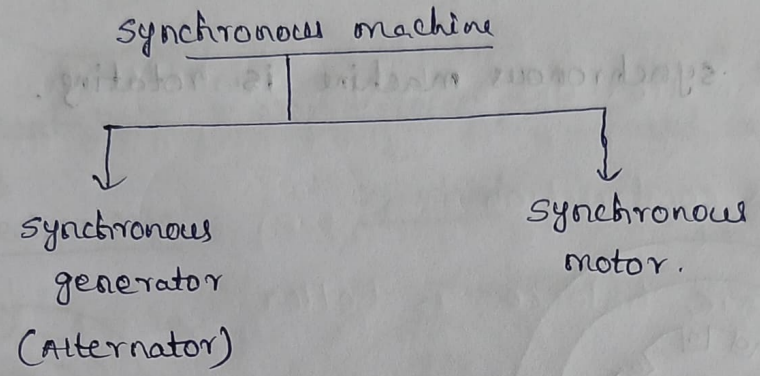
11/04/23

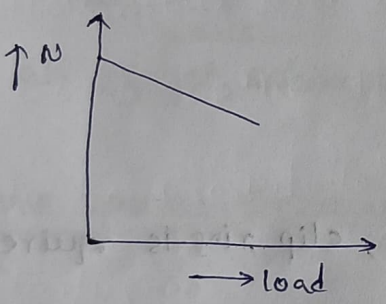
Three-phase synchronous machines:

→ The machines which run at synchronous speed,

$$N_S = \frac{120f}{P}$$



For DC Generator:



→ But for alternator, speed should not be decreasing and accordingly designed either inc(or)dec | ie, invariant quantity.

→ If f is not constant, we cannot use the voltage so we here to maitain 50Hz constant value.

→ As $f = \frac{PN_S}{120}$, to maintain frequency constant, the speed must be constant value

→ Alternator is constant speed generator.

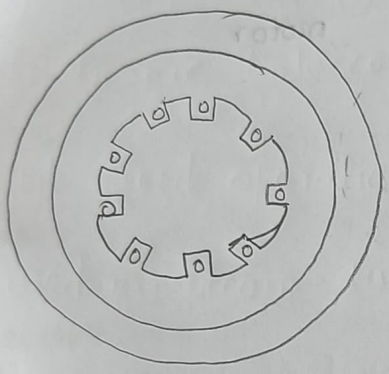
Construction:-

Stator — Rotor

→ Field winding placed in rotor but armature winding placed in stator

→ field of synchronous machine is rotating.

(*)



(*)

→) If we place A-W in inner part, slip ring is required

Advantages of rotating magnetic field:

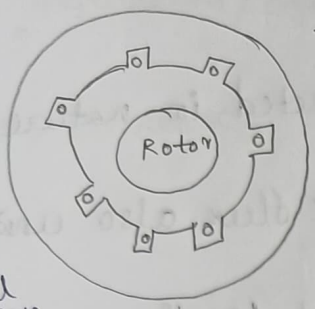
1) The size of machine is reduced.

2) The terminal of the armature easily available if we place armature winding in stator

3) The insulation also easily available when placed in stator.

4) ~~If~~ pulling technique is more easy if we placed armature winding in stator.

→ slip rings not required.



→ stator is similar to induction motor.

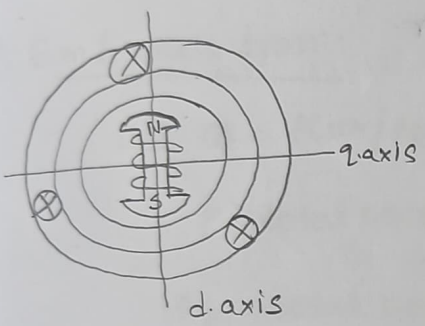
Hydral station

→ Salient pole & Non salient pole → used for thermal station.

↓ cylindrial

↓ projection pole

→ Turbo alternator



→ air gap is uniform

→ air gap of salient pole is not uniform.

⊛ Some special feature of salient pole m/c:

→ The pole of m/c are projected in nature.

→ The air gap of m/c are non-uniform.

→ The magnetic flux is also non-uniform due to non-uniform of air gap.

→ It has large dia & small axial length of rotor.

→ The m/c is generally low speed machine.

→ It is used in hydraulic turbine (or) diesel engine.

For

Non-saleint pole:-

→ The air gap machines is uniform

→ Pole of machines are not projected in nature.

→ Due to uniform airgap, magnetic flux also uniform

→ It has smaller dia & large axial length.

→ Noise less construction.

→ The dynamic balance is better.

→ High speed operation

→ used in steam turbine

⊛ Frequency of the induced emf:-

Let P = total No of pole

$n = \frac{N}{60}$ & $P = \frac{P}{2}$

P = Pair of pole

N = speed in rpm

n = speed in rps

f = frequency of generated voltage

Now, one rotation of rotor, the armature coil cut by $\frac{P}{2}$ north pole & $\frac{P}{2}$ south pole. Since one cycle is generated in arm. coil and when a pair of field pass over the coil. The no. of cycles generated in one rotation of rotor will be = no. of pair of poles.

∴ No. of cycle / Regulation (or) rotation = No. of pairs of pole = P

Also, No. of regulation / ~~cycle~~ sec = n

Now, frequency = $\frac{\text{No. of cycle}}{\text{sec}}$

$= \frac{\text{No. of cycle}}{\text{regulation}} \times \frac{\text{regulation}}{\text{sec}}$

$= P \times n$

⊛ Emf equation:-

Let ϕ = flux/pole

P = total no. of pole

Z_p = total no. of conductor

T_p = No. of turns.

n = rps

Each stator conductor cut a flux $P\phi$ for one rotation.

$$E_{avg} = \frac{P\phi}{1/n} = Pn\phi = 2f\phi \qquad \boxed{P = \frac{P}{2}} \quad \therefore f = \frac{Pn}{2}$$

∴ Induced emf per phase $= 2f\phi$

for '2' no. of conductor $= 2f\phi Z_p$

[we know that $\boxed{Z_p = 2T_p}$]

∴ Induced emf per phase $= 4f\phi T_p$

Since, the $\frac{\text{R.m.s}}{\text{avg}} = 1.11$ (form factor) ∴ Induced emf in rms

$$\boxed{E_{rms} = 4.44 \times f \times \phi \times T_p} \rightarrow \text{(for AC generator)}$$

k_d = distribution factor — since alternator

K_p = pitch factor

$$\therefore \boxed{E_{rms} = 4.44 f \phi T_p k_d k_p}$$

⊛ Advantage of distributed winding:-

① The harmonic emf is reduced and wave form also improved (near to sinusoidal)

② some harmonic can be eliminated directly from the distributed winding

③ The distributed winding reduce the armature reaction

④ The core of motor is better utilized

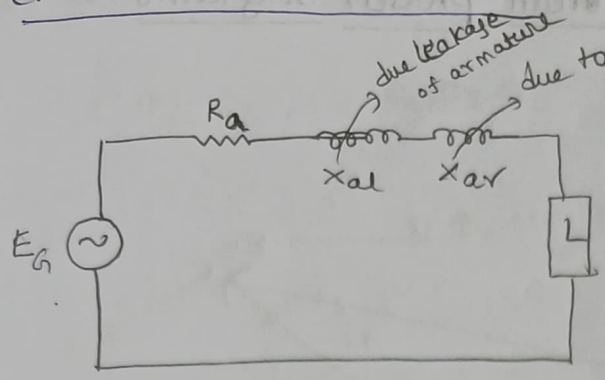
⊛ short pitch winding:-

→ The wave form improved and also harmonic reduced

→ Less copper is required due to short pitch winding

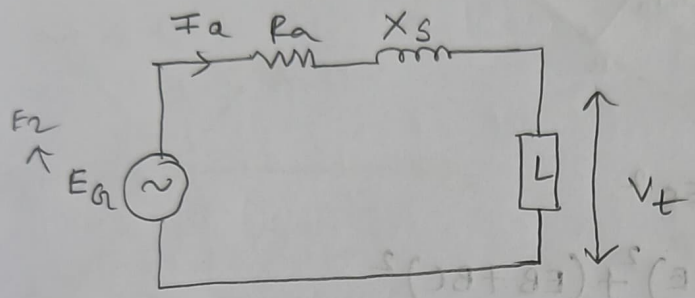
→ The inductance of winding also reduced.

→ The mechanical strain of coil also increased



$X \propto f$

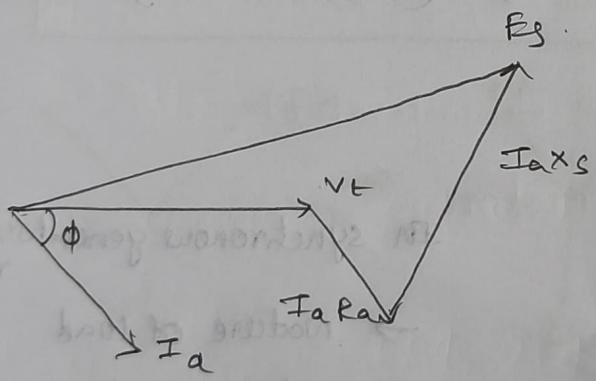
As $f = 0$ in dc generator so we wouldn't considered $X \rightarrow$ reactance ✓.



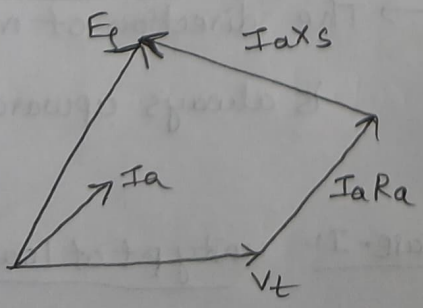
$E_g = V_t + I_a R_a + I_a X_s$

② Phasor diagram:-

① Lagging P.f of load:-

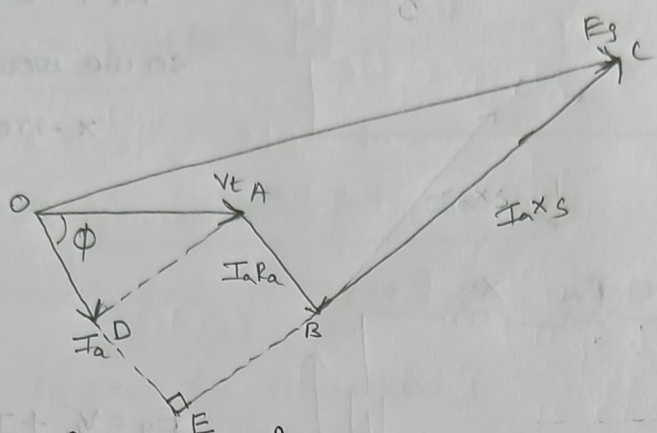


② Leading P.f of Load:-



⑦ Expression of Emf forom phasor diagram:-

For lagging P.f:-



ΔOCE, $OC^2 = OE^2 + EC^2$

$= (OD + DE)^2 + (EB + BC)^2$

$= (V_t \cos\phi + I_a R_a)^2 + (V_t \sin\phi + I_a X_s)^2$

$$E = \sqrt{(V\cos\phi + I_a R_a)^2 + (V_t \sin\phi + I_a X_s)^2}$$

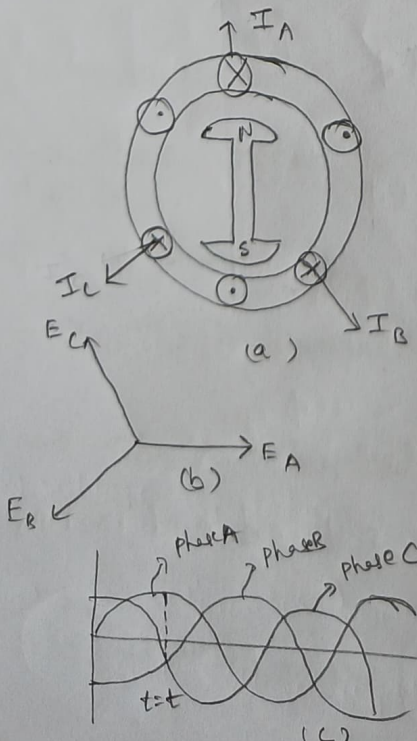
⑧ Armature Reaction:-

In synchronous generator, armature reaction depends on

→ Nature of load

→ Load inc or dec

→ The direction of magnetic field is always upward direction.

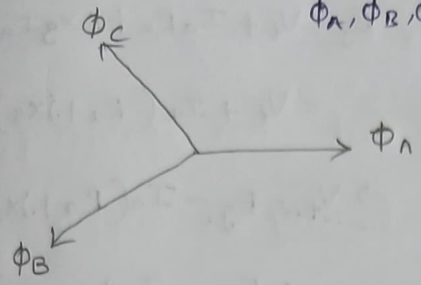


Case-I:- unity p.f of load:

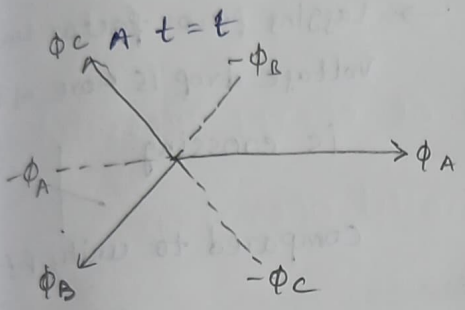
The current I_A, I_B, I_C are in phase with E_A, E_B, E_C

→ Due to I_A, I_B, I_C, flux will be generated.

Φ_A, Φ_B, Φ_C



Now from fig (c)

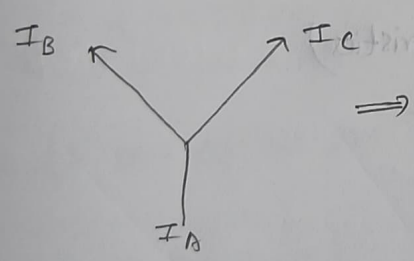


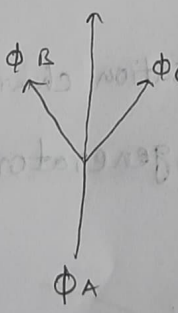
the effect of armature reaction is cross magnetisation effect as main field is 90° with Φ_A, Φ_B, Φ_C

Case-II:

Lagging P.f of load:-

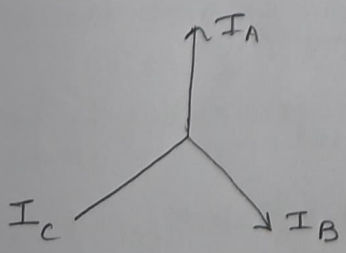
The current I_A, I_B & I_C

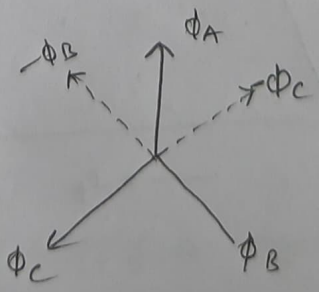




Here the effect of armature reaction is demagnetisation effect

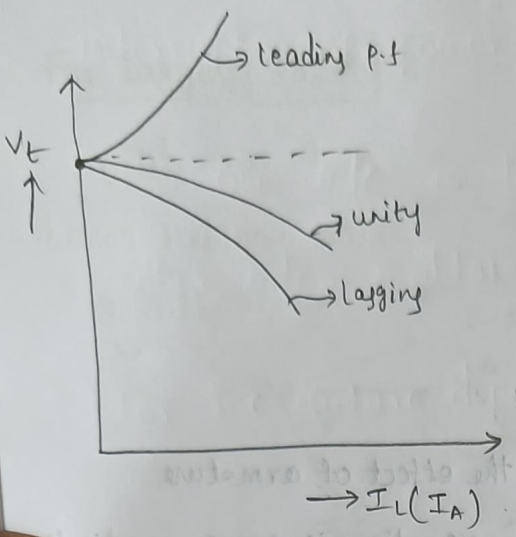
→ For leading P.f of load:-





the effect of armature reaction is remagnetisation effect.

⊛ Load characteristics of alternator:-



$$E_g = V_t + I_a R_a + j X_g I_a$$

$$= V_t + I_a (R_a + j X_s)$$

$$\Rightarrow V_t = E_g - I_a (R_a + j X_s)$$

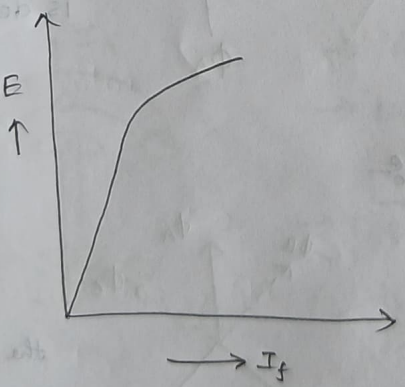
$$= E_g - I_a Z_s$$

For
→ Lagging power factor load voltage drop is more as it is crossing compared to unity p.f

⊛ To overcome voltage drop of lagging p.f we connect the capacitor to the system.

⊛ O.C.C:- (magnetisation characteristics)

⊛ same as dc generator. ✓



⊛ voltage regulation:-

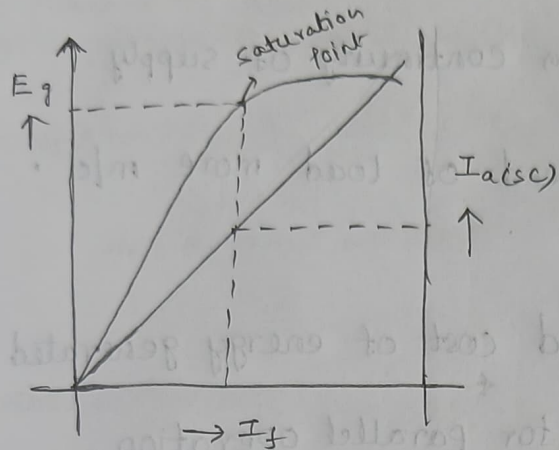
→ ~~The alternator~~ without loading the alternator we can measure.
~~find~~ voltage regulation by following methods.

① synchronous Impedance:-

to measure the voltage regulation by above method we conduct two tests.

→ No-load test → (E Vs I_f)

→ short circuit test ($I_{A(SC)}$ Vs I_f)



→ Z_s = open ckt voltage / short ckt current

** If we apply ac voltage we measure impedance

to measure resistance we apply dc voltage

to convert R_{dc} to R_{ac} :

$$R_{ac} = 1.5 R_{dc}$$

→ due to skin effect AC resistance is more.

$$\therefore X_s = \sqrt{Z_s^2 - R_a^2}$$

② Parallel operation:

need of parallel operation:

→ More alternator we can supply a bigger load than a single alternator

→ During the period of light load, one or more alternator may be shutdown to run rest of alternator at max efficiency.

→ If there is Breakdown of generator, there is no interruption of power supply.

→ When one m/c is taken out for servicing, the other m/c's maintain continuity of supply.

→ For the future depend of load more m/c.

→ The operating cost and cost of energy generated per unit energy reduced for parallel operation.

→ To full fill parallel operation

→ Busbar voltage & incoming m/c V_t must be same.

→ The frequency of busber voltage & incoming m/c voltage must be same.

17/04/23

⑧ synchronous motor:-

→ synchronous motor is not a self-starting motor as like induction motor.

→ DC voltage is zero.

→ has no any starting torque because open circuited area voltage is not applied.

⊛ How can we make the synchronous motor self-starting:-

→ Damper winding

↓

→ Another type of winding placed in rotor

① placed in the rotor

→ ② This windings are short circuited itself.

→ couple (or) torque generated then rotor rotates and synchronous motor starts.

↓

due to short circuited

⊛ Method of starting ?

If there is no damper winding then how

→ First run synchronous motor as alternator

→ Alternator is synchronised with infinite Busbar. then primemover disconnected.

→ Now alternator draw from infinite busbar which makes it continuous rotation even when primemover disconnected.

⊛ Application :- power factor correction

condensor → capacitor.

* When synchronous motor run at over excited mode, it gives leading p.f of load. so that's why synchronous motor considered as synchronous condensor & it is used as power-factor correction in practical application.

⊛ Hunting :

Questions

(*) Working principle?

(*) Why not self starting?

(*) condenser Application

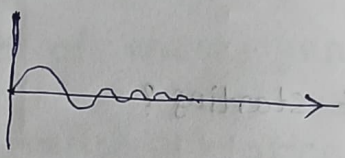
(*) Hunting.

Hunting:-

→ When we apply load speed will dec from 1500 to (say 1490)

then it rises to 1510 then comes to 1495

then 1505 to 1500



→ If load is rated then speed dec to 1300, then sound is come, this is hunting.

Problem:-

(1)

$$I_L = P = \sqrt{3} V_L I_L \cos\phi$$

$V_L = 13500$

Star connected:-

$$V_{ph} = \frac{V_L}{\sqrt{3}}, \quad I_L = I_{ph}$$

delta connected:-

Reverse of above.

$$E = \sqrt{(V\cos\phi + I_a R_a)^2 + (V\sin\phi + I_a X_s)}$$