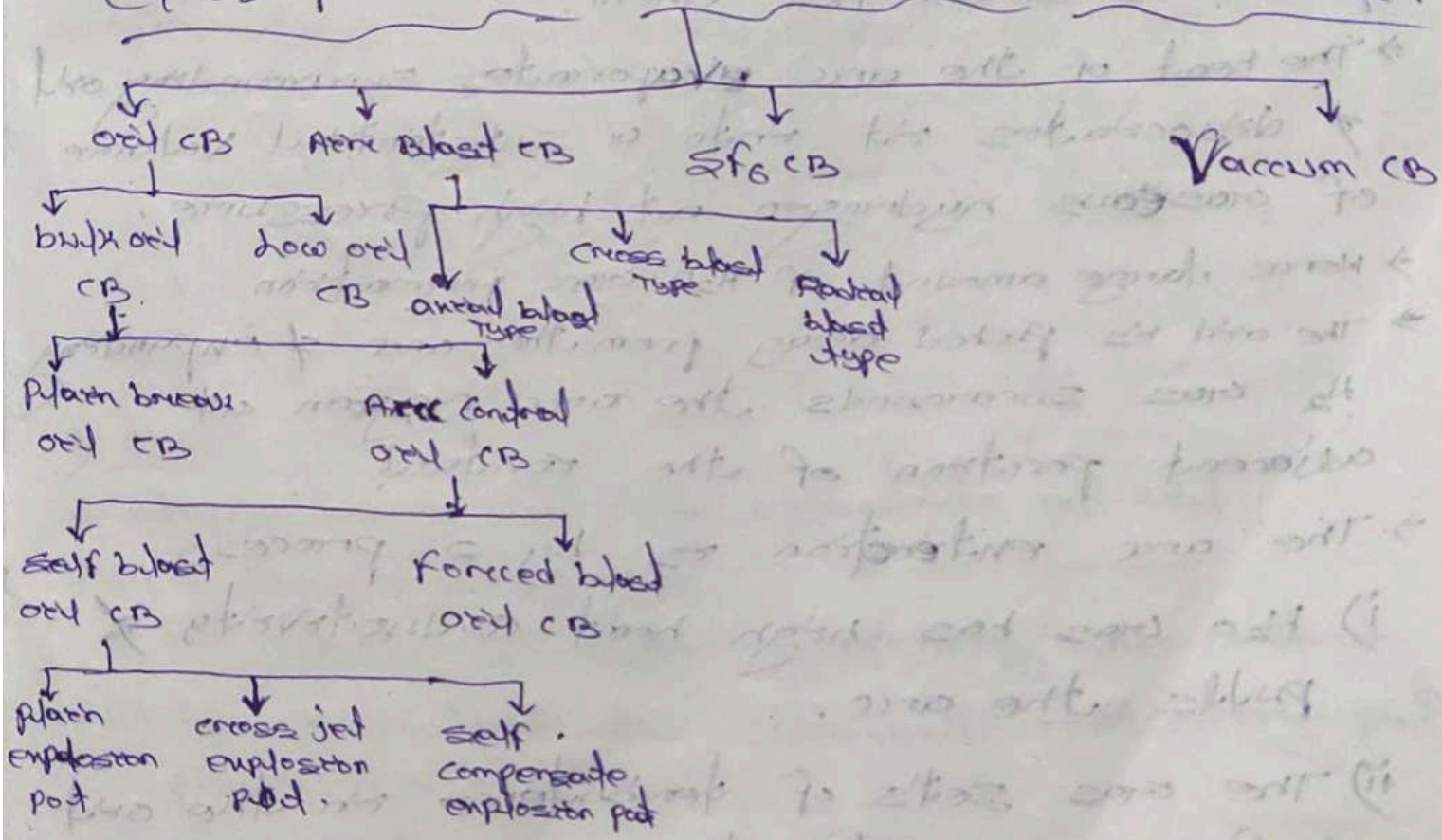
It is the transient voltage that appears across the contacts at a near to zero during arcing period.

Recovery

It is a normal frequency voltage that appears across the contacts of the CB after final arc extinguishes

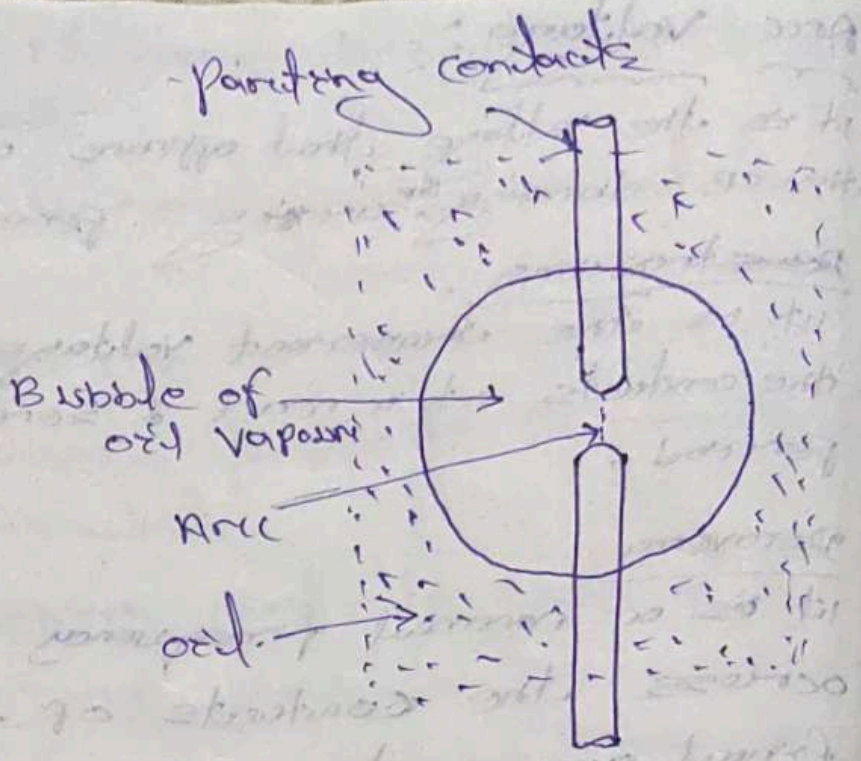
→ It approximately system voltage

Classification of circuit breakers.



Dt:- 28.5.22

Oil CB



→ Here oil is used as arc quenching medium
→ When fault occurs, the contacts are open under oil & arc is struck betn them.
→ The heat of the arc evaporates surrounding oil & dissociates it into a substantial volume of gaseous hydrogen at high pressure.
→ Here large amount of H_2O gas formation
→ The oil is pushed away from the arc & expanding H_2 gas surrounds the arc region at adjacent portion of the contact.
→ The arc extinction is by 2 process
i) H_2O gas has high heat conductivity & pulls the arc.
ii) The gas sets of turbulence in the oil & forces a into the space betn the contacts
Hence it eliminate the arcing produced from the arc path. the arc is extinguish & ckt is interrupted

Advantages:

- ⇒ It absorbs the arc energy to decompose the oil into gases, which are excellent the cooling purpose,
- ⇒ It acts as a insulator & permit small clearance both the conductor & arc component.
- ⇒ The surrounding oil presence cooling surface nearer to the arc.

Disadvantages:

- ⇒ It is inflamable & there is of risk of fire.
- ⇒ It may form an explosive mixture with air.
- ⇒ The arcing product such as carbone removing oil & its qualities deteriorates with successive operation.

Types of oil CB

It is 2 types

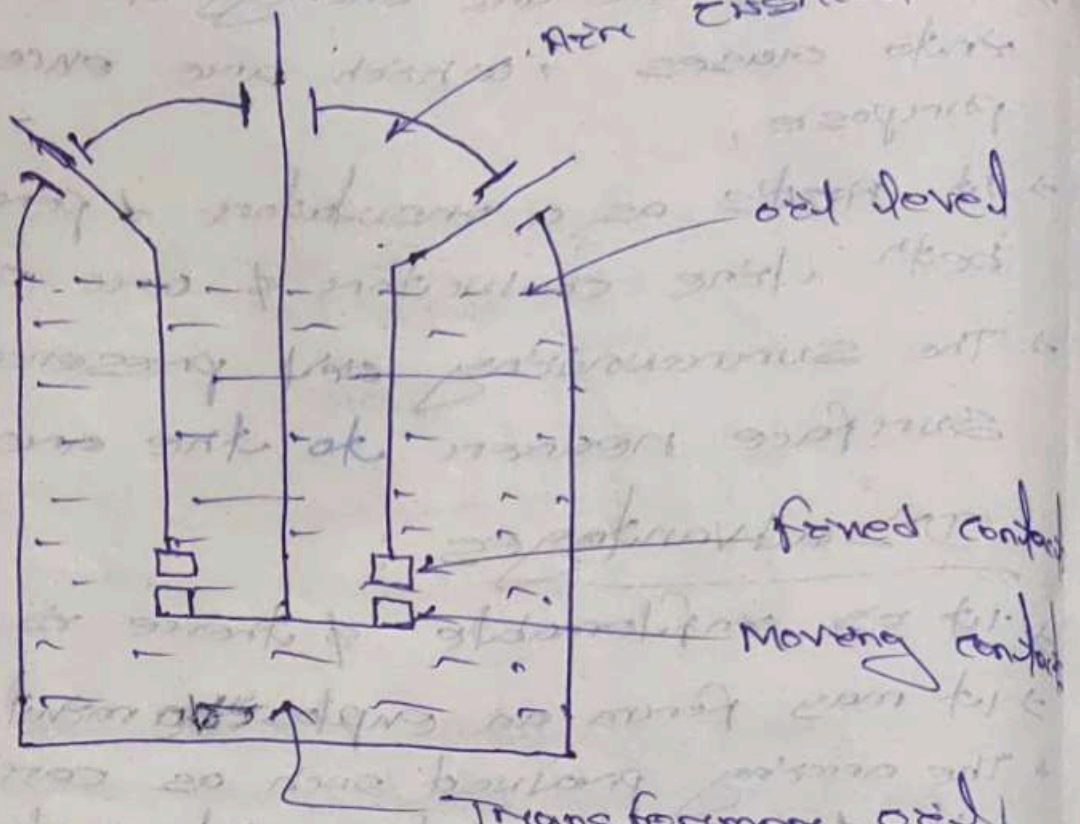
i) Bulk oil CB

2) Low oil CB

1) Bulk oil CB:

- ⇒ It is uses a large quantity of oil.
- ⇒ oil has 2 purposes
  - i) It extinguishes, and opening the contact.
  - ii) It insulate the current conducting path from one another,
- ⇒ It is 2 types
  - i) Plane break oil CB
  - 2) Arc control

i) Plane break oil CB :



⇒ It is the easiest CB
⇒ It has very simple construction.
⇒ It consist of fixed & moving contacts enclosed in a strong weather - tight earthtank containing oil upto a certain level.
⇒ There is an air cushion above the oil.
⇒ Air cushion :
It provide space to allow the reception of arc gases with out generation of unsafe pressure in the dome of the CB
⇒ It absorbs mech. shop of the upcoming normal

Working

Under normal operating cond^n. the fixed or moving contact close & the breaker carries normal cxt I.

⇒ when a fault occures moving contact get the separate by the fixed contact & arc is struck which vaporises of the oil into H_2O gas

dt:- 02.06.2022

* The arc extinguision is facilitated by the following process.

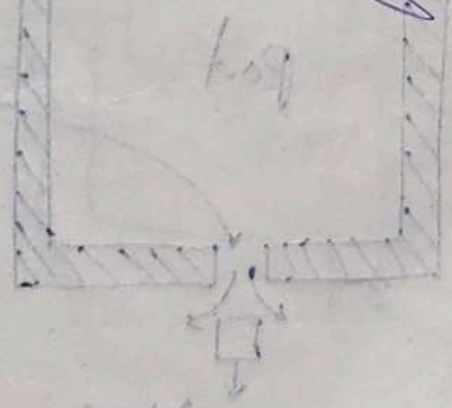
i) The hydrogen gas bubble generated around the arc cools the arc column & helps in deionisation of the medium betn the contacts.

ii) The gas sets up turbulence in the oil & helps in eliminating the arcing product from the arc path.

iii) As the arc lengthens due to the separating contacts, the dielectrics strength of medium is increase.

Disadvantages:

* This breakers have long & inconsistence arc time.
* They do not permit high speed interception.
* It is used for low capacity installation for voltages upto 11kV.



Arc control oil CB:

It is 2 types

1) Self blast oil CB.
2) forced " " ".

i) Self blast oil CB is 3 types

i) Plain explosion pot
ii) Cross jet " "
iii) Self compensate " "

1) Self blast oil CB:

Here gases produce during arcing arc confine to a small volume by the use of an insulating rigid pressure chamber or pot. surrounding the contact.

→ since the arc gases are restricted by the chamber, a very high pressure is developed to forced the oil & gas through the around the arc extinguished.

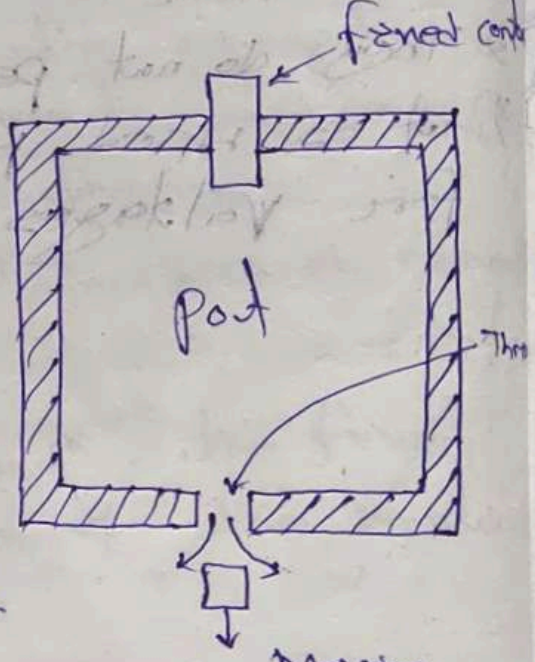
→ As the pressure is generated by the arc itself, such breakers are called self blast oil CB.

i) Plain explosion pot:

It is a rigid cylinder of insulating material & encloses the fixed & moving contacts.

→ The moving contact is a cylindrical rod passing through a restricted opening at the bottom

→ when fault occurs moving contact separates & arc is struck



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

→ The high pressure forces the oil & gas through & round the arc to extinguish it.

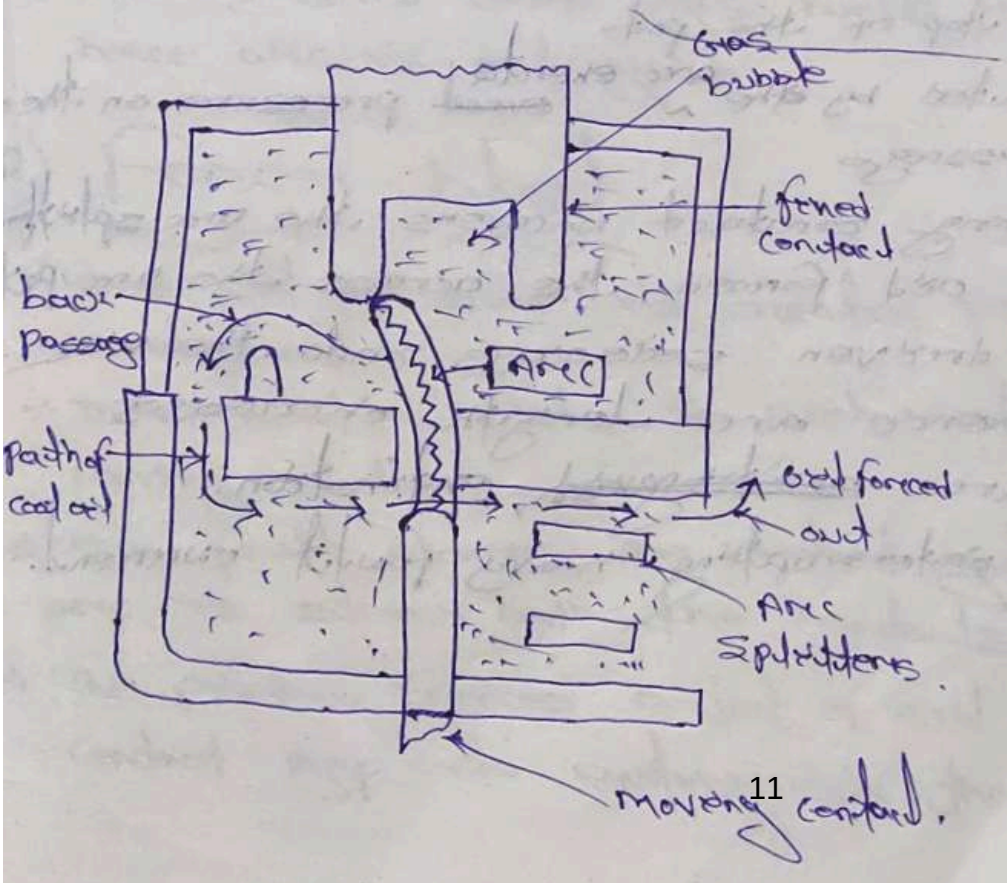
→ Final arc extinguishing occurs after the moving contact leaves the pot because emergency of moving contact is followed by a violent rush of gas & oil through throat produces rapid extinguishing.

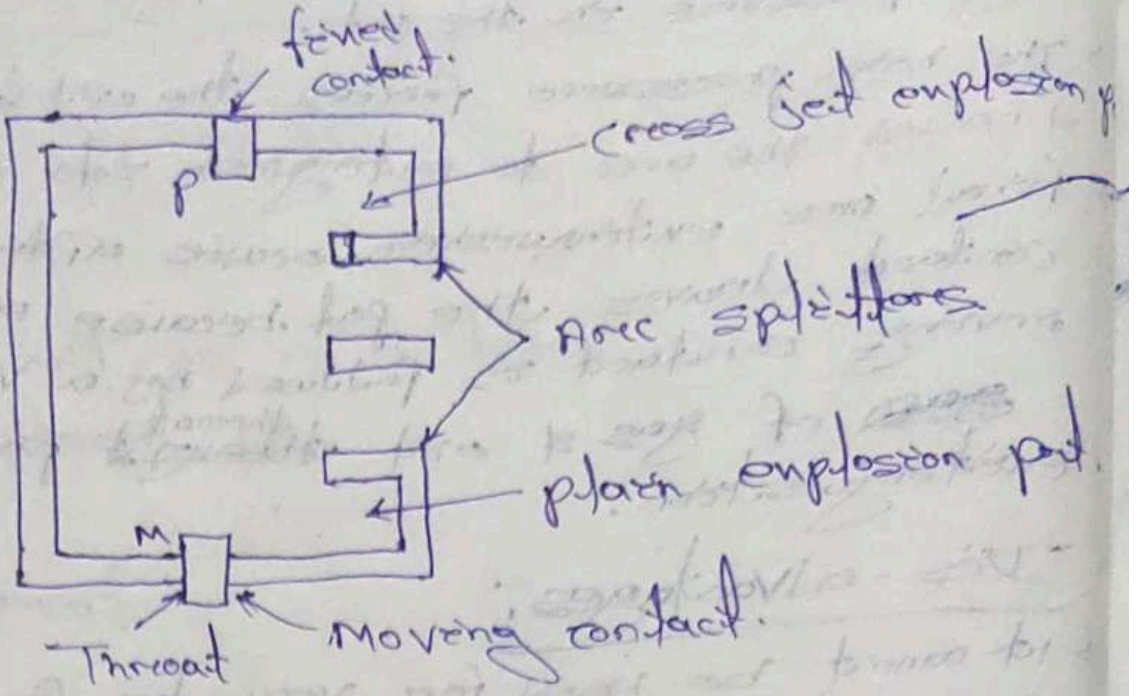
Dis-advantages:

→ It cannot be used for very low or very high fault currents.

→ Hence it operates on moderate short ckt I.

ii) Cross jet explosion pot:





→ it is made of insulating material.
→ it has channels one side which act as arc splitters.
→ Arc splitters help it increase the arc length.
→ hence it extinguishes the arc.

Working

→ when fault occurs, the moving contact of the CB begins to separate.
→ As the moving contact withdrawn the arc is struck on the top of the pot
→ The gas generated by the arc exerts pressure on the in the back passage.
→ when the moving contact uncovers the arc splitter duct's fresh air forced the across the arc path
→ The arc is driven sideways into the arc splitters hence arc length increases & causing arc extinction.
→ It is efficient interrupting heavy fault current.

Dt: 03.06.22

iii) Self compensated explosion pot:

it is combination of plain explosion pot & cross jet explosion pot.

→ it consist of two chamber

i) Upper chamber:
it is the cross jet explosion pot with slab arc splitter duct's

ii) Lower chamber:
plain explosion pot

* when the stored out current is heavy, the rate of generation of the gas is very high. & the device behaves as a cross jet explosion pot.
→ when the moving contact separate the arc on covers the arc splitters.
→ when low stored out I occurs, the rate of gas generation is small & the tip of the moving contact to which the lower chamber
→ During this time gas builds up sufficient pressure arc is extinguish

2) Forced blast

Here oil pressure is created piston cylinder arrangement.
→ The moment of piston is mechanically coupled to the moving contact.
→ when fault occurs, the contact get separated & arc is struck both the contacts.
→ The piston forces a jet of oil towards the contact gap to extinguish the arc.

necessary oil pressure doesn't depend upon the fault current

* Advantages:
  - The quantity of oil required is reduce.
  - It is independent of the amount of fault I to be interrupt

2) How oil CB

oil has two function:

i) To insulate the live part.

ii) To extinguish the arc.

* Disadvantages are

→ increase the expers.
→ tank size.
→ weight of the breaker.
→ Increase the fire risk problem.
→ Increase the maintenance.

Some facts:

About 10% of total oil in bulk oil CB is used for arc extinction.

→ This led to development of low oil CB.

→ It employes solid material for insulation purpose.

→ It uses small quantity of oil just for arc Construction.

→ There are two compartments separated from each other & filled with oil.

i) upper chamber -
Extinguish breaking chamber

ii) lower chamber -
Supporting chamber.

* Two chambers are separated by each other partition

→ This arrangement has 2 advantages.

ii) circuit breaking chamber required small volume of oil which is used for arc extinguishing

iii) The amount of oil replaced is reduced as the oil in the supporting chamber doesn't get contaminated by the arc.

1) Supporting chamber:

It is a porcelain chamber mounted on a metal cha
→ It filled with oil which is physically separate upper chamber.

→ The oil inside the supporting chamber & the annular space formed between the porcelain insulation & barrelled paper is employed for insulation purposes only

ii) Circuit breaking chamber

It is a porcelain enclosure mounted on the top of the supporting chamber

→ It is filled with oil.

→ It contains

i) upper & lower fixed contact

ii) Moving contact

iii) Turbulator

Dt:- 04.06.2023

→ moving contact is hollow
→ it includes a cylinder which moves down over a fixed piston.
→ The turbulator is an arc control device.
→ It has both axial & radial vents
→ The axial venting ensures interruption of low I fa
→ Radial venting holds the interruption of heavy I

Top chamber:

→ it is the metal chamber.
→ it is mounted on the ext breaking chamber.
→ it provides expansion space from the oil CB compartment
→ it also provide with a separator ~~that~~ which prevent any loss of oil.

Working operation:

When a fault occures, the moving contact is pulled down by the tripping spring. hence arc is stru
→ The arc energy vaporises the oil & produces gases under high pressure.
→ This action constrains the oil to pass through a control hole in the moving contact & results in forcing series of oil through the respective passages of turbulator
→ The process of turbulation is one in which section of the arc successively quest by the effect of separate

Advantages:-
→ It requires less quantity of oil
→ It is smaller space.
→ There is reduce ~~force~~ risk of force
→ Maintenance problem ~~are~~ reduced.

dis-advantages:
due smaller quantity of oil, the degree of carbonisation is ↑
→ There is difficulty of removing the gases from the contact space.
→ The dielectric strength of oil deteriorates rapidly

Maintenance of oil CB:-
→ check the current carrying parts of arcing contact.
→ " " dielectric strength of the oil.
→ " " insulation for possible damage.
→ " " closing & tripping mechanism.

Air-blast CB
→ It employ as a high pressure air-blast, an arc quenching medium.
→ The contacts are open in a flow of air blast established by the opening of blast valve.
→ Air blast cools the arc & sweeps away the arcing products to the atmosphere
→ It ↑ the dielectric strength of medium.
→ It prevents from re-establishing of arc, hence arc is extinguished & flow of I is interrupted.

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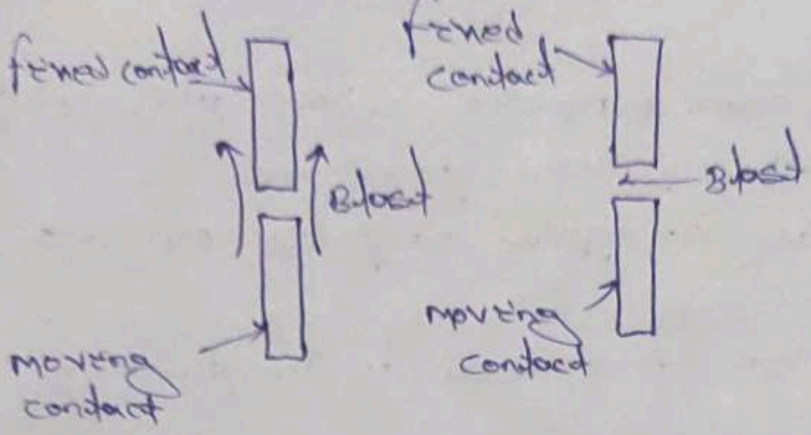
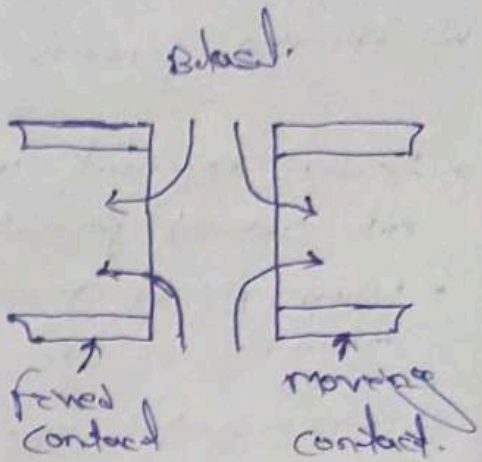
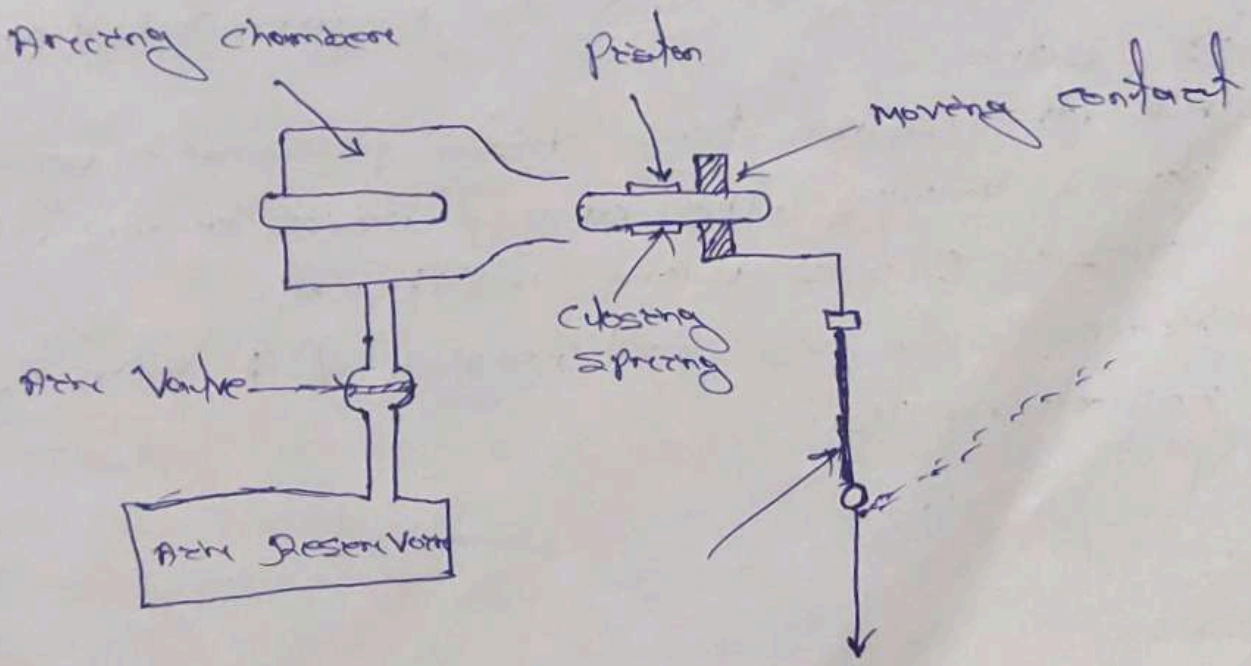
Types of Air-blast CB:

1) Axial blast CB
2) Cross " "
3) Radial " ".

1) Axial blast air CB:





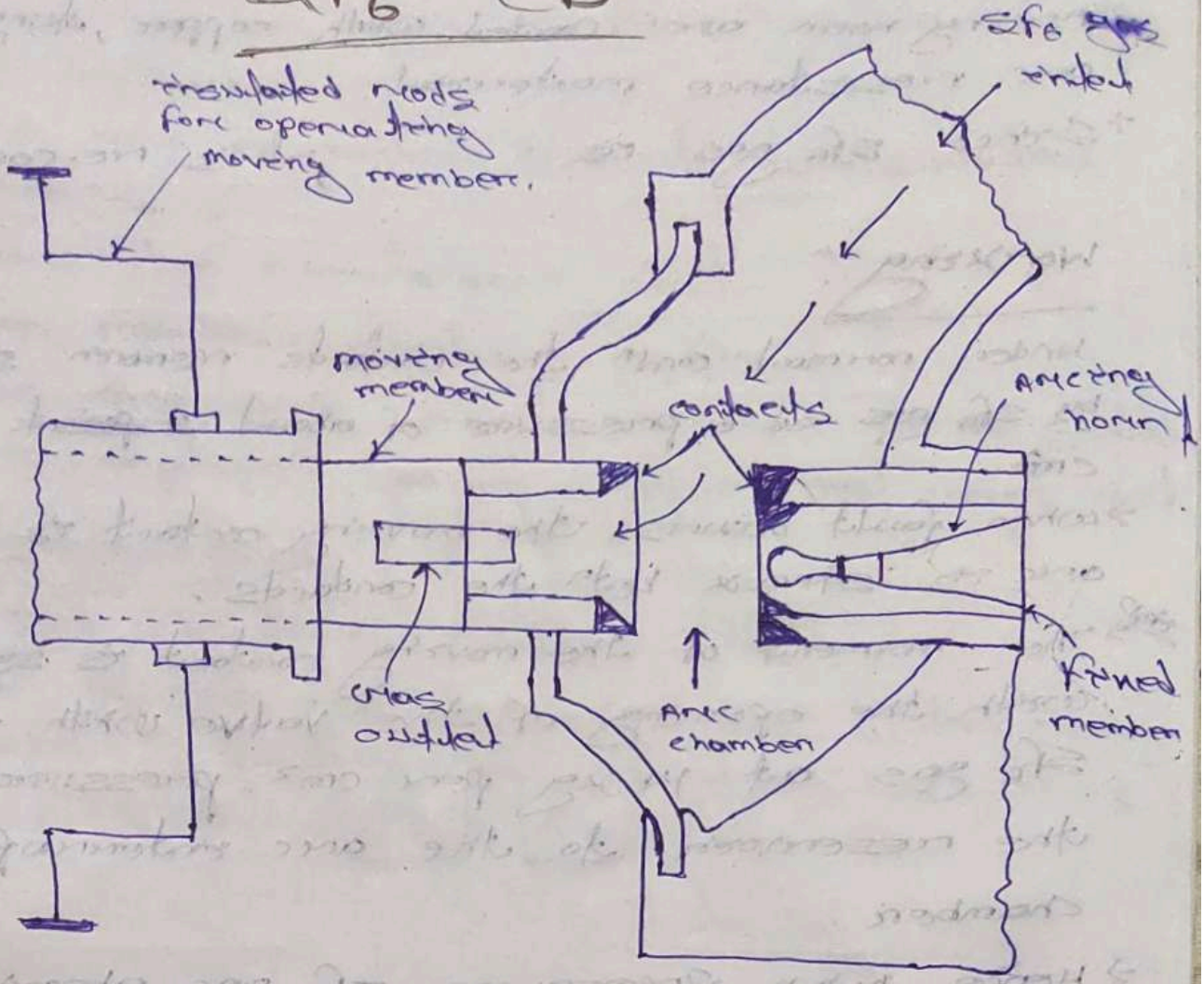


In the diagram there are

i) Fixed contact
ii) Moving "
iii) Piston
iv) closing spring
v) Air valve
vi) Air reservoir
vii) Arcing chamber.

- Under normal cond' fixed & moving contact are held at closed position by spring pressure.
- When fault occurs the tripping impulse causes opening of the
- Air valve connect CB reservoir to the arcing chamber
- The high pressure air entering the arcing chamber pushes the moving contact against spring pressure
- Hence moving contact is separated & an arc is struck.
- At the same time high pressure air blast closed along the arc & takes away the ionised gases along with it.
- Hence arc is extinguish & ckt is interrupted.

SF_6 CB



→ Here SF_6 gas is used as arc quenching medium
→ It is an electro negative gas, which is attract the electrons.
→ It has strong tendency to absorbe free electro

Construction:

→ It consists of fixed & moving contacts.
→ This are enclose in the chamber for arc interruption chamber.
→ This chamber contains SF_6 gas. ~~This chamber is called arc interruption chamber~~
→ Fixed contact is a pole cylindrical with rectangular holes in the size to permit SF_6 gas

tips of the fixed contact, moving contact & moving horn are coated with copper, tungsten arc resistance materials.

→ Since SF6 gas is re-condition

Working:

Under normal cond^n the contacts remain surrounded by SF6 gas at a pressure of about 2-8 kg/cm².

→ When fault occurs, the moving contact is moved & arc is struck b/n the contacts.

→ The movement of the moving contact is synchronized with the opening of the valve which permit SF6 gas at 14 kg per cm² pressure from the reservoir to the arc interruption chamber.

→ Hence high pressure SF6 gas absorbs free electrons in the arc path, it builds of dielectric strength of the arc path & hence arc extinguishes.

→ After the breaker operation valve is closed by the action of a set of spring.

Advantages:

→ It has very short arcing time
→ Dielectric strength of SF6 gas two to three time that of air.
→ It can interrupt large currents
→ It gives noise less operation.
→ It has no exhaust to atmosphere like air blast CB

→ It keeps the interior dry
→ There is no risk of fire because SF_6 is non-inflammable
→ There are no carbon deposits so insulation problems.
→ It has low maintenance cost.
→ It has minimum auxiliary equipment.
→ Since they are totally enclose, they are suitable where explosion hazards like coal mines exist

Disadvantages:

→ SF_6 gas is very costly.
→ Since SF_6 gas has to be re-cond^n after every operation, addition equipment is required this purpose.

Application:

→ It has been developed for voltages 115 kV to 230 kV, power rating 10 MVA to 20 MVA & interrupting time less the 3 cycles.

Vacuum CB

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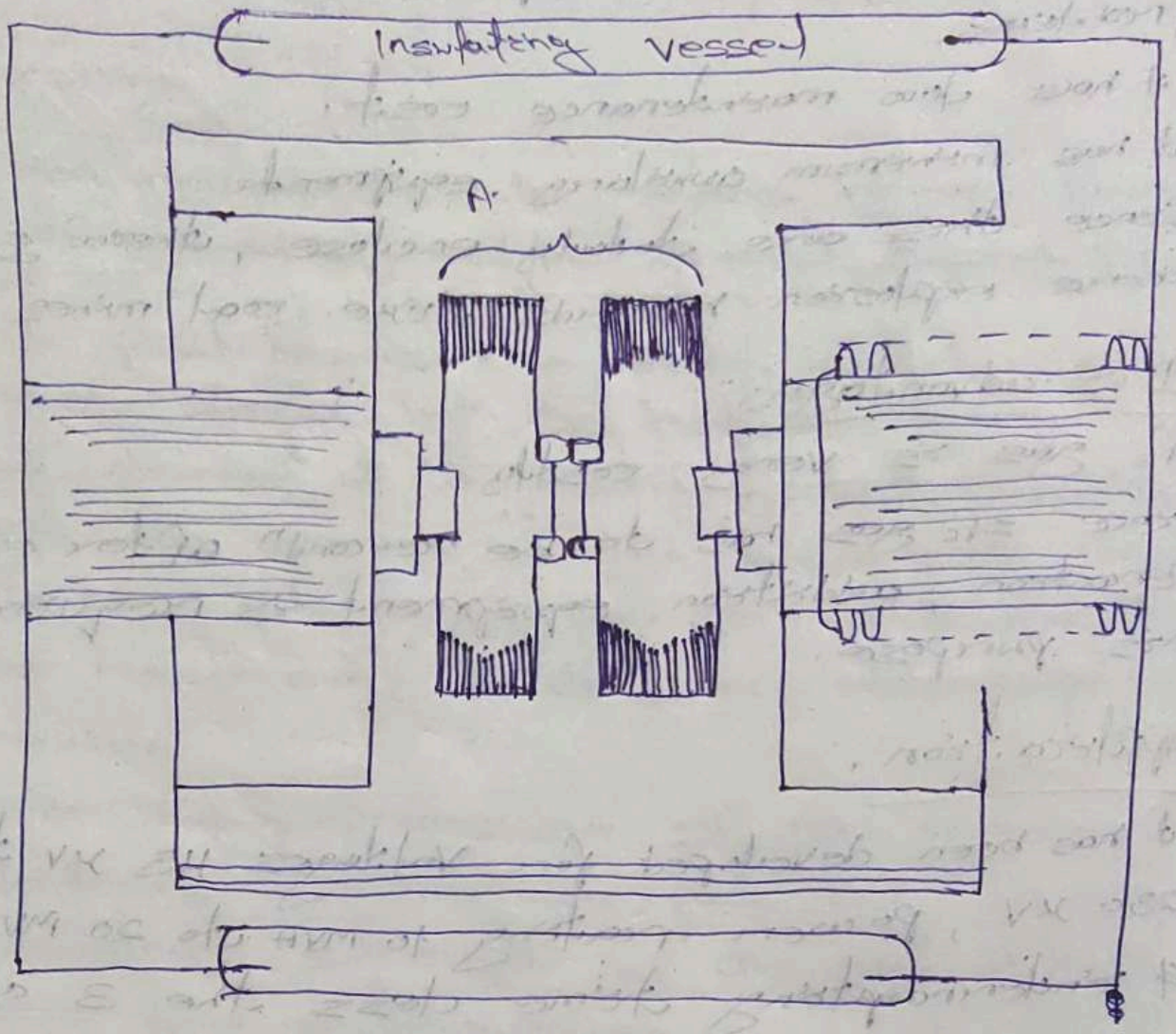
Vacuum CB



→ in this CB vacuum is used as the arc quenching medium.
→ it occures highest dielectric strength

working

When the contacts of the breaker are open in vacuum an arc is produce both the contacts by the ionisation of metal vapour of contacts.

→ The Here arc is quickly extinguished because the metallic vapour, electrons, ions produce during arc rapidly condense on the surface of these CB contacts

Hence dielectric strength quick recovery

⇒ It consist of fixed, moving contact. arc shield enclosed in the vacuum chamber
⇒ The movable member is connected to the control mechanism by stainless bellows
⇒ The function of bellows:
It enables the permanent sealing to eliminate the possibility of

working:

⇒ When fault occurs moving contact separate from the fixed contact.
⇒ Hence the arc is struck
⇒ production of arc is due to the ionization of metal ions & depends upon the material of contacts.
⇒ Hence the arc is extinguish quickly because the metal vapours, electrons, ions produce during arc are diffuse in a very short time.

ADV

⇒ There are no fire hazards
⇒ compact, reliable & have longer life.
⇒ There is no generation of gas.
⇒ They can interrupt any fault current.
⇒ They required little maintenance.
⇒ quiet in operation.
⇒ They can sucessfully withstand lightning surges

⇒ They have low arc energy.

Applications:

They are employed for the outdoor app. for 220 kV to 66 kV

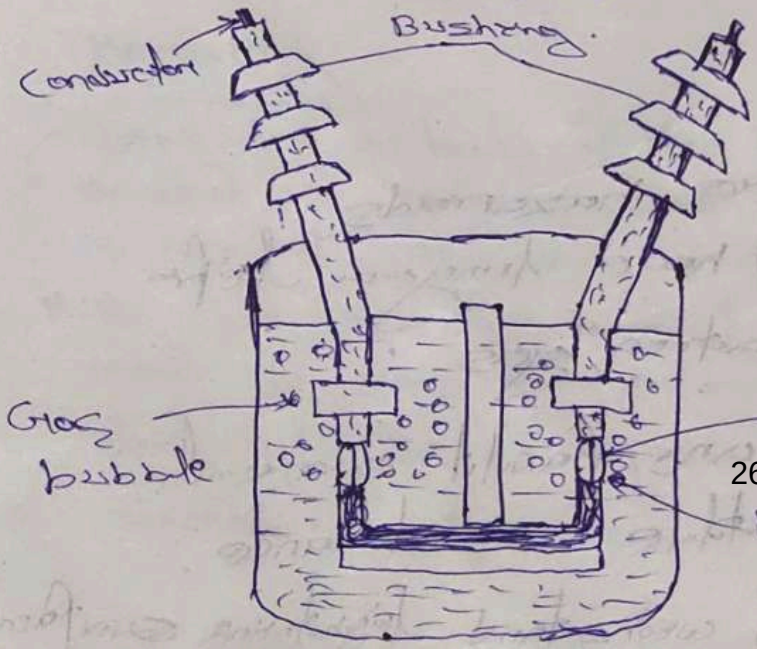
⇒ They are installed where distances are quite large & Accessibility the remote area is difficult, like in India.

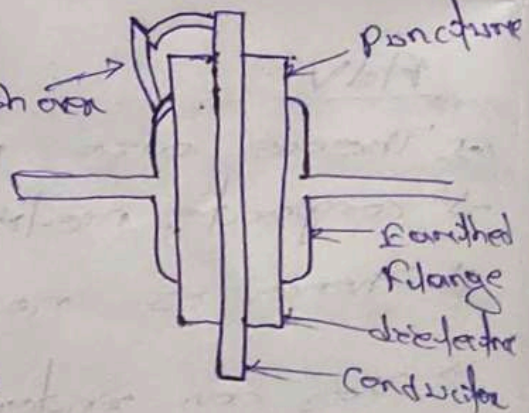
Switch gear Components

1) Bushing
2) CB Contacts
3) Instrument T/F
4) Busbar & Conductors

1) Bushing:

* Its function is to prevent electrical breakdown both the enclose conductors & the surroundings are metal work





Difference betn puncture & flashover

puncture:

Predetrec failure of the insulation material of the bushing.

Flashover:

Breaz down betn the expose conductor & either Bushing & arc metal.

CB contacts:

It is required to carry normal as well as short ckt current.

⇒ There are 3 types of CB conta

i) Tulip type contact

ii) finger & wedge contact.

iii) Butt contacts

Instrument TP

It is 2 types

i) Current TF

ii) Potential TF

In CB we need measuring & protecting devices which can work satisfactorily. It is mounted on the power line

Busbar & conductor

The I carried members in an CB are fixed & moving contact & the conductores connecting this to the point external to the breaker

⇒ In outdoor switchgear these connection are directly to the OH line

In indoor switchgear the incoming conductors in the CB are connected to the bus bar.