DC - Generator

DC - Generator is a Electrical machine that can be change mechanical energy to electrical energy.

* working principle of DC generator:-

whenever a conductor or coil is made to move in DC generator magnetic field region It cut the magnetic flux and cause change in flux linking to it hence E.m.f is induced.

The direction of induced e.m.f is to be determind by applying flemings right hand rule. Generator principle follow faradays law of voltage and e.m.f generation where direction of generated flaming right hand thumb rule

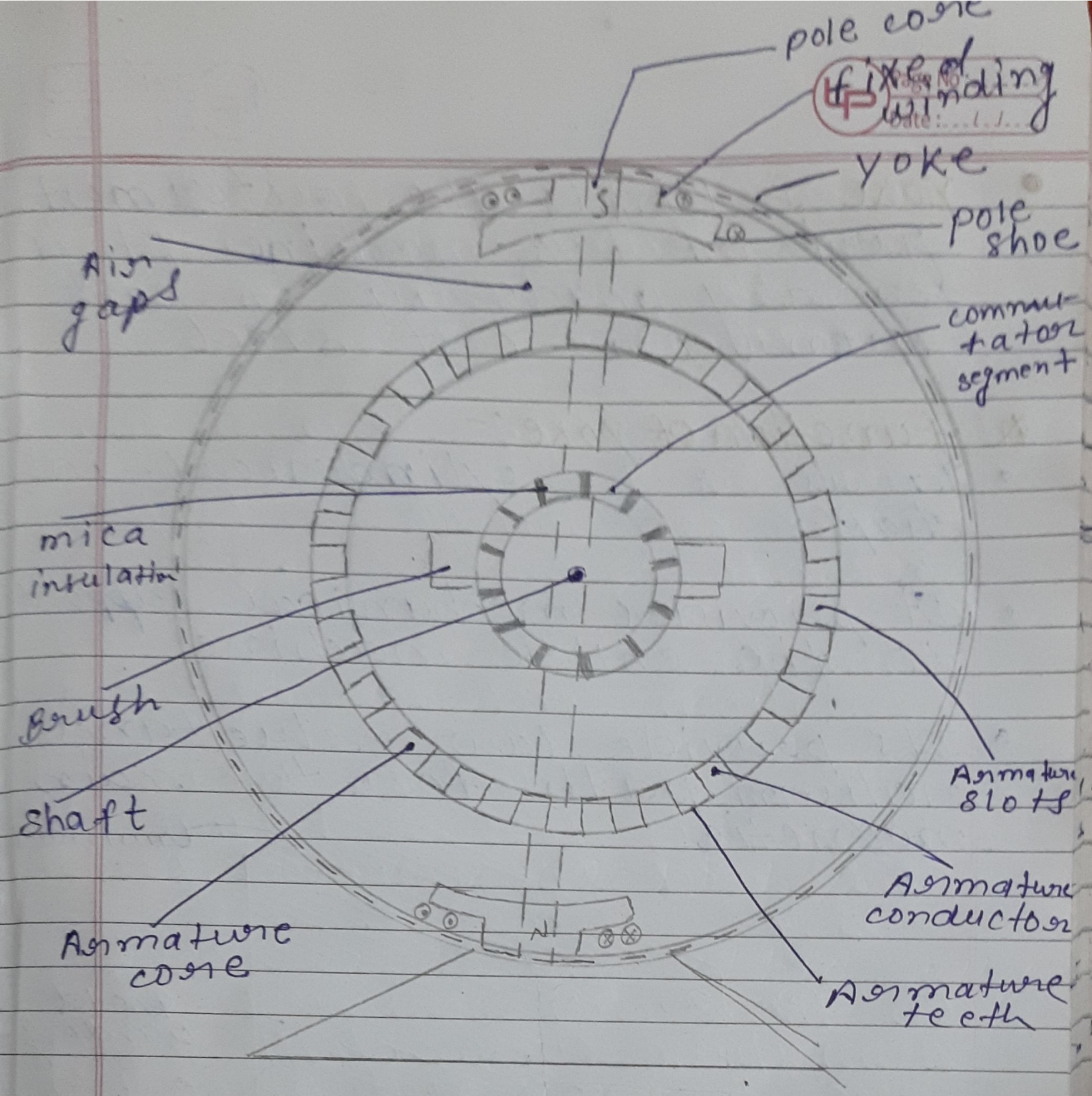
* construction features of DC machine:-

→ DC machine consists three parts

(I) magnetic field windings (system)

(II) Armature

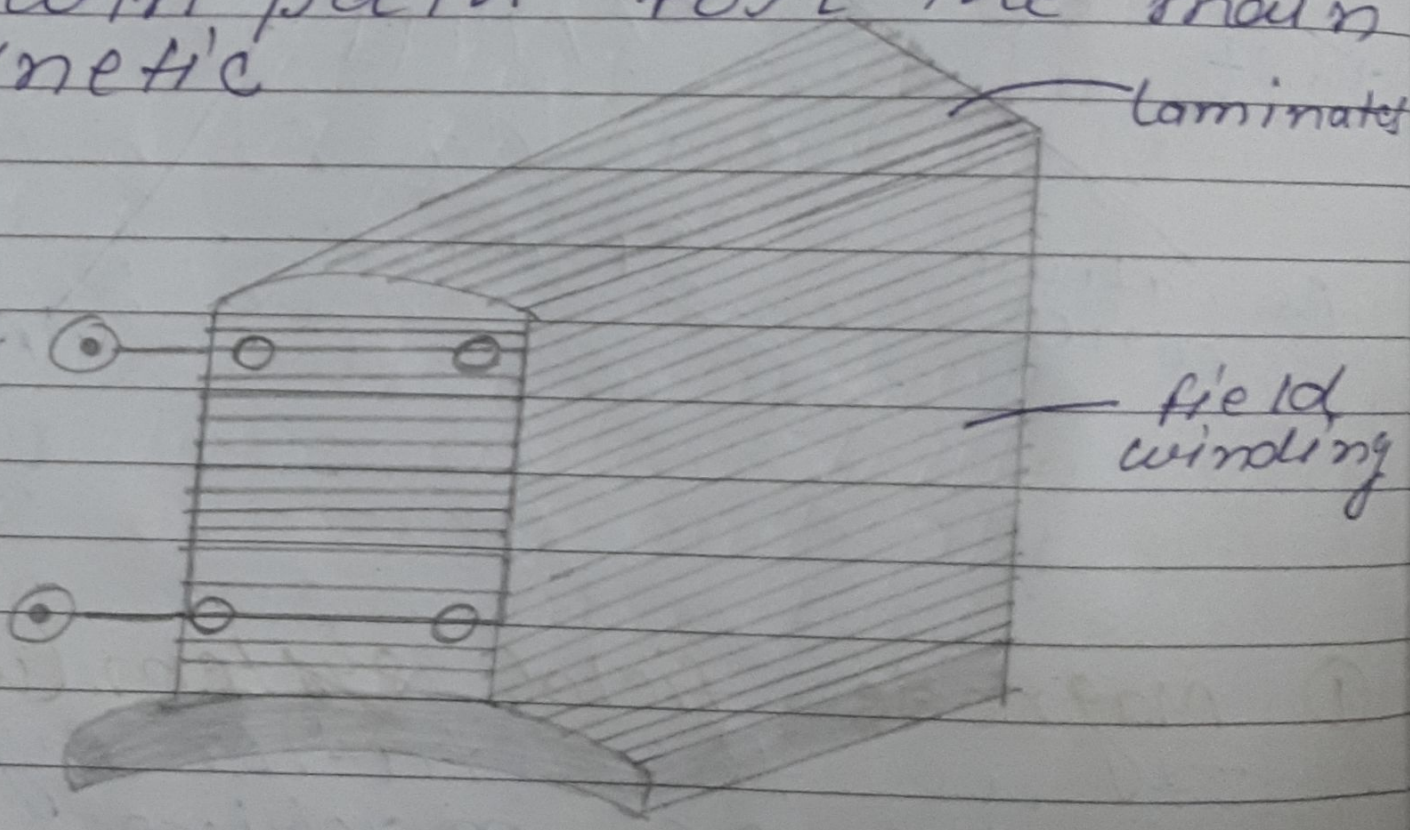
(III) commutator and Brushes



① Magnetic field system (windings)
It is the stationary part of the DC machine expect brush consitude magnetic field system. It is comprised of poles core field winding yoke, pole shoe.

- yoke :- It is the outermost part of D.C machine It is generally made up of cost iron or cost steel.

* function of yoke:-
- It is a cylindrical in shape
- It provides mechanical support to the entire machine
- Its provide law reluctance return path for the main magnetic



pole shoe and pole core are made up of cost steel material. pole core need not to be laminated but pole shoe must be laminated to avoid eddy currents

* pole core functions :-
field winding is to be wonded over the pole core

* function of pole shoe :-
- provide mechanical support for the field winding that is it helps to hold the field coils of field winding on pole core

- It cause low Reluctance for main magnetic flux by increasing the crossectional area

- It spreats the field flux uniformaly into the air gap.

* field winding :- It is winding or coil which is responsible for produced required magnetic flux or field

countine windings
produce is used for the plament of is used winding over the pole core.

DC current is allowed to flow through field winding so that D.C flux can be produce

(ii) Armature :- It is a rotating part of D.C machine where e.m.f or voltage is to be generated.

Armature core is made up of silicon steel lamination.

Silicon is used to avoid hysteresis loss and lamination is used to avoid eddy current loss.

On the outer periphery of Armature core slots outer core punched out place or accomade armature conductive or winding.

* Armature winding :- It is a winding in which e.m.f or voltage to be induced.

* Armature conductor :-
Armature conductors are inter connected to each to form a coil or windings

- It is distributed in slots round the periphery of armature

* commutator and Brushes
→

commutator is used to convert generated Ac into DC.

- In case of DC motor commutator is used to convert DC to AC.

* E.m.f equation of DC-Generator :-

let P = Total number of pole

Z = Total No. of conductor

ϕ = flux produce by each pole (average flux)

N = speed of Armature (rotor)

A = Total No. of parallel path

voltage generated or E.m.f induced in each conductor if, rotor (armature) revolve for one rotation is given as

$$E_{avg/conductor} = \frac{\text{Total flux cut by each conductor in one revolution}}{\text{Time taken to complete one cycle.}}$$

$$E_{avg/conductor} = \frac{P\phi}{\frac{60}{N}}$$

$$E_{avg/conductor} = \frac{P\phi N}{60}$$

E_{avg} (Total) = $E_{avg/conductor}$ × No. of conductor in each parallel path.

$$E_{avg} = \frac{P\phi N}{60} \times Z/A$$

$$\therefore E_{avg} = \frac{P\phi N Z}{60A}$$

parallel lap winding ($A = P$) high current
wave winding ($A = 2$) high voltage

Q:- Calculate the highest speed at which
(a) 50 H_z (b) 60 H_z alternator can operated

→

since it is not possible to have fewer than 2 poles the minimum value of $P = 2$

for minimum value of P the speed N will be a maximum

(a) $f = 50$ $P = 2$ $N_S = \frac{50 \times 120}{2}$

$= 3000$ r.p.m

(b) $f = 60$ $P = 2$ $N_S = \frac{60 \times 120}{2}$

$= 3600$ r.p.m

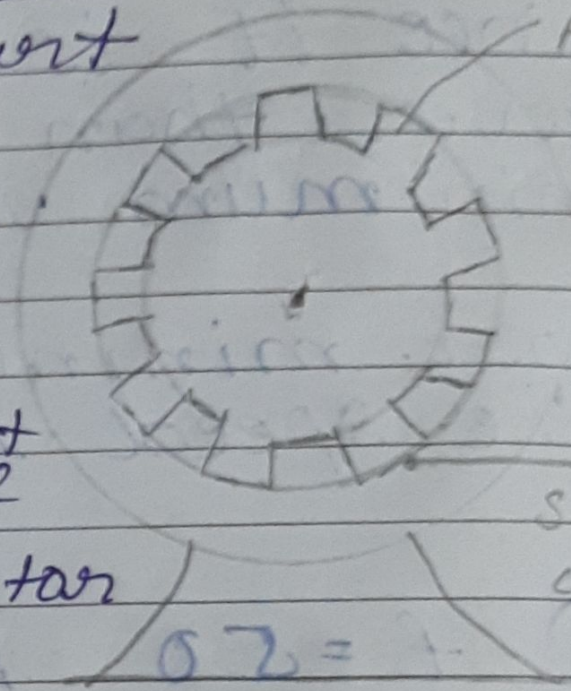
* construction of three phase synchronous machine

The A.C generator are usually made up of two parts

(i) Stator (ii) Rotor

Stator :-

(i) Alternator consist Armature winding The arrangement armature is stationary and armature winding is called stator or static (fixed) part of Alternator



(ii) It provide mechanical support to total No. of pole in Alternator

(iii) It is provid safety against environmental effect such as rain, dust etc

(iv) The main work of stator it provide returning path of flux

(v) It is made-up of cast iron or laminated silicon steel small size machine generally used cast iron

(vi) laminated silicon steel is less the eddy current and hysteresis loss.

(vii) Rotar :- Alternator also consist magnetic field. the arrangement of magnetic field is rotation the rotating field system in alternator is called Rotor.

- It provide in two parts.

(i) Salient or projected pole type.

* In this type of rotor all the pole project out from the surface of the rotor
* con centraeted windings are used
* Damper bars are used to damp out the rotor oscillations
* Non-uniform air gap
* Radial air gap length helps machine to generate sinosoidal e.m.f

* Ends are connected to a dc source through brushes and slipring.
* Large no. of poles and operate at lower speed
* larger diameter and short axial length
* drive by water or hydro-turbine.

(ii) Non-salient pole type

* High grade nickel-chrome molybdenum steel
* Distributed winding
* used in high speed machine
* Greater mechanical strength and more accurate dynamic balancing.
* Derive by steam turbines

Armature is stationary magnetic field is rotating

* uniformaly air gape.

* working prinicipal of Alternator

(i) The working principle of AC generator is based on the electromagnetic induction same as that of the DC generator Alternator also consist of the armature winding and magnetic field. In this arrangement Armature is stationary and magnetic field is rotating there armature winding is called stator and magnetic field is called rotor.

(ii) The stator is made up cast iron or teminated silicon steel which holds ups the armature core. It consist of inner slots for placing the armature conductors. The rotor consist N and S poles fixed on its outer periphery. The magnetic poles are magnetised from dc source

(iii) It is obtained from a small DC shunt generator which is mounted on the alternator shaft. As the magnetic field is rotating, the DC current is supplied from the two slip rings.

(iv) When the rotor rotates the stitionary stator conductors are cut by magnetic field and there for e.m.f is induced As the magnetic poles N and S are placed alternately, they induced an e.m.f and armature current

(v) This armature current flow in the one direction and then in the other direction due to this reason the e.m.f produced is alternating in nature. the frequency depends on the N and S poles. This direction tell us flaming right hand rule.

$4.44\ \phi_c \cdot K_d$

* Difference between salient pole and Non-salient pole.

Salient pole Rotor	Non-salient pole rotor
① Salient pole rotor is suitable for only low speed machines like fan, cular Ac, water pump etc.	① Non-salient pole rotor suitable for high speed machines like turbine, train's motor etc.
② It has non-uniform air gap.	② It has uniform air gap.
③ Rotor has large diameter and small axial length.	③ Rotor has small diameter and large axial length.
④ Rotor is mechanically weak	④ Rotor is not mechanicaly weak
⑤ It is used for law speed applications upto 600 rpm	⑤ It is used for high speed applications upto 3000 rpm

⑥ hydrolic Turbine and IC engines are used as a prime movers	⑥ steam turbine and electric motors are used as a prime mover

Q. operation of three phase Alternator :-

→

when the rotor is rotated by a prime mover (motor turbine e.t.c) the stator winding is cut by magnetic flux of rotor poles due to electromagnetic induction an e.m.f induced in the armature winding (stator winding). This induced e.m.f is alternating nature because the north and south poles of the rotor Alternately pass the armature winding Conductor we can determined the direction of induced e.m.f by fleming right hand rule.

when a rotor is rotated the three phase voltage generator in the generator winding.
The magnitude of generated voltage depends upon the speed of the rotational of rotor and the DC excitatio

However the magnitude of the generated voltage in each phase of the armature is same But displaced by 120° electrical from each other in space

$$V_R = V_m \sin \omega t$$

$$V_Y = V_m \sin (\omega t - 120°)$$

$$V_B = V_m \sin (\omega t + 120°)$$

OR

$$\pm V_m \sin (\omega t - 240°)$$

* E.M.f equation of alternator

ϕ = flux produce each pole (Average flux)

P = Total number of poles

f = frequency of generated voltage (Hz)

N = speed of rotor in r.p.m

Z_{ph} = Total number of conductor per phase

T_{ph} = Total number of coil (turn) per phase

K_c = coil span factor

K_d = distribution factor

Voltage generated or e.m.f induced in each conductors if rotor rotates a one rotation

$$E_{avg}/\text{conductor} = \frac{P \phi N}{60}$$

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Average E.m.f induced per phase

$$E_{avg}/phase = \frac{P\phi N}{60} \times Z_{P_n}$$

$$= \frac{P\phi N}{60} \times 2\frac{T_{P_n}}{2}$$

$$\left[\because T_{P_n} = \frac{Z_{P_n}}{2}\right]$$

$$= 2 \times \frac{P\phi N}{60} \times 2T_{P_n} \times \frac{1}{2}$$

$$= 4\, T_{P_n} \times \phi \times \frac{PN}{120}$$

$$E_{avg}/phase = 4\, T_{P_n}\, \phi \cdot f$$

$$\left[\because f = \frac{PN}{120}\right]$$

R.M.S values of e.m.f induced per phase.

E_{P_n} = Average value per phase × form factor

$$E_{p_n} = 4 T_{p_n} \phi f \times 1.11$$

$$E_{p_n} = 4.44 \phi f T_{p_n}$$

Taking into consideration the coil span factor (K_c) and distribution factor (K_d) of the winding.

Actual E.m.f induced per phase

$$E_{p_n} = 4.44 K_c \cdot K_d \cdot \phi f \cdot T_{p_n}$$

* full pitch fractional winding

→

when the two coils side of the same coil are 180° electrical degree apart winding is called full pitch windings

In the full pitch coil the induced e.m.f is maximum or greater then short pitch winding.

* Advantage:-

- It is offer better circuit utilization.
- Higher torque and current ratio.
- Higher efficiency.

* Disadvantage:-

- It is required long lenth copper wire so the amount of copper & ~~losses~~ are increases.

* Short pitch or fractional pitch winding.

→ when the two side of the same coil less 180° electrical degree apart of windings is called short pitch windings

* Advantage :-
- Improved wave form
- Reduce copper usage
- Reduce losses

* Disadvantage of short pitch
- Its reduce the total voltage arround the coils
- Increase copper.

* coil span factor :-

The ratio of induced e.m.f in a coil when the winding is short pitch to the induced e.m.f in the same coil when it is full

pitch is called coil span factor or pitch factor or chorded factor. It is less them unity

$$K_c = \frac{2E \cos \beta/2}{2E} = \cos \beta/2$$

$$\boxed{K_c = \cos \beta/2}$$

* Distribution factor :-

It is define as the ratio of the e.m.f induced with the distributed winding to the e.m.f induced if in the concentrated winding It is less them unity

$$\boxed{K_d = \frac{e_v}{e_a} = \frac{\sin \frac{m\alpha}{2}}{m \sin \frac{\alpha}{2}}}$$

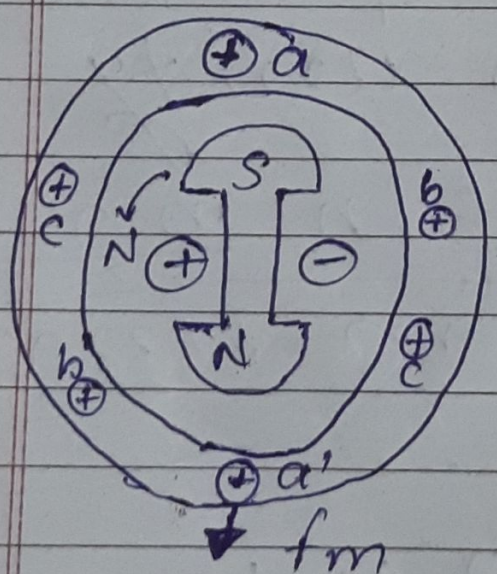
* winding factor :-

$$\boxed{K_w = K_c \times K_d}$$

* The effect of Armature (Stator) flux on the produced by rotor field poles is called Armature reaction of Synchronous generator.

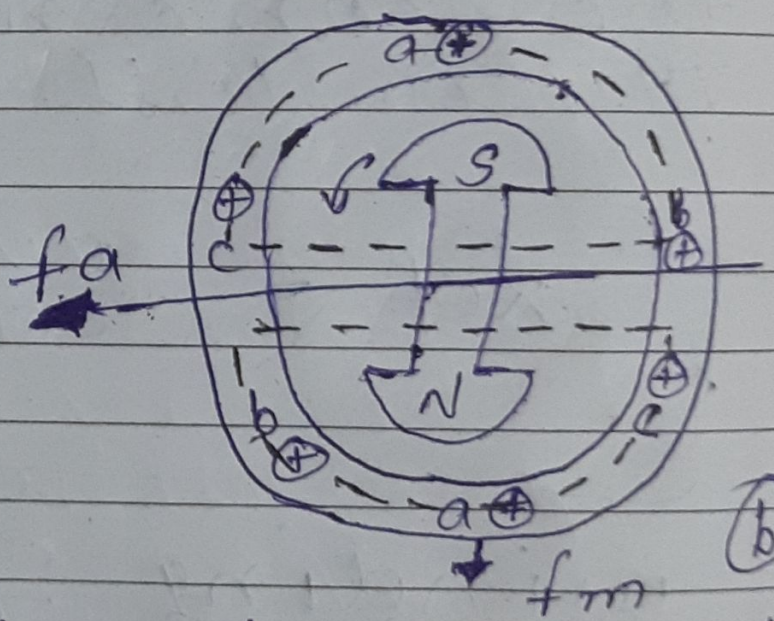
① unity power factor :-

→ concider a two pole alternator rotating in anticlockwise direction. The three phases are represented by concentric coils a-a', b-b' and c-c' which are diplaced by 120° electrical from each other where's a, b and c is starting terminal and a', b' and c' is end terminal.



(a)

EMf induced in the armature conductor due to rotation of field



(b)

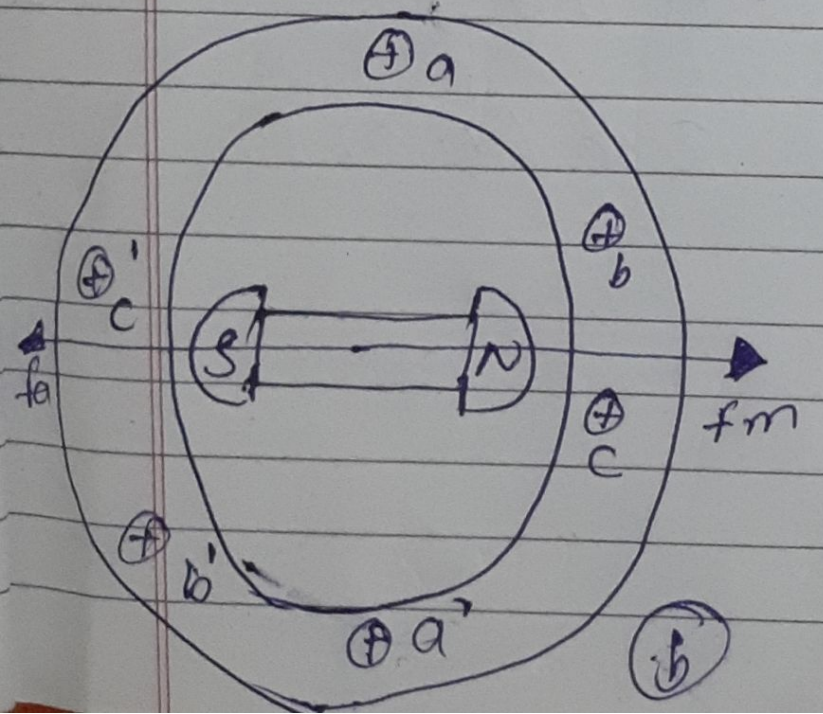
Armature field produced due to current carrying armature conductor

The position of the main magnetic field fm produced by the exciting field coils.

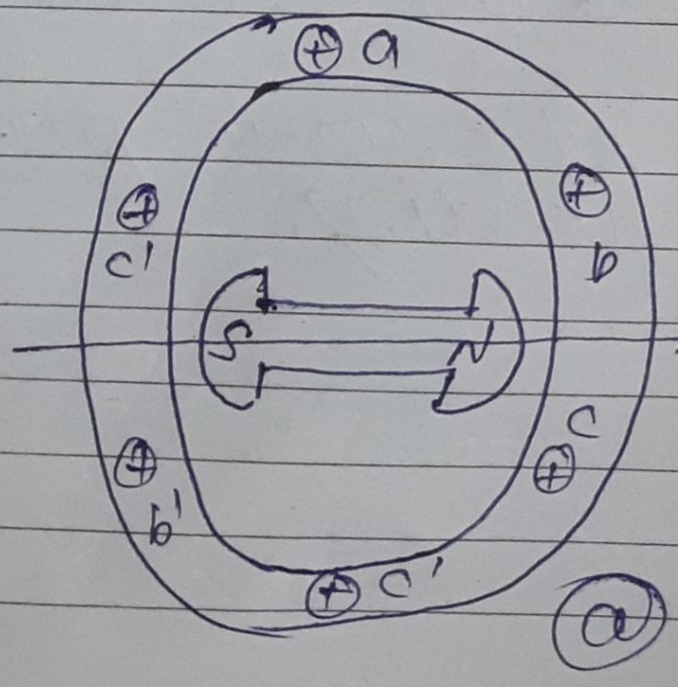
when a load of unity power factor connected to the alternator current flow through the coils which is in phase with the induced e.m.f as shown in fig.

The armature field fa is perpendicular of the main magnetic field fm and produced cross magnetising effect fa lags behind the fm by 90°

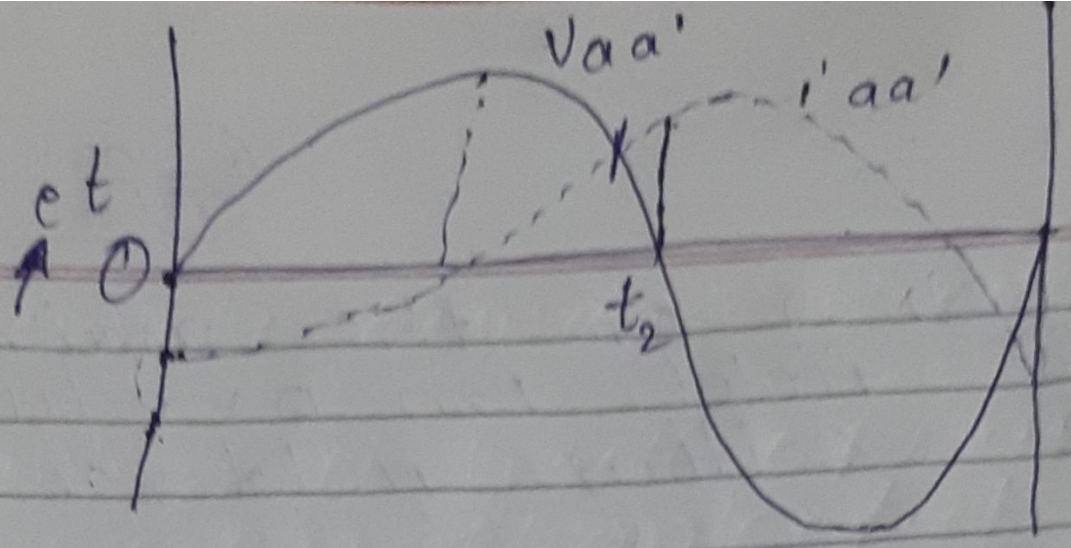
* At zero power factor lagging :-



(b)



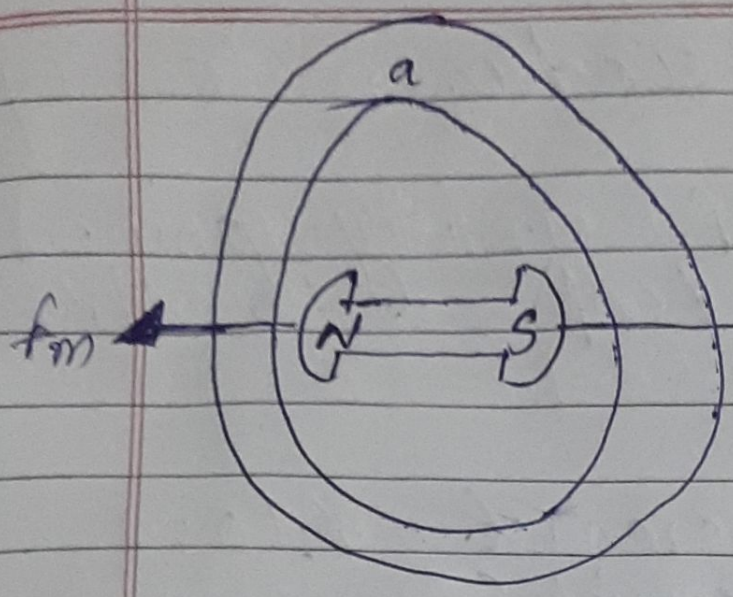
(a)

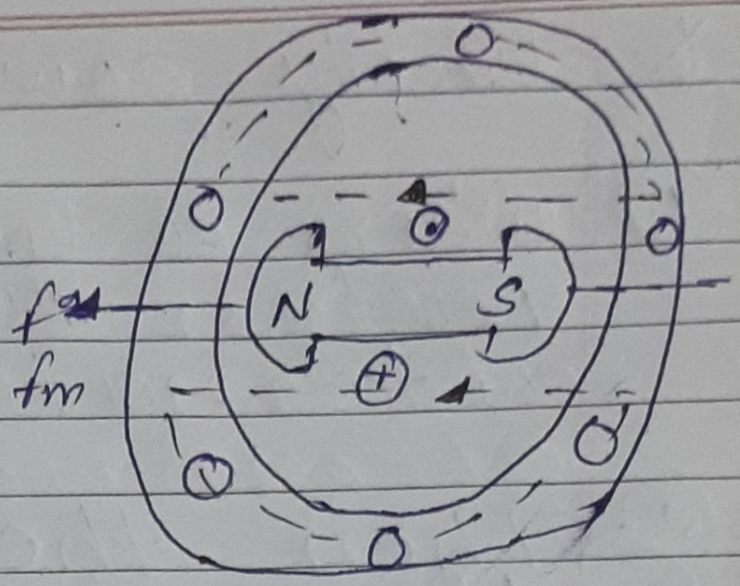


when a pure inductive load at zero p.f lagging is connected to the alternato current flow through the coil which lag behind their respective induced e.m.f by 90° electrical.

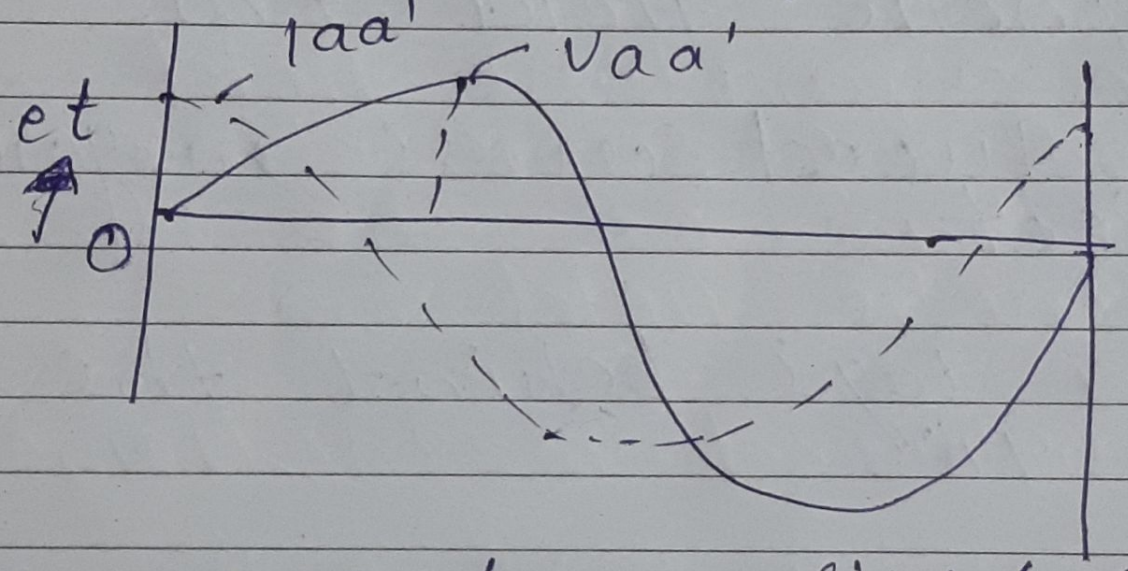
The armature field fa acts in opposite direction to that of main magnetic field ϕ_m and produced non-magnetising effect fa lags behind the fm by 180° its lag by 90° because of a pure inductive and 90° because armature reaction.

* At zero power factor leading.





when a pure capacitive load at zero p.f leading connected to the alternator, current will flow through the coils which leads their respective induced e.m.f by 90° electrical



The armature field fa acts as a same direction as that of the main magnetic field fm and produced magnetising effect fa lead behind the fm by 90° capacitive load.

* unity power factor :-

(1) When a load of unity power factor connected to the alternator.

(2) Then the current flow through the coils

(3) which is in phase with the induced e.m.f

(4) The armature field fa is perpendicular of main magnetic field fm.

(5) produced cross magnetising effect.

(6) fa lags behind the fm by 90°

{ lagging p.f → Inductor
  leading p.f → capacitive }

* zero power factor lagging

① when a pure inductive load at zero power factor lagging is connected to the alternature.

② Then the current flow through the coil

③ coil which lag behind their respective induced e.m.f by 90° electrical

④ The armature field fa acts in opposite direction to that the main magnetic field ϕm or fm

⑤ produced no-magnetising effect,

⑥ fa lags behind the fm by 180°. its lag by 90° because of a pure inductive and 90° because armature reaction.

* zero power factor leadi

(1) when a pure capacitive loa connected at zero pow factor connected to the alternator

(2) Then the current will flow through out the coils

(3) coil which leads their respective induced e.m.f by 90° electrical

(4) The armature field fa acts the same direction as that of the main magnetic field fm

(5) produced magnetizing effect

(6) fa lead behind the fm by 90° capacitive load.