MACHINES II

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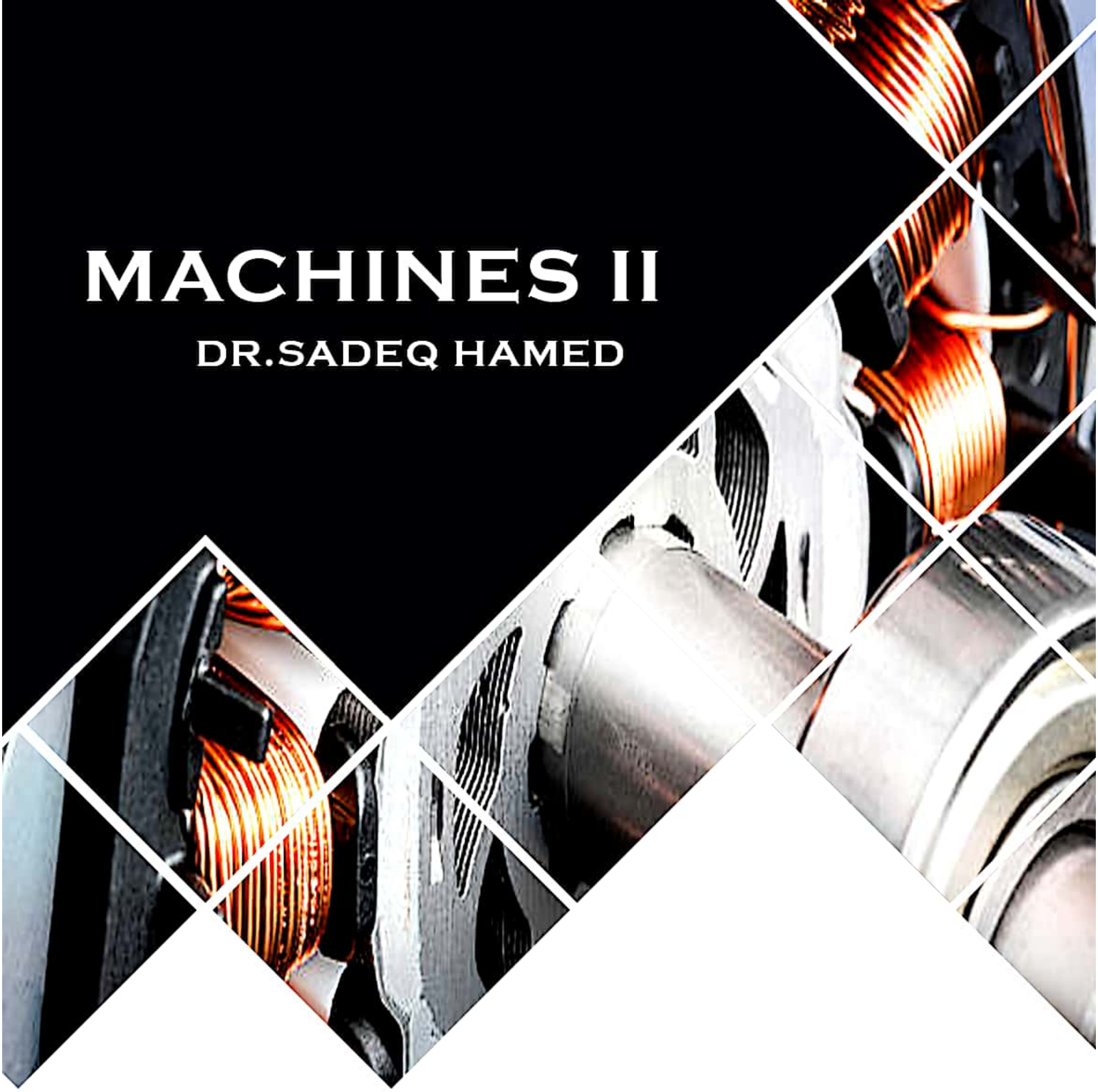


BY:FARAH ALLAN

POWERUNIT

Lecture [1]:-
A.C. Machines

Two major types:-

- Induction machines ⟹ Pure AC, mainly used as motors
- Synchronous machines ⟹ Combination of AC (stator or armature) and DC (rotor), mainly used as generators (alternators).

* cheapest machine between all types of machines is Induction.

* → these machines are mainly 3-phase; machines above 5 kW → 3-ph

Both types:- have same principle of operation. Basic concept of these machines is the Rotating field.
⇓
have fixed speed and amplitudes created in the Stator (armature).
→ Yoke: ferromagnatic cylinder with at least 6 slots.

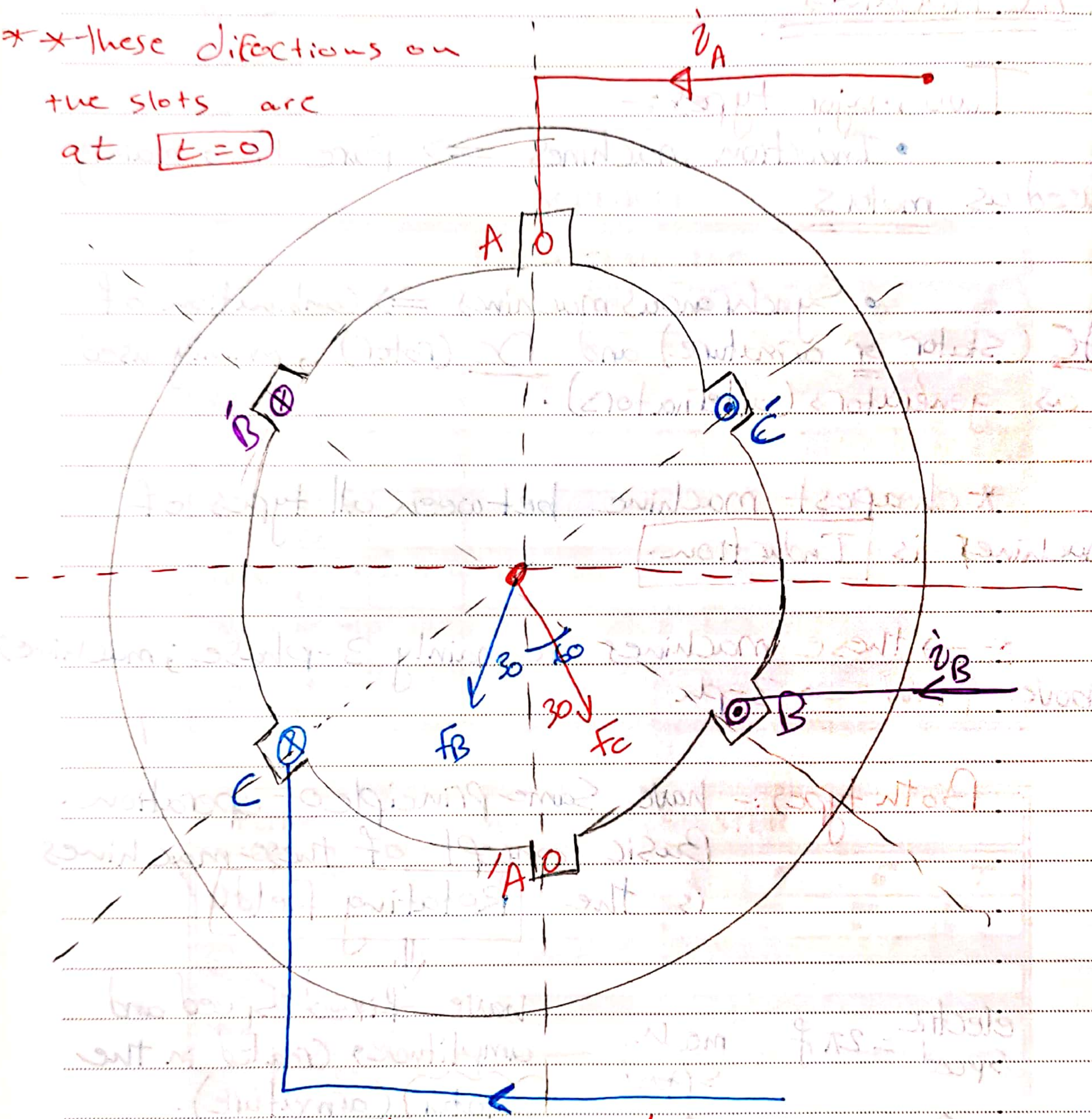
electric speed = $2\pi f$ mech speed

$$* \ W_e = P * W_m$$

P ↓ pole pairs

Mech speed: Inversly propotional to the number of Poles.

* *these directions on the slots are at $t=0$



* *each 2 slots belong to a certain phase.

A: A` ⟶ phase A

B: B` ⟶ phase B

C: C` ⟶ phase C

* these coils are excited 3-phase balanced currents from a 3-phase power supply.

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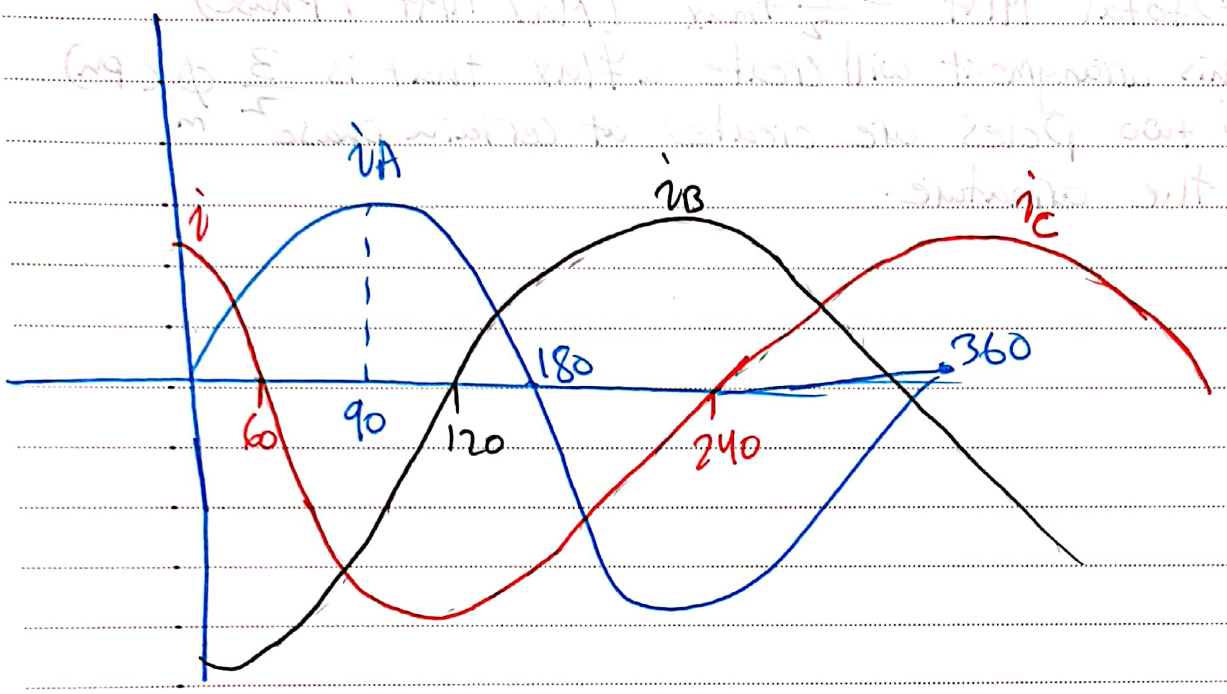


$i_A = I_m \sin(\omega t)$

$i_B = I_m \sin(\omega t - 120)$

$i_C = I_m \sin(\omega t - 240)$

$t = 0 \rightarrow \omega t = 0\,rad$

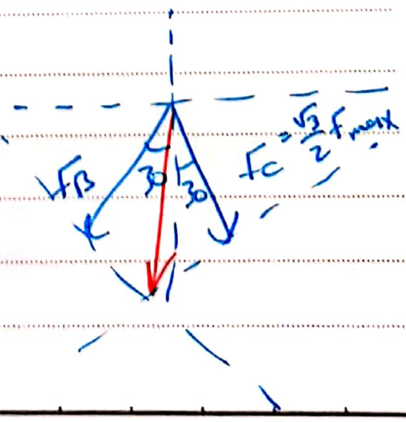
* $i_A = 0 \longrightarrow$ $\boxed{MMF = N_{ph} * i_A} = 0$

* $i_B = I_m \sin(0 - 120) = -\frac{\sqrt{3}}{2} I_m$

$f_B = N_{ph} * i_B = N_{ph} * -\frac{\sqrt{3}}{2} I_m = -\frac{\sqrt{3}}{2} f_{max}$

* $i_C = I_m \sin(0 - 240) = \frac{\sqrt{3}}{2} I_m$

$f_C = \frac{\sqrt{3}}{2} I_m * N_{ph} = \frac{\sqrt{3}}{2} f_{max}$



* $\vec{F}_{total} = \vec{f}_A + \vec{f}_B + \vec{f}_C = \sqrt{3} * \frac{\sqrt{3}}{2} f_{max}$

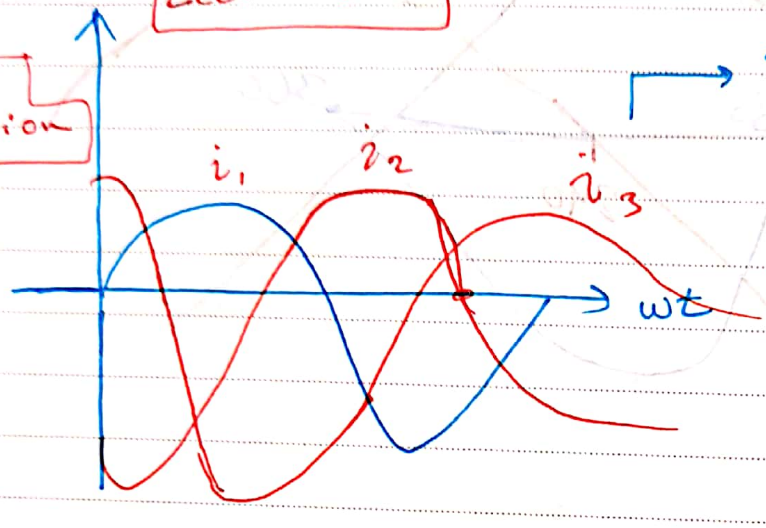
$= \frac{3}{2} f_{max}$

=> total MMF $= \frac{3}{2} F_{max}$ (Max MMF / Phase)

* this arrangment will create a flux that is $\frac{3}{2} \phi_{m}$ (ph) and two poles are created at certain phase in the armature.

Lecture [2]

H.W solution

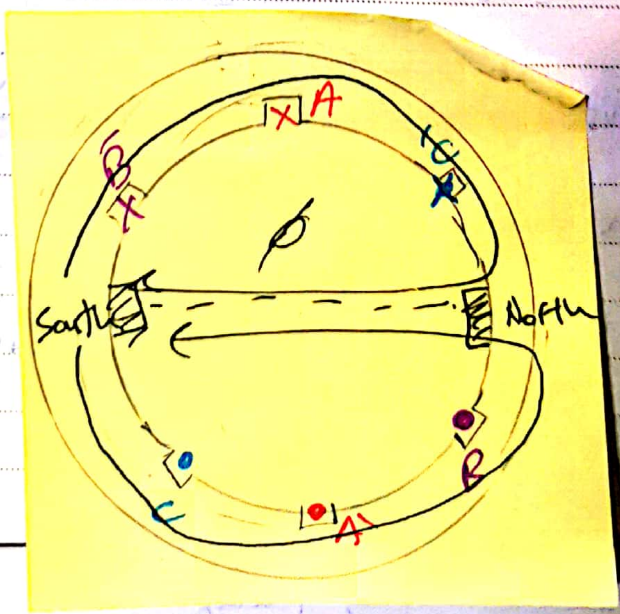


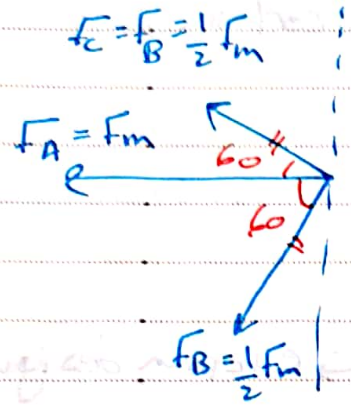
at wt=90

$i_1 = I_m \sin(\omega t) = I_m \sin(90) = I_m$

$i_2 = I_m \sin(\omega t - 120) = I_m \sin(90 - 120) = \frac{-I_m}{2}$

$i_3 = I_m \sin(\omega t - 240) = I_m \sin(90 - 240) = \frac{-I_m}{2}$





so

$$\Rightarrow \bar{F}_t = \bar{F}_A + \bar{F}_B + \bar{F}_C$$
$$= F_m + \frac{F_m}{2} = \frac{3}{2} F_m$$

*** Results** :- By having such an arrangement an MMF is created.

This field has

a) Constant amplitude, that is $\frac{3}{2} F_m$, where F_m is maximum MMF per phase.

This is true irrespective of the No. of windings or even poles.

b) The MMF created is rotating at a speed, that is N_s (RPM), usually refered to as the "synchronous speed"

السرعة التوافقية

Angular speed: $\omega_s = \frac{2\pi N_s}{60}$ rad/sec

* N_s is a function of:

① the supply frequency. (f)

② the No. of poles.

$N_s = \frac{60 f}{P}$, (P) is the No. of pole pairs

* to control the speed of the Rotating field N_s, supply frequency should be varies up or down.

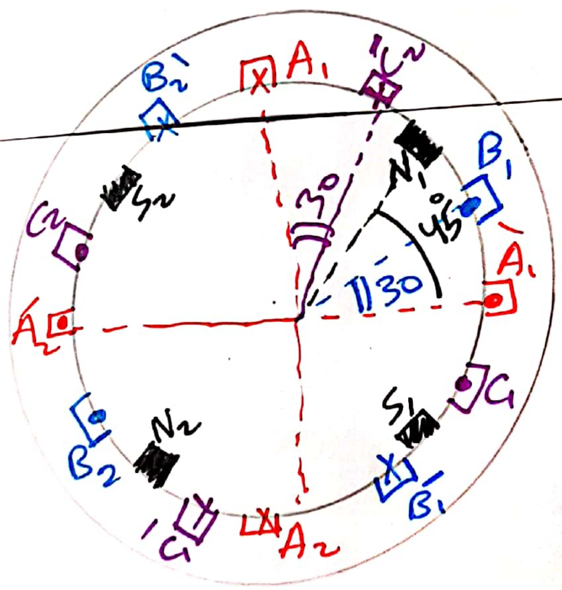
The No. of poles is usually fixed for a certain machine (P=1 or 2 or 3 ...)

$N_s = \frac{60}{1} f$ or $\frac{60}{2} f$, $\frac{60}{3} f$ ....

f= 50Hz → 3000 RPM, 1500 RPM, 1000 RPM → european design.

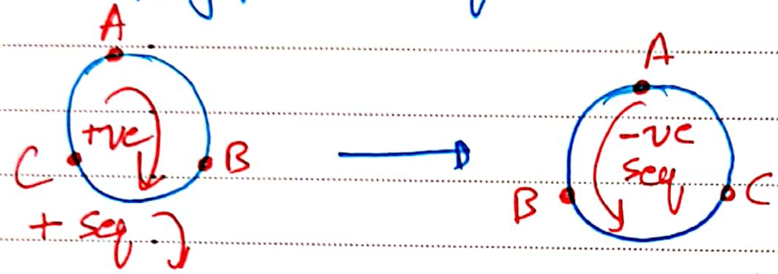
f= 60 Hz 3600, 1800, 1200 RPM .. → US design

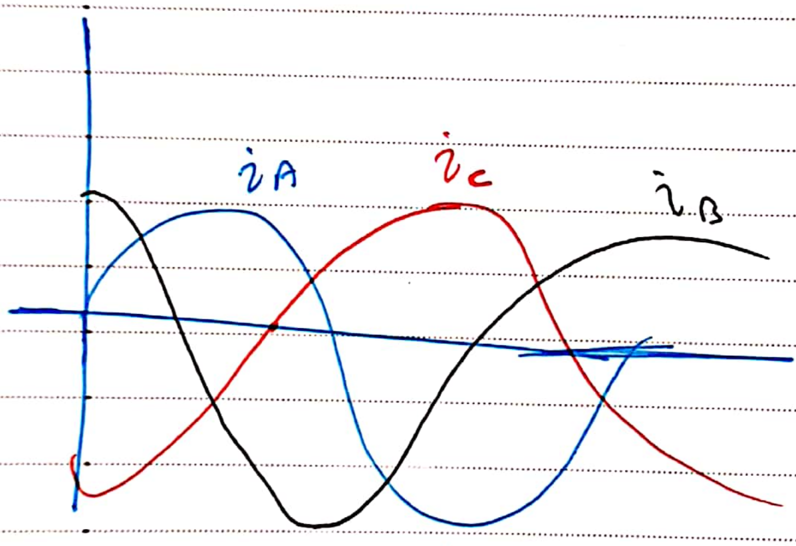
c) By the shown winding arrangement, two poles can be created. higher No. of poles can be achieved through winding arrangement, below is an example of a 4 pole machine.



* when the electric angle is 90°, the feild MMF moves $\frac{90}{P} = \frac{90}{2} = 45°$

* To change the direction of rotation of a 3-ph motor, the supply phase sequence is to be changed.

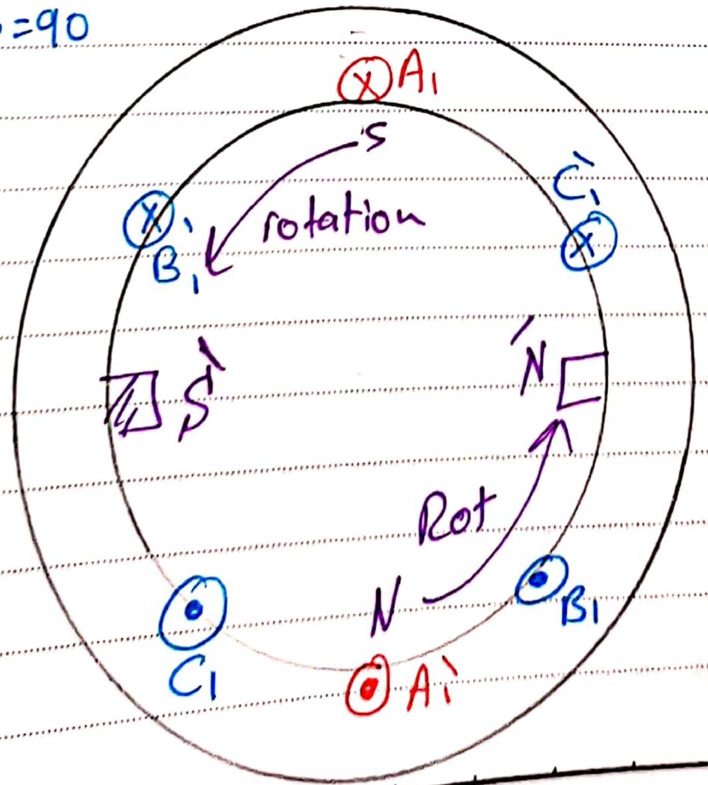




⟹ on the machine we change the wire between i_B & i_c.

try: at $\omega t = 60$

at, $\omega t = 90$



ABC ⊕

into ACB ⊖

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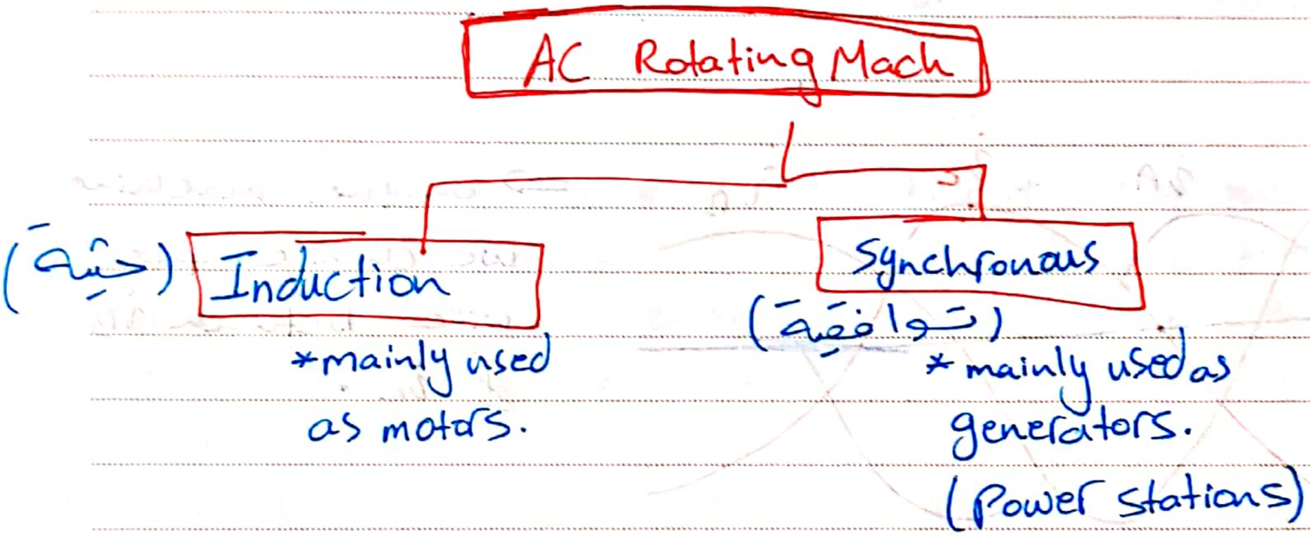
Lecture [3]

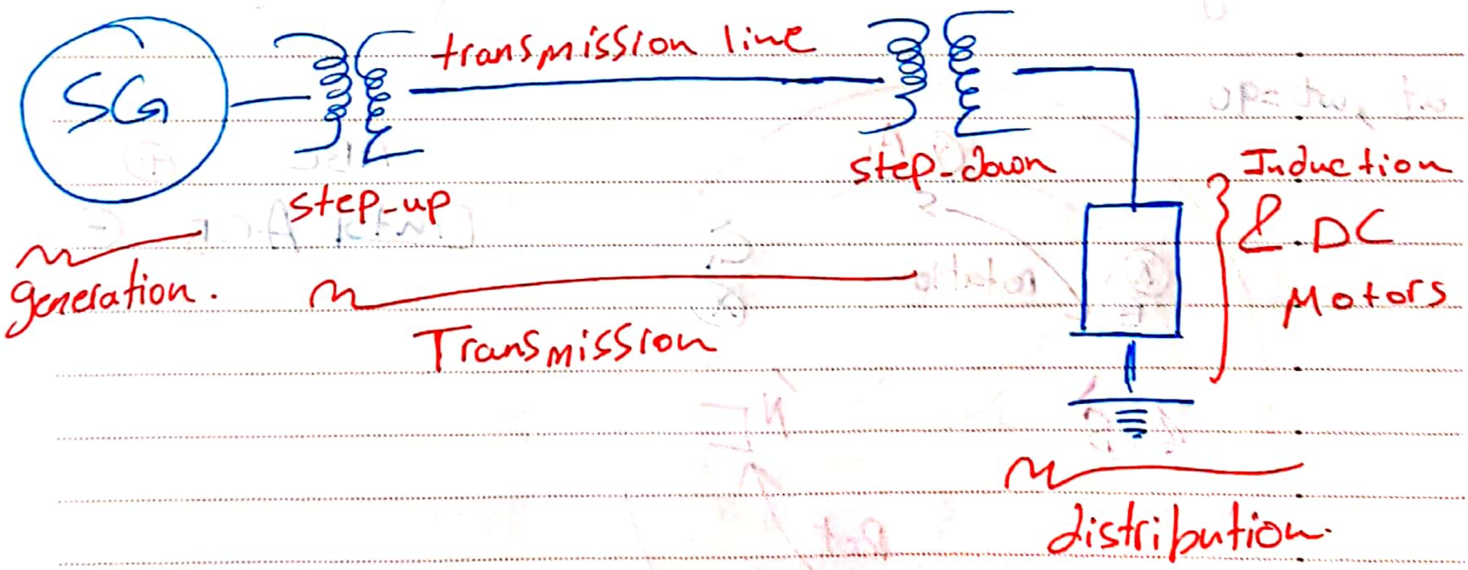
$$\omega_s = \frac{2\pi N_s}{60} = \frac{2\pi f}{60} = \frac{\omega_e}{P}$$

$$\omega_e = P\omega_s$$

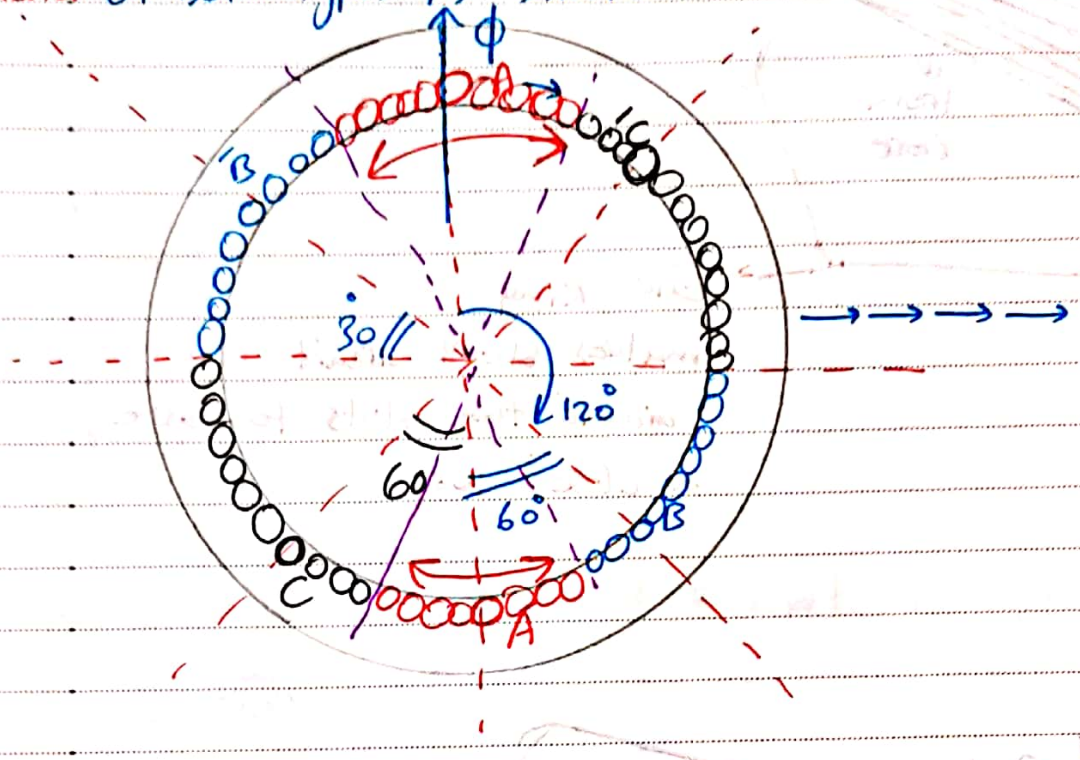
$$\omega_e \geq \omega_s$$

**AC Rotating machines:-





* Stator of both types is similar.



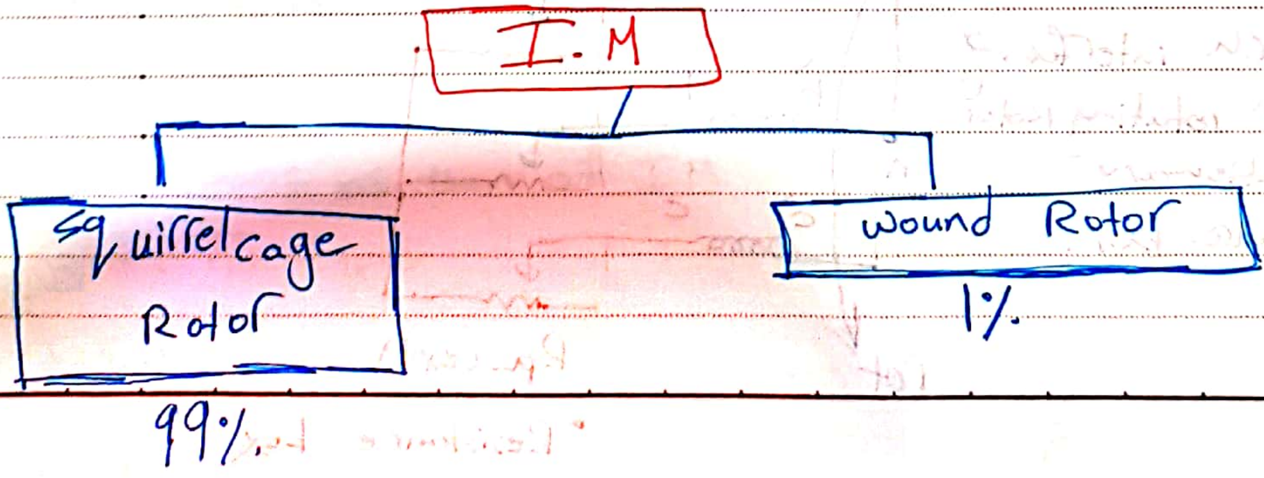
Created EMF

$$E_{ph} = 4.44\, k_w * f \phi N_{ph}$$

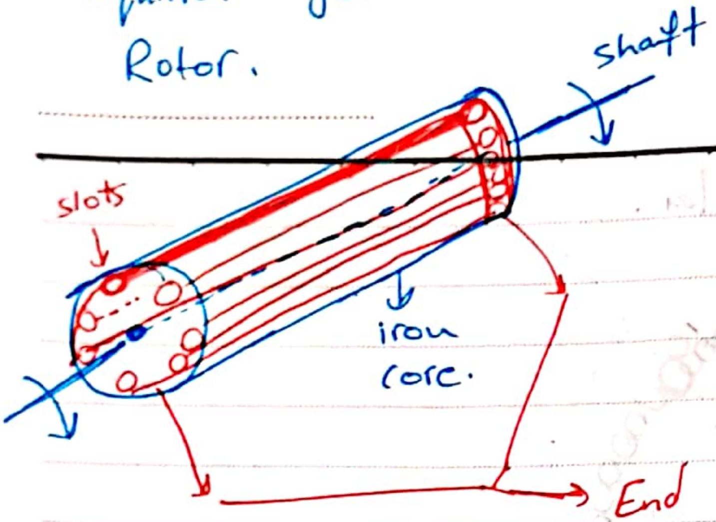
↳ winding factor ≈ 0.93 → 0.97

$k_w \simeq 1$

** Rotor of Induction machine

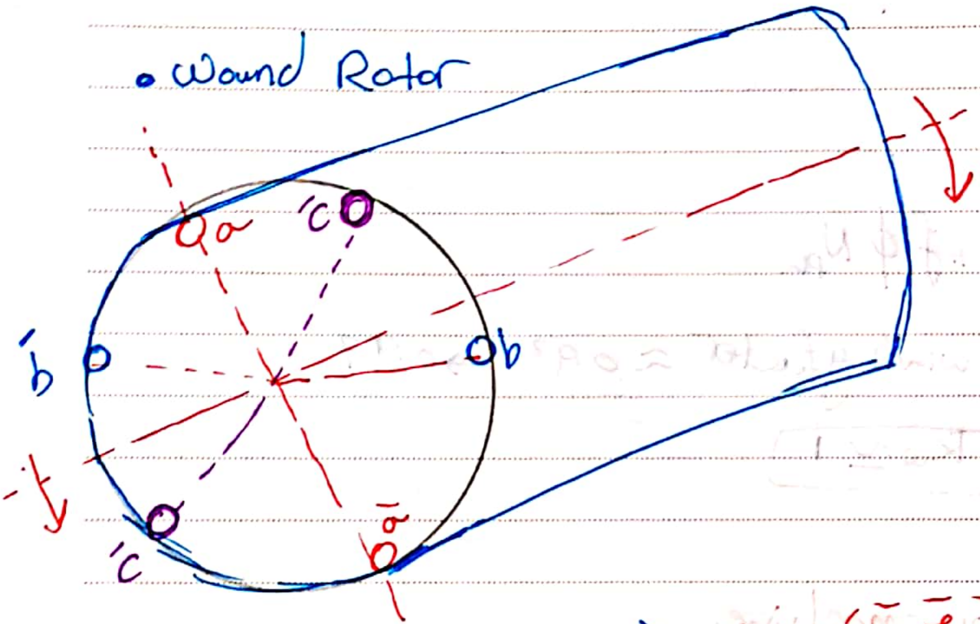


• Squirrel-cage Rotor.

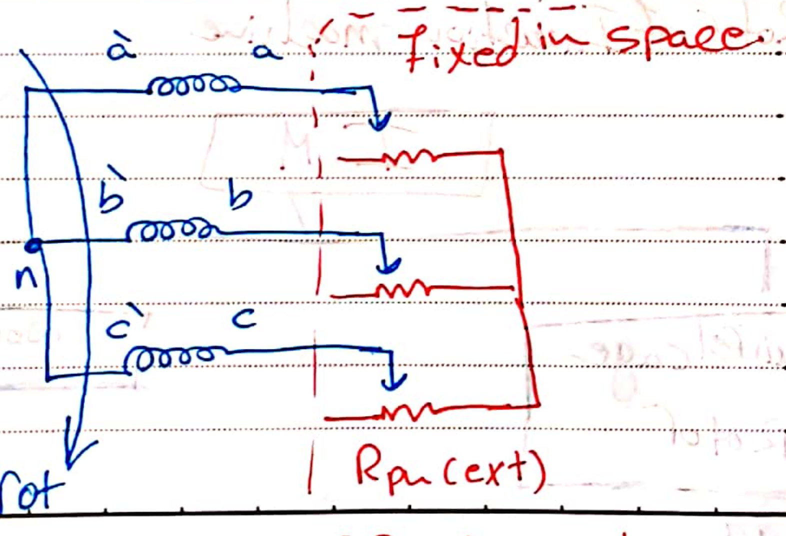


End Ring makes short circuit around the slots to have a closed loop.

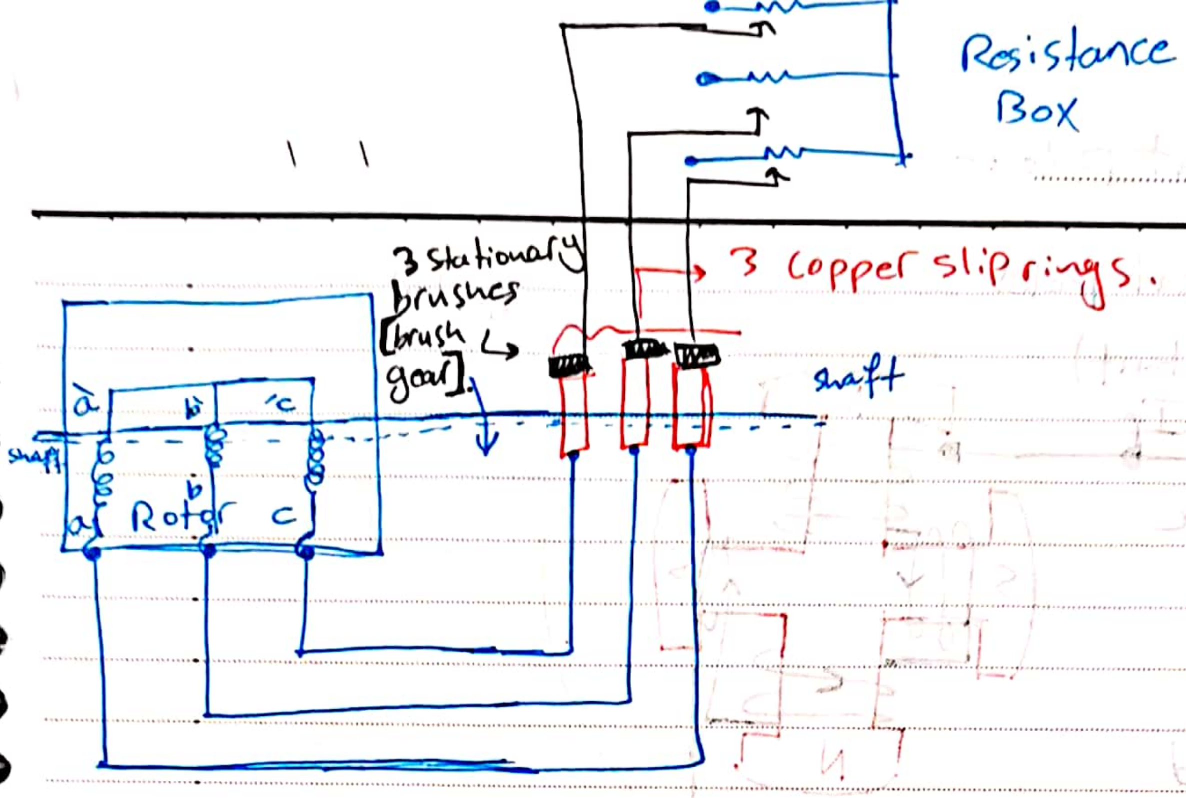
• Wound Rotor



** Mech interfacing between rotating Rotor and stationary resistance box.



• Resistance box



* Wound Rotor cost is almost 3 that of squirrel cage.

** Lecture [4]

IM (Asynchronous Machine) $[N_m \lessapprox N_s]$

1) Squirrel-Cage.
   - simple & cheap.

2) Wound Rotor
   - expensive (2→3) cost of sq.
   - excellent for starting purposes. (reduce starting current and increase starting torque).

** Synchronous Machines :- $[N_m = N_s]$

Stator: Same as that of IM

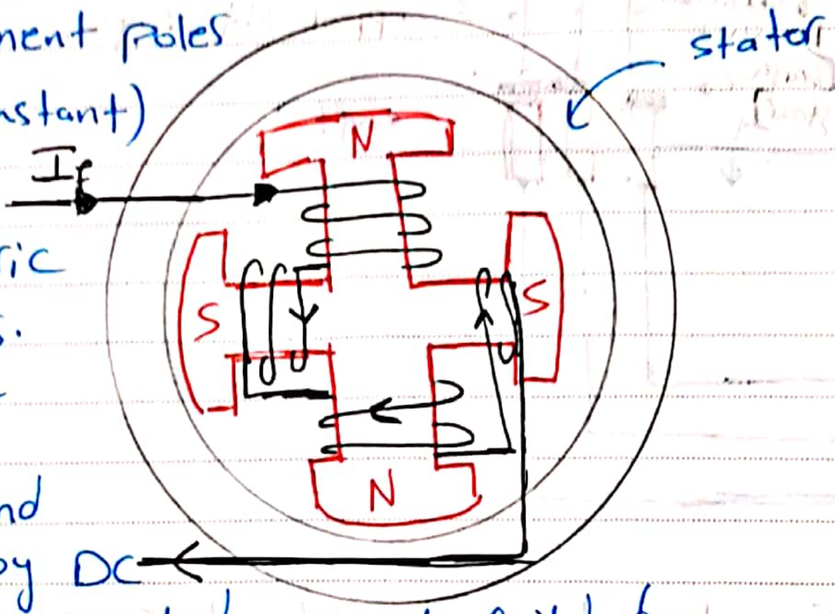
Rotor: Two types

1) Salient - poles. (ذات أقطاب بارزة)
   ↳ relating Low-Speed Machine. // driven by hydrolic turbines.

2) Round Rotor.

- Salient pole :-

a) Permenent poles (ϕ = constant)

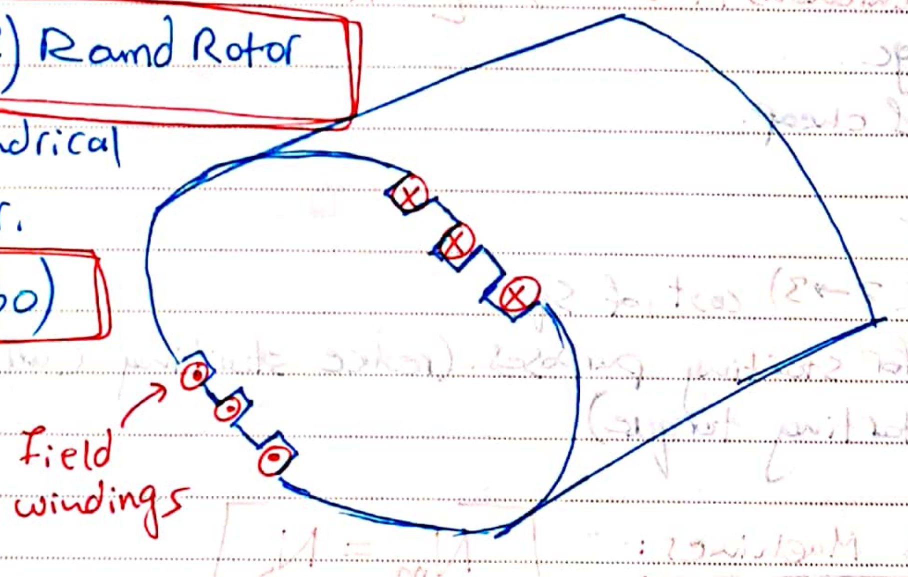


b) electric Poles.
- electric coil is wound and excited by DC current to created magnet feild ϕ.

(ϕ is Variable by Varrying I_f (feild current)).

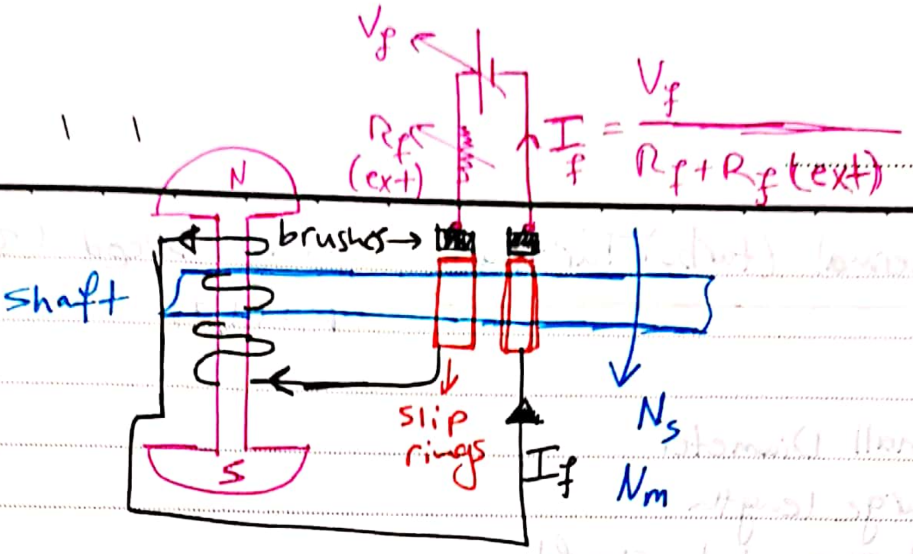
2) Round Rotor /cylindrical Rotor.

(turbo)



* two - poles machine.

↓ high speed : $N_s = \frac{60 f}{P}$ → P = 1 or 2



** Synchronous machines

Two types:

a) Salient pole.

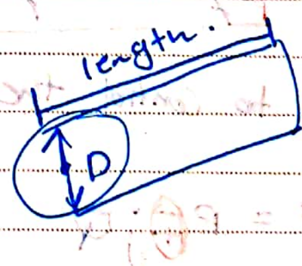
b) Cylindrical (Round-Rotor).

* Major types in terms of the input power:

[1] Hydraulic → driven by hydraulic turbine.
hydrolic turbine driven SG

- relatively low speed
  (lary No of poles) 6, 8, 10 ...

- large Rotor Diameter
  power ∝ diameter, length



- Small length.
- Vertically shaft

/ /

2 Thermal (turbo) Turbines. → high speed (3000 or 1500)

$P = (1, 2)$

- Small Diameter
- large length
- Horizantal shaft.

** Excitation systems:-

I_f → field current is required to be controlable.

a) to control Internal EMF = E_a or E_f

$$E_f = 4.44 * K_w * N_{ph} * f * \phi$$

(f → speed related.)

$$f = \frac{P N_m}{60}$$

$$\phi = K_f I_f \quad (K_f \text{ constant})$$

$$\Longrightarrow \boxed{E_f = K \cdot I_f}$$

b) to control the generated reactive power **Q**, by field current I_f, and hence the **power factor**.

$$S = P \pm jQ$$

⊖ → leading PF → for ~~generators~~ Motor.

⊕ → lagging PF → generators