

LECTURE NOTES ON

ELECTRICAL MACHINE

4TH SEMESTER ETC



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Unit-1 : Electrical material

Electrical material :-

The material which conduct electricity due to free electron when an electric potential difference is applied across them is called as electric material.

OHMS Law :-

At constant all physical quantity (temperature, pressure) in a close loop the current flowing through a conductor is directly proportional to the potential difference betⁿ two end point at the conductor.

$$V = I \times R$$

$$\rho - \text{Row}$$

$$I = \frac{V}{R}$$

$V \propto I$ (in case temperature is constant)

$$I \propto \frac{1}{R} \uparrow$$

$$R = \rho \frac{L}{A}$$

$$A = \pi r^2$$

$$\rho = \frac{A \times R}{L}$$

$$\rho \rightarrow \text{Resistivity}$$

Properties & uses of different conducting material

(1) Low Resistivity :-

- * Conductivity of a conductive material is inversely proportional to Resistivity.
- * So a conductive material should have low resistivity. so it will have better resistivity.

(2) Low temperature coefficient :-

It means change of resistance which change in temperature should be low.

Ex:- In case of Hz sum of the resistance transmission line which are very long will increase. So more voltage drop and power loss occurred.

(3) Sufficient mechanical strength :-

* In the case winding of transformer and overhead line conductors use for transmission and distribution of electric power. Conductor are subjected to mechanical strength.

* Therefore to withstand mechanical stress the conductivity material should possess sufficient mechanical strength.

(4) Ductility :-

* It is the properties of material which allow drawn out into a wire.

(5) Drawability :-

* Conductor are required different size & shape. Conductive material should be drawn into difference size & shape.

(5) Solderability :-

* Conductor have to be jointed. The joint should have accurate minimum constant resistance.

* So if the joint is soldered then minimum contact resistance.

(6) Resistance of corrosion :-

The conductive material should be such that if it is not corroded when it is used in outdoor atmosphere.

Application :-

* House wiring.

* Transmission & distribution. \rightarrow ACR use conductor.

ACR \rightarrow (Aluminium constant Resistivity).

* ACR conductor.

* Use in winding of electrical machine & transformer.

* Use for resistance welding electrode.

* Use as filament in incandescent electrical heater.

Insulating materials :-

Those materials through which electricity does not flow are current electric insulating materials such as paper, plastic rubber mica wood etc.

Insulating material Properties & use of various insulating material :-

Properties :-

- (i) Visual properties.
- (ii) Electrical properties.
- (iii) Mechanical properties.
- (iv) Chemical properties.

(i) Visual Properties :-

(a) appearance

(b) colour.

(c) ~~crystal~~

(c) crystallinity.

(d) These count some extended towards the customer selection of the insulating material.

Mechanical properties :-

(a) Density :-

Electrical insulator are use in the basis of volume & not weight.

Viscosity :-

* The viscosity is the resistance of a fluid (liquid or gas) to a change in shape - or movement of neighbouring portions relative to one another.

* This Properties is important in case of liquid dielectric city uniform viscosity leads to uniform electrical

thermal properties

Moisture observation :-

Moisture water lowers the electrical resistance & also its dielectric strength.

* This may also result serving explain of material.

Electrical properties :-

(i) insulation Resistance :-

This is a properties by virtue of which a material resist flow of electric current it should be as high as possible.

Dielectric strength :-

* Dielectric strength is defined as the electrical strength of an insulating material.

* It is a maximum potential gradient that the material can withstand.

* If the operating voltage gradient increase then at a particular voltage break down will occur & can its insulation properties permanently.

Dielectric constant :-

A quantity measure the ability of a insulating material to store electrical energy in an electric field. for different measuring material capacitance is different.

$$C \propto \frac{A}{d}$$
$$C = E \frac{A}{d}$$

where, A = Area

d = distance betⁿ two plates capacit^r

E = dielectric material.

Dielectric losses :-

- * Insulator absorb & absorb electric energy and it reduce that energy in the form of Heat it is known as dielectric losses.
- * There is some electric losses the electric loss is called dielectric loss.
- * So in this case the angle betⁿ changing current & applied voltage is always less than 90° .

Chemical Properties :-

(1) Resistance to external :-

Insulating material should be resistance to oil or liquid, gas, flames, Acid & Alkalies. The material should not go under oscillation & Hydrolysis even under adverse condition.

Resistant to chemical in soil :-

Effect of water :-

Water directly lower the electrical properties such as electrical resistance dielectric strength.

Uses :-

* Solid insulator :-

- * The Application of insulating material are electrical rubber mats, power & electronic system, cable & transmission lines etc.
- * Use in welding machine, electric welding oven etc.

Example :- ~~Varka~~ cotton, mica, paper, rubber, glass.

- * use for winding of small magnet coil. (Armature winding, Chok, transformer coil), X-Ray tube, ..

Liquid insulator :-

- * Liquid insulator use in transformer and oil circuit breaker where this help to disposal the heat generated by convection.

* Exm :- silicon oil, mineral oil.

Gaseous insulator :-

- * A dielectric gas, or insulating gas, is a dielectric material in gaseous state. its main purpose is to prevent or rapidly quench electric discharges.

Exm :- air, sulphur hexafluoride, nitrogen, SO_2 , SO_4 .

Various magnetic material & there uses :-

There are 3 types magnetic material.

- (i) Paramagnetic material.
- (ii) Diamagnetic material.
- (iii) Ferromagnetic material.

(i) Paramagnetic material :-

The material which are not strongly attracted by magnetic material is known as paramagnetic material.

Exm :- (i) Aluminium is not a magnetic material.

(ii) Magnesium :- tin,

- * These are relative permeability as small but positive or just for generator slightly than 1.
- * For Exm :- The permeability aluminium is 1.00000065 .
- * permeability - magnetizes and demagnetize.
- * Such material are magnetize only when placed on super strong magnetic field and out of the direction of the magnetic field.
- * When a strong magnetic field is applied the permanent magnet dipoles orient themselves parallel to the applied magnetic field & give rise to the positive magnetizations.
- * Since orientation of dipoles parallel to the applied magnetic field, the magnetization is very slow.

Di

Demagnetical material :-

The material which are repelled by magnetic field, such as zinc, lead

- * When the diamagnetic material is placed on an external magnetic field, the material is weakly magnetised in such a way that it repels the external field is known as demagnetic material.
- * Example:- Copper, gold, antimony, silver, lead and hydrogen.
- * The permeability of the material is slightly less than 1.
- * permanent magnet are absent in them.
- * so very little or no application electrical engineering.
- * Exm:- The permeability bismuth is (0.00083) (0.00083)

Ferro magnetic material :-

The which are strongly attracted by a magnetic is called ferro magnetic material.

Exm:- iron, Cobalt, nickel, steel

Application :-

- * magnetic element present Harddisks hence, to use computer to extra information.
- * It is also use in food processing for separating small metallic resources.
- * Ferromagnetic materials commonly used for nonvolatile nonvolatile information storage in tapes, hard drives etc. They are also used for information-processing due to the interaction of electric current and light with magnetic order.

Date - 27.02.23

Unit-2	DC Generator	Unit-2
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Machine :-

- * The machine is the part of instrument which comprises a several part for doing a particular task for utilising mechanical energy is called machine.

DC Generator :-

Generator is a electrical machine which convert mechanical energy to electrical energy. which work on the principle of Faraday's Law of electro magnetic induction.

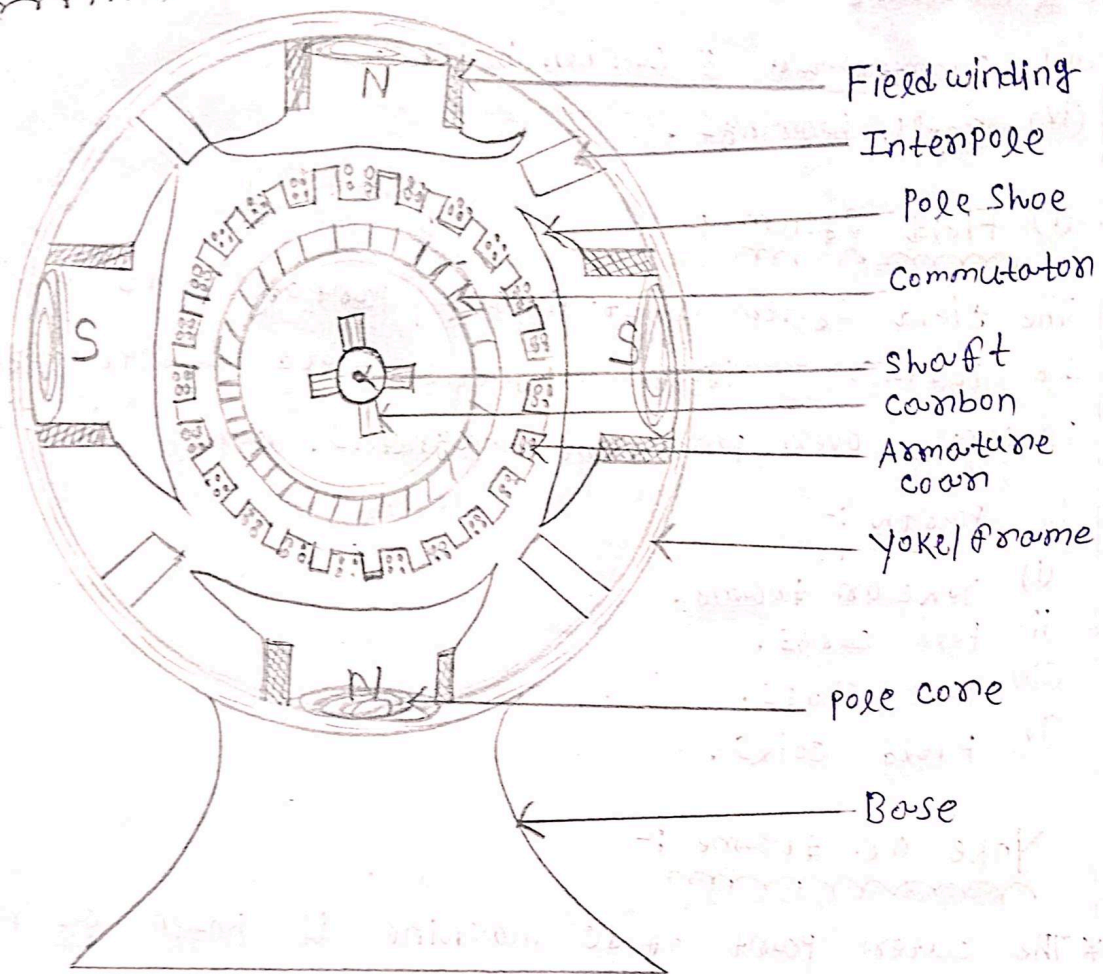
Faraday's Law :-

Whenever a conductor is placed in a varying magnetic field, an electromotive force is induced. if the conductor circuit is closed, a current is induced, which is called induced current.

Generator are 2 types :-

- (i) AC Generator (ii) DC Generator.

DC Generator :-



* DC Generator is a Generator which convert mechanical energy to dc voltage source.

* An electric generator based on the principle that, when even a current carrying conductor placed on the magnetic field flux is cut by the conductor & e.m.f is induced, which will cause a current to flow if the conductor circuit is close.

* Direction of the induced emf is given by the Fleming's Right hand Rules.

Construction of DC Generator :-

DC generator consist of 4 parts

(i) Field system.

(ii) Armature circuit.

(iii) Commutator & carbon brush.

(iv) Ball bearings.

(i) Field System :-

The field system is stationary part of a DC machine. It produces uniform magnetic field. Electromagnets are preferred over permanent magnets. Also consist of

4 parts :-

(i) Yoke or frame.

(ii) Pole cores.

(iii) Pole shoes.

(iv) Field coils.

Yoke or frame :-

* The outer part of DC machine is known as Yoke or frame.

* In small machine Yokes are made of cast iron but for larger machines rolled steels are used.

Yoke performs two purposes :-

* It provides mechanical strength & support for poles to be pivoted & protects to find flux. / To act as protecting cover for whole DC machine.

(ii) Pole cores :-

* Pole cores are circular section and if used to carry the insulated field coils.

* Pole cores are not laminated for small machine.

* But for large advanced machines laminated steel sheets are used.

* The thickness of the lamination varies from 1mm to 0.25 mm.

(ii) Armature circuit.

(iii) Commutator & carbon brush.

(iv) Ball bearings.

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Reluctance :-

It is property of a magnetic material which opposes the magnetic flux is known as reluctance.

Pole Shoes / Pole Shoe :-

- * Pole shoes support the field coils and serve two purposes.
- * They spread the flux in the air gap.
- * Reduces the air gap between stator and rotor being larger in cross-section.

* The pole core / pole shoe are made of the cast steel. The pole is laminated to reduce the losses.

* The pole are such the following purpose.

- (i) its support the fieldwinding.
- (ii) They spread out the magnetic flux over the Armature most uniformly.

* It increase the cross section Area of the magnetic circuit at the result. the reluctance of the magnetic part reduce.

Field coils :-

* The field coils or winding are made of copper wires or strips.

* The purpose of field coil is to provide the required mmf (flux) to induce the desired potential difference.

* Fieldwinding :-

Each pole core as work on more fieldwinding placed over it. to produce a magnetic field.

* It is made of copper wire.

* The coils are wound on the former on it is placed around the pole core. when the direct current passes through the field winding, magnetic flux produce.

Armature circuit :-

* It is the rotating part of the DC machine. The purpose of the armature is to rotate the conductor inside the magnetic field.

* It consists of coils of insulated wire wound around an iron core and emf is induced in it when rate of change of flux occurs due to rotation of the armature. The armature core is made of high permeability silicon steel. Also they are laminated.

Commutator & carbon brush :-

Commutator acts as mechanical converter. It converts AC to DC in case of DC generator & converts DC to AC in case of DC motor. In a DC machine the armature e.m.f. is alternating in nature. Also commutator provides an electrical connection between the rotating armature coils and stationary external circuit. Carbon brushes are made of carbon and its function is to collect current from the rotating commutator and supply to the external load circuit. (in case of DC generator) (In case of DC motor)

Carbon brushes are used to give supply to the rotating commutator. The brushes are held under pressure on commutator by spring for smooth contact.

Ball bearings :-

Ball bearings are used to hold the rotor shaft with the static support. For small machine ball bearings are used in both ends of shaft. For

large machine, roller bearings are used in both ends of shaft for large machines, roller bearings are used at the driving end.

Armature winding

* The slots of the Armature, contain whole insulated conductors that are connected in suitable manner this is known as Armature winding.

* The Armature winding is place where, conversion from Mechanical Power \longleftrightarrow Electrical Power

* Armature winding two types:

(i) Lap winding.

(ii) Wave winding.

(i) LAP winding :-

In Lap winding $a = P$ where,

a = Number of parallel paths.

P = Number of whole pole

Wave winding :-

In wave winding $a = 2$ (always 2).

Working principle of DC Generator :-

* According to Faraday's law of E.M.F induction when conductor placed in a varying magnetic field \therefore E.M.F induced in that conductor.

* ~~The magnitude~~

* The magnitude of induced E.M.F can be calculated from of DC Generator.

Application of DC Generator :-

Classification of DC Generator :-

(i) Separately excited DC Generator.

(ii) Self excited DC Generator.

Self excited DC Generator

DC Series Generator

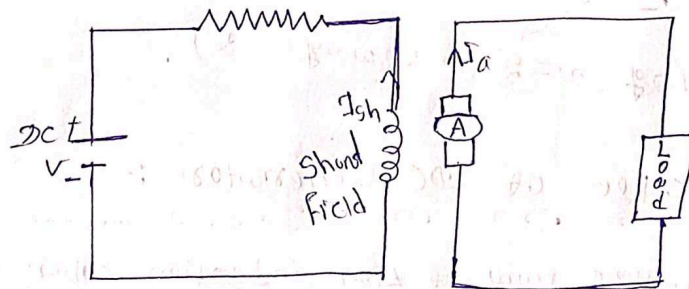
DC Shunt Generator

DC Compound Generator

DC Long shunt Compound Generator

DC Short shunt Compound Generator

Separately excited DC Generator :-



* A DC generator whose field magnet winding is supplied from an independent external DC source is called a separately excited DC generator.

$$E_g = \frac{P \Phi N Z}{60 A}$$

where P = number of pole

E_g = Generated e.m.f

ϕ = magnetic flux.

N = speed

Z = number of conductor.

A = Number of parallel path.

* Terminal Voltage

$$V = E_g - I_a R_a \quad (V = IR)$$

$$V = IR$$

where,

I_a = Armature current.

R_a = Armature resistance.

$$E_g = V + I_a R_a \quad \text{given current / Resistance}$$

Power developed :-

$$P = V \times I_a$$

$$P = E_g \times I_a$$

Power delivered to load :-

developed power - losses

Problem No :- 1

Date - 4.03.23

A shunt Generator delivers 450 Am at 230 V and the Resistance of the shunt field at the Armature are 50Ω & 0.03Ω respectively. Calculate Generated e.m.f

Ans:-

Given data

$$I_L = 450 \text{ Am}$$

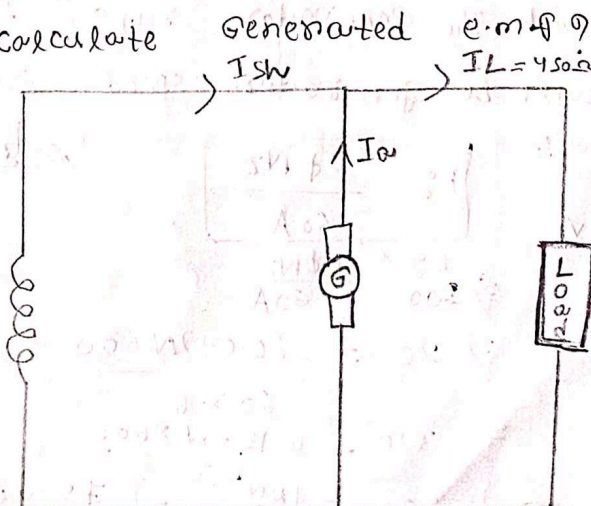
$$R_a = 0.03 \Omega$$

$$V = 230 \text{ V}$$

$$R_{sh} = 50 \Omega$$

$$E_g = V + I_a R_a$$

Find



$$I_a = I_L + I_{sh}$$

$$\Rightarrow I_a = I_{sh}$$

$$I_{sh} = \frac{V}{R_{sh}} = \frac{230}{50} = 4.6 \text{ A}$$

$$I_a = I_L + I_{sh}$$

$$\Rightarrow I_a = 450 + 4.6 = 454.6 \text{ A}$$

$$E_g = V + I_a R_a$$

$$\begin{aligned} E_g &= V + I_a R_a \\ E_g &= 230 + 454.6 \times 0.03 \\ &= 243.63 \text{ V} \end{aligned}$$

$$* E_g = V + I_a R_a$$

$$\begin{aligned} \Rightarrow V &= E_g - I_a R_a \\ \Rightarrow V &= 243.63 - (454.6 \times 0.03) \end{aligned}$$

$$\Rightarrow V = 229.992 \text{ V} \quad (\text{Ans})$$

Problem No: 2

wave winding
A=2

$$(ii) E_g = \frac{P \phi N Z}{60 A}$$

$$\Rightarrow 300 = \frac{6(0.02)N \times 600}{60 \times 2}$$

$$\Rightarrow 300 = \frac{6(0.2)N \times 600}{60 \times 2}$$

$$\Rightarrow 300 = \frac{0.12 \times N \times 600}{60 \times 2}$$

$$\Rightarrow 300 = \frac{72N}{120}$$

$$\Rightarrow 300 = 0.6N$$

$$\Rightarrow 0.6N = 300$$

$$\Rightarrow N = \frac{300}{0.6} = 500 \text{ R.P.M (Ans)}$$

Problem No: 2 :- Date - 06.03.23

A 6 pole lap wound generator has 600 conductors, the flux per pole is 0.02 above. (i) Calculate the speed at which the generator runs to generate 300 V?

(ii) What will be generator speed e.m.f with wave wound?

Given data:-

$$E_g = 300 \text{ V}$$

$$Z = 600$$

$$\phi = 0.02$$

$$a = 6$$

$$P = 6$$

$$E_g = \frac{P \phi N Z}{60 A}$$

$$\Rightarrow 300 = \frac{6(0.02)N \times 600}{60 \times 6}$$

$$\Rightarrow 300 = \frac{6(0.02)N \times 600}{60 \times 6}$$

$$\Rightarrow 300 = \frac{0.12 \times N \times 600}{360}$$

$$\Rightarrow 300 = \frac{72N \times 60}{360} \Rightarrow 72N = 300 \times 360 \Rightarrow N = \frac{108000}{72} = 1500$$

$$\text{So, } N = 1500$$

Date - 09.03.23

Self-excited :-

* A DC Generator whose field magnet winding is supplied current for output of generator itself is called a self excited generator.

* There are 3 types exciting generator

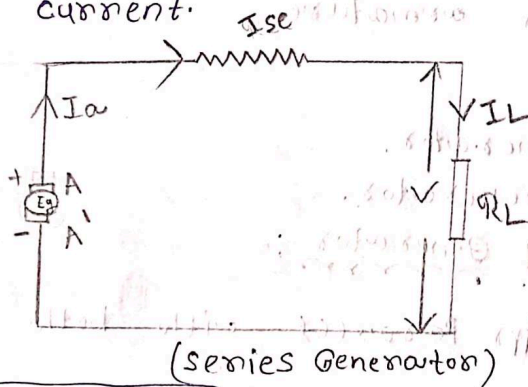
(i) Series Generator.

(ii) Shunt Generator.

(iii) Compound Generator.

(i) Series Generator :-

In this generator field winding connected in series with Armature winding so that whole Armature current flow through the field winding & series field winding & load current.



$$E_g = V + I_a R_a + I_{se} R_{se}$$

V = terminal voltage

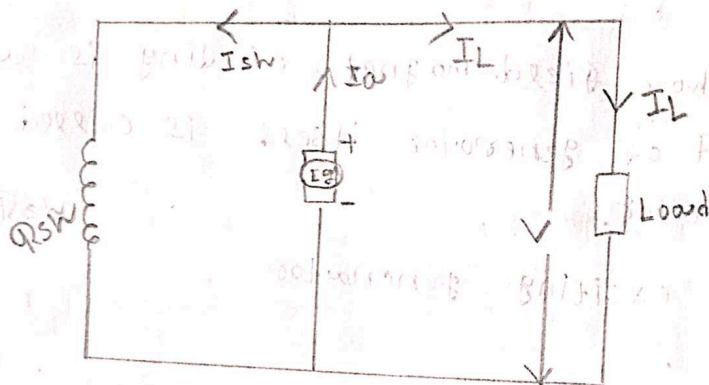
$$I_a = I_{se} = I_L$$

$$V = E_g - I R_a$$

Shunt Generator :-

* Field winding is connected in parallel with armature winding. The shunt winding has many turns having high resistance has many turns having high resistance.

* Therefore only a armature current flows through shunt field is rest flows through load.



$$I_{sh} = \frac{V}{R_{sh}}$$

$$I_a = I_L + I_{sh}$$

$$I_a = I_L + I_{sh}$$

$$\Rightarrow I_{sh} = I_a - I_L$$

$$V = E_g - I_a R_a$$

$$\Rightarrow I_L = I_a - I_{sh}$$

Compound Generator :-

* In a compound generator there are two of field windings on each pole - one is in series with armature & other in parallel with armature.

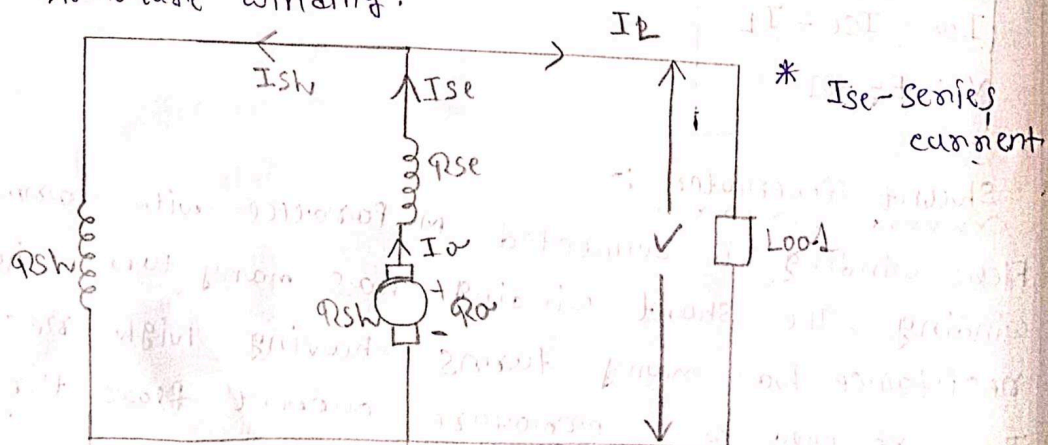
* It is of 2 types :-

(i) Long Shunt compound Generator.

(ii) Short Shunt compound Generator.

(i) Long Shunt Compound Generator :-

* Shunt field winding is in parallel with both series field in Armature winding.



* Long Shunt Current $I_{sh} = \frac{E_g \times I_a}{V \times I_a}$

$$I_{se} = I_a = I_L + I_{sh}$$

$$I_{sh} = \frac{V}{R_{sh}}$$

$$V = E_g - I_a(R_a + R_{se})$$

$$I_a = I_{se}$$

$$I_a = I_{sh} + I_L = I_{se}$$

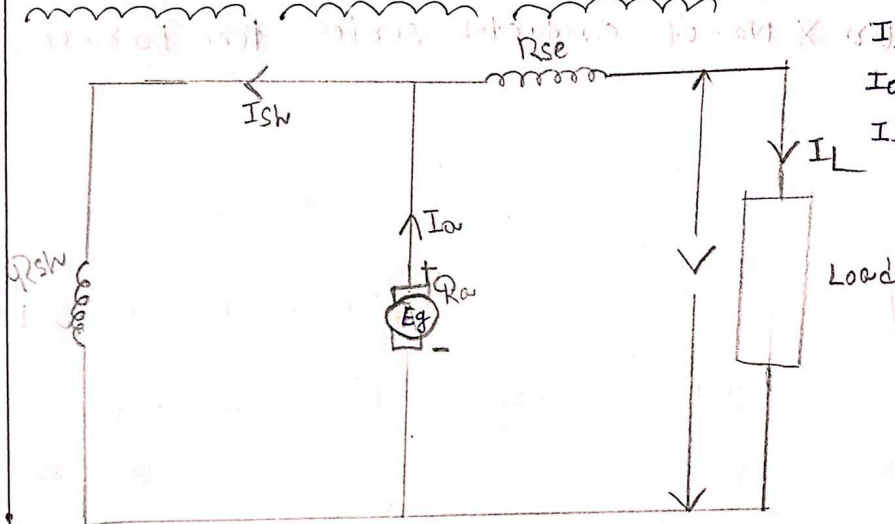
$$E_g = V + I_a R_a + I_{se} R_{se}$$

$$E_g - I_a R_a - I_{se} R_{se} = V$$

$$\Rightarrow E_g - I_a R_a - I_a R_{se} = V$$

$$\Rightarrow E_g - I_a(R_a + R_{se}) = V$$

Shunt shunt Compound Generator :-



$$I_{se} = I_L$$

$$I_a = I_{sh} + I_L$$

$$I_{sh} = \frac{V}{R_{sh}}$$

$$I_{se} = I_L$$

$$I_{sh} = \frac{V + I_{se} R_{se}}{R_{sh}}$$

$$V = E_g - I_a R_a - I_{se} R_{se}$$

* shunt field current $I_{sh} = \frac{V + I_{se} R_{se}}{R_{sh}}$
 * parallel develop in Armature R_a

$$(P_d) = E_g \times I_a$$

$$* \text{ parallel deliver to load } (P_L) = V \times I_a$$

E.M.F Equation of DC Generator :-

E.M.F = Electro motive force.

Let ϕ = flux/pole in wb

Z = Total number of armature conductor

N = Speed of Armature in r.p.m.

P = Number of pole.

E_g = E.m.f of Generator.

A = Number of parallel paths.

* flux cut by one conductor in one revolution of the Armature is $d\phi = P\phi$ in wb.

* Flux unit is weber.

* Time Taken to Complete ^{one} revolution

$$dt = \frac{60}{N} \text{ second}$$

* e.m.f generate cut conductor $\frac{d\phi}{dt} R = \frac{P\phi}{60N}$

$$= \frac{P\phi N}{60}$$

* e.m.f generator $E_g = \text{e.m.f per parallel path.}$

* E.M.f / conductor \times No. of conductor series per parallel path.

$$\frac{P\phi N}{60} \times \frac{Z}{A}$$

$$\Rightarrow \boxed{\frac{P\phi N Z}{60 A}}$$