

Date: ____-____-____

Power System operation and protection

Unit 01 :-

Power System Components

Unit 02 :-

Power System faults stability.

Unit 03 :-

Active & Reactive
power Control

Unit 04 :-

Element of protection
& circuit Interrupting Devices

Unit 05 :-

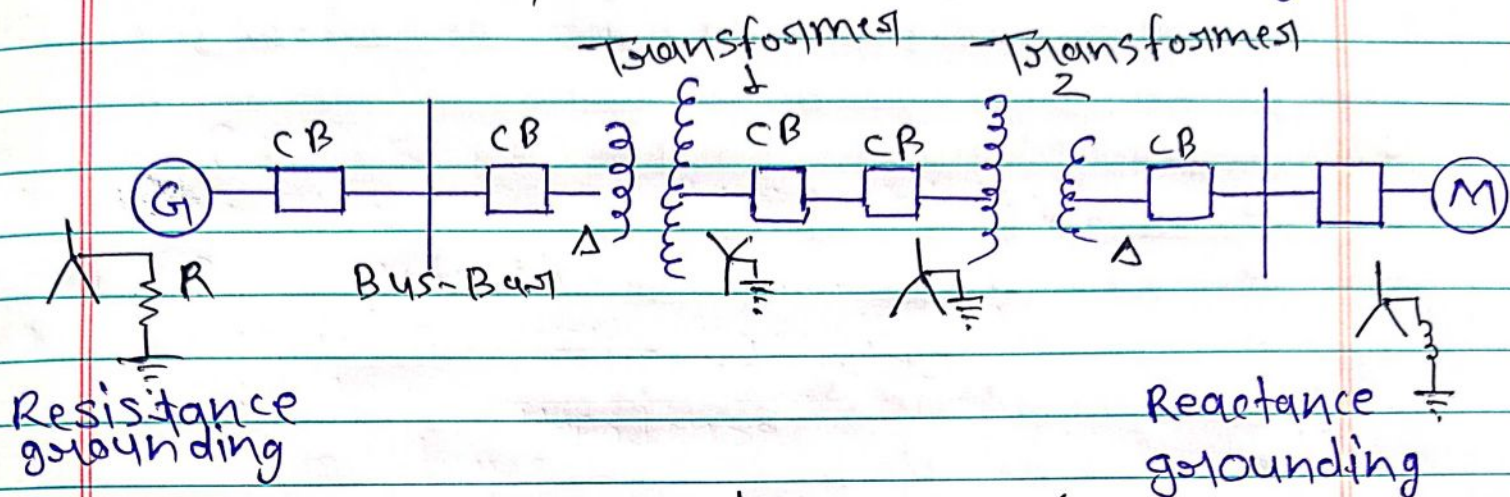
Protection Relays and
Circuit Breakers.

Unit 01

Power System Components
(Representation of power system).

- 1.1. Single line representation of power system.
- 1.2. Per Unit (P.U) system.
- 1.3. Complex power flow.
(concept of Load angle (δ) & power factor angle (θ)).
- 1.4. Simplified representation of synchronous Machines.
- 1.5. Power Angle Curve of a synchronous generator.

1.1. Single Line Representation of a power System. (single line diagram).



The single line diagram of power system.

Represents following electrical equipments:-

- (1) Generator (G)
- (2) Transformer
- (3) Transmission Line
- (4) Bus-Bar
- (5) Circuit Breaker (CB)
- (6) Motor (M)

⇒ Neutral Grounding used:-

- (i) Generator → Resistance grounding
- (ii) Motor → Reactance grounding

1.2. Per Unit (PU) System :-

→ The per unit value of any quantity is defined as the ratio of actual value in any unit to the Base value in the same unit.

$$\text{Per Unit Value} = \frac{\text{Actual value in any unit}}{\text{Base Value in the same unit}}$$

★ Base Value :-

Base Voltage :- Rated Voltage of the machine

Base Current = Rated Current of the machine

$$\text{Base Impedance} = \frac{\text{Base Voltage}}{\text{Base Current}}$$

$$\text{Base power} = \text{Base Voltage} \times \text{Base Current}$$

$$Z_{pu} = \frac{\text{Actual impedance}}{\text{Base impedance}}$$

(per unit impedance) $\leftarrow 0.1 + j 0.2$

$\leftarrow 0.1 - j 0.2$

* Per Unit System Advantage :-

- (1) Circuits are simplified
(change in voltage range in)
- (2) Voltage have same per unit in all part of the system from EHV to distribution
- (3) For circuit connected by transformer per unit system is particularly.
- (4) Calculation become easier.

1.3 Complex Power :-

→ Complex power is basically the representation of electrical power in the form of complex number. A complex number consists of real part & imaginary parts.

Complex power :-

$S = P + jQ \Rightarrow$ for Inductive load,

$S = P - jQ \Rightarrow$ for Capacitive load.

$$S = VI^* \\ = VI \cos \phi + jVI \sin \phi$$

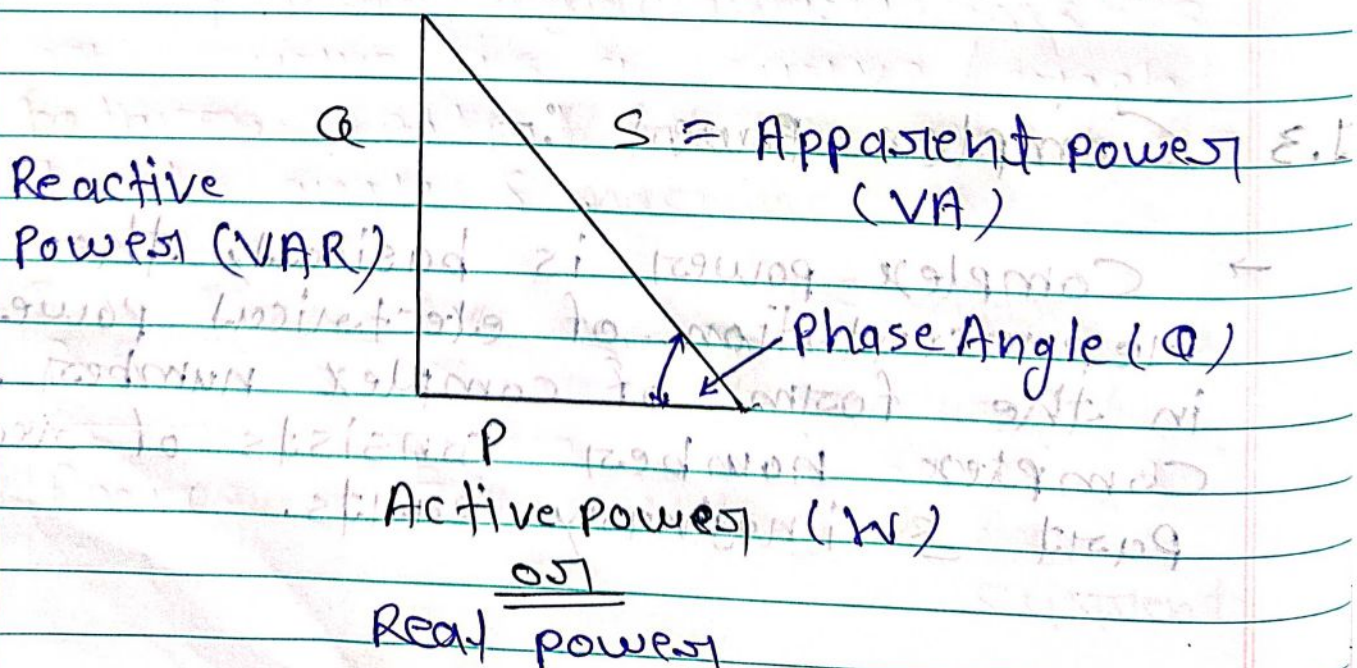
$$= VI (\cos \phi + j \sin \phi)$$

$$S = VI \cos \phi + jVI \sin \phi$$

Real parts
(P)

Imaginary parts
(Q)

$\Rightarrow$ Power Triangle :-



$$\cos \phi = \frac{\text{Base}}{\text{Hypotenuse}}$$

$$\cos \phi = \frac{P}{S}$$

$$P = S \cos \phi$$

$$(\because S = VI)$$

$$P = VI \cos \phi \dots\dots (1)$$

$$\sin \phi = \frac{\text{Perpendicular}}{\text{Hypotenuse}}$$

$$\sin \phi = \frac{Q}{S}$$

$$Q = S \sin \phi \quad (\because S = VI)$$

$$Q = VI \sin \phi \dots\dots (2)$$

from

$$(1) \text{ \& } (2)$$

$$S^2 = P^2 + Q^2$$

$$S = \sqrt{P^2 + Q^2}$$

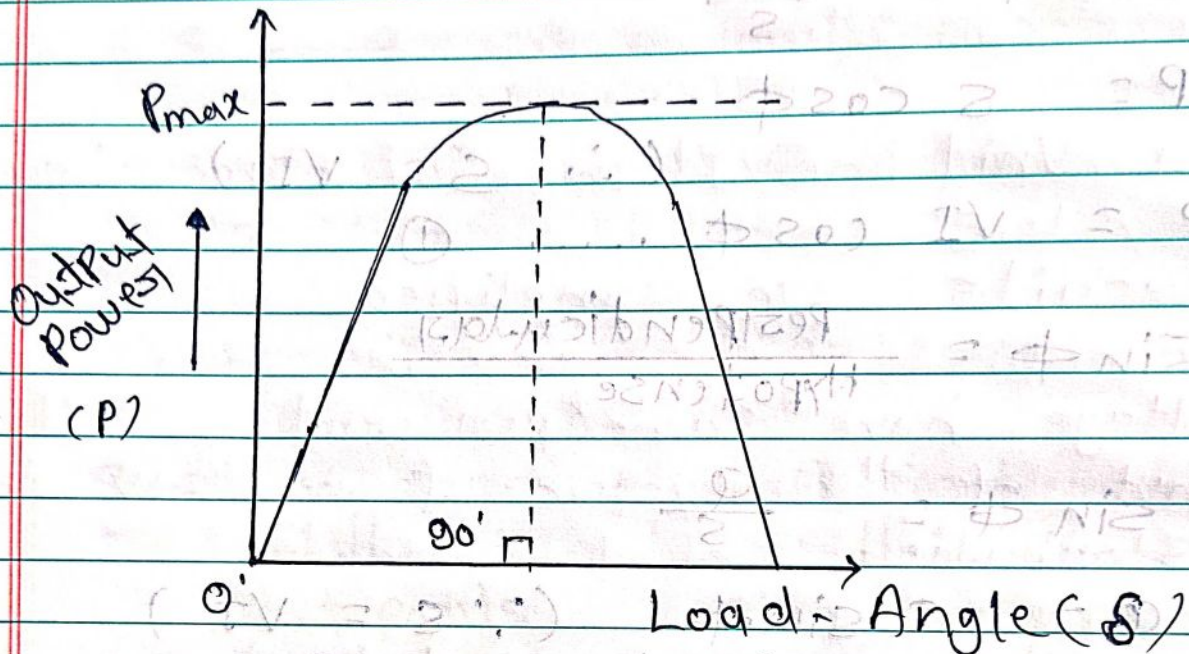
$$S = \sqrt{(VI \cos \phi)^2 + (VI \sin \phi)^2}$$

$$S = \sqrt{(VI)^2 (\sin^2 + \cos^2)}$$

$$S = \sqrt{(VI)^2}$$

$$S = VI \dots\dots (3)$$

1.5. Power - Angle Curve of a Synchronous Generator.



$$P_{out} = \frac{EV}{X} \sin \delta$$

→ The power-angle characteristics (or) curve is a curve/graph between output power (P) & Load-angle (δ).

$$P_{max} = \frac{EV}{X} \sin 90^\circ$$

$$P_{max} = \frac{EV}{X} \quad (\because \sin 90^\circ \approx 1)$$

Unit - 02

Power System Faults and Stability.

1. Symmetrical faults
 - LLL
 - LLLG
2. Unsymmetrical Faults
 - Line to line faults
 - Line to ground
 - Double line to ground
3. Short Circuit Capacity (SCC) of a bus.
4. Stability :-
 - Transient stability
 - steady-state stability.
5. Swing - Curve / swing equation.
6. Equal - Area Criterion.
7. Methods of Improving stability.

Symmetrical & Unsymmetrical faults. in Power system.

Types of faults

(i) Shunt Faults

(ii) Series faults.

(a) Symmetrical faults.

(b) Unsymmetrical faults.

(a) one - open

conductor faults

(b) Two - open

conductor faults.

(a) Symmetrical faults :- $\geq 3 \phi$ faults.

(b) Unsymmetrical faults :-

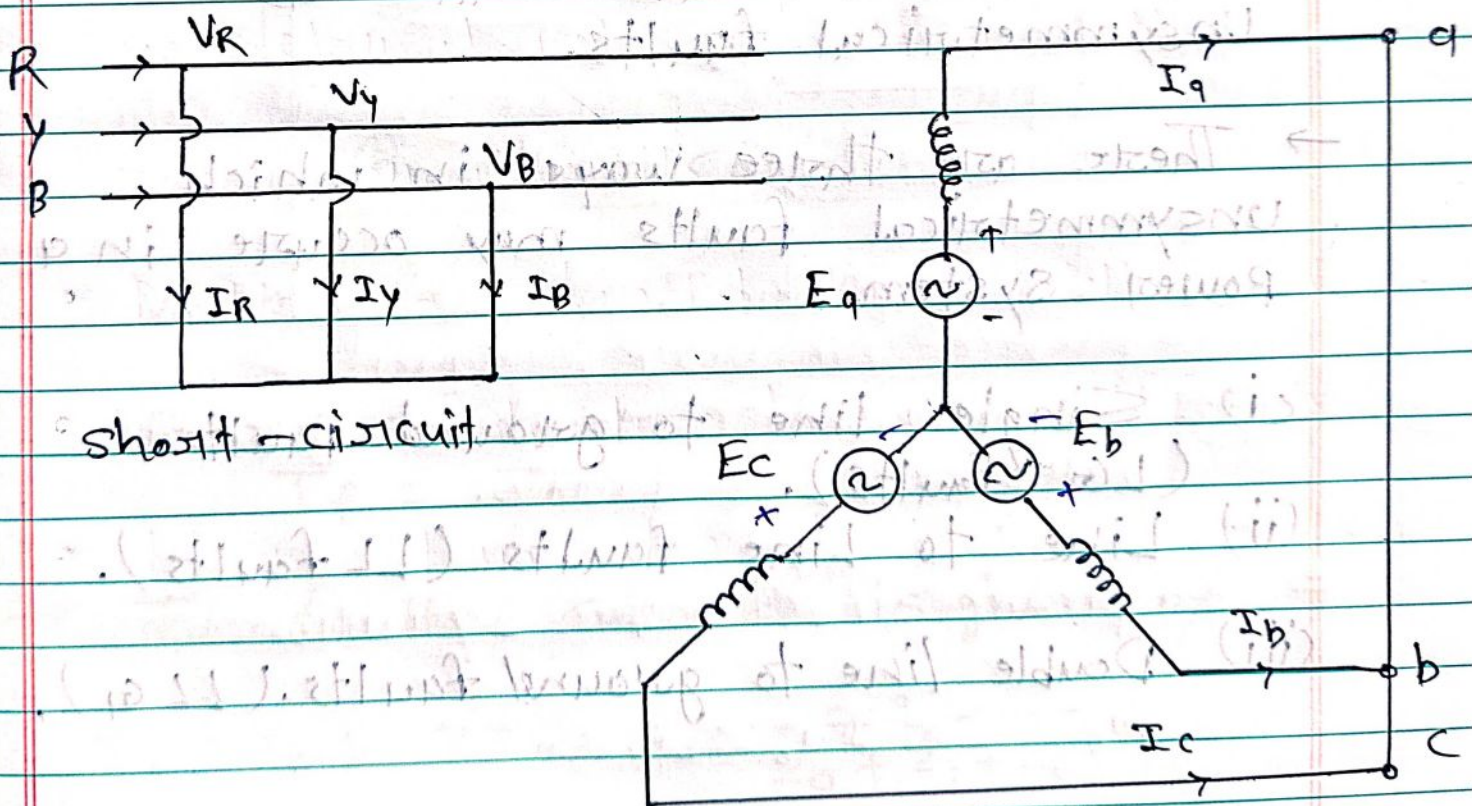
- Double line / Line to Line faults. (LL).
- LG (Single line to Ground faults).
- LLG (Double line to Ground faults).

S.N.	occurrence of faults in the power system in increasing order	The various types of faults in the increasing order of severity.
1.	3 ϕ faults - 5% (LLL & LLLG)	Open-conductor faults (Least severe)
2.	Double line to ground (LLG) - 10%	Line to ground faults (LG).
3.	Line to Line faults (LL) - 15%	Line to Line faults (LL faults).
4.	Line to Ground faults (LG) - 75% (Most common faults).	Double line to ground faults (LLG)
5.		3- ϕ faults (Most severe faults.)

(1). Symmetrical Faults:-

→ The faults on the power system which gives rise to symmetrical current (i.e. equal fault current in the line with 120° displacement) is faults Symmetrical faults.

→ The symmetrical faults occurs when all the three conductors of a 3- ϕ line are brought together simultaneously into a short-circuit condition.



Boundary condition

- ① $V_a = V_b = V_c$
- ② $I_a = I_b + I_c = 0$

→ The symmetrical faults condition are analyzed on per phase basis using Thevenin's theorem or Bus Impedance matrix.

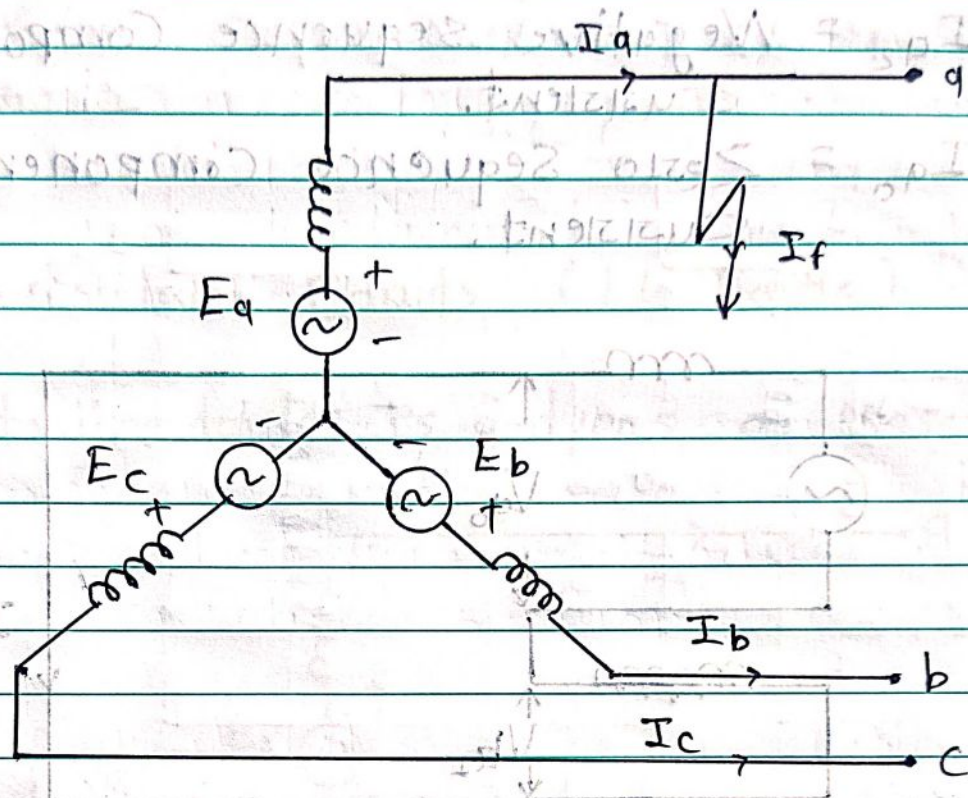
(2) Unsymmetrical faults :-

→ The faults on the power system which gives rise to unsymmetrical faults. currents (i.e. Unequal faults currents in the line with unequal phase displacements), are called as Unsymmetrical faults.

→ There are three ways in which unsymmetrical faults may occur in a power system.

- (i) Single line to ground fault (LG faults).
- (ii) Line to Line faults (LL faults).
- (iii) Double line to ground faults (LLG).

(i) Line to Ground faults (LGI faults) :-



Boundary Condition

$$V_a = 0, I_b = 0, I_c = 0$$

Faults Current is

$$I_f = I_a$$

→ The faults current is given by,

$$I_f = I_a = 3I_{a_1} = \frac{3E_a}{Z_0 + Z_1 + Z_2}$$

⇒ Note :-

- Z_1 = Positive sequence Impedance
- Z_2 = Negative Sequence Impedance
- Z_0 = Zero Sequence Impedance.

I_{a1} = Positive sequence component of current.

I_{a2} = Negative sequence component of current.

I_{a0} = Zero sequence component of current.

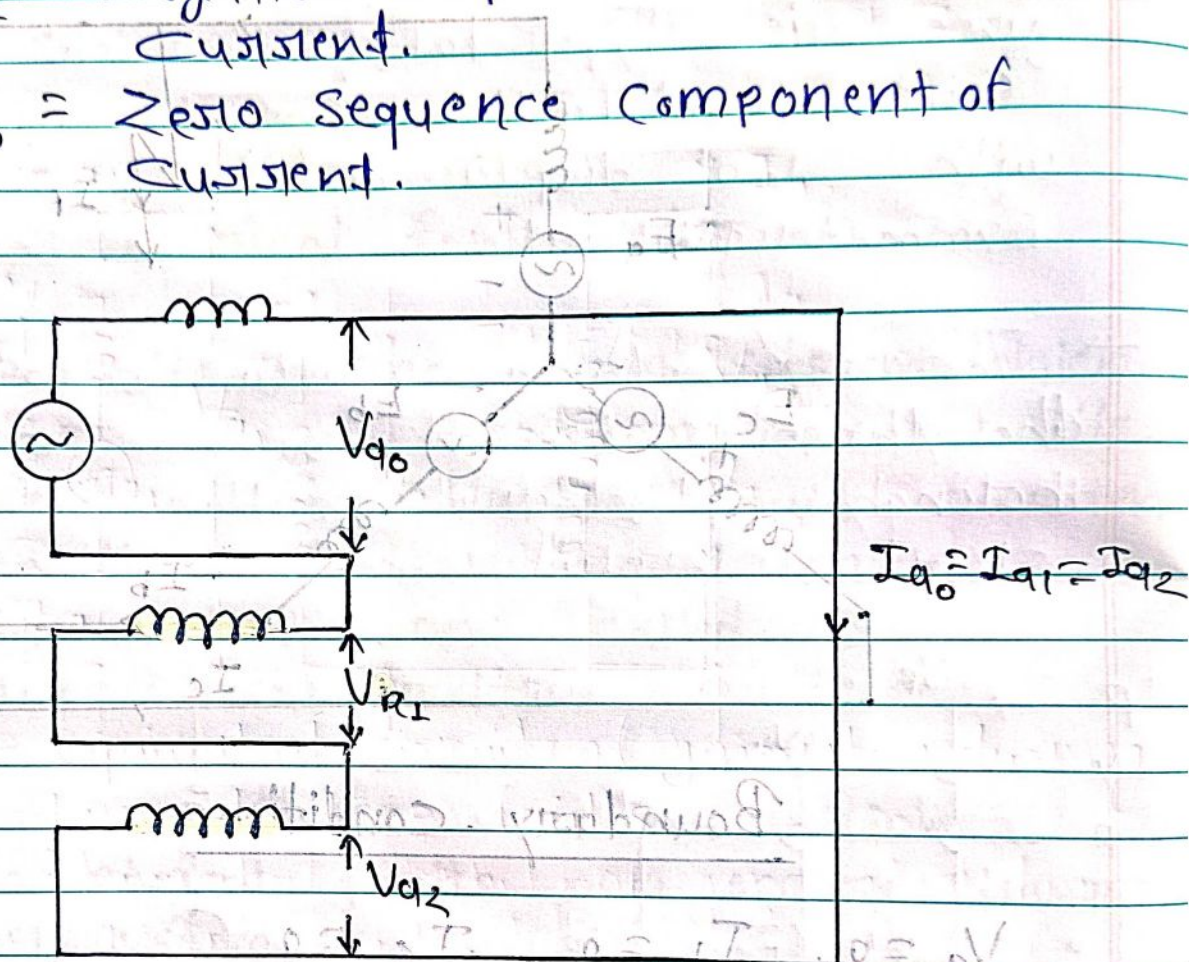


Fig. :- Equivalent circuit of generator during LG faults.

⇒ Sequence Network Equation :-

$$V_{a0} = -I_{a0} Z_0$$

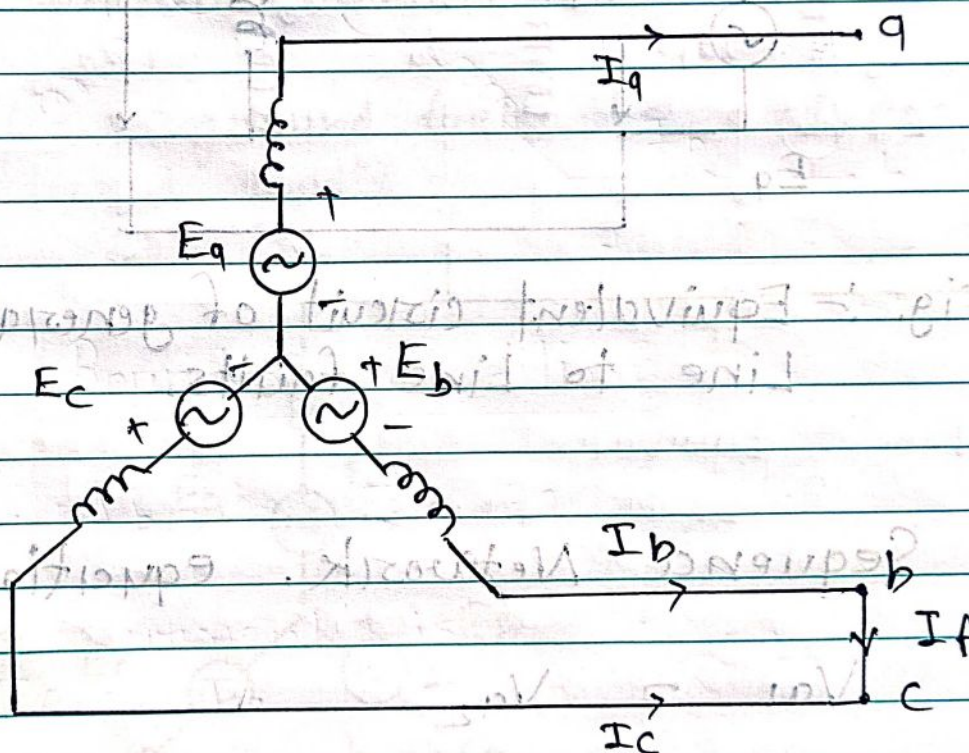
$$V_{a1} = E_a - I_{a1} Z_1$$

$$V_{a2} = -I_{a2} Z_2$$

⇒ Note :- Line to ground (LG) faults is the most common type of faults that occur in a power system.

(ii) Line to Line Faults (LL Faults) :-

→ Line to line faults is a types of Unsymmetrical faults.



Boundary condition

$$V_o = V_c, \quad I_a = 0$$

$$I_b = I_c = 0$$

$$I_b = -I_c$$

→ The Faults - Current is given by,

$$I_f = I_b = -j\sqrt{3} I_{a1} = \frac{-j\sqrt{3} E_g}{Z_1 + Z_2}$$

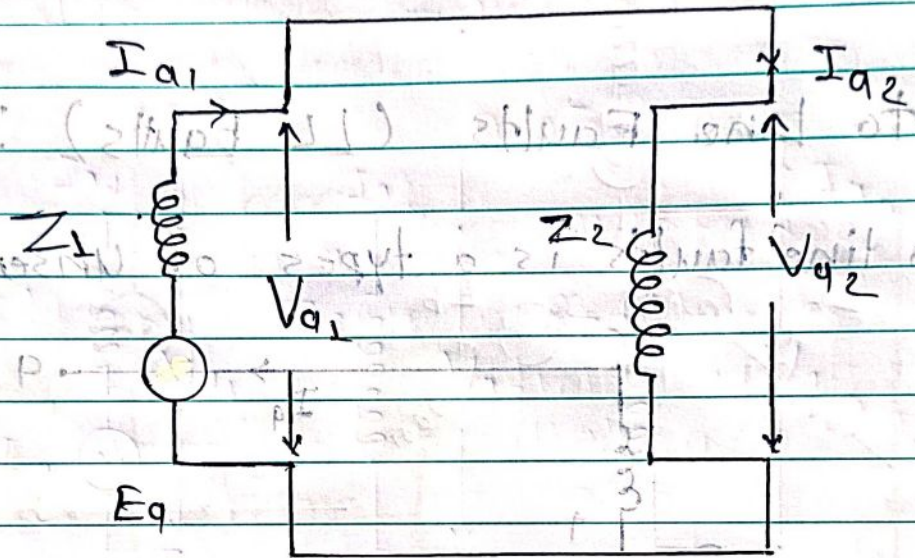


Fig. :- Equivalent circuit of generator during Line to Line faults.

⇒ Sequence Network. equation :-

$$V_{a1} = V_{a2}$$

$$E_g - I_{a1} Z_1 = I_{a2} Z_2$$

$$E_g = I_{a1} Z_1 + I_{a2} Z_2$$

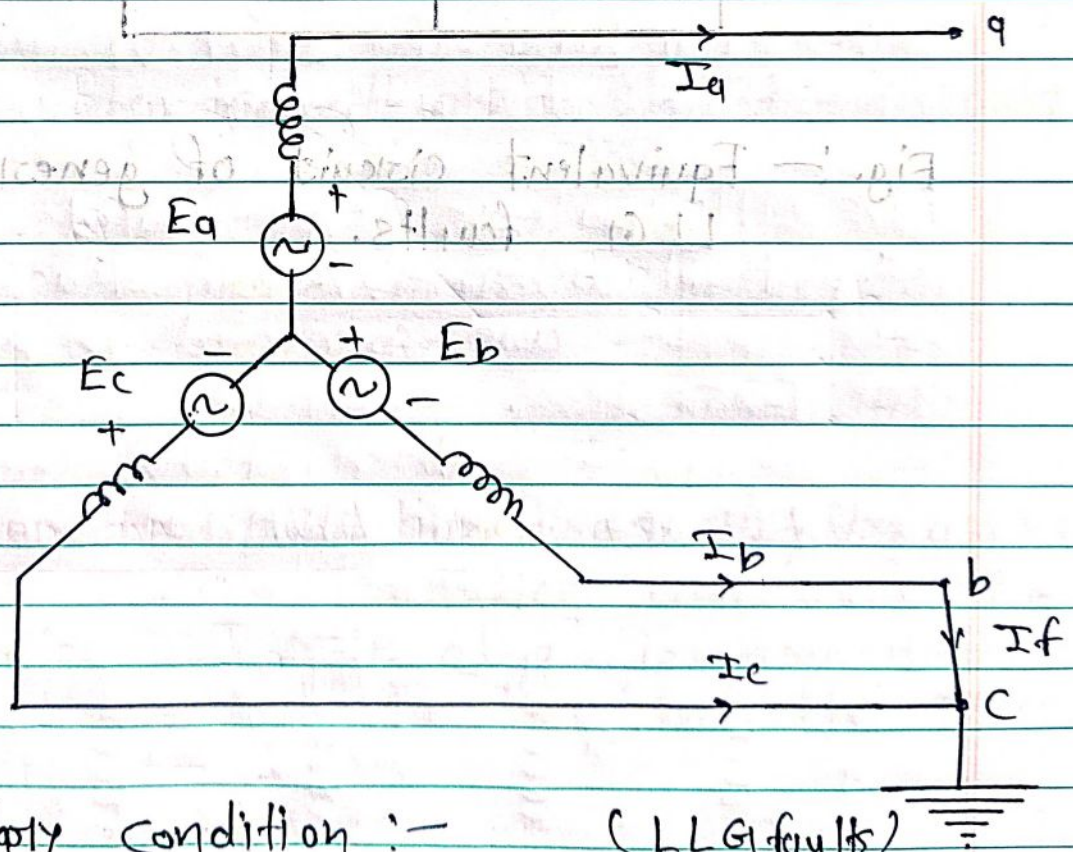
Since $I_{a1} = I_{a2}$

$\Rightarrow Z_1 =$ Positive Sequence Impedance
 $Z_2 =$ Negative Sequence Impedance.
 $Z_0 =$ Zero Sequence Impedance.

$I_{a1} =$ +ive sequence component of current.
 $I_{a2} =$ -ive sequence component of current.
 $I_{a0} =$ zero sequence component of current.

(iii) Double Line to Ground Faults (LLG) :-

→ Double line to ground faults is a types of unsymmetrical faults.



Boundary condition :- (LLG faults)

$$V_b = 0, V_c = 0, I_a = 0$$

$$I_f = I_b + I_c$$

→ The fault current is given by,

$$I_f = I_1 + I_2 + I_0$$

$$I_f = \frac{E_g}{Z_1}$$

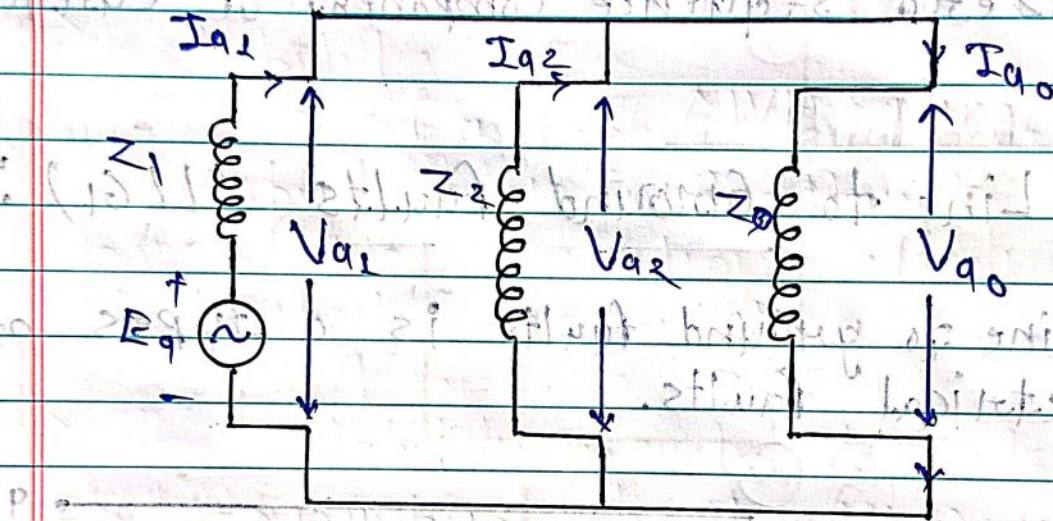
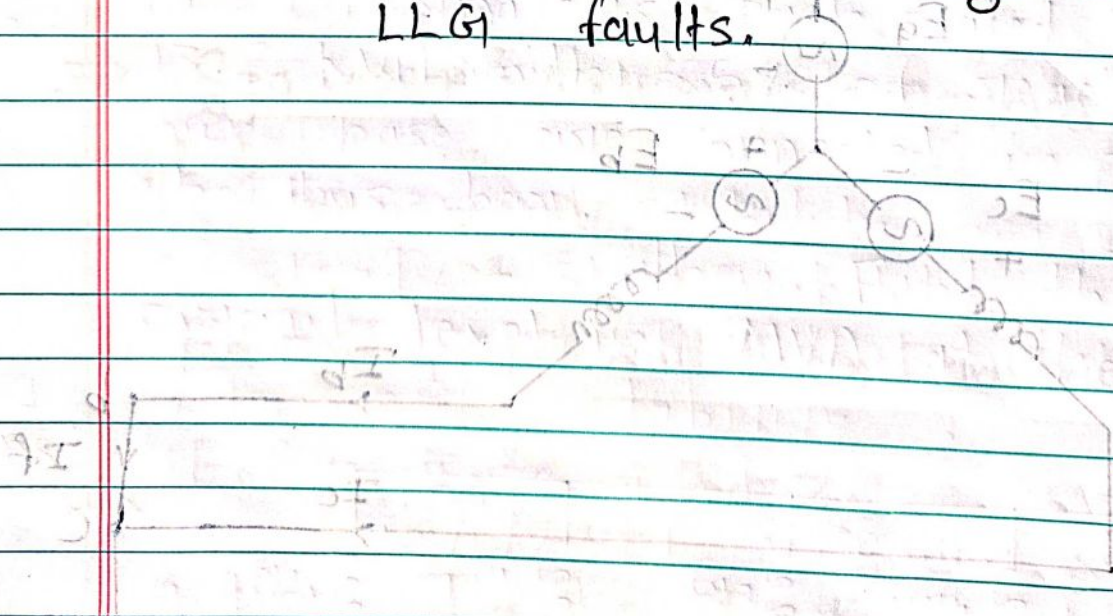


Fig. :- Equivalent circuit of generator during LLG faults.



Short Circuit Capacity of a Bus, (SCC) or short-circuit MVA.

⇒ Definition :-

→ short-circuit capacity of a bus is a measure of electrical strength of the bus.

It determines the

- (1) Dimension of the bus-bar
- (2) Interrupting Capacity of a circuit Breaker.

→ It is also called as - Short-circuit MVA (or) Faults MVA.

$$\text{SCC} = \frac{\text{Base MVA}}{\text{Reactance (X)}}$$

Q.1. A Transformer is stated as 11 kV / 0.4 kV, 500 kVA, 5% reactance what is the short-circuit MVA of a Transformer when connected to an infinite bus.?

Ans. - Given by :-

$$\text{kVA Rating} = 500 \text{ kVA}$$

$$\text{MVA Rating} = \frac{500}{1000} \text{ MVA}$$

$$\text{MVA Rating} = 0.5 \text{ MVA}$$

$$\% \text{ Reactance } (\%X) = 5\%$$

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

$$= 0.05 \text{ Per Unit}$$

$$\therefore \text{SCC of a bus} = \frac{\text{MVA Rating}}{\text{Reactance}}$$

$$= \frac{0.5}{0.05} = 10 \text{ MVA}$$

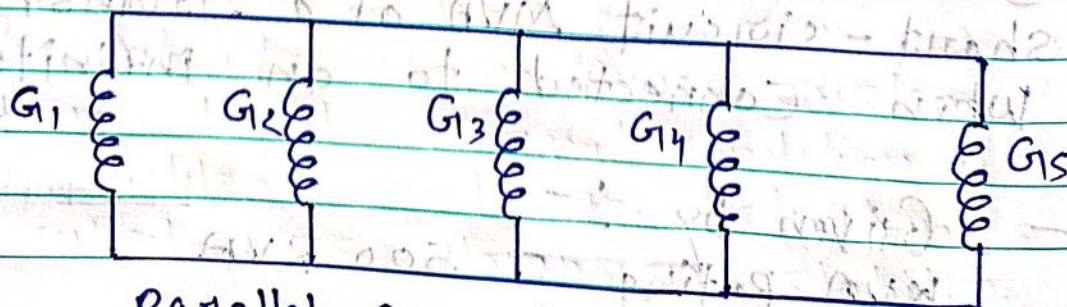
$$\text{SCC of a bus} = 10 \text{ MVA}$$

Ans. ✓

Q. 2. Five Alternators each rated, 5 MVA, 13.2 kV with 25% of reactance on its own base are connected in parallel to the bus-bar.

Then, Find the short-circuit level in MVA at the bus-bar?

Ans. ✓



Parallel connected in generator

Given by :-

$$\% \text{ Reactance } (\% X) = 25\%$$

$$= \frac{25}{100}$$

$$\% \text{ Reactance } (\% X) = 0.25 \text{ per unit}$$

$$\text{Generator Rating} = 5 \text{ MVA}$$

Base MVA

$$\text{Sec of a bus} = \frac{\text{Reactance (in P.U)}}{\text{Base MVA}}$$

$$\text{Reactance per unit in total} = \frac{0.25}{5} = 0.05 \text{ P.U}$$

$$\therefore \text{Sec of a bus} = \frac{5 \text{ MVA}}{0.05 \text{ P.U}} = 100 \text{ MVA.}$$

Ans.

(C.T. 1st)

Power System Stability :-

- (i) Transient Stability
- (ii) Steady-state stability

⇒ Stability :-

The ability of the power system to return to its normal or stable condition after being disturbed is called as "stability".

→ The stability mainly depends on the behaviour of the synchronous machine after a disturbance.

These are two types of stability in a power system.

- (i) Transient stability,
- (ii) steady-state stability.

(i) Transient Stability :-

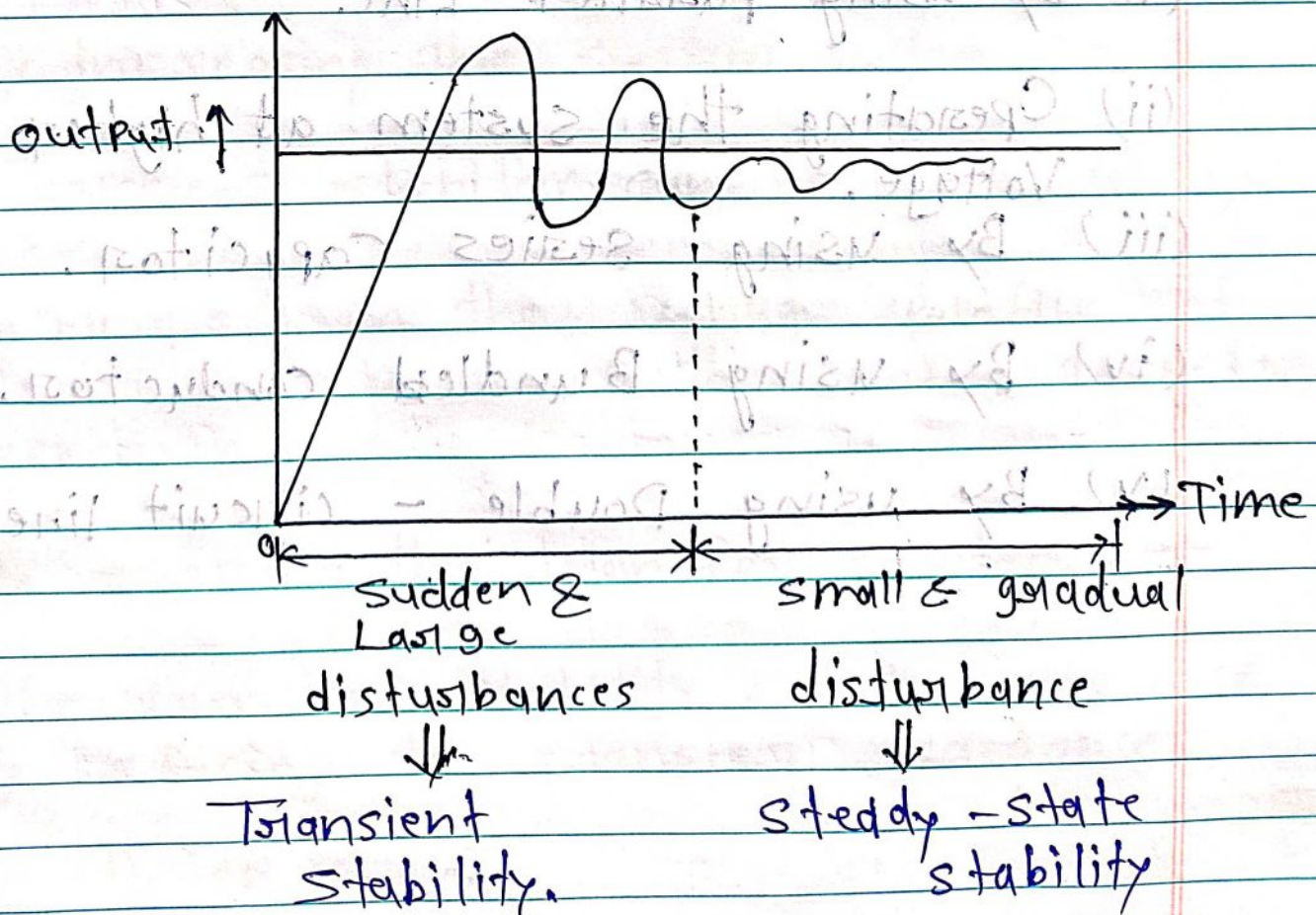
→ The ability of the power system to return to its normal condition after a "sudden" & large disturbance is called as "Transient stability".

→ The large disturbance occurs through — sudden removed or of Load, line switching operation when faults occur in a system.

(2) Steady - state stability :-

→ The ability of a power system to regain its synchronism after a small & gradual disturbances is called as "steady - state stability".

→ The small disturbance occurs due to gradual power changes.



Steady - state stability limits :-

→ The Steady - state stability limits is the maximum power that can be transferred without the system becoming unstable under the steady - state condition.

$$SSSL \cong P_{max} = \frac{EV}{X}$$

$X \rightarrow$ Transfer reactance

⇒ Methods of Improving SSSL :-

(i) By using parallel Line.

(ii) Operating the system at highest Voltage.

(iii) By using series Capacitor.

(iv) By using Bundled Conductor.

(v) By using Double - circuit line.

Exam

Q: (1) Explain Transient stability? What are the methods of improving transient stability.

Ans: :- Transient stability :-

→ The ability of the power system to return to its normal condition after a Sudden & Large disturbances is called as "Transient stability."

→ The large disturbance occurs through sudden removal of Load, line switching operation when faults occur in a system.

⇒ Methods of Improving Transient stability:-

(1) By increasing the system voltage :-

→ Transient stability can be improved by increasing the system voltage. Increase in the voltage profile of the system increases the power transfer capability.

(2) By reducing the transfer reactance:-

→ The transient stability can be improved by reducing the transfer reactance.

$$P \propto \frac{1}{X}$$

(3) By Using high speed circuit Breaker

→ High speed circuit breaker helps to clear the faults as quickly as possible. Thus it helps to improve Transient stability.

(4) By Turbine Fast Valving.

(5) Use of Auto - Reclosing.

(6) Single pole Switching.

(7) Using lightning Arrestor.

(8) Automatic Voltage Regulator.

Swing Equation :-

→ The swing equation in a power system represents the motion dynamics of the rotor of a synchronous generator.

It explains the relative motion between the rotor & synchronously rotating magnetic field.

$$M \frac{d^2 \delta}{dt^2} = P_a = P_s - P_e$$

$$\frac{d^2 \delta}{dt^2} = P_s - P_{\max} \sin \delta$$

When,

P_s = Shaft Power,

M = Moment of Inertia (Kg-m^2),

δ = Rotor angle (Electrical radians),

$P_{\max}$ = Maximum Power output (in watt),

P_e = electrical power output from generator (in watt).

P_a = Accelerating Power.

$\frac{d^2\delta}{dt^2} \Rightarrow$ Angular acceleration of the stator.

$P_m =$ Mechanical input to the Rotor.

$P_e = P_{max} \sin \delta$

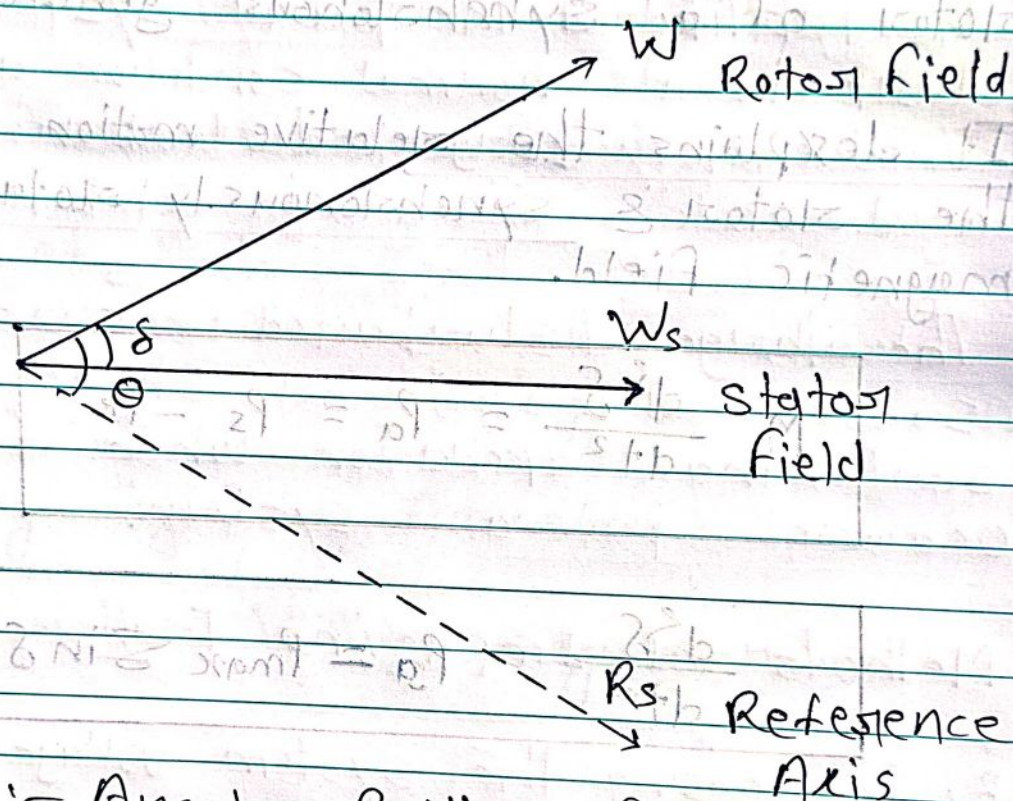


Fig. :- Angular Position of The stator.

$\Rightarrow$ Derivation of the Swing equation :-

$$T_m - T_e = J \left(\frac{d\omega}{dt} \right)$$

When,

$T_m =$ Mechanical Torque

$T_e =$ Electrical Torque

$\omega =$ Angular Speed

J = Moment of inertia of Rotor.

→ The Transient stability of a power system can be assessed by swing equation.

In simple terms the "Swing equation" equates the acceleration of the rotor to the difference between mechanical input power & electrical output power.

It is a second-order differential equation.

Importance of Swing equation :-

- (1) It helps in determining transient stability.
- (2) It explains the behaviour of synchronous machine during small disturbances.
- (3) It helps in estimating critical clearing faults using Swing Curve.

Swing Curve in power system :-

→ The swing curve is a plot between the rotor angle (δ) & time (t) obtained by solving the "Swing Equation."

→ The swing curve provides us the information about the transient behavior of synchronous machines.

⇒ The swing curve consists of 3 stages :-

- (I) Accelerating Swing
- (II) Steady swing
- (III) Diverging swing.

→ By analyzing the swing curve we can determine the critical clearing time which is the maximum time by which a fault must be cleared.

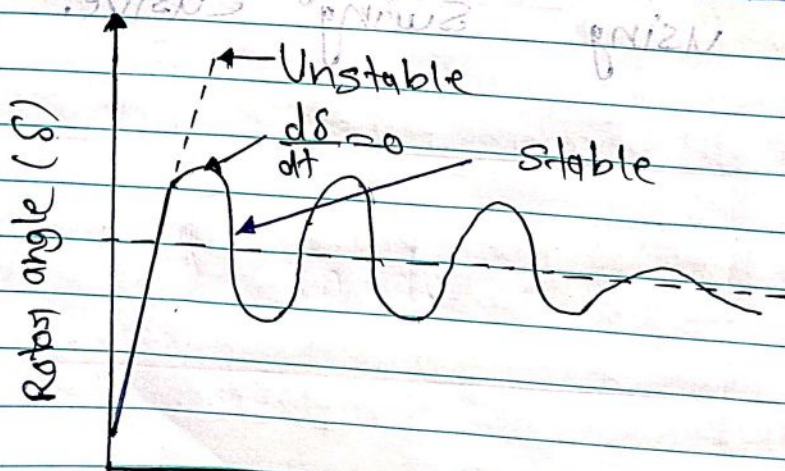


Fig. :- Swing Curve

Equal Area Criterion :-

→ Equal Area Criterion is a method that allows to determine transient stability of electrical power system in a simple & comprehensive way.

→ It is also a graphical solution to the basic swing equation.

→ The equal area criterion gives the information regarding the stability limit.

$$\frac{d\delta}{dt} = \sqrt{2 \int_{\delta_0}^{\delta} \frac{(P_s - P_e)}{M} d\delta}$$

Where,

$\delta \Rightarrow$ rotor angle.

$\delta_0 \Rightarrow$ Rotor angle when the machine operates under synchronous speed.

$P_s \Rightarrow$ Mechanical Power.

$P_e \Rightarrow$ Electrical Power.

$M \Rightarrow$ Moment of Inertia.

$$\frac{d\delta}{dt} = 0$$

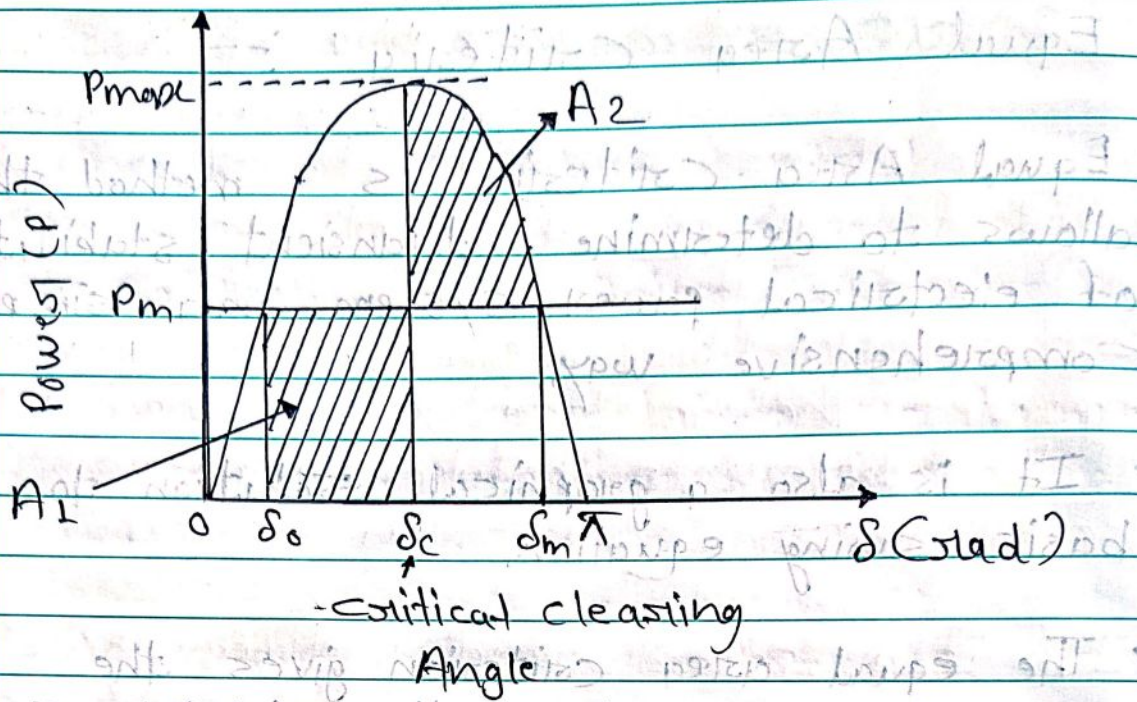


Fig. :- Power Angle Curve.

$$\int_{\delta_0}^{\delta} \frac{2(P_s - P_m)}{M} d\delta = 0$$

$$\int_{\delta_0}^{\delta} \frac{2(P_s - P_m)}{M} d\delta = 0$$

$$\int_{\delta_0}^{\delta} P_A d\delta = 0$$

⇒ Application of Equal Area Criterion :-

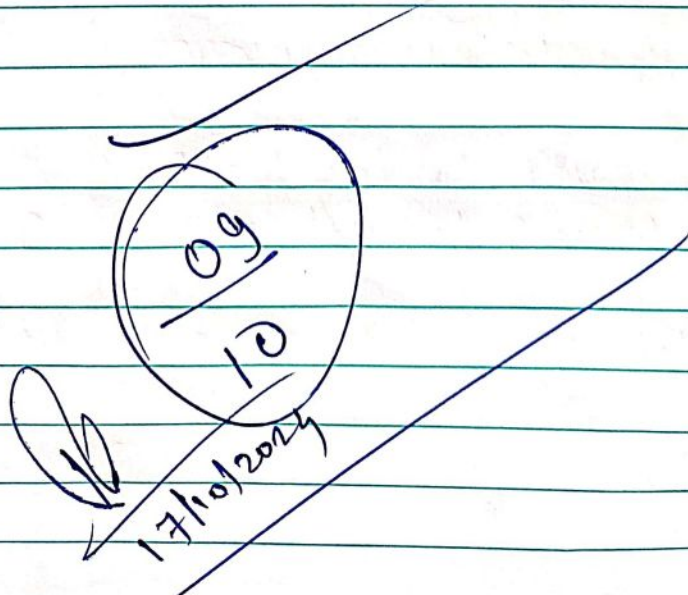
- (1) For Determining Stability limit.
- (2) Online Stability Monitoring.
- (3) Weak Point Identification.

[For system to be stable,
the Accelerating area (A_1) should be
less than the Decelerating area (A_2).

$A_1 < A_2 \Rightarrow$ system is stable.

$A_1 = A_2 \Rightarrow$ Critically stable.

$A_1 > A_2 \Rightarrow$ System is unstable.]

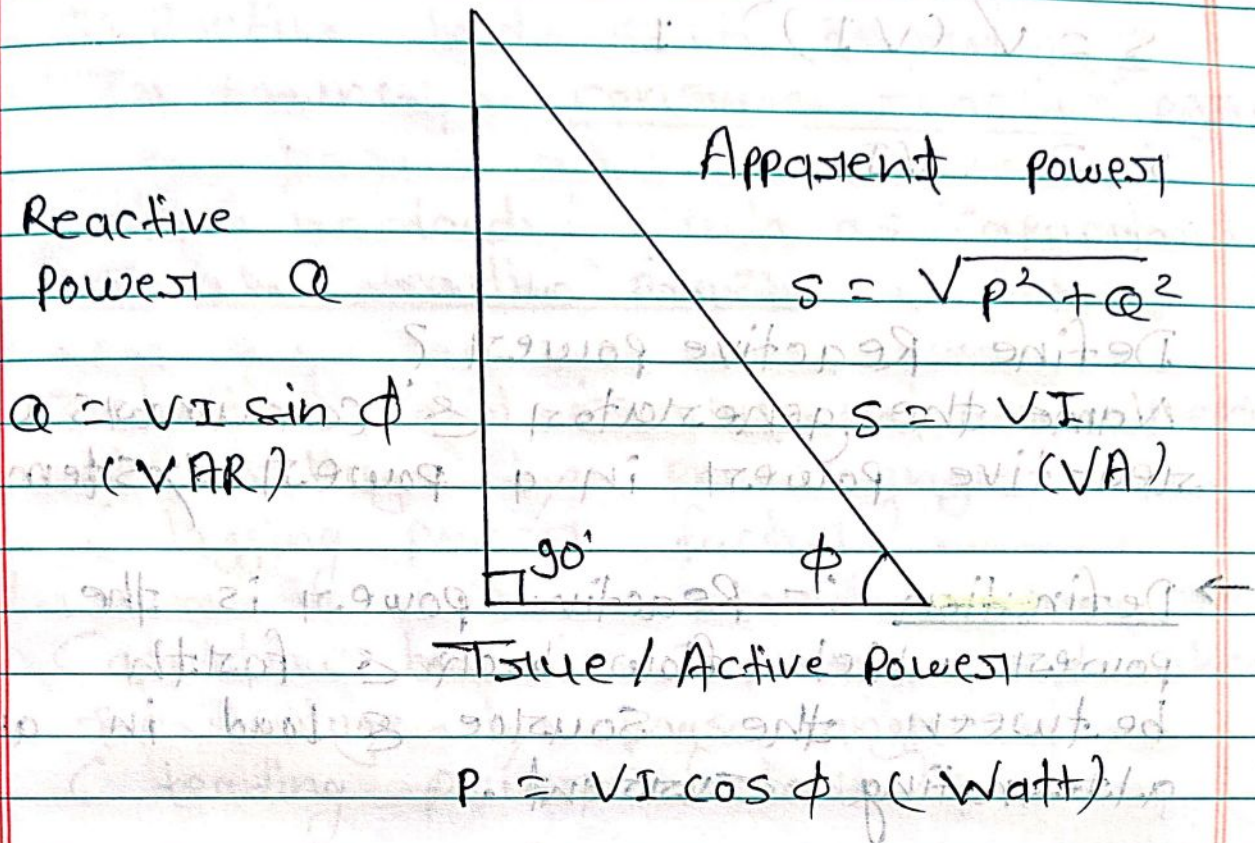


Unit - 03

Active & Reactive control

- (1) Introduction to Active & Reactive power
- (2) Effect of DC excitation on lagging & leading operation of synchronous machine.
- (3) V-curve of a synchronous M/c.
- (4) Voltage control in power system

Active Power :-



$$\Rightarrow \cos \phi = \frac{P}{S}$$

$$P = S \cos \phi$$

$$P = VI \cos \phi \quad \therefore (S = VI)$$

$$\Rightarrow \sin \phi = \frac{Q}{S}$$

$$Q = S \sin \phi$$

$$Q = VI \sin \phi \quad \therefore (S = VI)$$

$$\Rightarrow S = \sqrt{P^2 + Q^2}$$

$$S = \sqrt{(VI \cos \phi)^2 + (VI \sin \phi)^2}$$

$$S = \sqrt{(VI)^2 (\cos^2 \phi + \sin^2 \phi)}$$

$$S = \sqrt{(VI)^2} \quad 1$$

$$S = VI$$

✗

Define Reactive power?
Name the generator & consumers of reactive power in a power system.

→ Definition :- Reactive power is the power which flows back & forth between the source & load in an alternating circuit.

It is denoted by " Q ", Unit of Reactive power is VAR (Volt-Ampere Reactive).

⇒ Generators of Reactive power :-

- (i) Synchronous generator
- (ii) Synchronous condenser
- (iii) Power electronic devices
- (iv) Shunt Capacitor
- (v) Shunt Inductor.

⇒ Consumers of Reactive power :-

- (i) Inductive load such as motor & Transformers consume reactive power.
- (ii) Capacitive load such as capacitors supply reactive power.

* Inductive load :- Current lags behind the voltage by phase angle ϕ .
(Lagging power factor).

* Capacitive load :- Current leads ahead the voltage by phase angle ϕ .
(Leading power factor).

Effect of changing field excitation on synchronous motor.

→ One of the most important characteristics of a synchronous motor is that, by changing the field excitation of the motor, its power factor can be made both lagging & leading.

→ The armature current is minimum at unity power factor (i.e. $\cos \phi = 1$) & more at lagging or leading power factor.

* Case - I :- Under excitation of Synchronous Motor.

→ The synchronous motor is said to be under excited, if the field excitation is such that ($E_f < V$).

Under this condition, the armature current I_a lags behind the supply voltage V & consumes lagging reactive power (i.e. / the motor p.f. is lagging).

* Case - II :- Over-excitation of Synchronous Motor.

→ The synchronous motor is said to be over excited, if the field excitation is such that $(E_f > V)$.

Under this condition the armature current I_a leads ahead the supply voltage V & consumes leading reactive power (i.e.) the motor power factor is leading.

* Case - III :- Normal - excitation synchronous motor.

→ If $(E_f = V)$, the synchronous motor is said to be Normal excited.

Under this condition, the reactive power of the motor is zero, (i.e. $\cos \phi = 1$).

Excitation of Synchronous motor.

S.N	field excitation	$I_a \angle V$	p.f
(i) under excitation	$E_f < V$	I_a lags behind V	lagging
(ii) Over excitation	$E_f > V$	I_a leads ahead V	leading
(iii) Normal Excitation	$E_f = V$	$I_a \angle V$ are on same phase	Unity.

Ans
Imp

(3). V-Curve of synchronous Motor :-

⇒ V-Curve :-

V-curve is a graph plotted between armature current (I_a) & field current (I_f).

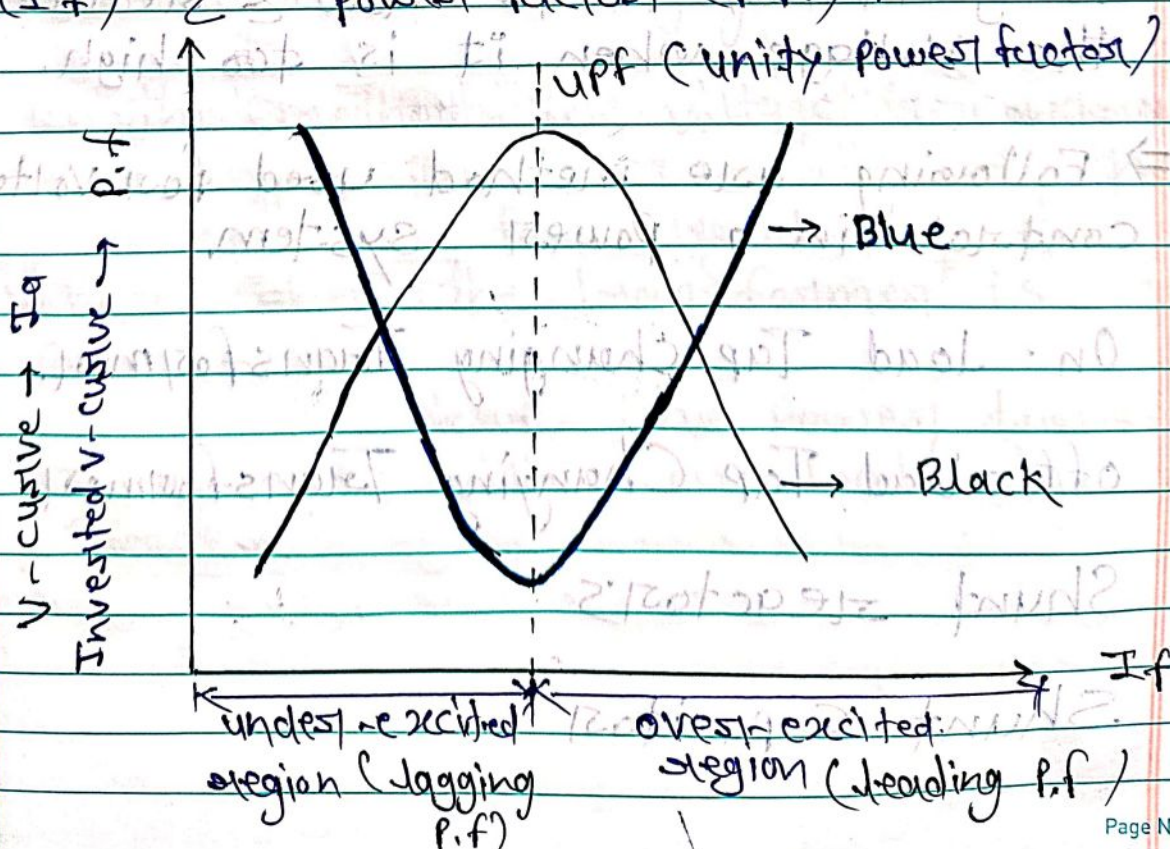
The shape of curve is similar to 'V' letter.

Hence it is named as "V-curve".

The power factor of the synchronous motor can be controlled by voltage the field current (I_f).

⇒ Inverted V-curve :-

Inverted V-curve is a graph plotted between field current (I_f) & power factor (P.f.).



① V-curve $\rightarrow I_a, V_s, I_f$

② Inverted V-curve $\rightarrow \text{p.f.}, V_s, I_f$

Method of Voltage control in a power system.

$\rightarrow$ The voltage of the power system may vary with the change in load.

$\rightarrow$ The voltage is normally high at light load and low at heavy load.

For keeping the voltage of the system in limit some additional equipment requires which increase the system voltage when it is low & reduce the voltage when it is too high.

$\Rightarrow$ Following are the methods used for voltage control in a power system.

- i On-load Tap Changing Transformer.
- ii off-load Tap Changing Transformer.
- iii Shunt reactors.
- iv Shunt Capacitors.

(v) Synchronous phase modifiers (OSP) (iii)
Synchronous Condensers

(vi) Static VAR System (SVS)

(i) Off-load Tap Changing Transformer:-

→ In this method, the voltage is controlled by changing the turn-ratio of the Transformer.

→ The Transformer is disconnected from the supply before changing the tap. Here, the tap-changing of the Transformer is done manually.

(ii) On-load Tap Changing Transformer:-

→ In this method, the voltage is controlled by changing the turn-ratio of the transformer for regulating the system voltage when the transformer is On-load.

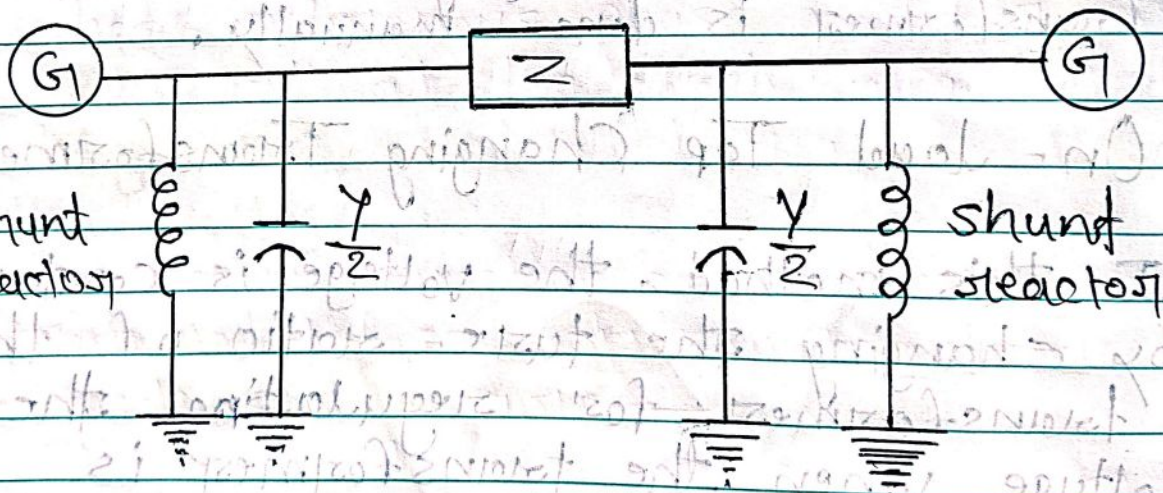
Here, the power transformer is provided with "on-load tap changer".

(iii) Shunt Reactor :-

→ The shunt reactor is the inductive circuit element which is connected between the line & Neutral.

The shunt reactor compensates the inductive current from the transmission line or the underground cable.

It is mainly used in long distance EHV & UHV Line.



Function of Shunt Reactor :-

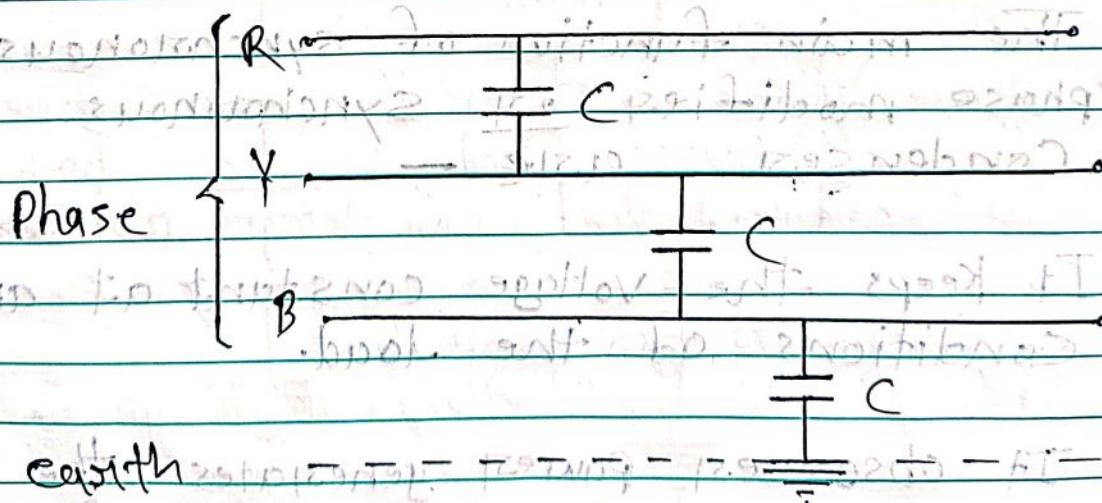
1. It is used in high voltage transmission system to stabilize the voltage during load variations.

2. It acts as a "Constant Absorber".
3. It increases the stability of the power system.
4. It compensates the inductive current in the power system.

(iv) Shunt Capacitor :-

→ The shunt capacitors are the capacitors connected in with the

→ It is a device which is used to improve the power factor by providing capacitive reactance in the electrical power system.



Main function of shunt capacitor :-

- (i) To improve the power factor.
- (ii) To improve the voltage profile of the power system.

Att

(V) Synchronous phase modifier or Synchronous Condenser

→ The synchronous phase modifier or synchronous condenser is a synchronous motor (Over-excited) without mechanical load.

→ The synchronous phase modifier is connected at the receiving end of the line.

The main function of synchronous phase modifier or Synchronous Condenser are -

- (i) It keeps the voltage constant at any conditions of the load.
- (ii) It absorbs power generates the reactive power by changing the field excitation.
- (iii) It improves the power factor of the system.

Imp
(vi)Static VAR Compensator :-

→ A static VAR Compensator is a parallel combination of controlled reactor and fixed shunt capacitor. The thyristor switch assembly in the SVC controls the reactor. The firing angle of the thyristor controls the voltage across the inductor and thus the current flowing through. In this way, the reactive power drawn by the inductor can be controlled.

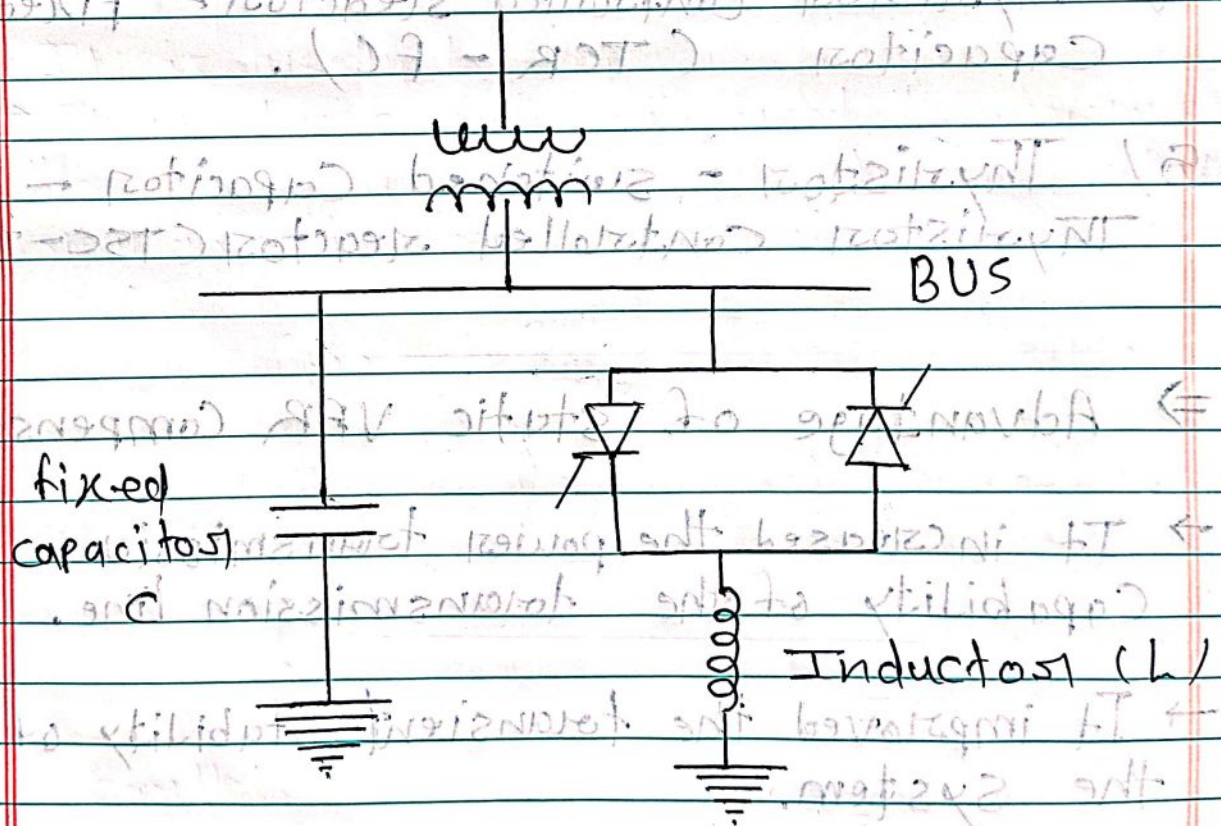


fig. # Static VAR Compensator.

→ The SVC is capable of step less adjustment of reactive power over an unlimited range without any time delay.

It improves the system stability and system power factor. Most commonly used SVC scheme are as follows.

- (1) Thyristor Controlled reactor (TCR).
- (2) Thyristor - switched Capacitor (TSC).
- (3) Self Reactor (SR).
- (4) Thyristor controlled reactor - fixed Capacitor (TCR - FC).
- (5) Thyristor - switched Capacitor - Thyristor Controlled reactor (TSC - TCR)

⇒ Advantage of static VAR Compensator

→ It increased the power transmission capability of the transmission line.

→ It improved the transient stability of the system.

→ It controlled the steady state and temporary overvoltages.

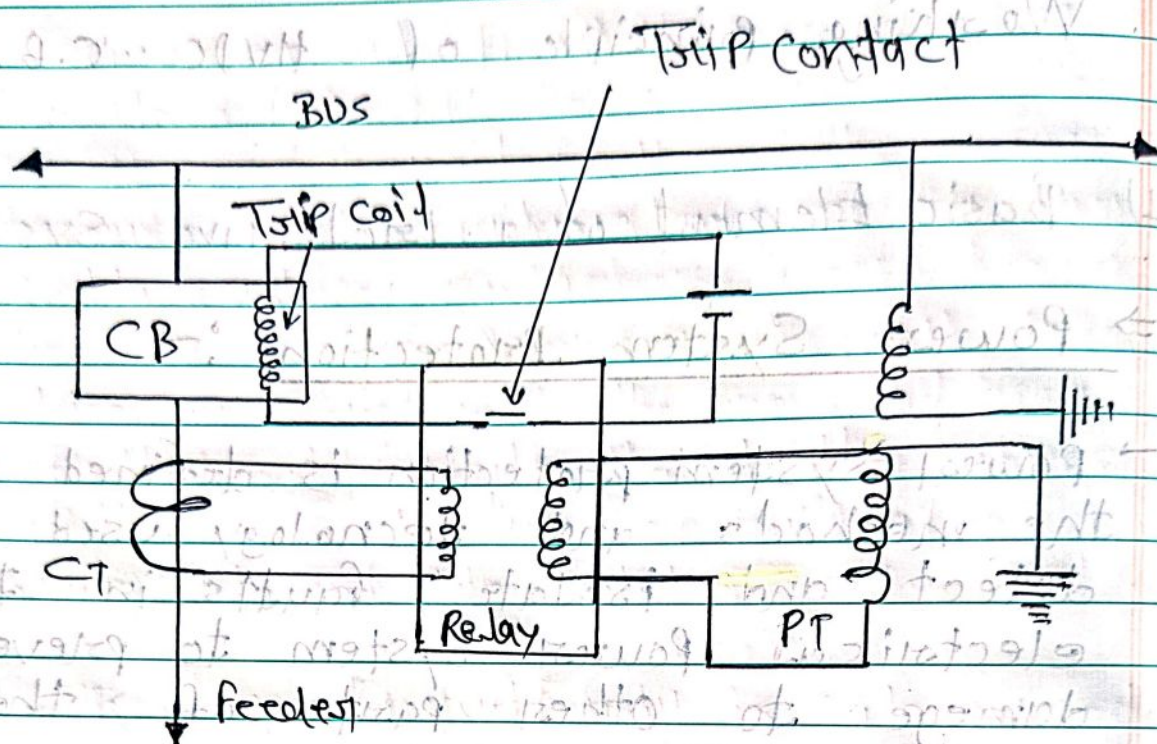
→ It improved the load power factor, and therefore, reduced line losses and improved system capability.

⇒ Static VAR Compensator has no rotating parts.

Unit - 04

Elements of Protection and Circuit Interruption Device.

- 4.1 Basic Element of a Protective system
- 4.2. Types, Causes, & effect of various faults.
- * 4.3 Back - up Protection
- * 4.4 CT - PT - connection Diagram
(Single phase & three phase)
- * 4.5 Current Limiting Reactor.
- 4.6* Neutral Earthing
Isolator & fuses.
- * 4.7 Construction, Working of circuit
Breakers.
 - (1) Air Blast circuit Breaker.
 - (2) SF₆ Circuit Breaker.
 - (3) Vacuum circuit Breaker (VCB).
- 4.8 Auto - reclosure, Arc phenomena &
Arc extinction.
- 4.9 Resistance switching.



Basic Connection diagram of protection Relay

4.2
#

Types of faults in power system.

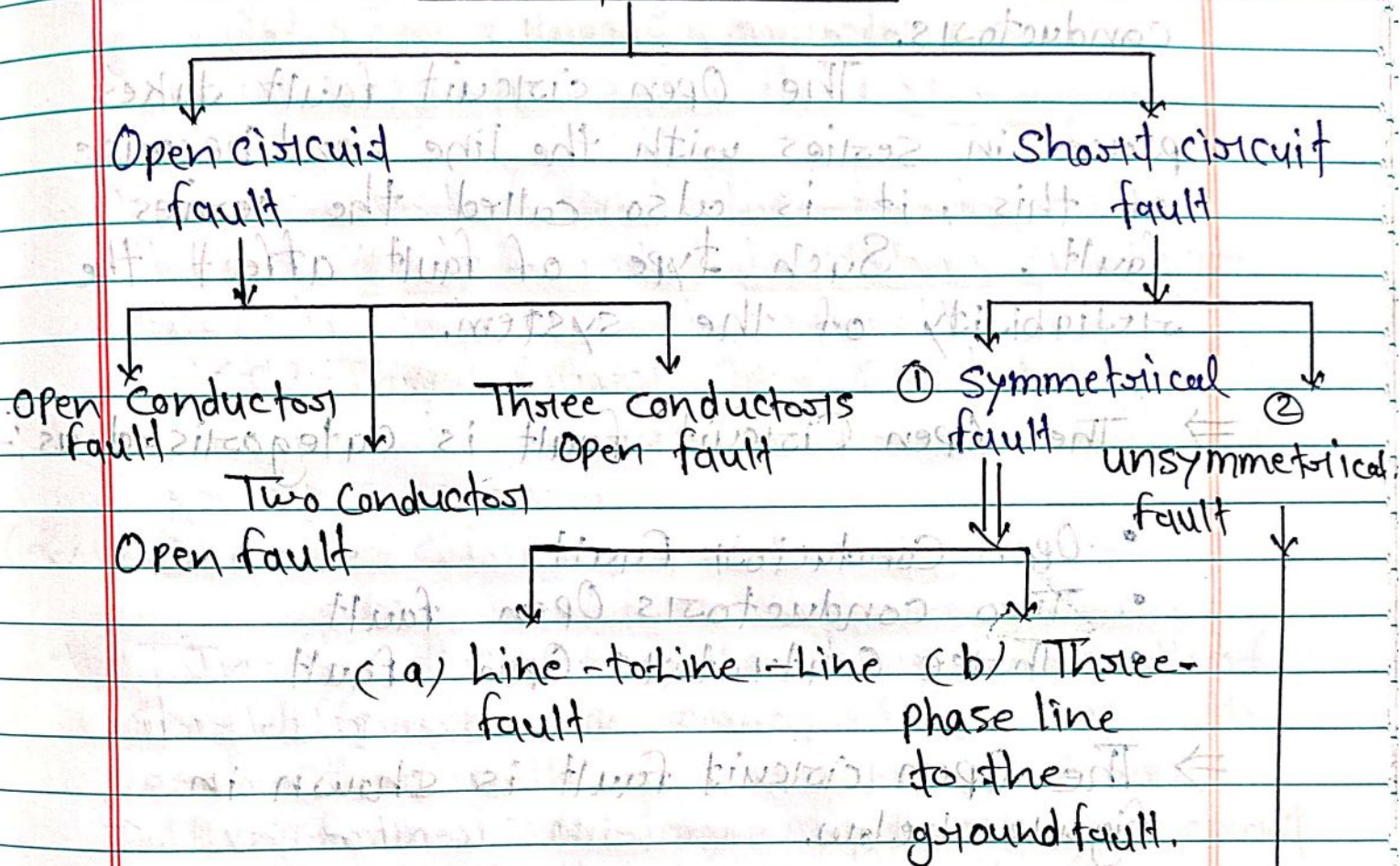
→ The faults in the power system is defined as the defect in the power system due to which the consistent is distracted from the intended path. The faults creates the abnormal condition which reduces the insulation strength between the conductors.

⇒ The faults in the power system is mainly categorised into two types they are :-

1. Open circuit Faults.
2. Short Circuit Fault.

⇒ The different types of power system fault are:-

Power system faults



① Single line-to-ground (L-G) fault ←

② Line-to-line fault (L-L fault) ←

③ Double line-to-ground (L-L-G) fault ←

(1) Open Circuit Fault :-

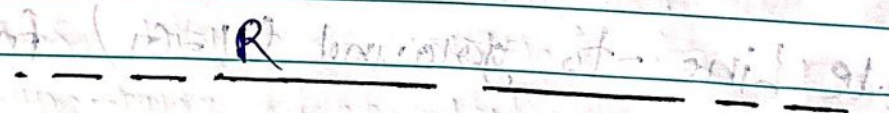
→ The open circuit fault mainly occurs because of the failure of one or two conductors.

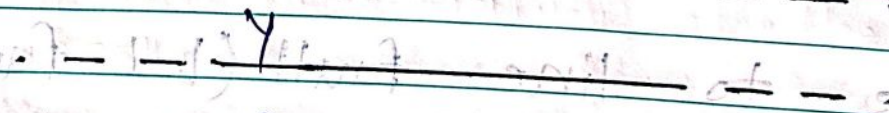
The Open circuit fault takes place in series with the line, and because of this, it is also called the series fault. Such type of fault affects the reliability of the system.

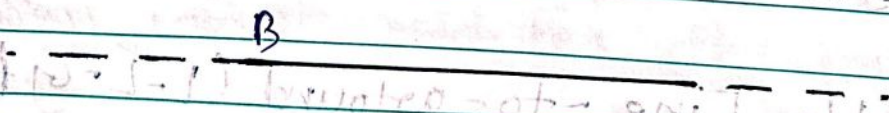
⇒ The Open Circuit fault is categorised as

- Open Conductor Fault
- Two conductors Open fault
- Three conductors Open fault

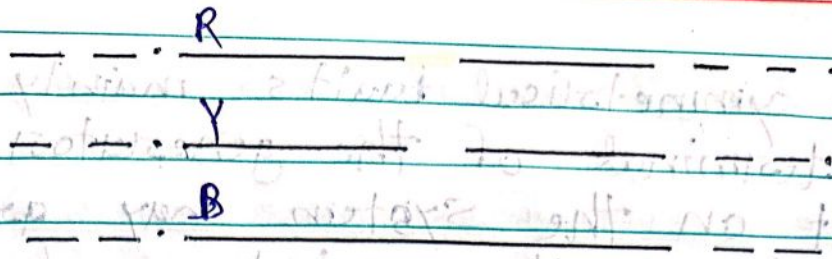
⇒ The Open circuit fault is shown in figure below.

→ 

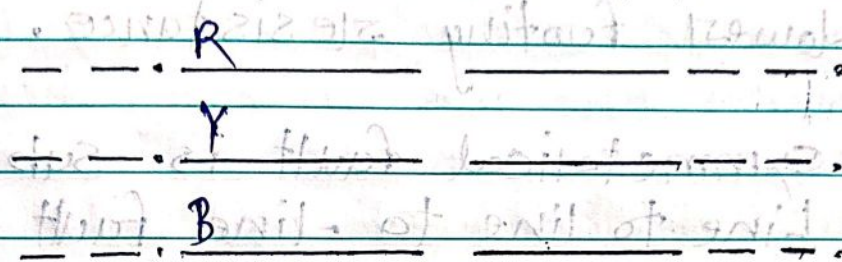
→ 

→ 

(a) single-phase Open Conductor



(b) Two - phase ^{open} Conductor.



(c) Three - phase Open Conductor

(2) Short - Circuit Fault :-

→ In this type of fault, the conductors of the different phase come into contact with each other or with a power line, power transformer or any other circuit element due to which the large current flow in one or two phase of the system.

The short - circuit fault is divided into the symmetrical and unsymmetrical fault.

★ Symmetrical fault :-

→ The faults which involve all the three phases is known as the symmetrical fault. Such types of fault remain balanced even after the fault.

The symmetrical faults mainly occur at the terminal of the generators. The fault on the system may arise on account of the resistance of the arc between the conductors or due to the lowest footing resistance.

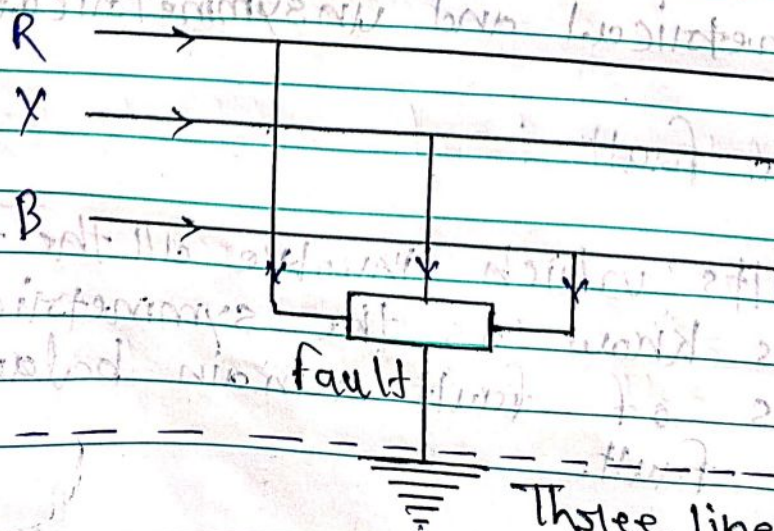
The symmetrical fault is sub-categorized into Line to line to -line fault and three-phase line to ground - fault.

(a) Line - Line - Line - Fault :-

→ Such types of fault are balanced, i.e. the system remains symmetrical even after the fault.

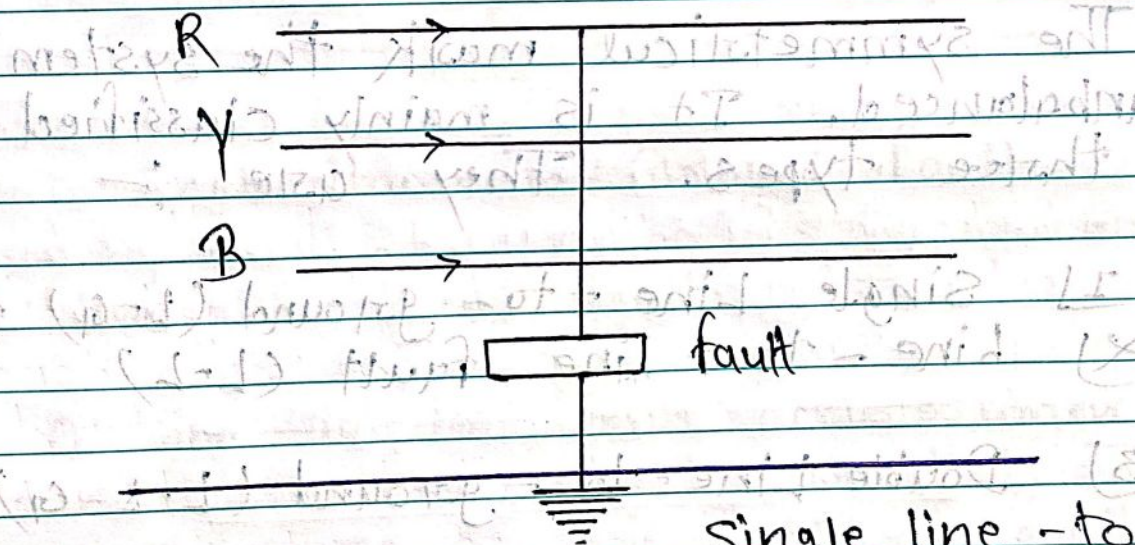
The L-L-L fault occurs rarely, but it is the most severe type of fault which involves the largest current.

This large current is used for determining the rating of the circuit breakers.



(b) Three-phase line to the ground fault
(L-L-L-G fault) :-

→ The three-phase line to ground fault includes all the three phase of the system. The L-L-L-G fault occurs between the three phase and the ground of the system. The probability of occurrence of such type of fault is nearly 2 to 3 percent.



Single line - to
ground fault.

Unsymmetrical fault :-

→ The fault gives rise to unsymmetrical current, i.e. current differing in magnitude and phases in the three phases of the power system are known as the unsymmetrical fault.

→ It is also defined as the fault which involves one or two phase such as L-G, L-L, L-L-G fault.

The symmetrical make the system unbalanced. It is mainly classified into three types. They are :-

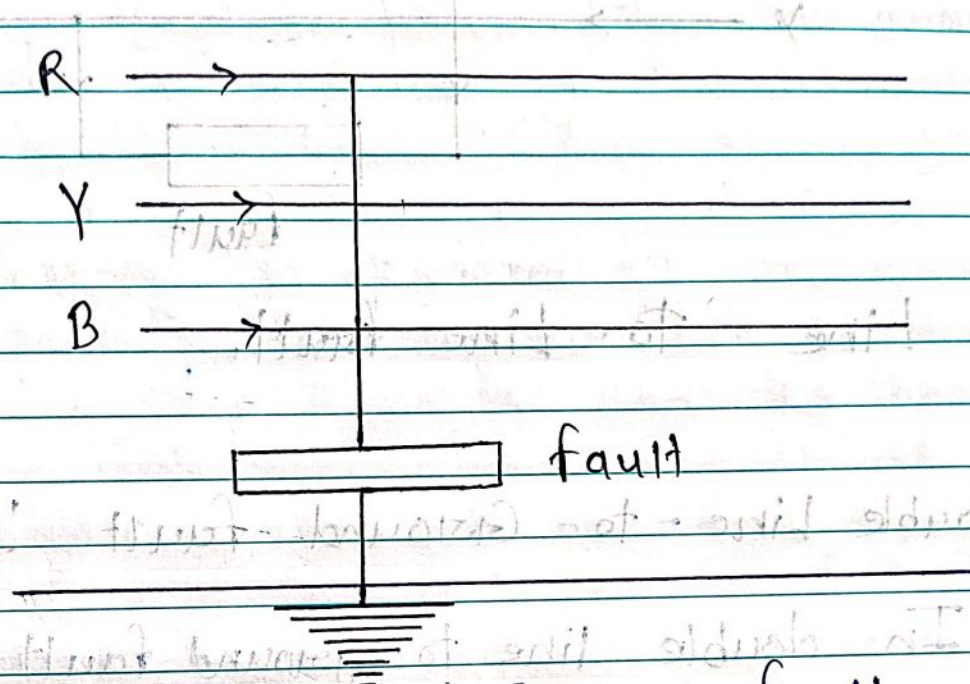
- 1) Single Line-to-ground (L-G) fault.
- 2) Line-to-Line fault (L-L)
- 3) Double Line-to-ground (L-L-G) fault.

→ The unsymmetrical fault is the most common types of fault occur in the power system.

1) Single Line-to-ground fault. :-

→ The single line to ground fault occurs when one conductor falls to the ground or contact the neutral conductor.

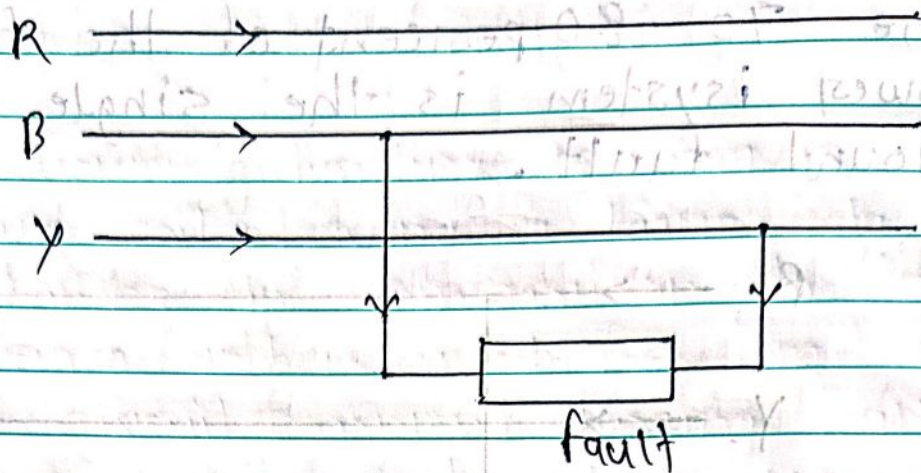
The 70 - 80 per cent of the fault in the power system is the single line-to-ground fault.



Single line - to - Ground fault.

2. Line - to - Line fault:

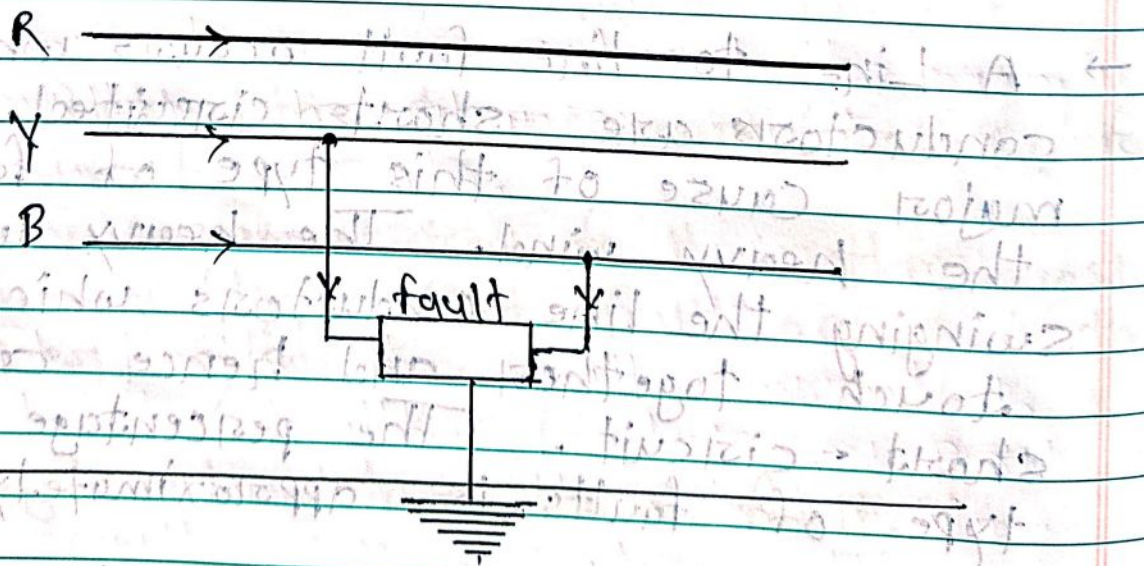
→ A Line - to - line fault occurs when two conductors are short circuited. The major cause of this type of fault is the heavy wind. The heavy wind swinging the line conductors which may touch together and hence cause short - circuit. The percentage of such type of faults is approximately 15 - 20%.



Line - to - Line fault.

(3). Double Line - to - Ground fault :-

→ In double line to ground fault, the two line come in contact with each other along with the ground. The probability of such types of faults is nearly 10%.



Single - line - to - Ground fault.

→ The symmetrical and unsymmetrical fault mainly occurs in the terminal of the generator, and the open circuit and short-circuit fault occur on the transmission line.

4.3

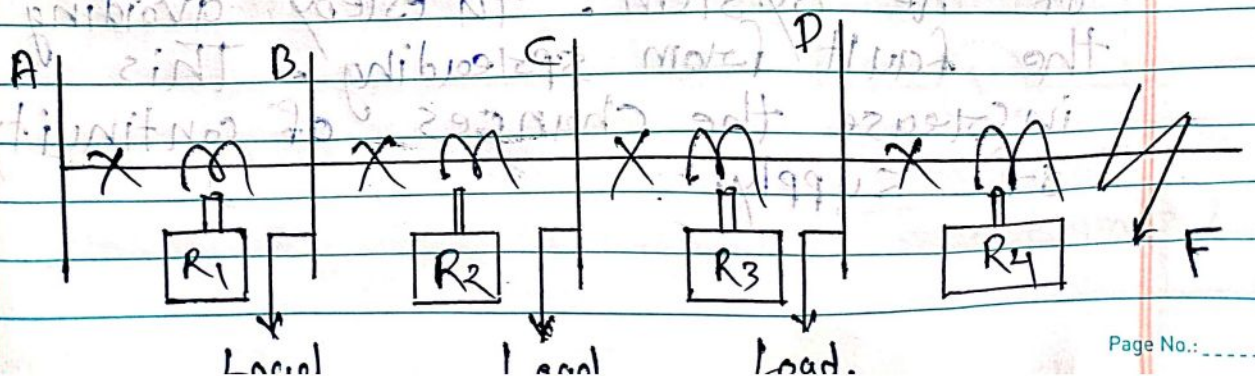
Back-up Protection :-

Sme

→ The backup protection provides the back up to the main protection whenever it fails in operation or is cut out for repairs. The backup protection is essential for the proper working of the electrical system.

→ The back-up protection is the second line of defence which isolates the faulty section of the system in case the main protection fail to function properly.

→ The back up protection may be provided either on the same circuit breaker which would be normally opened by the main protection or in the different circuit breakers.



4.5

#

Current Limiting Reactor :-

→ The current limiting reactor is an inductive coil having a large inductive reactance in comparison to their resistance and is used for limiting short circuit current during fault condition. Current-voltage reactor also reduced the voltage disturbances on the rest of the system.

⇒ Functions of Current Limiting Reactor:

- Current limiting reactor reduces the flow of short circuit current so as to protect the appliances from mechanical stress and overheating.

- Current reactor reduced the magnitude of voltage disturbances which is caused by short circuits.

- It limits the fault current flow into the healthy feeders, thus protects the fault from spreading. This increase the chances of continuity of supply.



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4.4.

CT and PT Connection diagram for Three phase system.

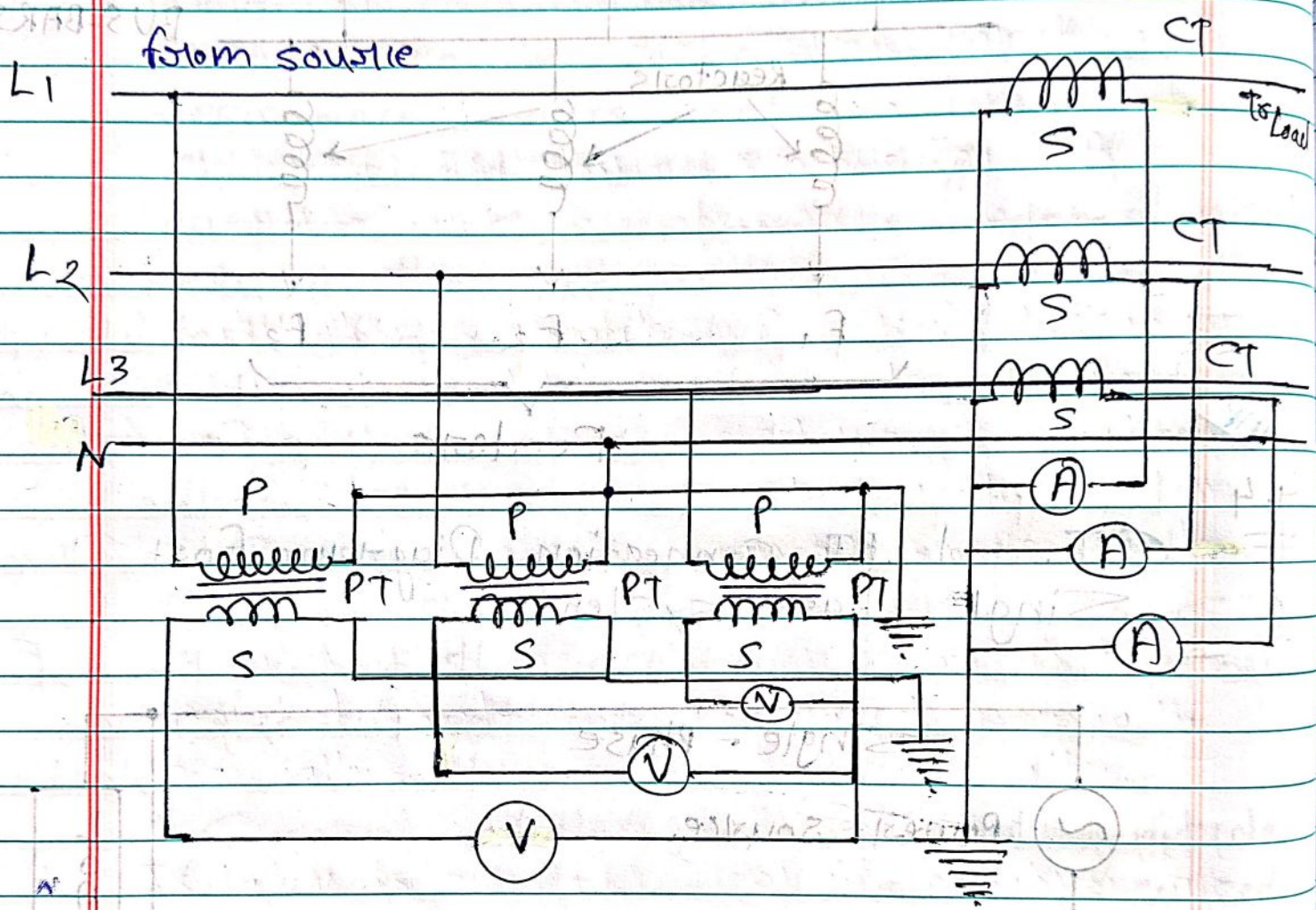
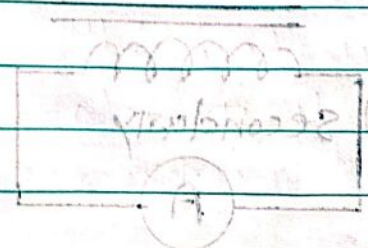
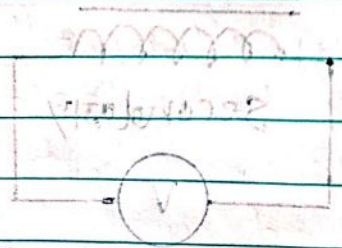


Fig:- CT & PT Connection diagram for three phase system.



(Potential)

Isolator, Fuse and Circuit Breaker :-

→ The Isolator and Circuit breaker both have similar function of disconnecting the electrical circuit.

Therefore, they are closely related each other.

⇒ Circuit Breaker :-

→ A circuit breaker is an electrical safety device which works like a switch.

The circuit breaker detects the faults with the help of a relay system and interrupts the current flow through the circuit.

→ The primary function of the circuit breaker is to protect the circuit from over load and short circuit.

A circuit breaker can be operated manually and automatically.

⇒ Isolator :-

→ An Isolator is a switch gear component which is used to disconnect or isolate the whole or a specific part of circuit.

The isolator is used when maintenance and repair work are to be done in an electrical system.

The isolator is a switch that can be operated under off load condition only.

SN.	Isolator	Circuit Breaker
(1)	Symbol of Isolator 	Symbol of C.B. 
(2)	An isolator is a simple mechanical switch.	A circuit breaker consists of an electromechanical switch and a ready system in a single unit.
(3)	Isolator can be operated only manually.	Circuit breaker can be operated manually & Automatically.
(4)	Isolator is an off-load device.	Circuit breaker is an on-load device.
(5)	The main function of isolator is to disconnect the faulty part of an electrical power system. So that it can be repaired.	The main function of the C.B is to protect the interior part electrical power system.
(6)	Isolator is less-costly	Circuit Breaker is expensive material.

Write the difference between Fuse and Circuit Breaker. :-

S.N.	Fuse	Circuit breaker.
(1)	Principle :- It works on the thermal and electrical properties of the conducting material.	Principle :- It works on the switching principle and electromagnetism.
(2)	Fuse can be used only once.	A circuit breaker can be used many numbers of time.
(3)	It detects and interrupts the fault.	It can only interrupt the fault. The fault detection is done by relay system.
(4)	The operation of a fuse is Automatic.	The operation of a circuit breaker can be both manual or Automatic.
(5)	Low cost	High cost.
(6)	Operating time :- 0.002 second	Operating time :- 0.02 to 0.05 second.
(7)	Low breaking capacity as compared to circuit breaker.	High breaking capacity.

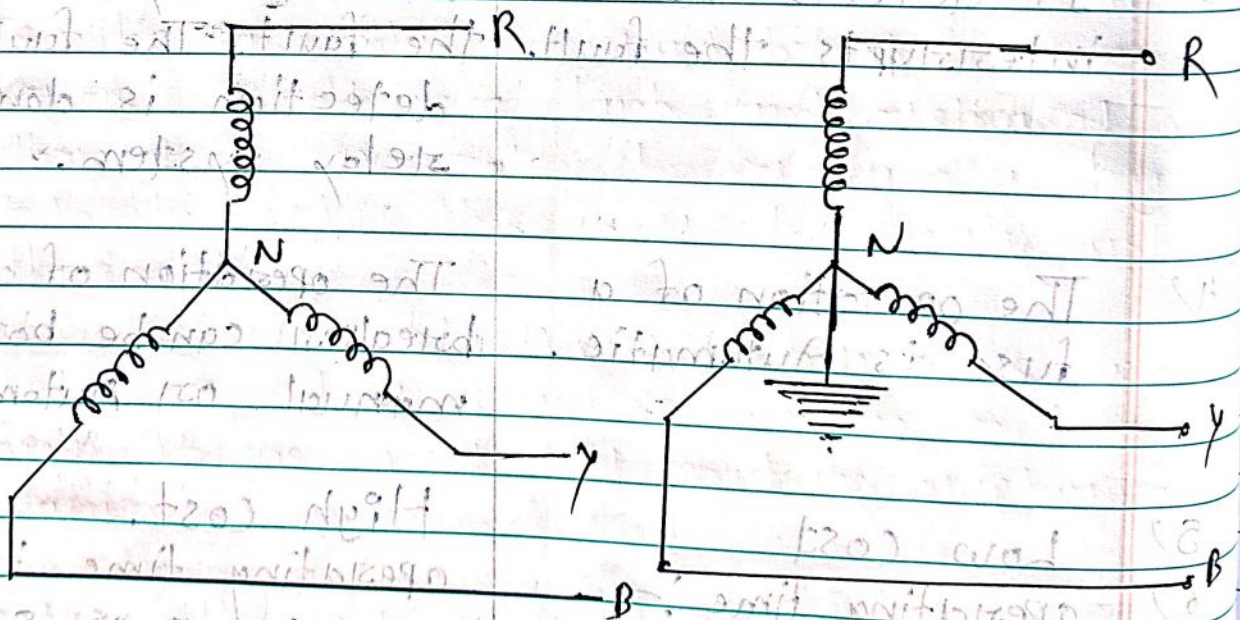
Neutral Grounding / Earthing :-

→ In neutral grounding system the neutral of the system or transformer is connected to the ground.

The neutral grounding is an important aspect of power system design because the performance of the power system regarding short-circuit, stability, protection etc. is greatly affected by the condition of the neutral.

(i) Ungrounded Neutral

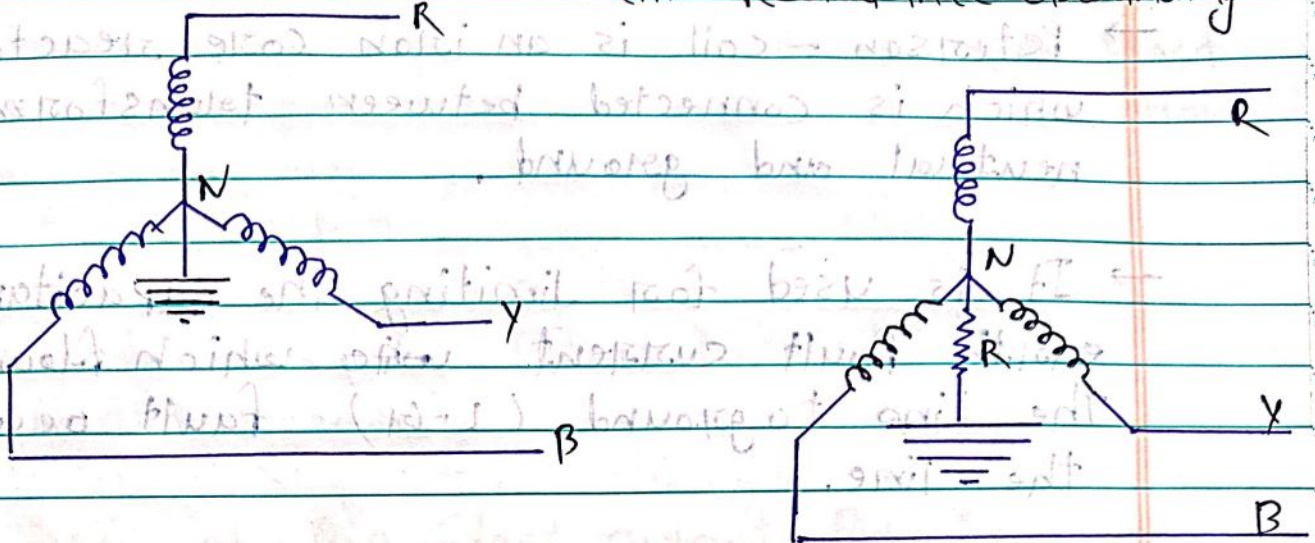
(ii) Grounding system



⇒ Methods of Neutral grounding :-

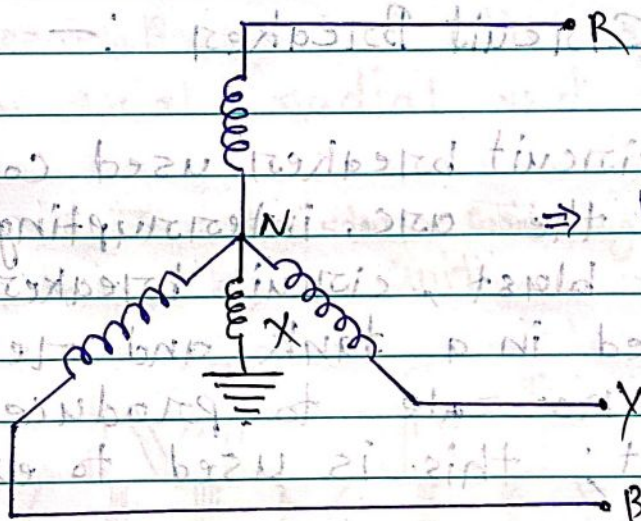
(1) Solid Grounding

(ii) Resistance Grounding



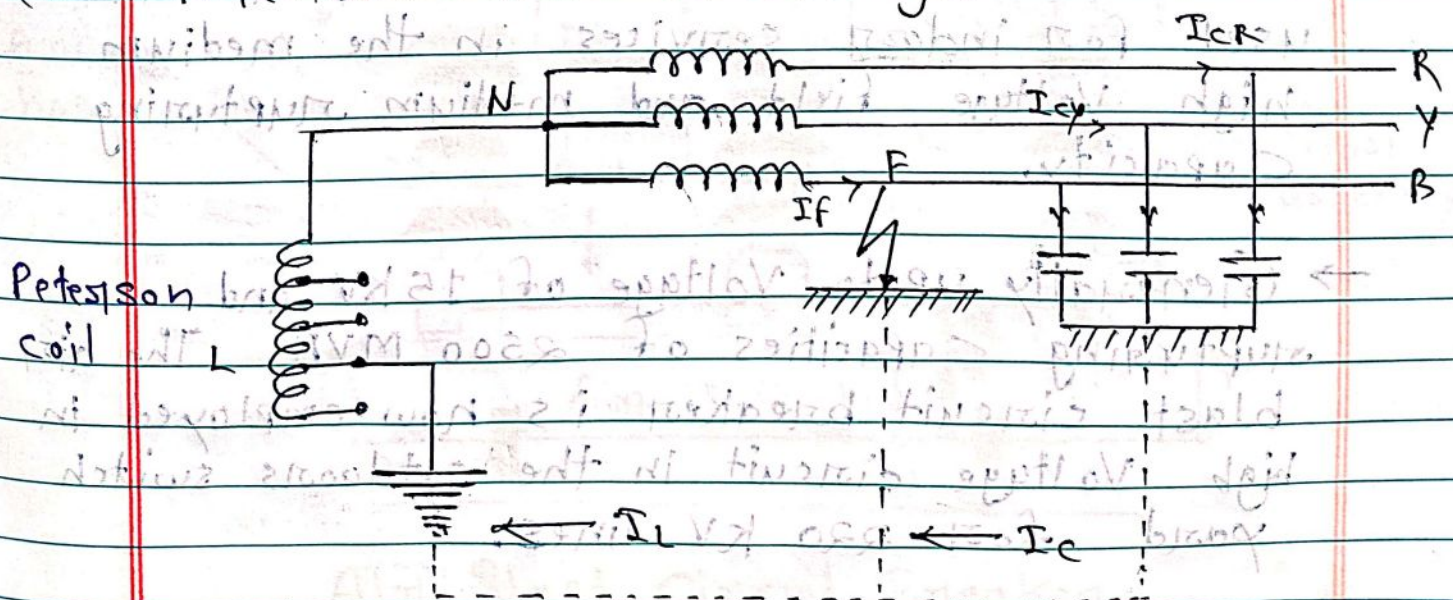
(iii) Reactance grounding :-

Usually used for Generator



⇒ Usually used for Motor

(iv) Peterson - coil Grounding :-



Line - Ground fault on Phase B.

- Peterson - coil is an iron core reactor which is connected between transformer neutral and ground.
- It is used for limiting the capacitance earth fault current which flow when the line to ground (L-G) fault occurs in the line.

Air Blast Circuit Breaker :-

- Air blast circuit breaker used compressed air or gas the arc, interrupting medium. In the air blast, circuit breaker compressed air is stored in a tank and released through a nozzle to produce a high-velocity jet; this is used to extinguish the arc.

Air blast circuit breakers are used for indoor services in the medium high voltage field and medium interrupting capacity.

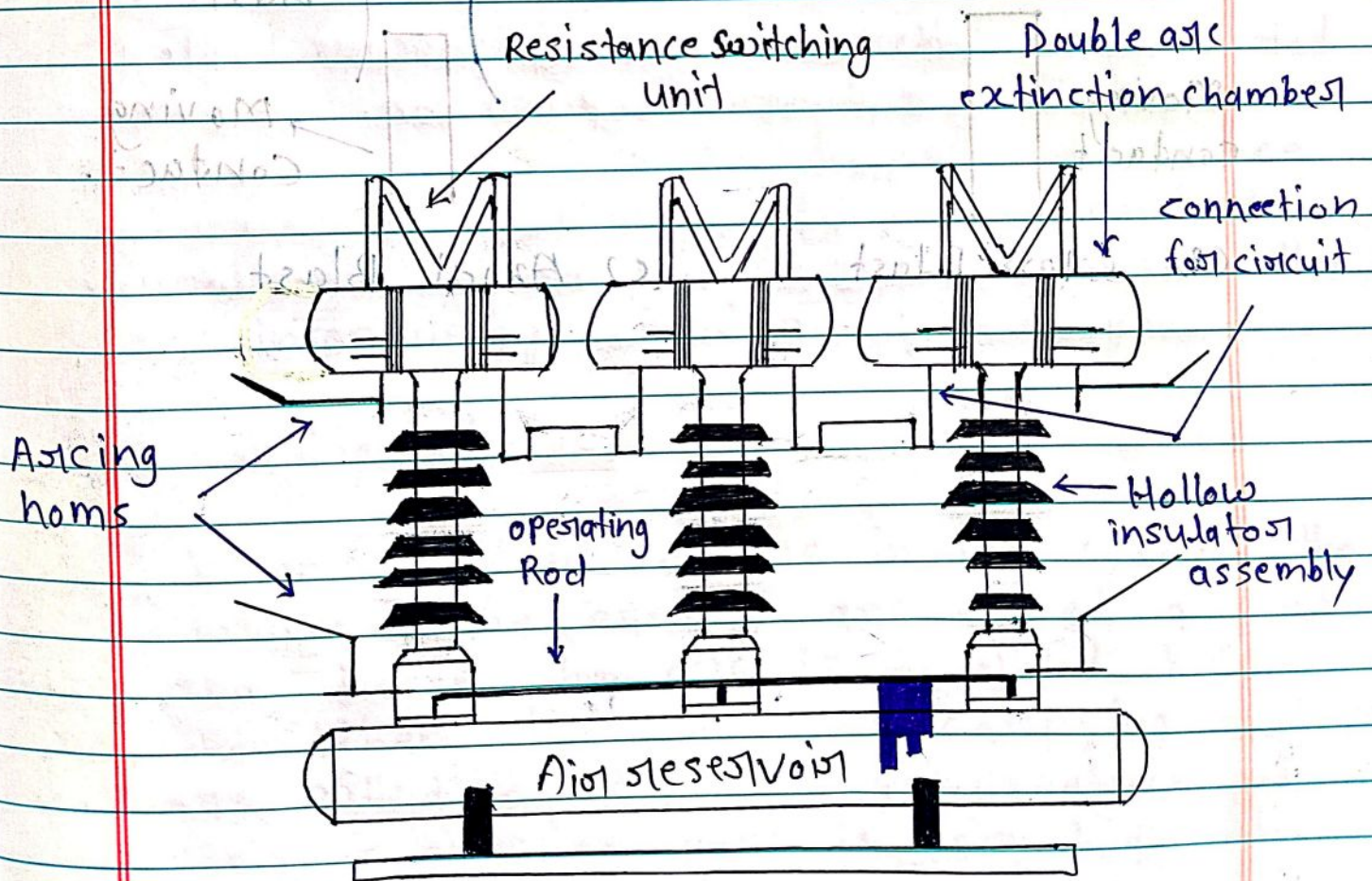
- Generally up to Voltage of 15 kV and interrupting capacities of 2500 MVA. The air blast circuit breaker is now employed in high voltage circuit in the outdoors switch yard for 220 kV lines.

⇒ The desirable features to be found in air blast circuit breakers are High-Speed Operation.

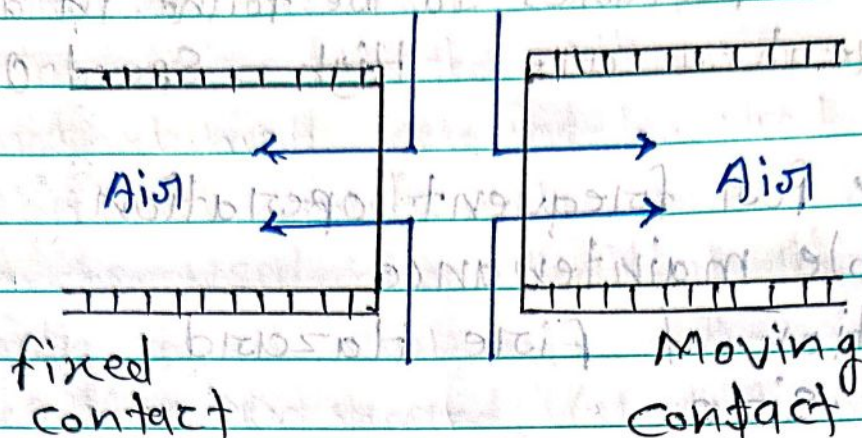
- Suitability for frequent operation
- Negligible maintenance
- Elimination of fire hazard
- Reduced size

⇒ Types of Air Blast Circuit Breaker :-

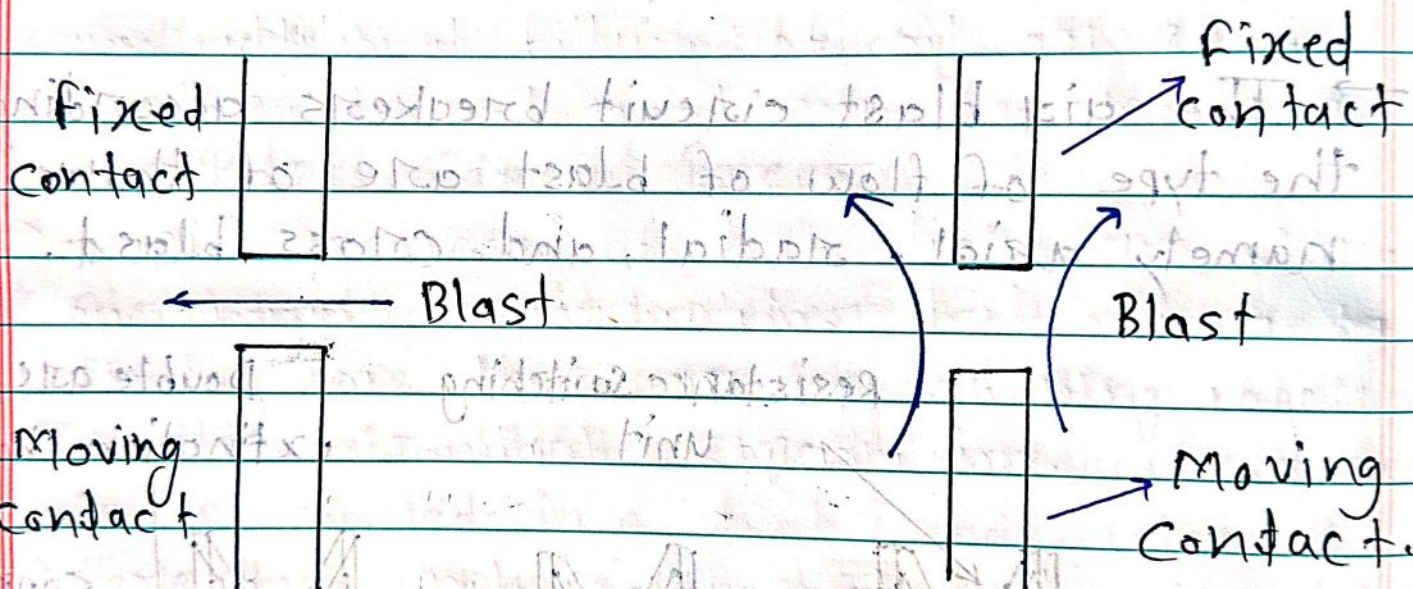
→ The air blast circuit breakers according to the type of flow of blast are of three types namely axial, radial, and cross blast.



Air Blast Circuit Breaker.

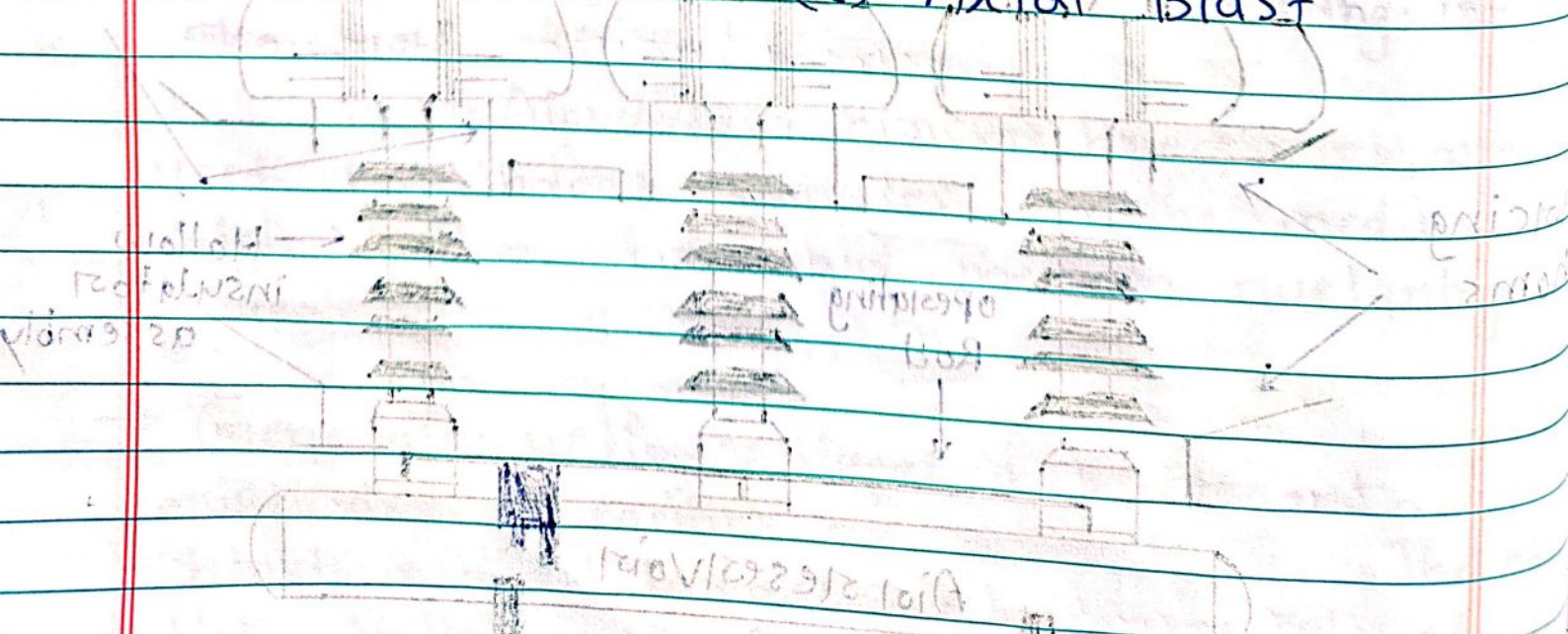


(A) Radial Blast



(B) Cross Blast

(C) Axial Blast



Imp 11

Vacuum Circuit Breaker :-

→ A breaker which used vacuum as an arc extinction medium is called a Vacuum circuit breaker. In this circuit breaker, the fixed and moving contact is enclosed in a permanently sealed vacuum interrupter.

The arc is extinct as the contacts are separated in high vacuum. It is mainly used for medium voltage ranging from 11 kV to 33 kV.

⇒ Construction of Vacuum Circuit Breaker.

→ It is very simple in construction as compared to any other circuit breaker. Their construction is mainly divided into three part, i.e. fixed contact, moving contact and arc shield which is placed inside the arc interrupting chamber.

⇒ Working of VCB

→ When the fault occurs in the system, the contacts of the breaker arc moved apart and hence the arc is developed between them. When the current carrying contacts are pulled apart, the temperature of their connecting part is very high due to which ionization occurs.

Due to the ionization, the contact space is filled with vapour of positive ions which is discharged from the contact material.

⇒ Advantages of Vacuum Circuit Breaker.

→ Vacuum circuit breaker does not require any additional filling of oil or gas. They do not need periodic refilling.

→ Rapid recovery of high dielectric strength on current interruptions that only a half cycle or less arcing occurs after proper contact separation.

→ Breaker unit is compact and self-contained. It can be installed in any required orientation.

Sulphur Hexafluoride (SF_6) Circuit Breaker. :-

→ A circuit breaker in which SF_6 under pressure gas is used to extinguish the arc is called SF_6 circuit breaker. SF_6 (Sulphur hexafluoride) gas has excellent dielectric, arc quenching, chemical and other physical properties which have proved its superiority over other arc quenching mediums such as oil or air.

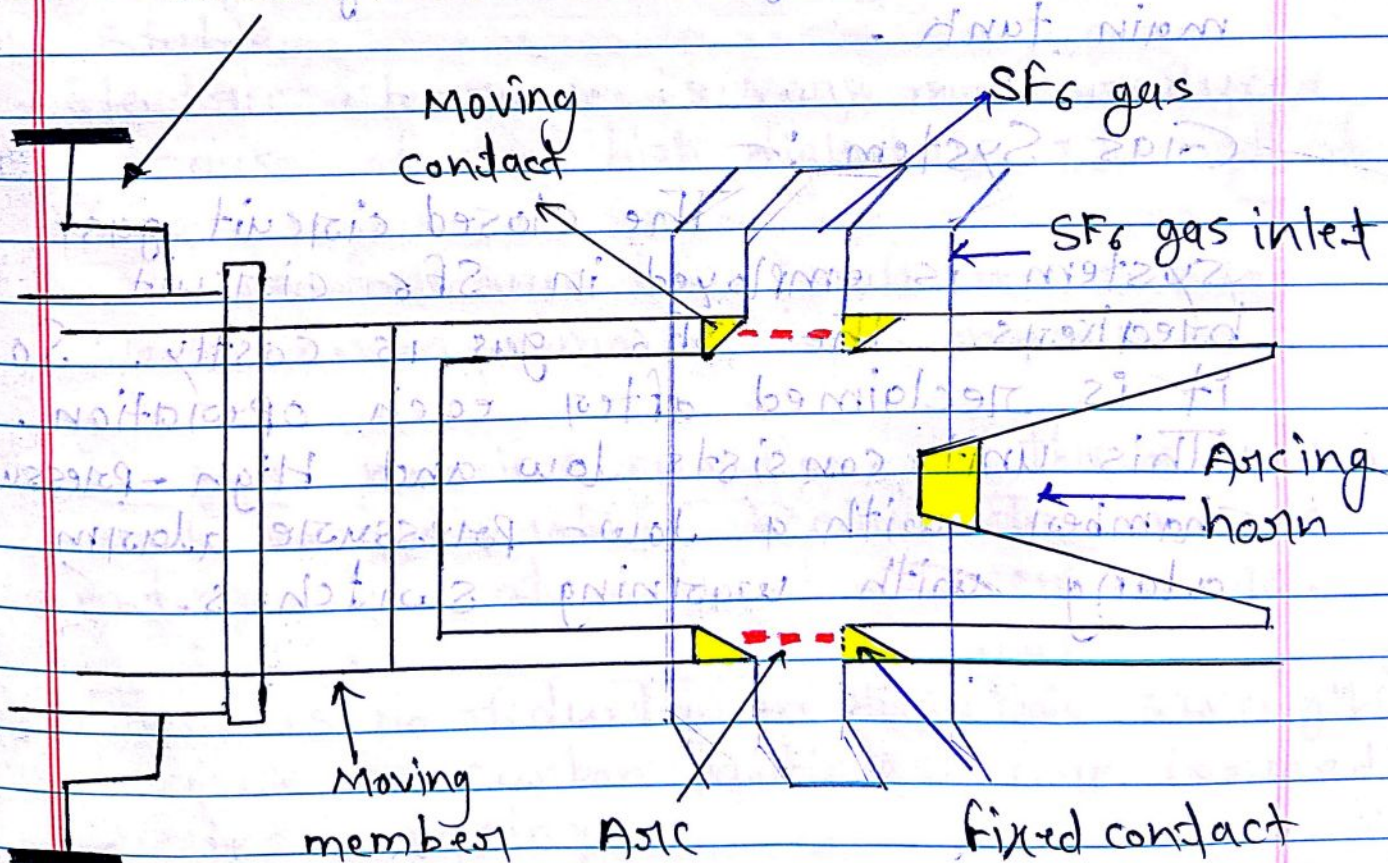
⇒ Properties of sulphur hexafluoride circuit breaker.

Sulphur hexafluoride possesses very good insulating and arc quenching properties. These properties are :-

- It is colourless, odourless, non-toxic, and non-inflammable gas.
- SF_6 gas is extremely stable and its density is five times that of air.
- It has high thermal conductivity better than that of air.

- SF_6 gas is strongly electronegative, which means the free electrons are easily removed from discharge.
- It is 100 times more effective as compared to arc quenching medium.
- Its dielectric strength is 2.5 times than that of air and 30% less than that of the dielectric oil.

Insulating rod for
Moving operated
members



Interrupter Unit of SF_6 Circuit Breaker.

⇒ Construction of SF₆ circuit Breaker.

→ SF₆ circuit breakers mainly consist of two parts, namely (a) the interruption unit and (b) the gas system.

→ Interruption Unit :-

This unit consists of moving and fixed contacts comprising a set of current-carrying parts and an arcing probe. It is connected to the SF₆ gas reservoir. This unit consists of slide vents in the moving contacts which permit the high-pressure gas into the main tank.

Gas System :-

The closed circuit gas system is employed in SF₆ circuit breakers. The SF₆ gas is costly. So it is reclaimed after each operation. This unit consists of low and high-pressure chambers with a low-pressure alarm along with warning switches.

⇒ Working Principle of SF₆ Circuit Breaker:-

In the normal operating conditions, the contacts of the breaker are closed. When the fault occurs in the system, the contacts are pulled apart, and an arc is struck between them.

⇒ Advantage of SF₆ Circuit Breaker.

1. SF₆ gas has excellent insulating, arc extinguishing and many other properties.
2. The gas is non-inflammable and chemically stable.
3. Electric clearance is very much reduced because of the high dielectric strength of SF₆.
4. Its performance is not affected due to variation in atmospheric condition.
5. It gives noiseless operation, and there is no over voltage problem because the arc is extinguished at natural current zero.
6. There is no reduction in dielectric strength because no carbon particles are formed during arcing.
7. It requires less maintenance and no costly compressed air system is required.

Resistance switching :-

→ Resistance switching is employed in circuit breaker having a High zero resistance of contact space. The resistance switching mainly used for reducing the restriking voltage & the transient surge voltage.

Defination :-

A fixed connection of resistance in parallel with the contact space or arc is called the resistance switching.

⇒ Resistance switching Circuit Diagram :-

→ Resistance switching is normally applied in air blast circuit breaker.

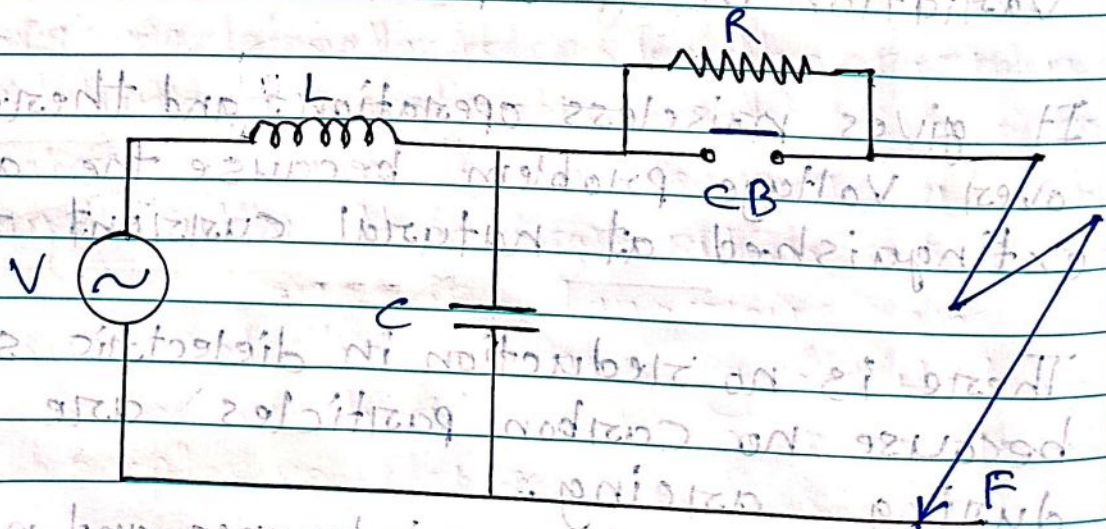
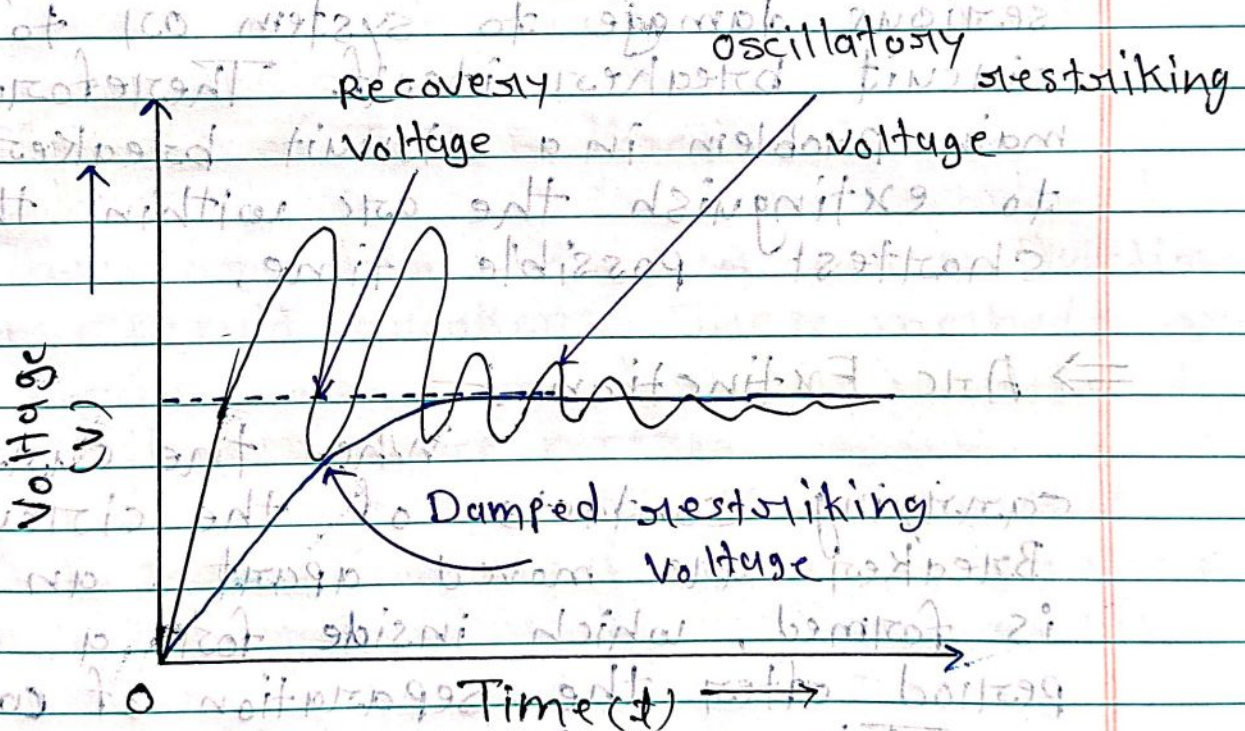


fig:- Resistance Switching circuit

→ When the fault occurs, the contacts of the circuit breaker are open, and an arc is struck between the contacts.

→ When the arc is shunted by the arc resistance (R), a part of arc current is diverted through the resistance.

→ Thus, the arc resistance is increased, leading to the further increase in current through the shunt resistance (R).



Arc phenomenon & Arc Extinction

⇒ Arc phenomenon :-

When the contacts of a circuit breaker are separated, there is a luminous electric discharge between these two contacts known as 'Arc'.

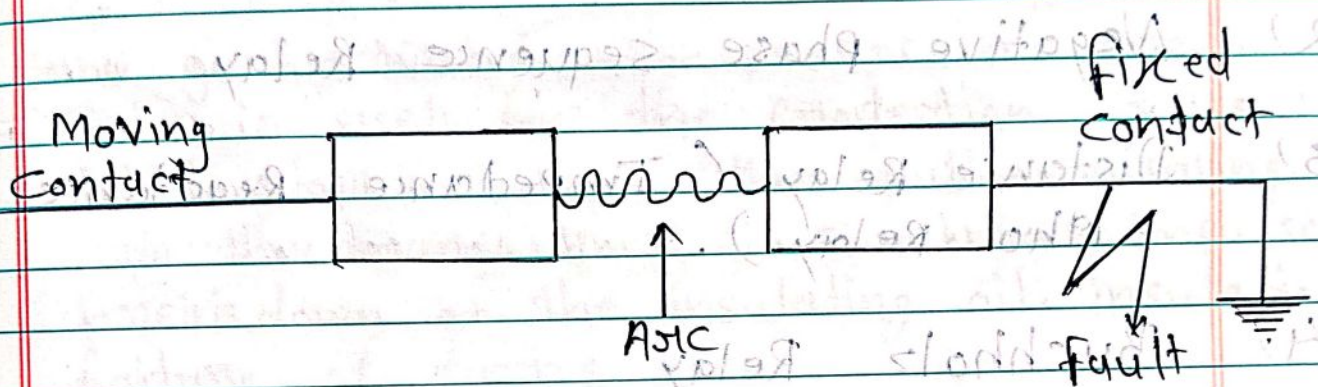
The production of the arc may delay the current interruption process and generate enormous heat which may cause serious damage to system or to circuit breaker itself. Therefore, the main problem in a circuit breaker is to extinguish the arc within the shortest possible time.

⇒ Arc Extinction :-

When the current carrying contacts of the circuit breaker are moved apart, an arc is formed, which insists for a short period after the separation of contacts. This arc is dangerous on account of the energy generated in it the form of heat which may result in explosive force.

→ The circuit breaker should be capable of extinguishing the arc without causing any disturbance to the equipment or danger to the personnel.

The arc plays a vital role in the behaviour of the circuit breaker.



⇒ Methods of ARC Extinction

→ There are two methods of arc extinction in circuit breakers. These methods are

- (1) High Resistance method
- (2) Low Resistance or Zero current Interruption method.

Unit 6 - 05

Protection Relay and circuit Breaker

- (1) Electromagnetic Induction Relay
(Construction & working)
- (2) Negative phase sequence Relay
- (3) Distance Relay (Impedance, Reactance, Mho Relay).
- (4) Buchholz Relay
- (5) Thermal Relay
- (6) Different protection of Transformer.
- (7) Restricted - Earth fault protection of Transformer.
- (8) Protection of parallel feeders & Ring mains.
- (9) Carrier Protection of Transmission Line
- (10) Merz Price Protection of Alternator.
- (11) Differential Protection of Bus - Bus.
- (12) Time - graded protection.

#

Buchholz Relay :-

→ Buchholz relay is a safety device which is generally used on in large oil immersed transformers (rated more than 3.15 MVA, 5 MVA, 10 MVA, 40 MVA).

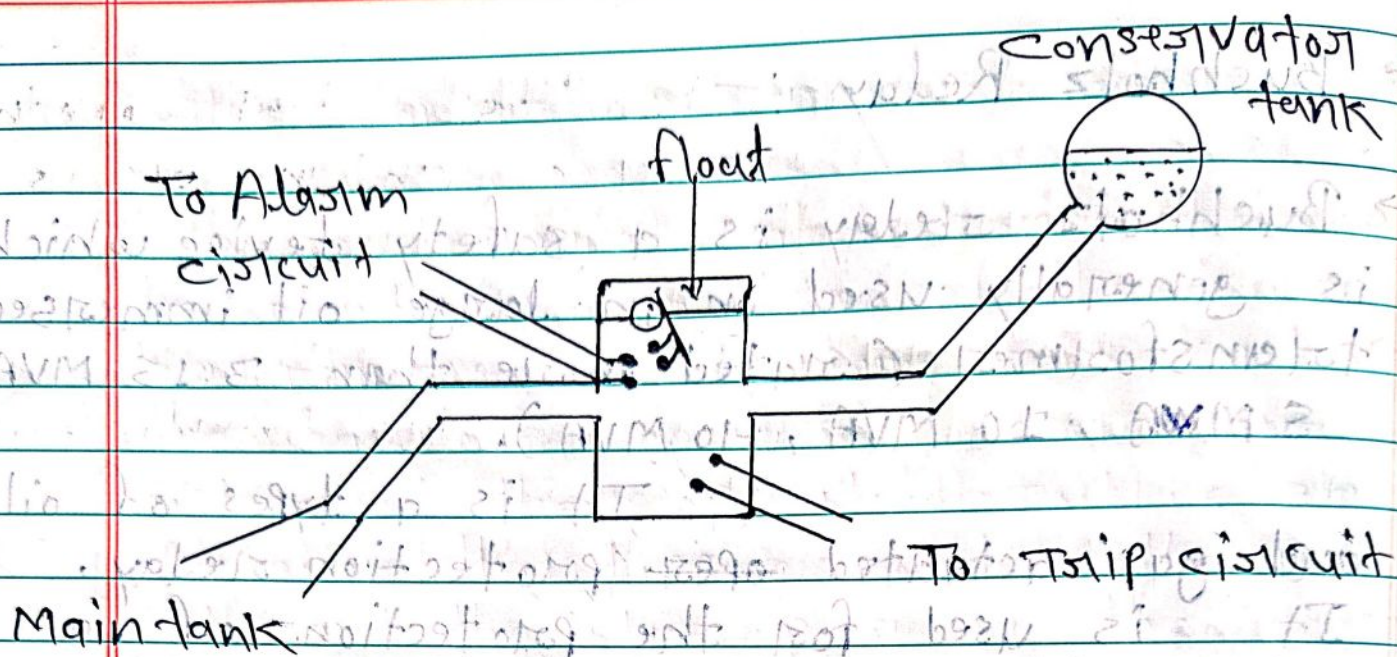
It is a types of oil and gas actuated ~~open~~ protection relay. It is used for the protection of a transformer from the fault occurring inside the transformer. Such as impulse breakdown of the insulating oil, insulation failure of turns etc.

It is used in transformer to protect against internal fault.

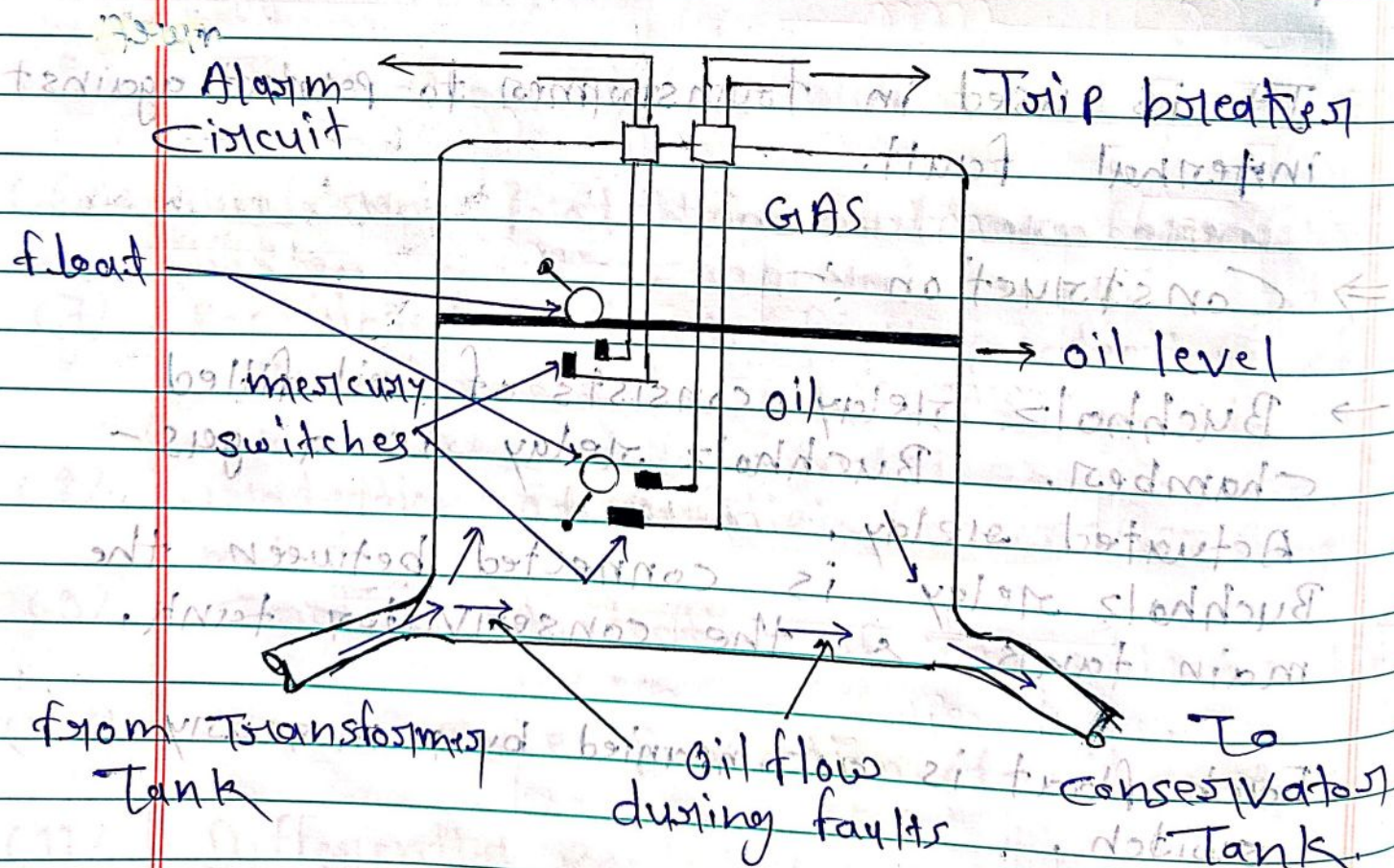
⇒ Construction :-

→ Buchholz relay consists of oil filled chamber. Buchholz relay is a gas-actuated relay. Buchholz relay is connected between the main tank & the conservator tank.

Each float is accompanied by a mercury switch.



Arrangement of Buchholz Relay



Differential Protection of a Transformer.

⇒ The transformer is one of the major equipment in power system. It is a static device, totally enclosed and usually oil immersed, and therefore the fault occurs on them are usually rare. But the effect of even a small fault may be very serious for a power transformer. Hence the protection of power transformer against possible fault is very important.

→ The fault occurs on the transformer is mainly divided into two type external fault and internal fault. External fault is cleared by the relay system outside the transformer within the shortest possible time.

The protection for internal fault in such type of transformer is to be provided by using differential protection system.

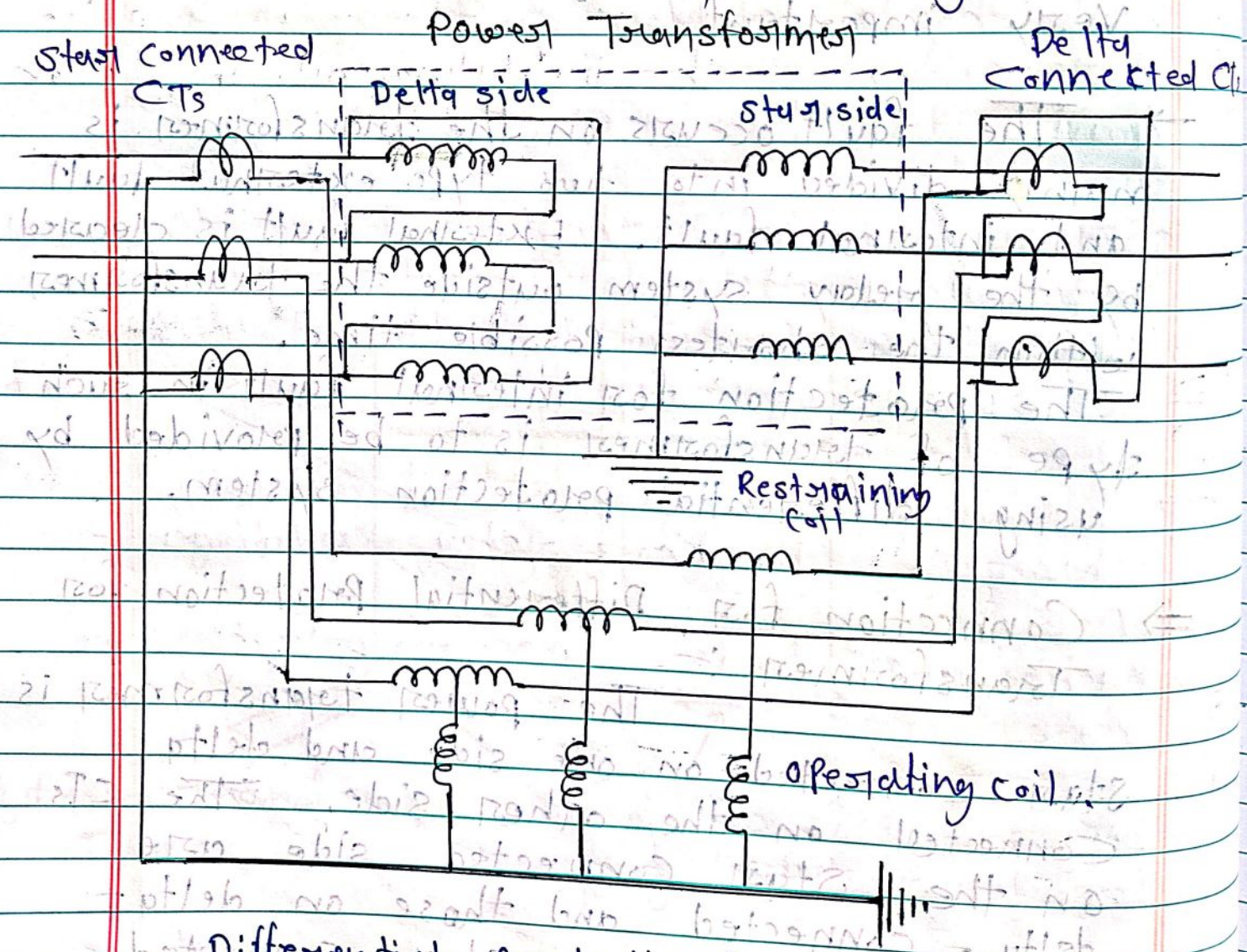
⇒ Connection for Differential Protection for Transformer :-

The power transformer is star connected on one side and delta connected on the other side. The CTs on the star connected side are delta connected and those on delta connected side are star connected.

The Neutral of the current transformer star connection and power transformer

Star connections are grounded.

→ The restraining coil is connected between the secondary winding of the current transformers. Restraining coils controls the sensitive activity occurs on the system. The operating coil is placed between the tapping point of the restraining coil and the star point of the current transformer secondary windings.



Differential protection for power Transformers.

Protection of Parallel Feeders & Ring mains.

⇒ Feeder Protection :-

Definition :-

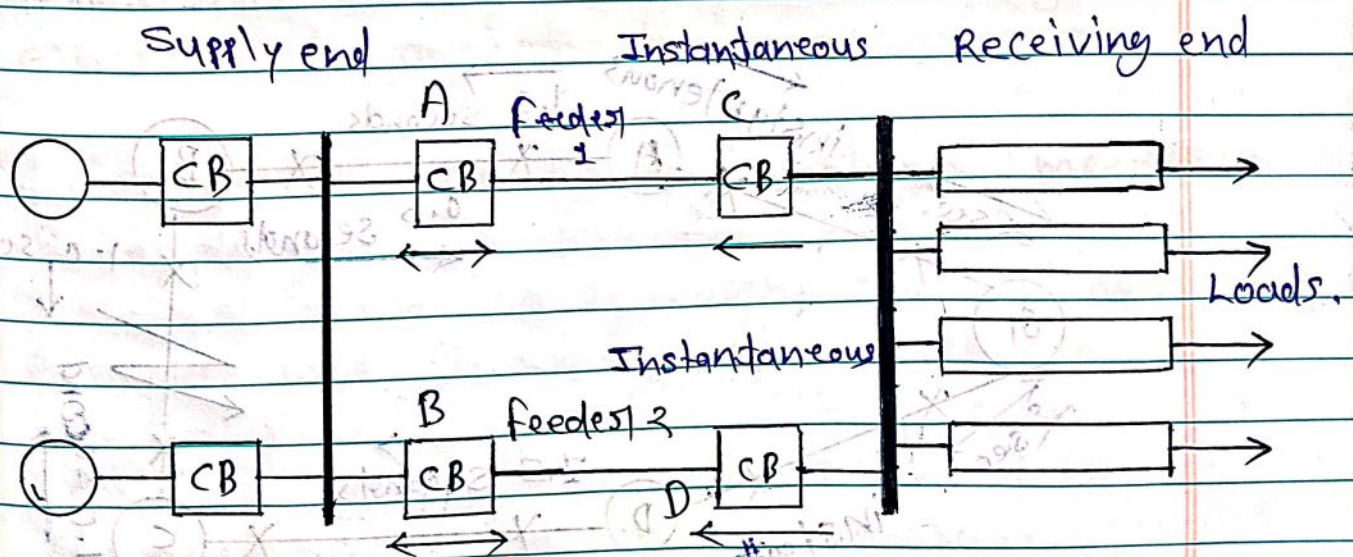
Feeder protection is defined as the protection of the feeder from the fault so that the power grid continue supply the energy.

The feeder injects the electrical energy from the substation to the load end.

So, it is essential to protect the feeder from the various type of fault.

⇒ Protection of parallel Feeders :-

The parallel connection of the supply is mainly used for the continuity of the supply and for sharing the load.



↔ Non-Directional

→ Directional

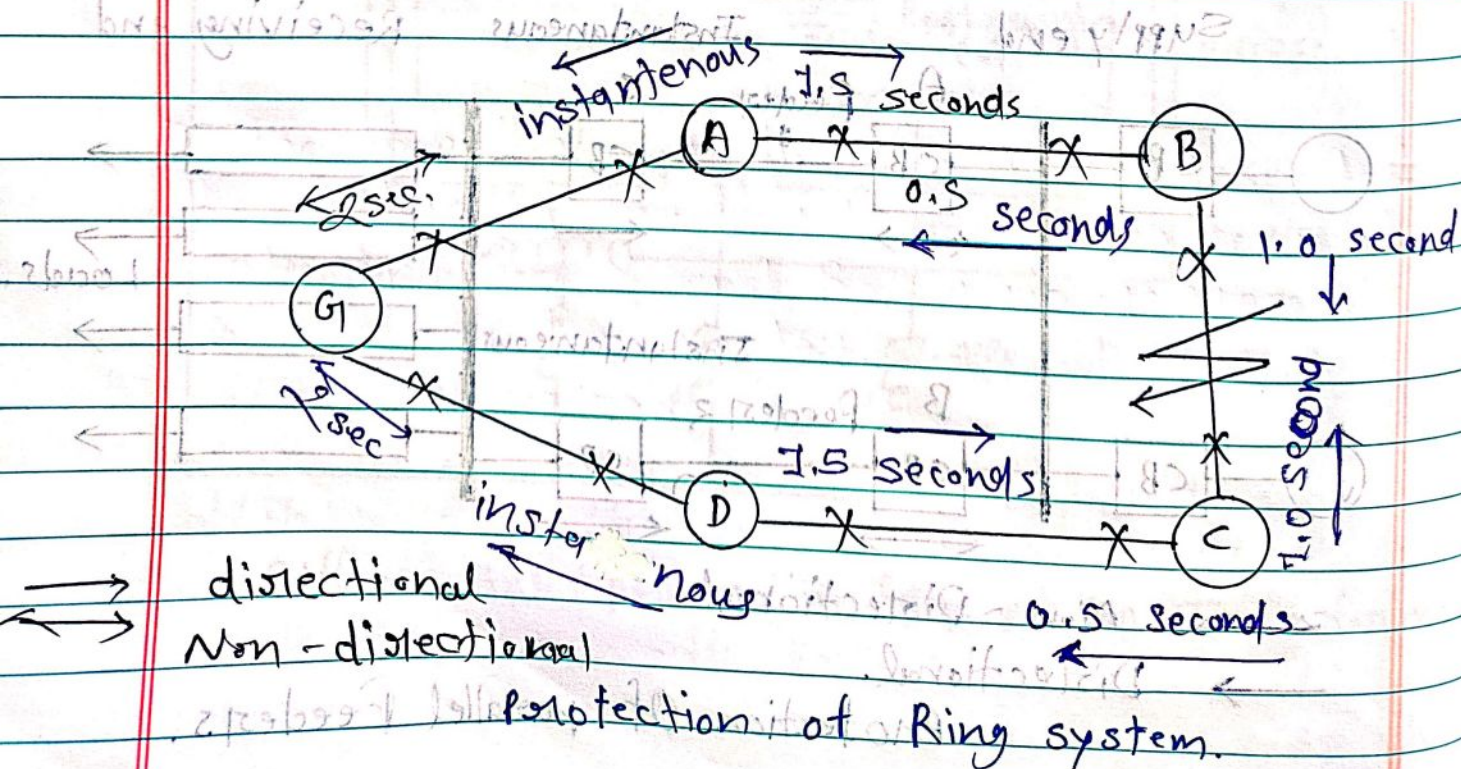
Protection Of parallel Feeders.

→ When the very heavy fault F occurs on any one of the lines, then the power is fed into fault from the sending end as well as from the receiving end of the line.

The direction of power flow will be reversed through the relay on D , which will be open.

Protection of Ring Main System :-

→ The ring main is a system of interconnection between a series of the power station by a different route. In the main ring system, the direction of power can be changed at will, particularly when the interconnections are used.



Imp +

Distance Relay (Impedance, Reactance, Mho relay) :-

Definition :- Distance protection relay is the name given to the protection, whose action depends on the distance of the feeding point to the fault.

The principal type of distance relay is impedance relay, Reactance relay and the Mho relays.

(1) Impedance Type Distance Relay :-

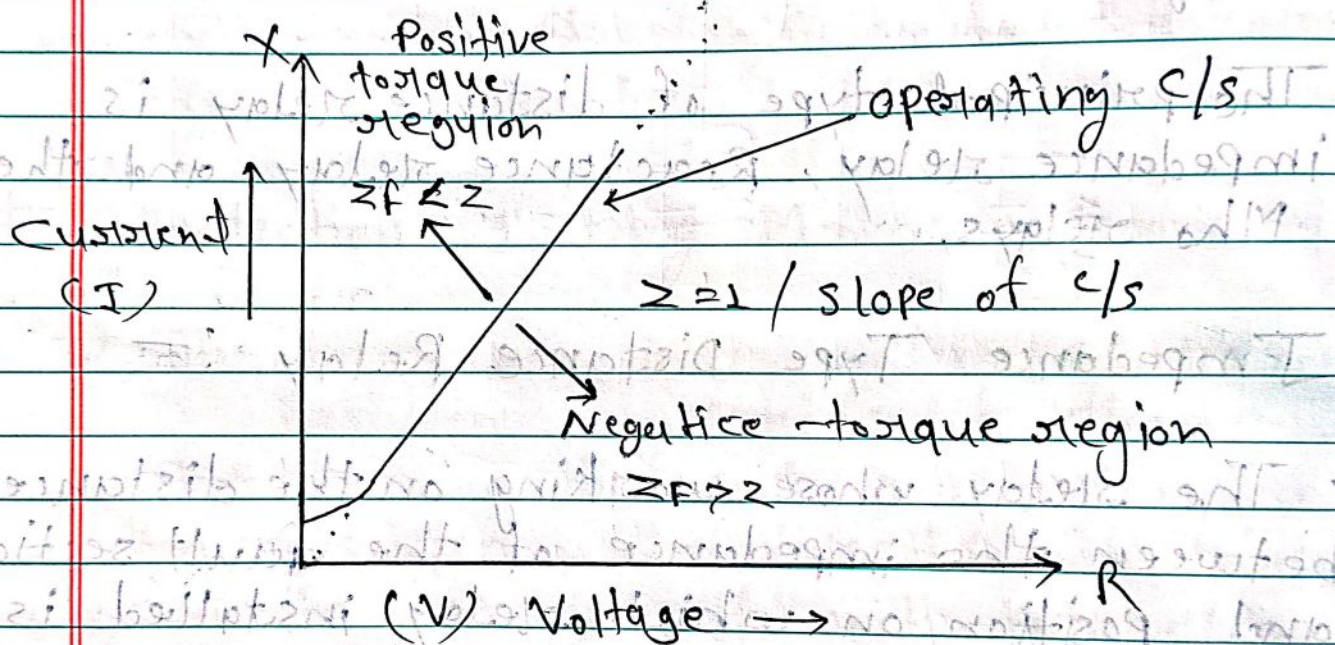
→ The relay whose working on the distance between the impedance of the fault section and position on which relay installed is known as the impedance relay or distance relay. It is a voltage controlled equipment.

⇒ Operating characteristic of an Impedance Relay :- The voltage and the current operating elements are the two important component of the impedance relay. The current operating element generates the deflecting torque while the voltage storage element generates the restoring torque.

$$T = K_1 I^2 - K_2 V^2 - K_3$$

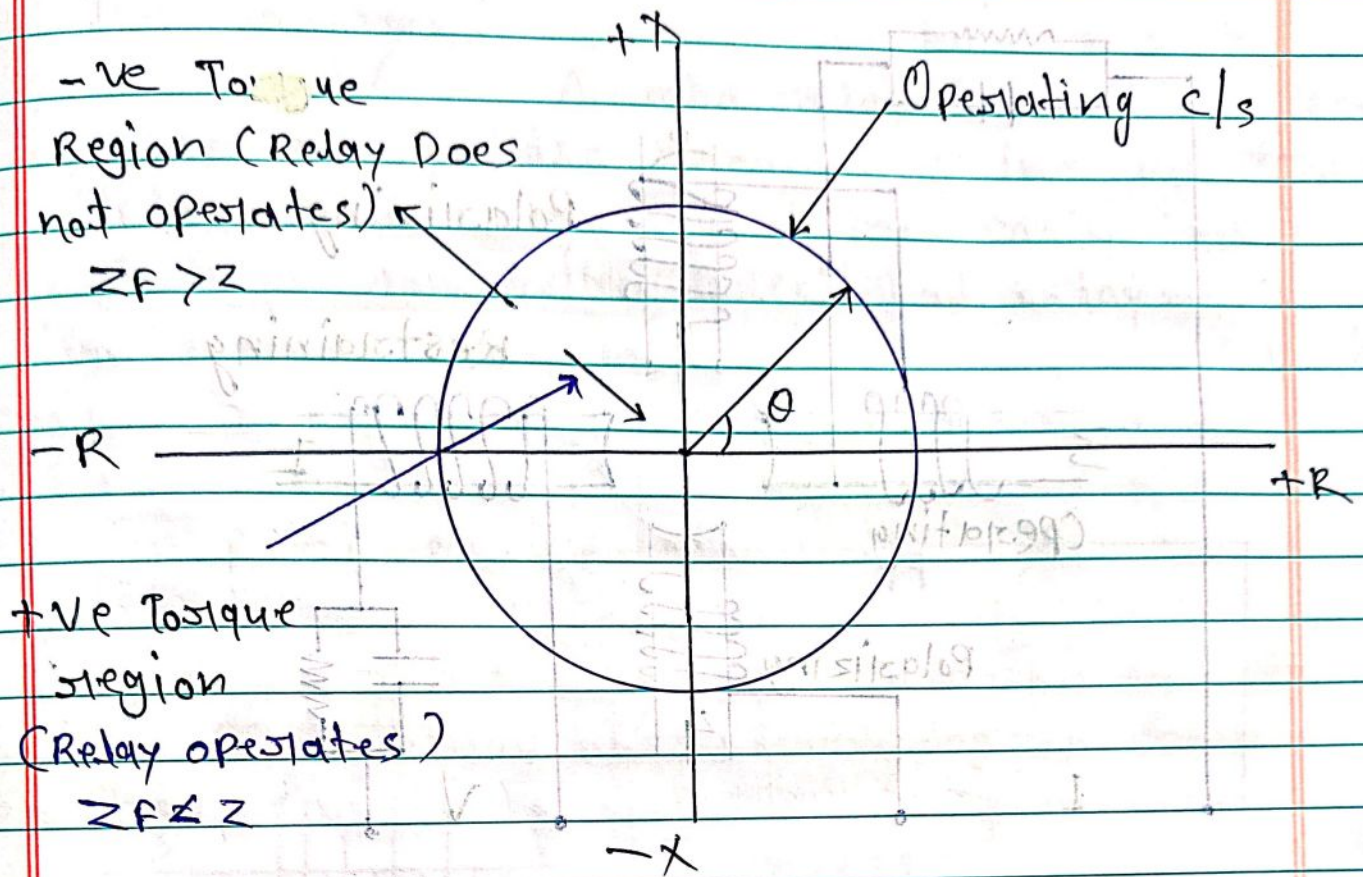
If the spring control effect becomes neglected, the equation becomes

$$z = \sqrt{\frac{K_1}{K_2}} = \text{constant}$$



Opening characteristic of an Impedance Relay.

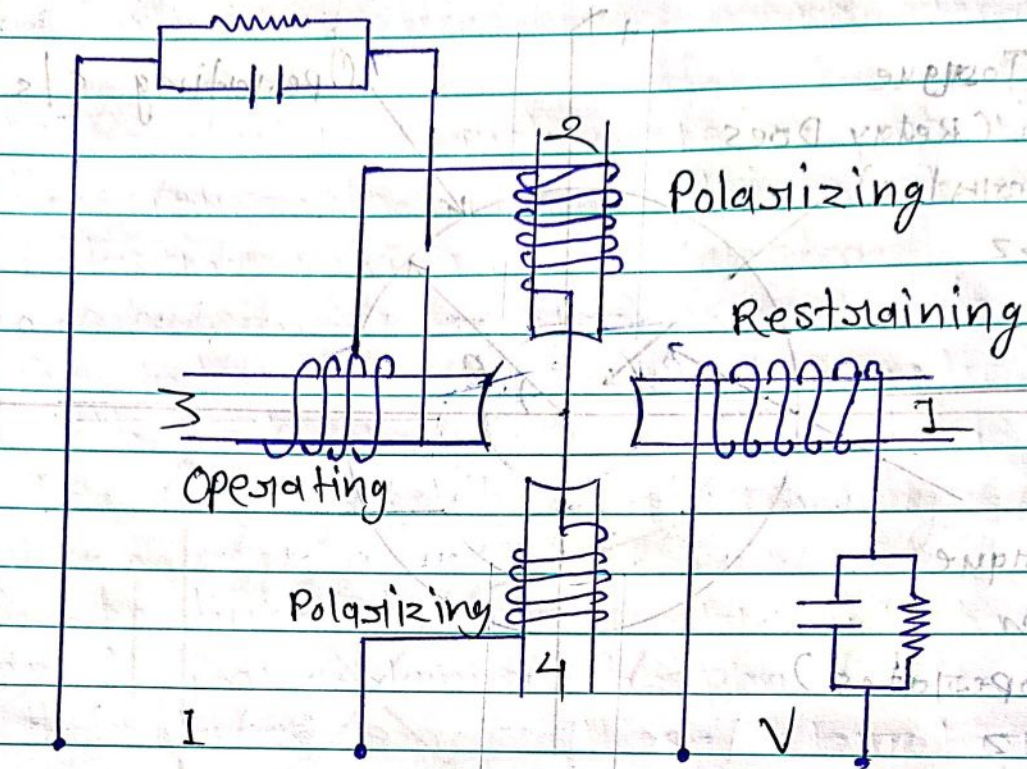
→ The impedance of the line is represented by the radius of the circle. The phase angle between the X and R axis represents the position of the vector.



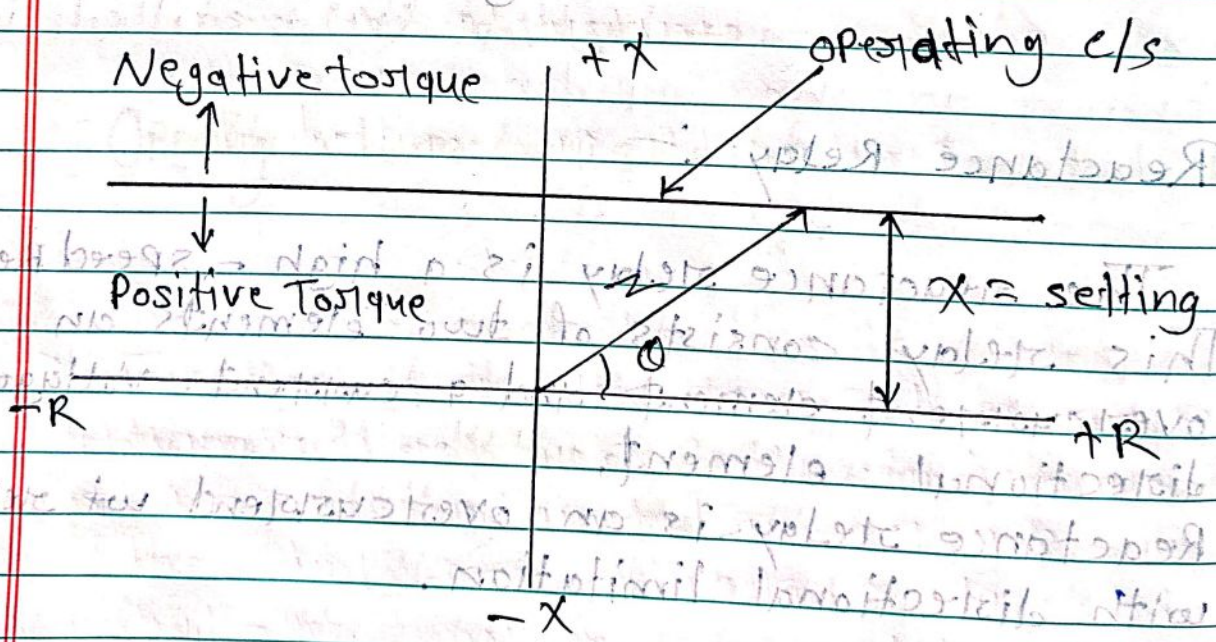
Operating characteristic of an Impedance Relay on an R-X Diagram.

(2) Reactance Relay :-

- The reactance relay is a high-speed Relay. This relay consists of two elements an overcurrent element and a constant-voltage directional element. Reactance relay is an overcurrent relay with directional limitation.

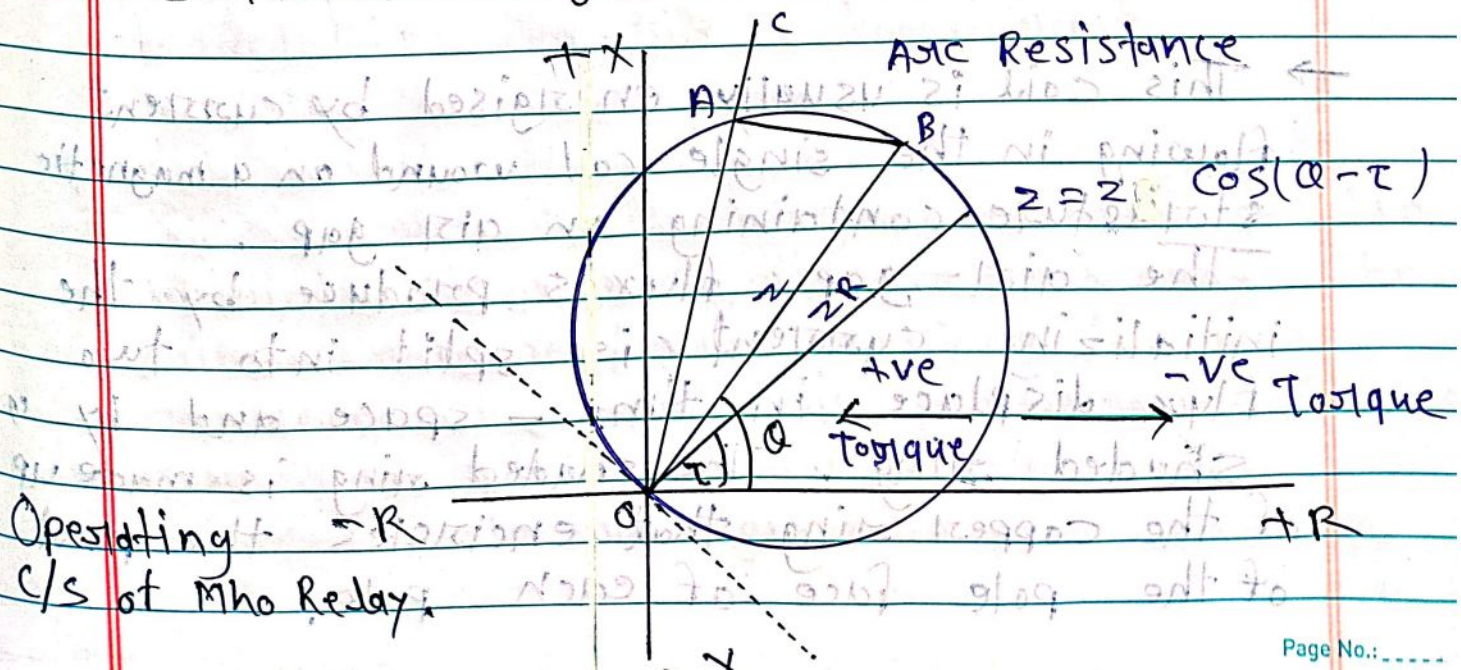
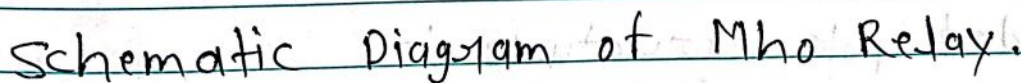


Reactance Type Distance Relay.



Operating characteristic of Reactance Type Distance Relay.

A mho relay is a high-speed relay and is also known as the admittance relay. It means a mho relay is a Voltage controlled directional Relay.



Imp

Electromagnetic Induction Relay.

→ The electromagnetic relay operates on the principle of a split - phase induction motor.

The force is developed by the interaction of electromagnetic fluxes with eddy current, that is induced in the stator by these fluxes.

⇒ The different type of structure has been used for obtaining the phase difference in the fluxes. These structures are.

(a) Shaded pole structure.

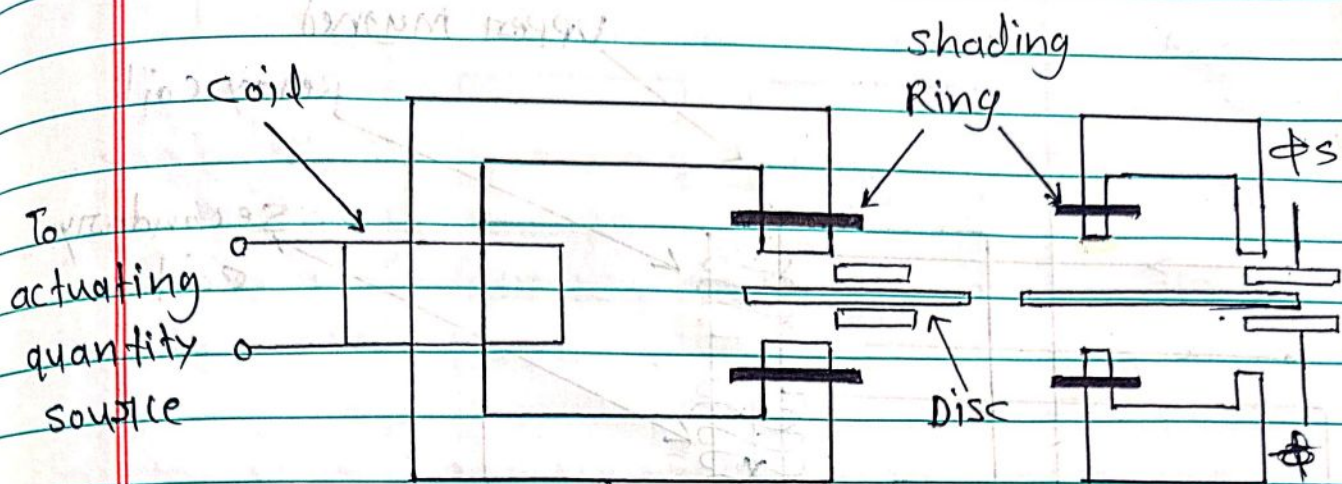
(b) Watt - hour meter or double winding structure.

(c) Induction Cup structure.

(A) Shaded pole structure :-

→ This coil is usually energised by current flowing in the single coil wound on a magnetic structure containing an air gap.

The air - gap fluxes produce by the initializing current is split into two flux displace in time - space and by a shaded ring. The shaded ring is made up of the copper ring that encircles the part of the pole face of each pole.

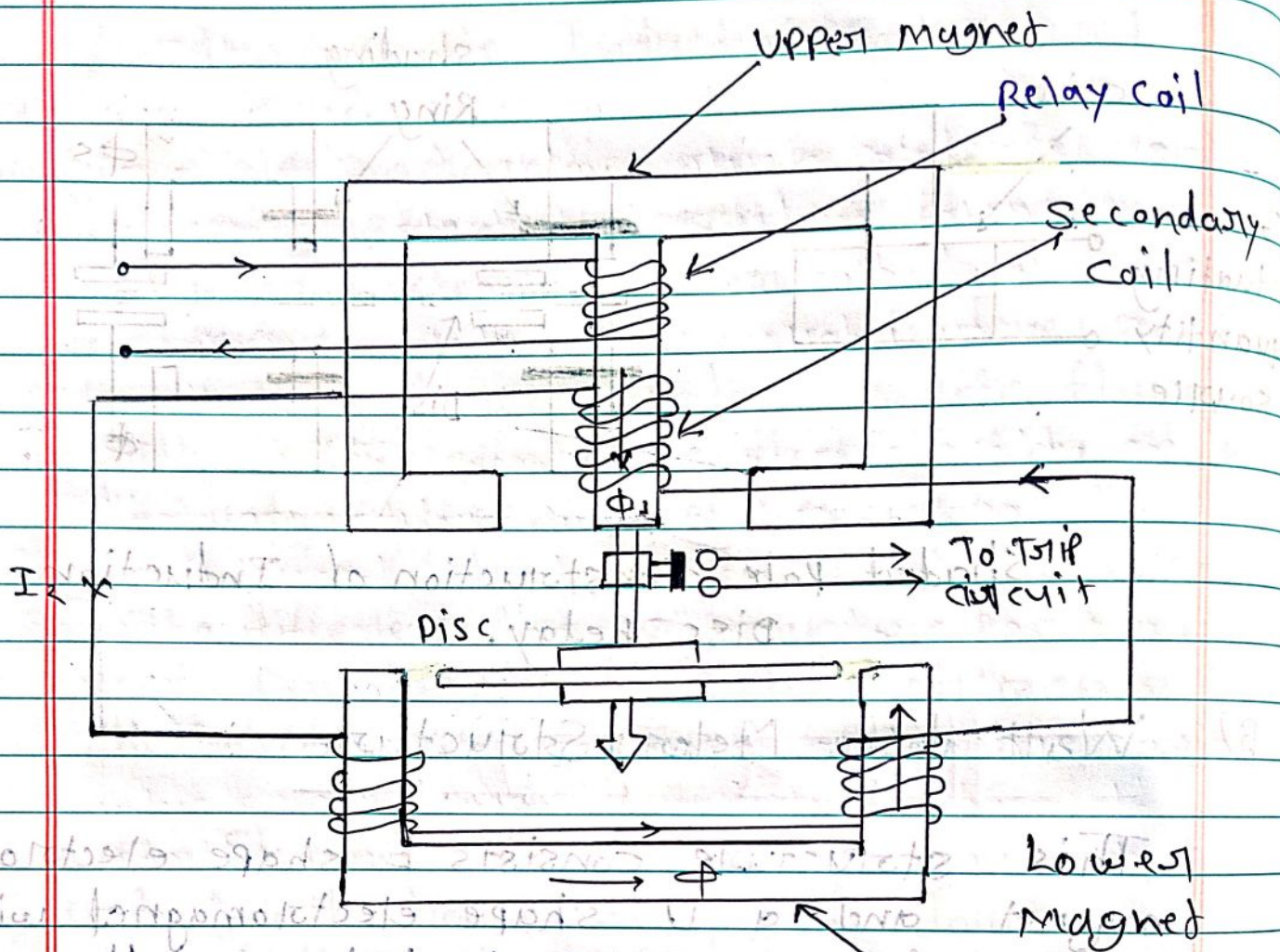


Shaded pole Construction of Induction Disc Relay.

(B) Watt-hour Meter Structure :-

This structure consists E shape electro-magnet and a U shape electromagnet with a disc free to rotate in between them. The phase displacement between the fluxes produced by the electromagnet is obtained by the flux generated by the two magnets having different resistance and inductance for the two circuit.

→ The E-shaped electromagnet carries the two winding the primary and the secondary. The primary current was carrying the relay current I_1 while the secondary winding is connected to the windings of the U-shaped electromagnet.

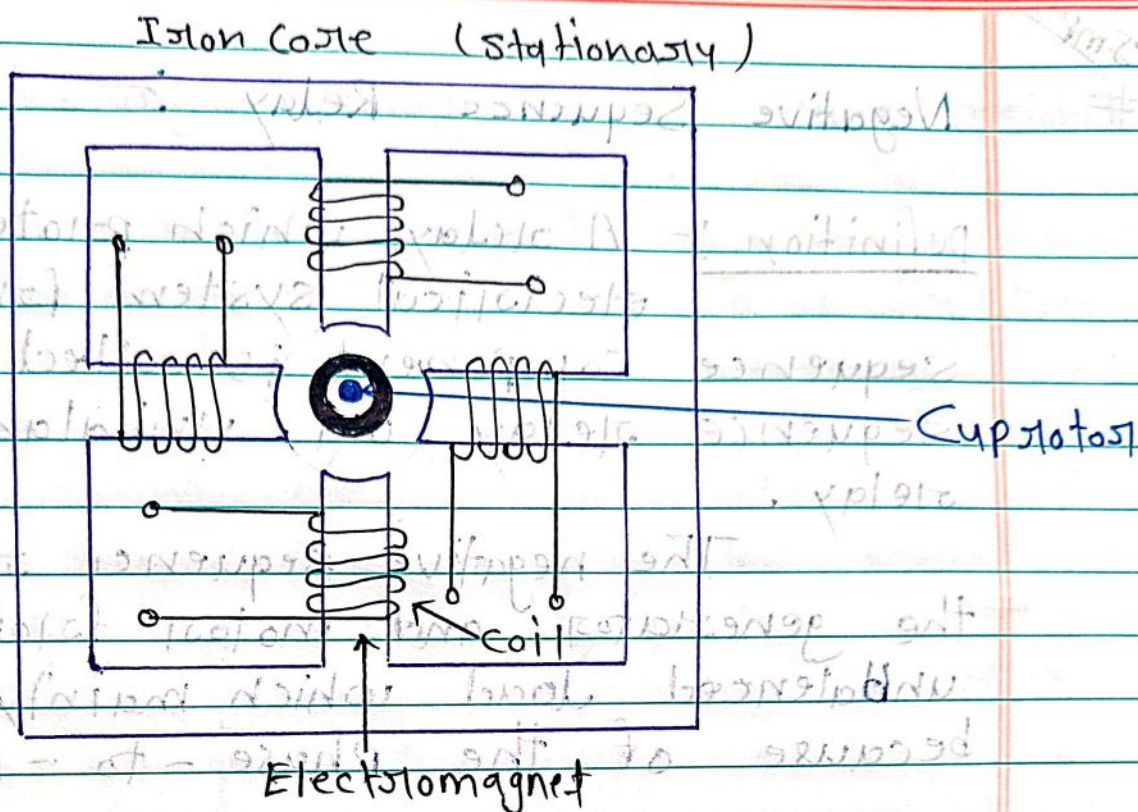


Watt-hour Meter Type

Induction Disc Relay

(C) Induction Cup Relay

→ The relay which works on the principle of electromagnetic induction is known as the induction cup relay. The relay has two or more electromagnets which is energized by the relay coil. The static iron core is placed between the electromagnets.



Induction Cup Relay

→ The more torque is produced in the induction cup relay as compared to the shaded and watt meter type relay.

Imp

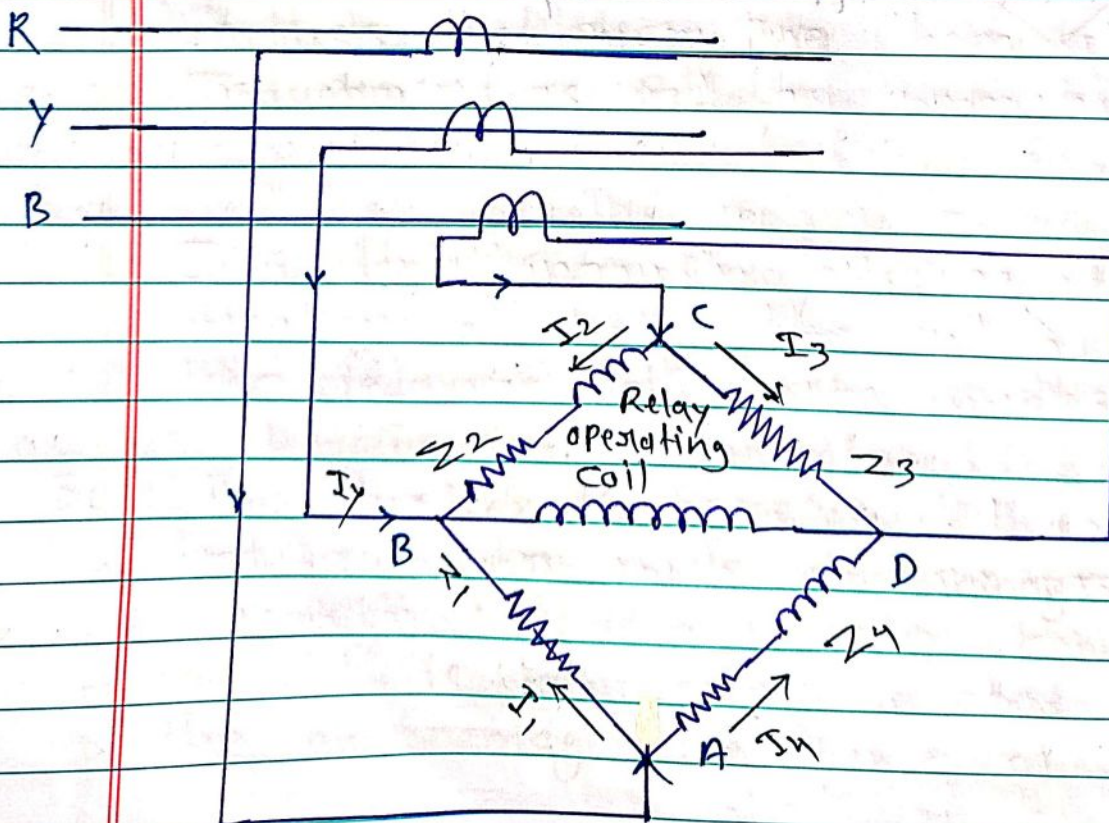
#

Negative Sequence Relay :-

Definition :- A relay which protects the electrical system from negative sequence component is called a negative sequence relay or unbalance phase relay.

The negative sequence relay protects the generator and motor from the unbalanced load which mainly occurs because of the phase-to-phase faults.

→ The negative sequence relay has earthing which protects them from phase to earth fault but not from phase to phase fault.



Negative Sequence Relay.

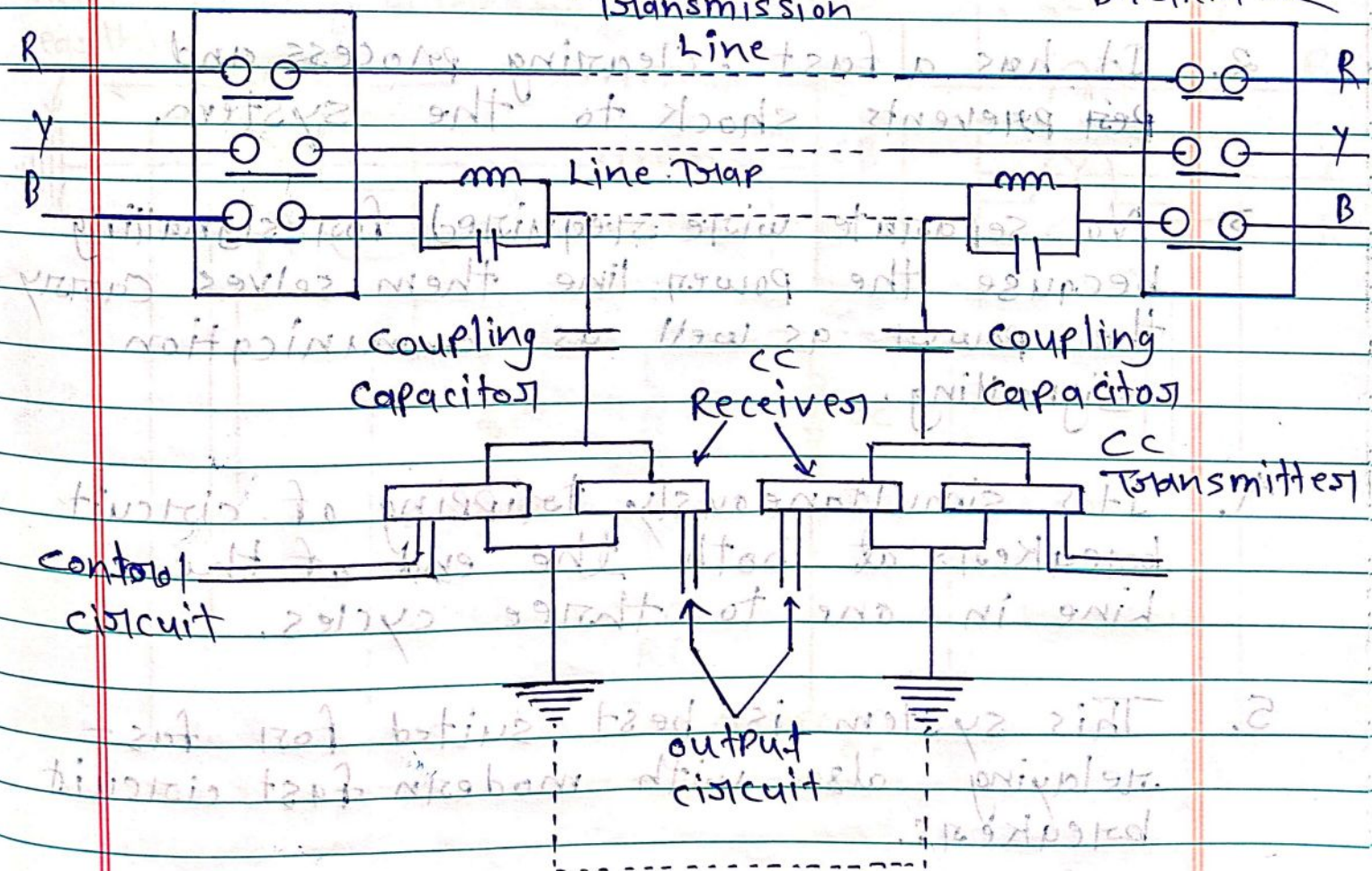
Carrier Current Protection of Transmission Lines:-

→ Carrier current protection scheme is mainly used for the protection of the long transmission line. In the carrier current protection schemes, the phase angle of the current at the two phases of the line are compared instead of the actual current.

Circuit Breaker - 1

Transmission Line

Circuit Breaker - 2



Carrier Current Transmission Line Protection Scheme.

→ And then the phase angle of the line decides whether the fault is internal and external. The main element of the carrier channel are a transmitter, receiver, coupling equipment, and line trap.

⇒ Advantage of Carrier Current protection:

1. It has a fast simultaneous operation of circuit breaker at both the ends.
2. It has a fast clearing process and prevents shock to the system.
3. No separate wire required for signalling because the power line themselves carry the power as well as communication signalling.
4. It's simultaneously tripping of circuit breakers at both the end of the line in one to three cycles.
5. This system is best suited for fast relaying also with modern fast circuit breakers.

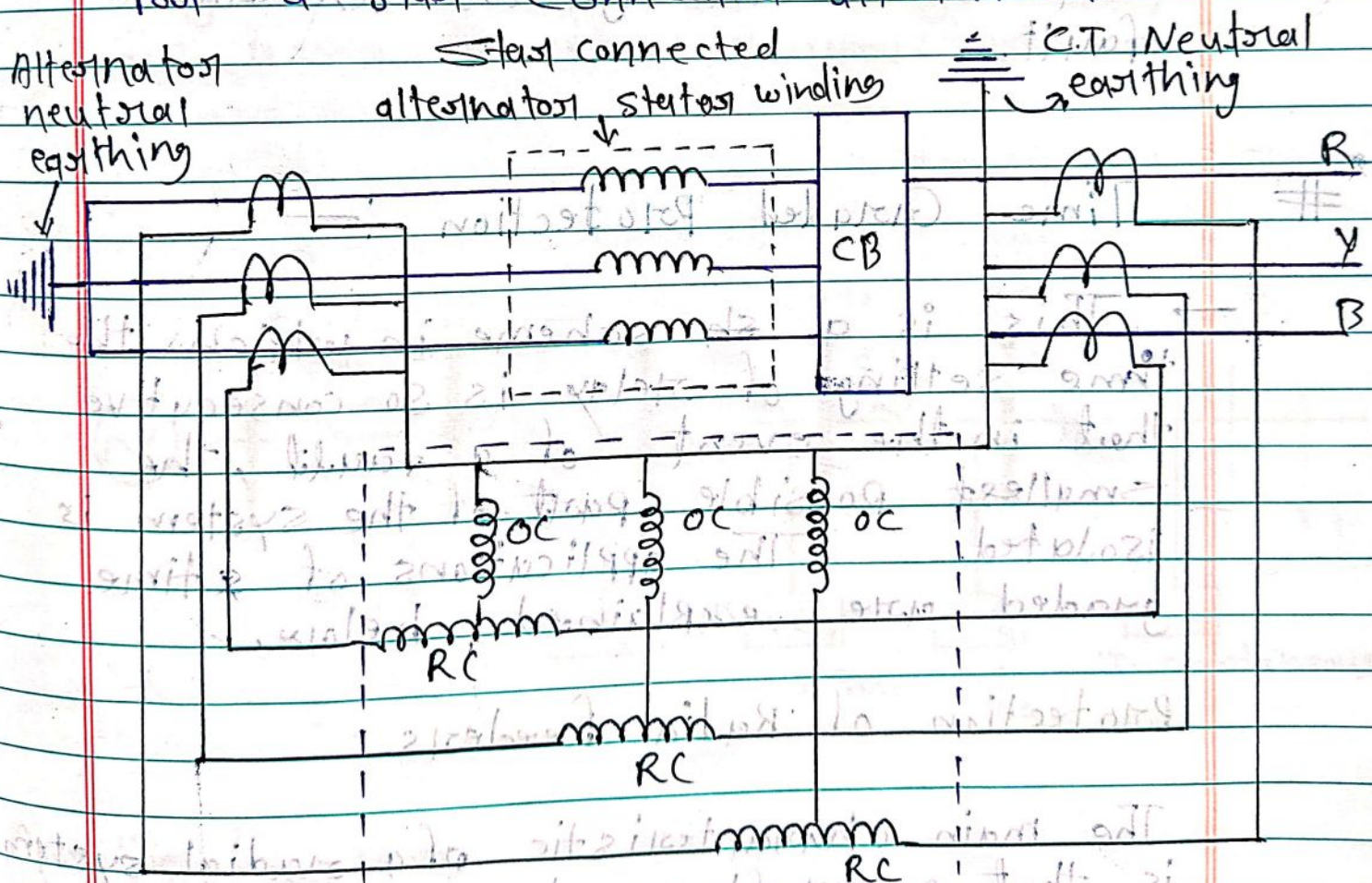
Imp

Biased Differential scheme (Merz-Price Scheme) for protection of Generators :-

→ This is most commonly used protection scheme for the alternator stator windings.

The scheme is also called biased differential protection and percentage differential protection.

The figure below shows a schematic arrangement of Merz-Price protection scheme for a star connected alternator.



⇒ The advantages of this scheme are,

- Very high speed operation with operation time of about 15 msec.
- It allows low fault setting which ensures maximum protection of machine windings.
- It ensures complete stability under most severe through and external fault.

Time Graded Protection :-

→ This is a scheme in which the time setting of relay is so consecutive that in the event of a fault, the smallest possible part of the system is isolated. The applications of time graded are explained below.

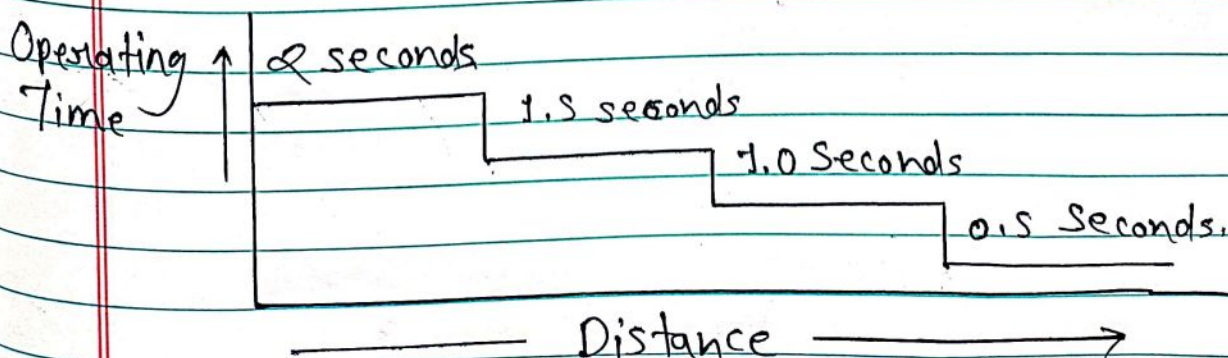
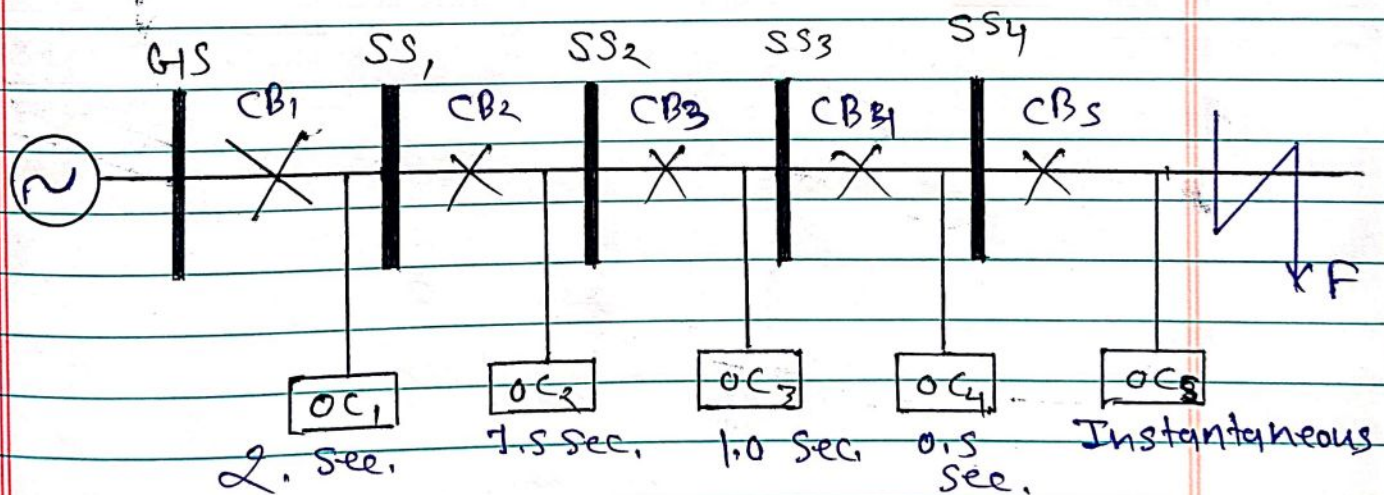
Protection of Radial Feeders

The main characteristic of a radial system is that power flow only in one direction, i.e. from the generator or the supply end to the load end. It has the drawback that continuity of supply cannot be controlled at the load

load end. It is the occurrence of a fault.

In a radial system when the number of feeders is connected in series as shown in the figure, It is desired that smallest possible part of the system should be off. This is conveniently achieved by employing time graded protection.

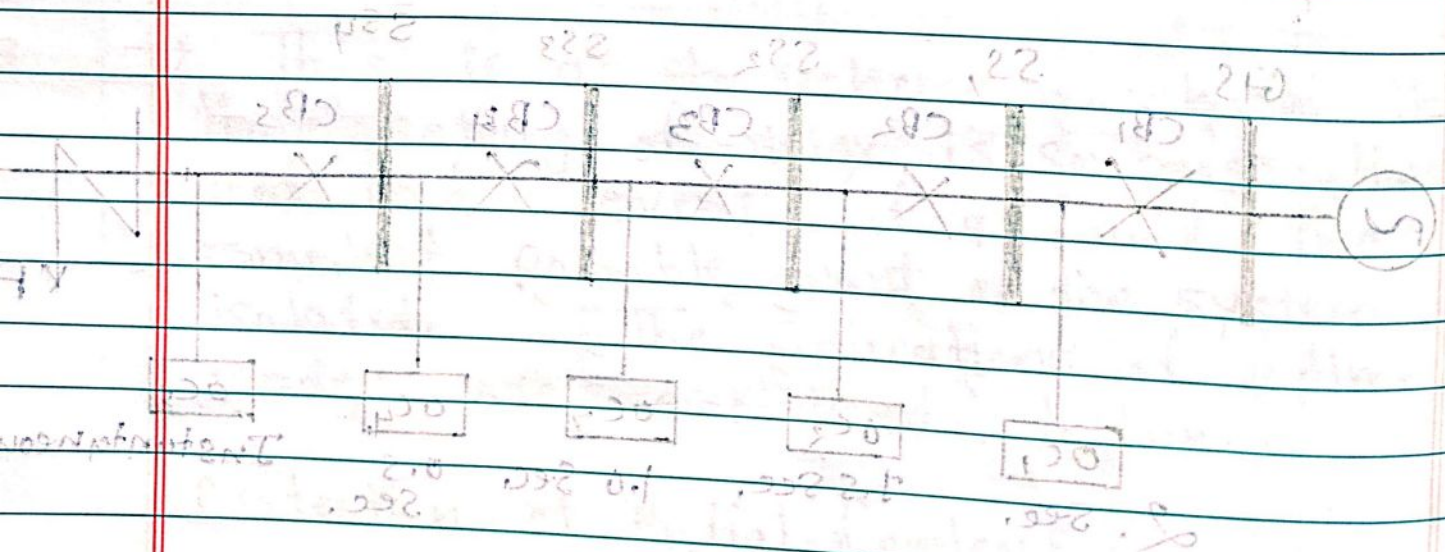
The overcurrent system should be adjusted in such a way that the longer the delay from the generating station the lesser the time of operation.



Time Graded Protection for Radial Feeders.

→ When the fault occurs on the SSy, the relay OCs should operate first and not any other i.e. the time required to operate the relay OC₄ must be less than the time required for relay OC₃ and so on.

This shows that the time setting required for these relay must be properly graded. The minimum interval of time which can be allowed for the two adjacent circuit breakers depends on its own clearance time, plus a small time for the safety margin.



Power System operation and protection

Unit 01 :-

Power System Components

Unit 02 :-

Power System faults stability.

Unit 03 :-

Active & Reactive
power Control

Unit 04 :-

Element of protection
& circuit Interrupting Devices

Unit 05 :-

Protection Relays and
Circuit Breaker.

