ELECTRICAL M/C

- 1. DC M/c
  - DC Generator
  - DC Motor
- A/C M/c
  - 1-ϕ M/c
  - 3-ϕ M/c
    - 2. 3-ϕ Induction motor
    - 3. 3-ϕ synchronus M/c
      - 3-ϕ syn. generator
      - 3-ϕ syn. motor

TRANSFORMER

- 4. 1-ϕ Trf.
- 3-ϕ Trf.

→ Power is generated by syn. machine known as Alternator.

Energy Conversion :

Electrical energy — Coupling device — Mechanical energy

(By nature is Electromagnetic)

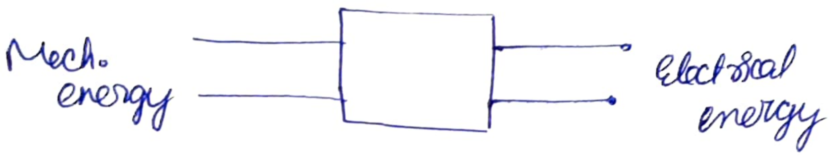
Types :-

1) Transducer → we can get diff. pattern of signal & used for measurement purpose

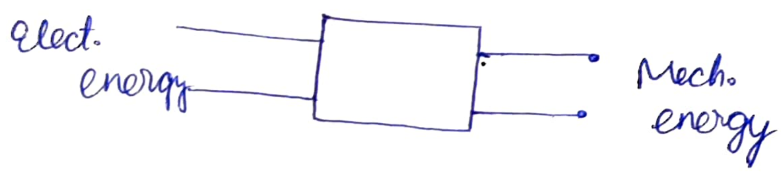
2) Force producing device → develop diff. pattern of force.
Ex → Relay, mag. limitation

3) Continuous Energy Conversion → rotating device & it convert electrical to mech. energy by rotation.
& it is by linear motion.

(a) Generator →



(b) Motor →

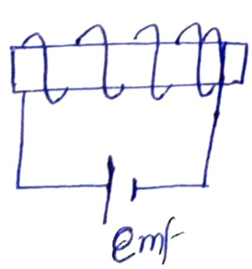


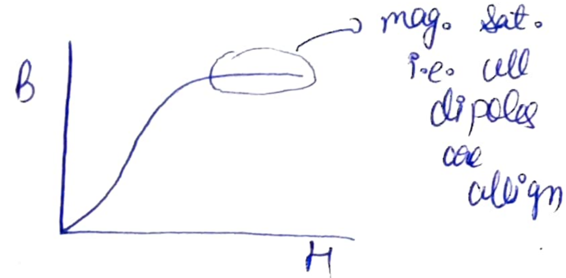
→ For generator ⇒ Total mech. energy = electrical energy O/P + Energy loss + Stored energy Loss

→ Mag. feild → Permanent magnet ⇒ (Used in hair dryer, toys, dynamo in car)
→ Electromagnet

→ In electromagnet EF is controlled by our demand but in permanent magnet that is not poss.

Electromagnet →



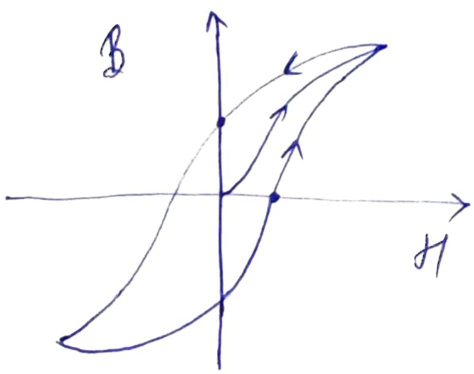


→ When emf is removed some mag. prop. or feild exist in the material due to "retentivity" pr.

→ And that some mag. feild is "Residual magnetism".

→ Retentivity is the pr. of material.

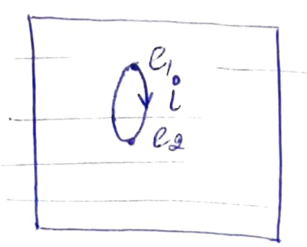
→ And to remove that some mag. pr. polarity of emf is rev.



→ B-H loop or Hysteresis loop (hysterisis means lagging)

→ Some energy is lost due to B-H Loop or hysterisis loop known as Hysterisis loss.

→



⇒ as $e_1 \neq e_2$. so there is p.d. hence current is induced in the mag. material known as "eddy current".

⇒ And due to this current loss is there known as "eddy current loss".

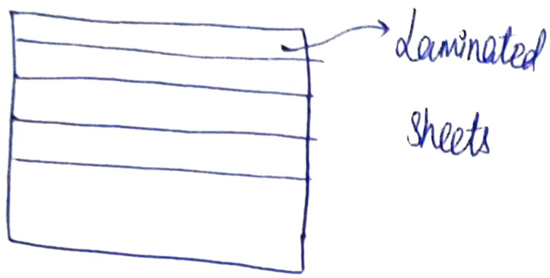
→ <u>To reduce hysterisis loss</u>:

→ Hysteris loss ∝ area of hysterisus loop.

→ Hysterisus loss is min. for ferromagnetic material like cast iron or cast steel.

→ Core is made up of ferro. material to reduce hysterisis loss.

Red. of Eddy Current Loss :



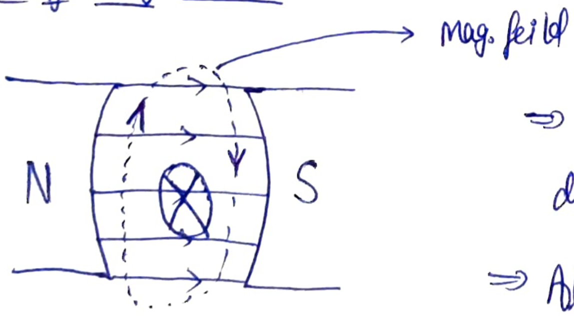
⇒ To reduce Eddy Current Loss, Design core of machine or material by laminated sheets due to which eddy current ↓ and due to this eddy current loss also ↓.

→ Cross & Dot Notation :

⇒ When current is away from observer → Cross Notation ⊗
⇒ " " " towards the " → Dot " ⊙

→ For Cross Notation of Current ⇒ MF is clockwise.
→ For Dot " " " ⇒ " " Anti-clockwise.

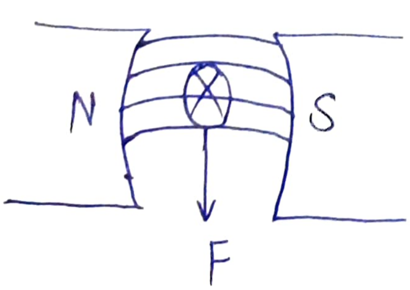
Dir^n of Mag. force :



(due to mag. + due to current)

⇒ At top Both MF has same dir^n so ⇒ additive in Nature

⇒ At Bottom both MF have opp. dir^n so they cancel out. ⇒ Subtractive in nature.



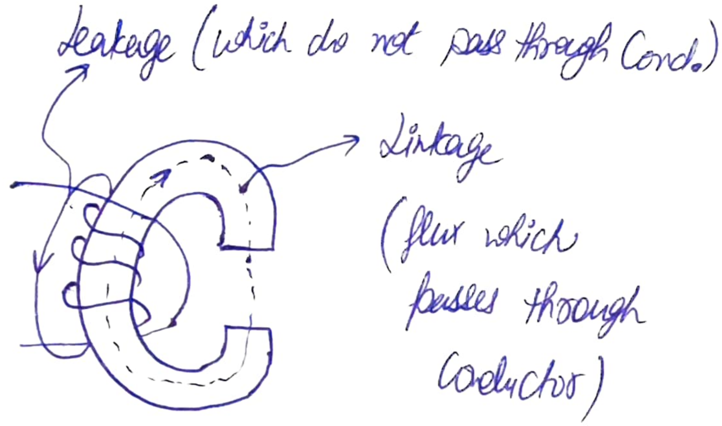
⇒ Dir^n of MMF is from Max. MF to min MF.

→ Basic prin. of Voltage Generation / Generator :

⇒ $\boxed{e \propto \frac{d\phi}{dt}}$ (lenz law)

→ FLUX :

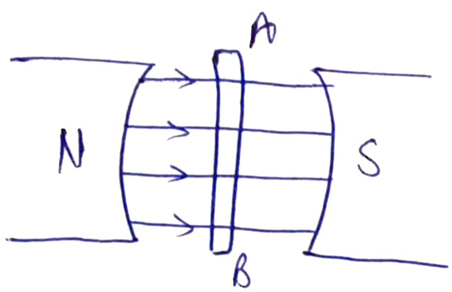
- Linkage (Faraday based on linkage flux)
- Leakage (Loss component of flux)



→ Basic req. of Voltage Generator :

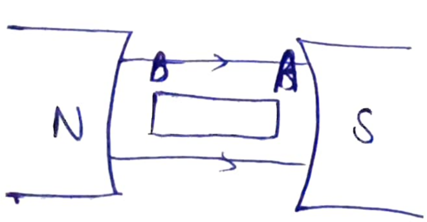
1). Mag. Feild.

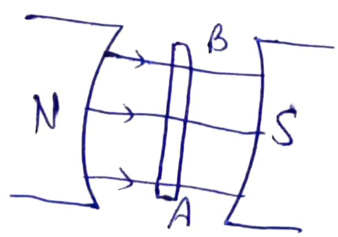
2). Conductor (It must be placed under the MF).

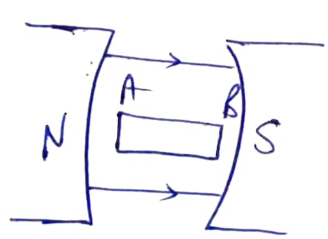


(1)

3). Prime mover.
(Turbine work as a Prime mover).
⇒ By which we can move or rotate the conductor.







(2)

Two po. by which $\left(\frac{d\phi}{dt}\right)$ is created :

1) The MF is const. or steady state but conductor is under motion. (Motion req.) → Dynamic Induced EMF.

2) The conductor is in static pos. but MF itself changable in nature. (No motion req.) → Static Induced EMF.
Or
Transformer Induced EMF
Or
Dyn

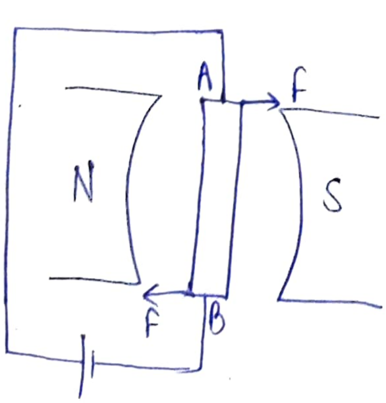
⇒ MF changes by AC current.

⇒ $e = Blu$

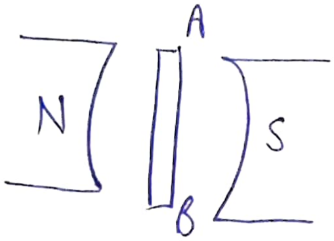
1). $e \propto B$ 2) $e \propto l$ 3) $e \propto u$

→ Generally u is ↑ to ↑ e rather 'B' & 'l'. due to energy balance i.e. energy changes from ME → EE.

Basic principle of Motor :



⇒ Faraday law of Electro-magnetic force.



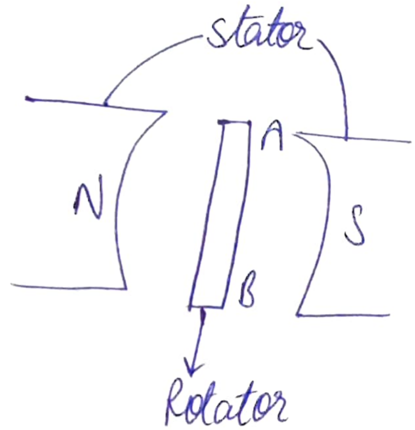
⇒ As a Constr. of DC generator or motor this is used.

⇒ To work as generator ⇒ Connect Prime mover across Conductor

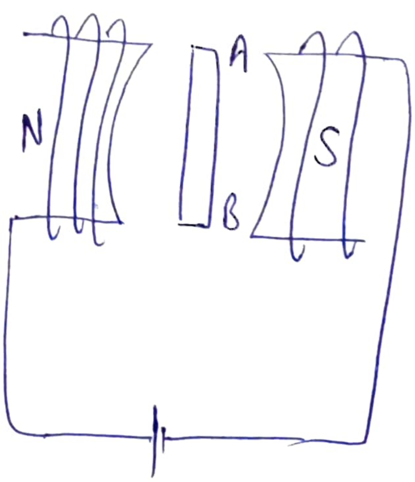
⇒ To work as motor ⇒ connect Battery across Conductor.

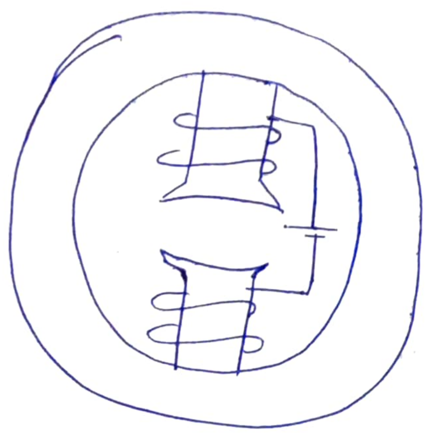
DC MACHINES :

Construction
- Stator (Static)
- Rotor (Armature) (Rotational)

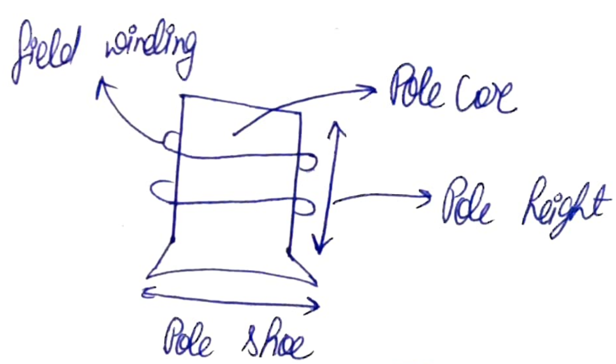


Stator : It is Cylindrical in nature.





This is an "Electro-magnet" as we placed the Coil.



⇒ At the pos. on mag material where we wound the Coil or Coupled the Coil is "Pole Core".

→ F^n of Pole Core :

1) To hold the Coil. And the Coil helps us to generate MF. So it is known as Feild Winding or Field Coil.
(To hold field winding

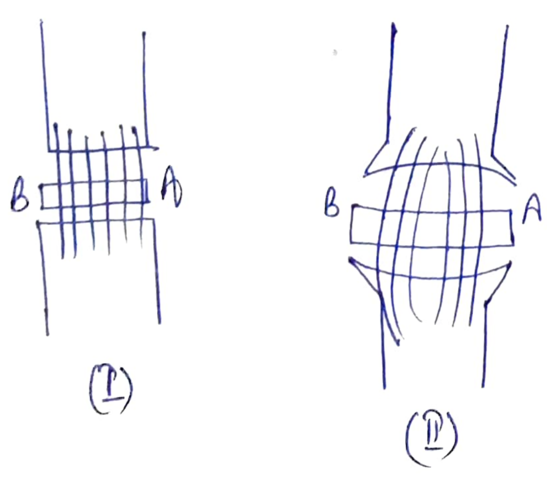
2) At Pole Core MF is generator.

Feild Winding → Helps us to generate MF.

2)

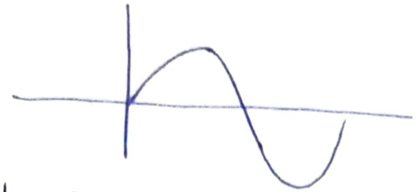
Pole Shoe → 1) To mechanically hold the field coil.

2) It helps us to ↑ length of conductor, more flux, more induced EMF.



⇒ If we design like (II) length of cond. is ↑

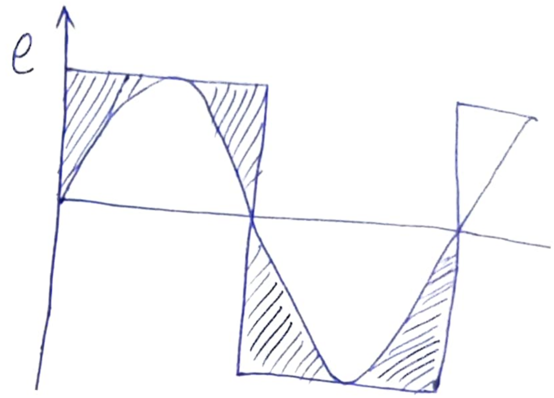
3) It also help us to give MF near Sinusoidal (i.e. Alternating)



4) To scatter MF to more length.

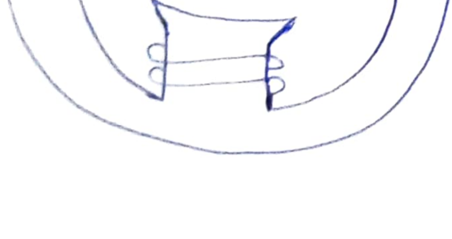
⇒ $\boxed{MMF = NI}$

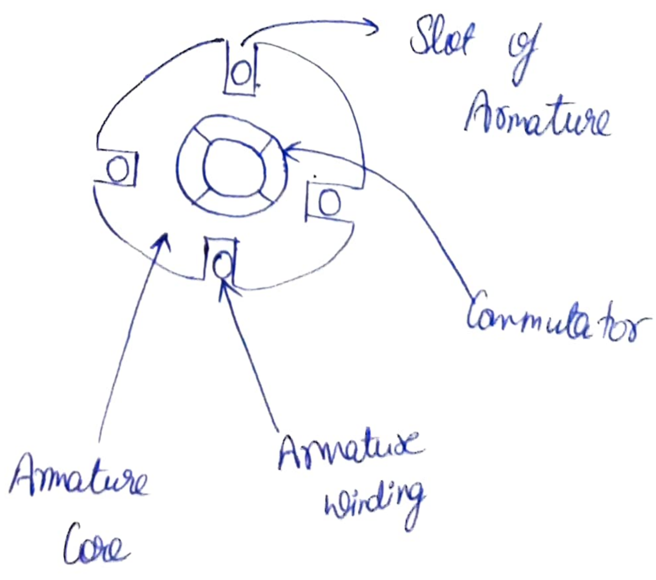
MMF in the coil is rectangular in nature. that's why induced EMF is also rectangular in nature.



<u>Stator</u> → Pole core & Pole height
→ Field winding
→ Pole shoe

<u>Armature (Rotor)</u> :





→ Armature Core → f^n is to hold the Arm. winding

→ Arm. winding → Voltage is developed along Arm. winding.
material of arm. winding is Copper.

**

Parts of DC M/c in details :

1). Yoke : Help us to provide continuation part for magnetic ~~path~~ line of force.

→ It provides inner support to the Electric motor.

2). Pole Core & Pole shoe

3). Field winding

4). Armature Core

5) Arm. winding

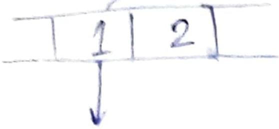
6). Commutator → ①. AC is Converted to DC.

② Helps us to provide Unidir. flow of Current.

③ Its material is hard drawn Copper.

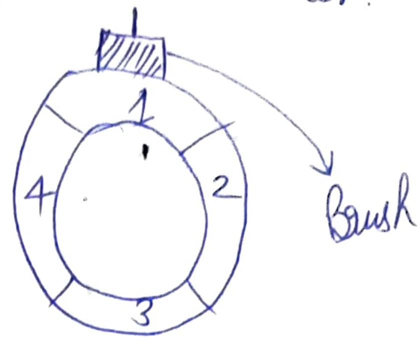
7). Brush & Ball Bearing

→ Material of brush is soft material (Carbon & graphite) as if it is made up of hard material it produces more friction. & hence commutator is damaged.



→ Seg. of Commutator is of mica Insulator.

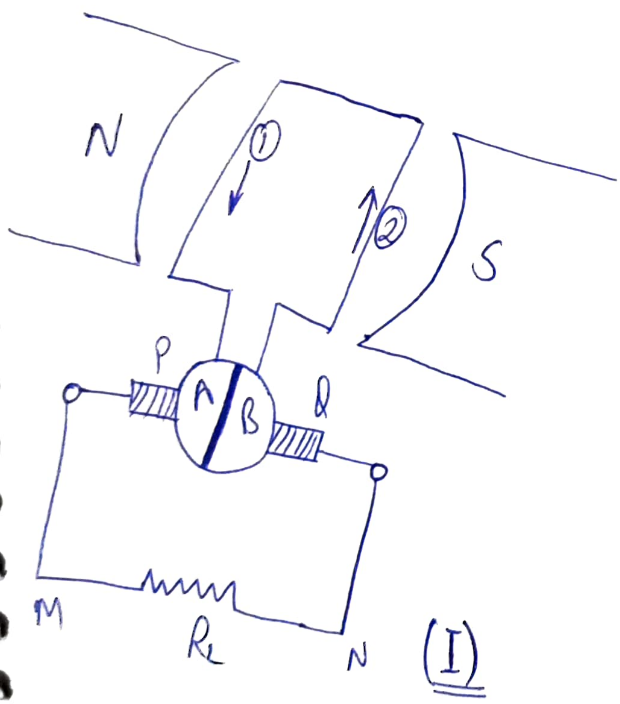
Segment of Commutator

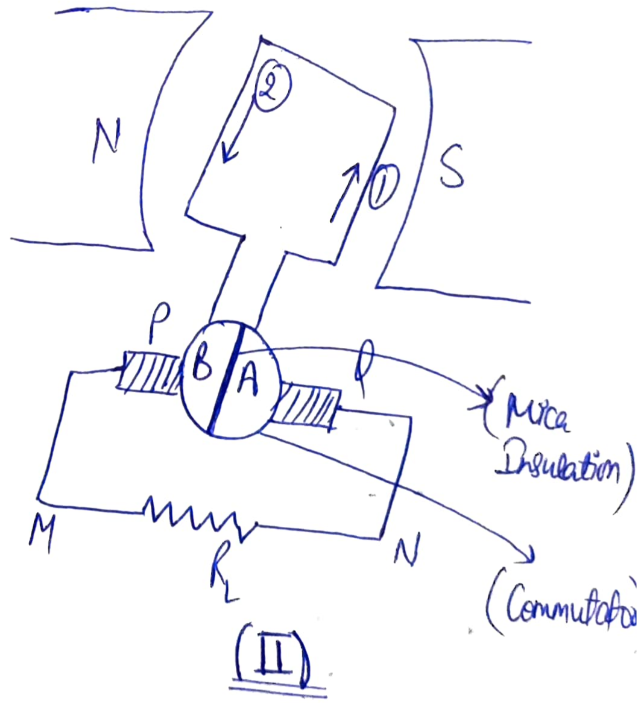


→ Each & every coil is connected to armature of Commutator.

8) Shaft

Function of Commutator :

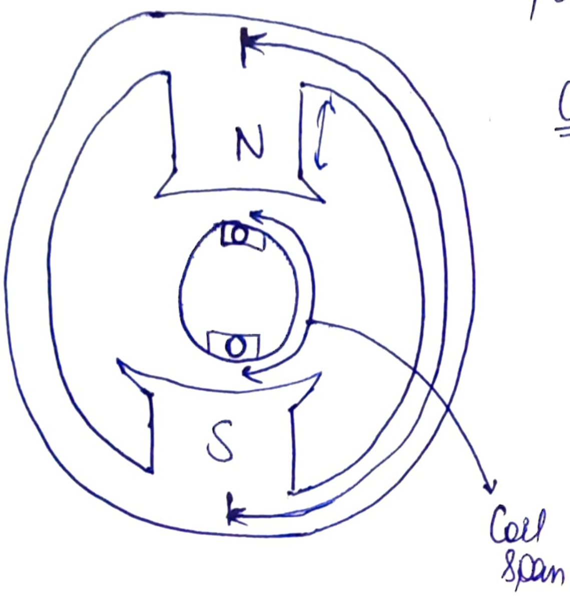




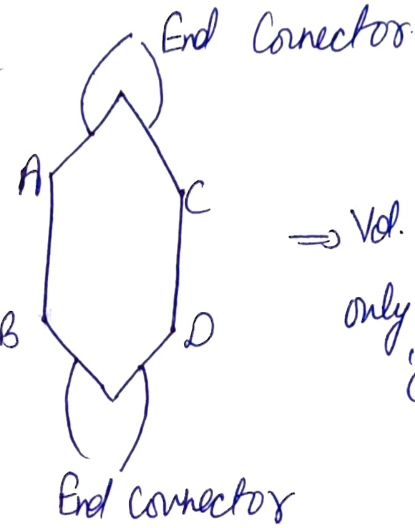
→ The Current & EMF generate will be Sinusoidal in Nature (A/C).

→ In the ext. ckt. current will always flow in uni-direction (DC)

Pole pitch : The peripheral dist. b/w ~~[illegible]~~ conjugated pole.



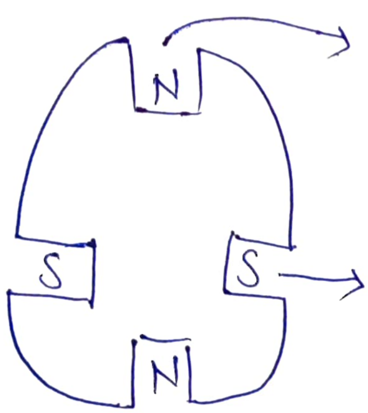
Coil :-



⇒ Vol. is induced only in 'AB' & 'CD'.

Coil span → dist. in b/w two coil sides for a single coil it is also peripheral dist.

⇒ $\alpha = 180^\circ$



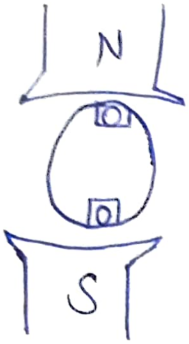
Mech. angle $= 90^\circ$

Electrical angle $= 180^\circ$

Type of armature winding :

1. Full pitch
2. Short pitch

Full pitch

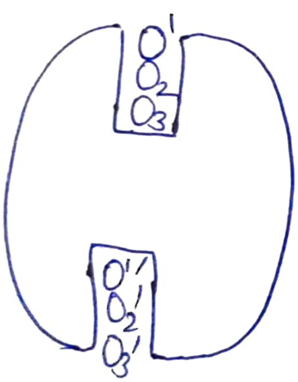


$\Rightarrow \alpha = 180°$

Short pitch

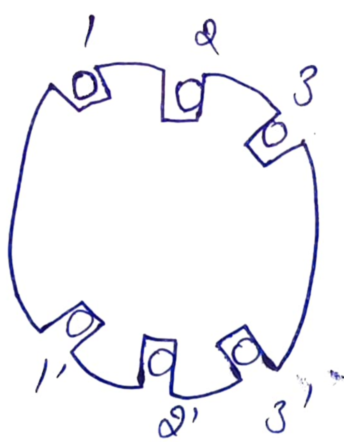
$\Rightarrow \alpha < 180°$

3. <u>Concentrated</u>



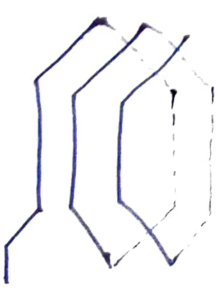
→ All armature winding are placed by particular slot.

4. <u>Distributed</u>

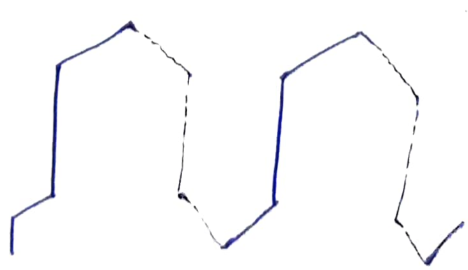


→ All coils are distributed through the periphery

5. <u>Lap Winding</u>



6. <u>Wave</u>



→ If the winding is in overlapping pattern.

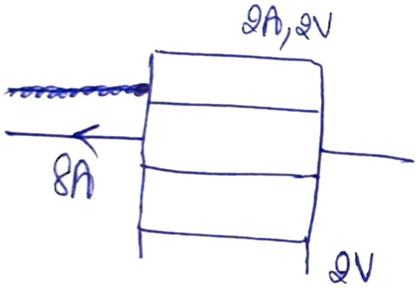
→ If the winding is in wave pattern

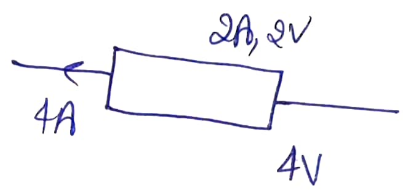
→ No. of || path = No. of pole.
i.e. $\boxed{A = P}$

→ No. of || path is always '2'. i.e. $(A = 2)$.

→ Used for High Current low voltage.

→ Used for High Voltage low Current.

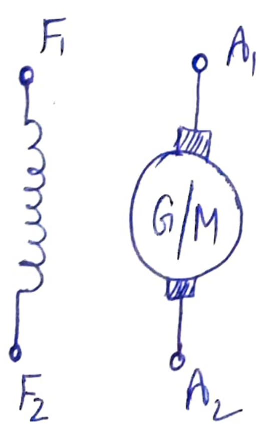




→ No. of brush = No. of pole
(More no. of brush is req.).

→ Only 2 brush is req.

Symbol of Electrical M/c :

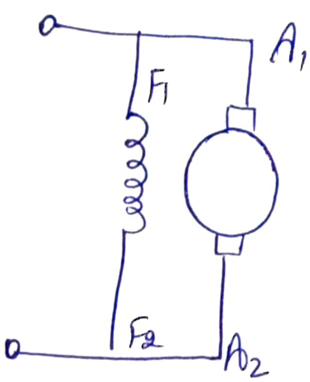


A_1, A_2 → Armature terminal

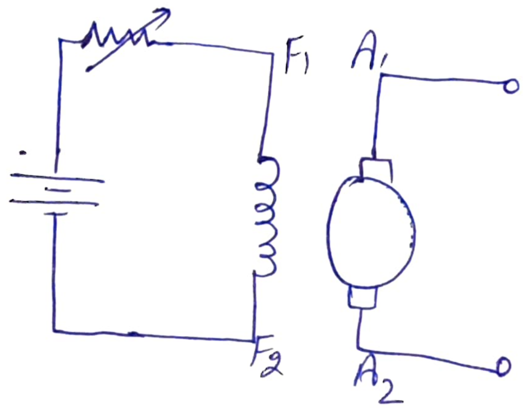
F_1, F_2 → field terminals

Excitation : Property by which MF is generated.
~~Ba.~~ ~~By~~ Acc. to excitation there are 2 type of DC M/C.

1. Self - excited

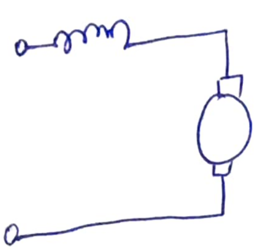


2. Seperately excited

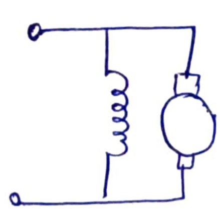


1. Self - excited	2. Seperately excited
→ feild & armature are inter-connected.	→ Feild & armature don't have any electrical connection.
→ ~~B~~ Nothing any ext. source or voltage is req. to generate MF.	→ External source (supply) is req. to generated MF.
→ Voltage drop is more.	→ Less voltage drop is there

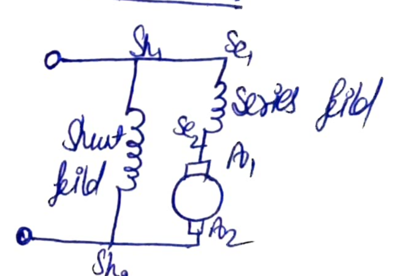
3. Series



4. Shunt



5. Compound



Both feild & armature are in series.

Both feild & Armature is in ||.

Some is connected in series & some in ||. it has both 'series feild' & 'shunt feild.'

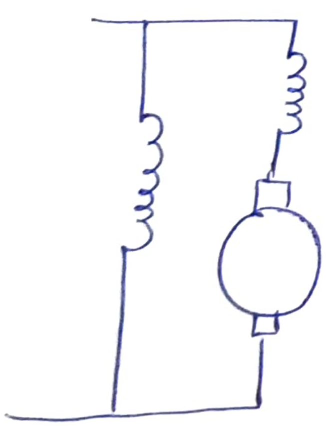
→ Main MF is generated by shunt feild as it has more no. of turns.

→ Series feild is connect series with armature so more current passes through series feild compared to shunt feild.

→ Series winding is thick & less no. of turns.

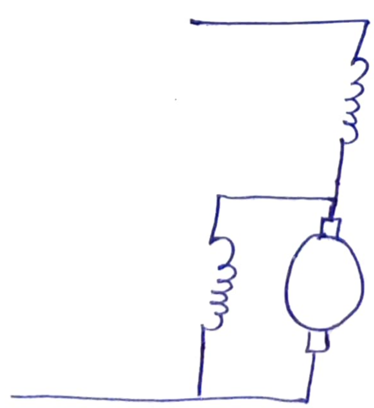
<u>Compound</u>

1. <u>Long</u> <u>Compounded</u>



→ Shunt feild || to both series feild & armature.

2. <u>Short</u> <u>Compounded</u>



→ Shunt feild Just || to the armature.

3. Cumulative

→ Series field helps the shunt field.

4. Differential

→ series field oppose the shunt field.

EMF eqn of DC Generator :

Let no. of pole = P , No. of ∥ path = A

Flux / Pole = ϕ , R.P.M = N

Total Conductor = Z , radius of arm = r

Now, for one rotation, Flux = $P\phi$

& time for one rotation = $\frac{60}{N}$

∴ generated EMF for one conductor, $e = \frac{d\phi}{dt}$

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

→ Now, effective conductor/ ∥ path = Z/A

∴ Induced EMF for Z No. of Conductor, $\boxed{e = \frac{P\phi N}{60}\left(\frac{Z}{A}\right)}$

★★ → We know that, $e = Blu$ [ANOTHER METHOD]

$l \rightarrow$ length of Conductor

Now, $B = \frac{P\phi}{2\pi r l}$ [here $B = \phi/A$, $A = 2\pi r l$ as armature is Cylindrical] and $u = r\omega = 2\pi N r$

$$e = \frac{P\phi}{2\pi r l} \cdot l \cdot \frac{2\pi N r}{60} \Rightarrow \boxed{e = \frac{P\phi N}{60}}$$

(Both methods gives same value)

$$\rightarrow \boxed{E = \frac{P\phi N}{60}\left(\frac{Z}{A}\right)}$$

$$\rightarrow \boxed{E_{lap} = \frac{P\phi N}{60}\left(\frac{Z}{P}\right)} \quad , \quad \boxed{E_{wave} = \frac{P\phi N}{60}\left(\frac{Z}{2}\right)}$$

Again, $E = \frac{P\phi N}{60}\left(\frac{Z}{A}\right)$

$$\rightarrow \boxed{E = kN\phi} \quad , \text{ where } k = \frac{PZ}{60A} = \text{Const.}$$

$\rightarrow E \propto \phi$ & $E \propto N$

[But particularly E will depend upon N & not ϕ]

{** Ques. $\Rightarrow$ why E only depends upon only N. Justify}

Now, for N_1 & ϕ_1 $\Rightarrow$ $E_1 = kN_1\phi_1$

for N_2 & ϕ_2 $\Rightarrow$ $E_2 = kN_2\phi_2$

$$\Rightarrow \boxed{\frac{E_1}{E_2} = \frac{N_1}{N_2}\frac{\phi_1}{\phi_2}}$$

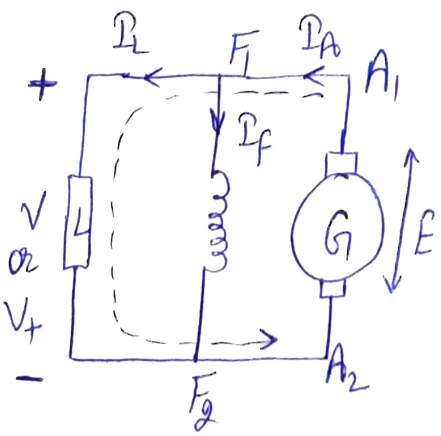
But if $\phi_1 = \phi_2 = \phi = \text{const.}$,

$$\boxed{\frac{E_1}{E_2} = \frac{N_1}{N_2}}$$

Again, $\because$ $\phi_1 \propto I_{f_1}$ & $\phi_2 \propto I_{f_2}$

$$\boxed{\frac{E_1}{E_2} = \frac{N_1}{N_2}\,\frac{I_{f_1}}{I_{f_2}}}$$

Some other eqn's of generator :



$\Rightarrow$ (Vol. is generated across Armature).

$I_L \to$ load Current

$I_f \to$ field Current

$I_A \to$ armature Current

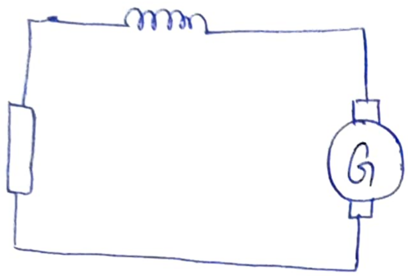
Now, $I_A = I_L + I_F$ or $\boxed{I_a = I_l + I_f}$ — (1)

Now, let $R_A = R_a$ = Armature resistance

KVL, $E - I_a R_a - V = 0 \Rightarrow \boxed{E = V + I_a R_a}$ — (2)

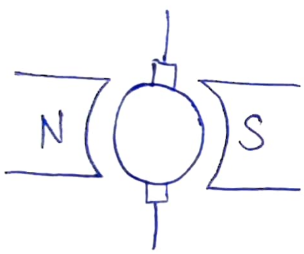
Again, $\boxed{V = I_f R_L}$ — (3)

Series Generator :



$I_a = I_L = I_f$

Armature Rxn :



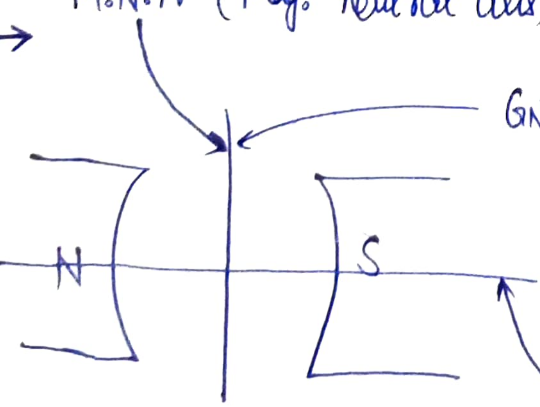
In generator there are 2 type of MF, Main MF & armature MF.

→ armature MF is developed only on load.

→ If there is no Load then no armature MF as no Current is generated.

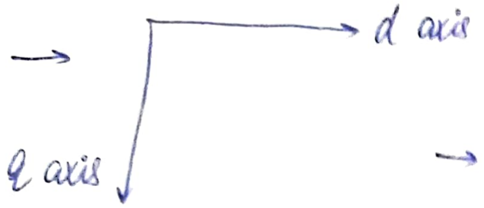
→ Interaction of two MF i.e. armature MF & Main MF is known as armature rxn.

M.N.A (Mag. neutral axis)



GNA (geometrical neutral axis)

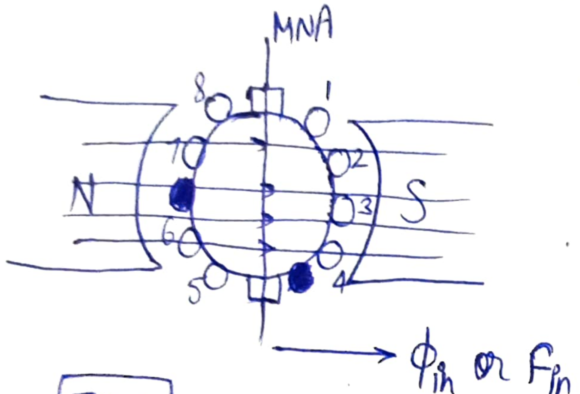
Polar axis or Direct axis (axis which is in b/w the magnet



(axis which is 90° apart)

→ Quadrature axis

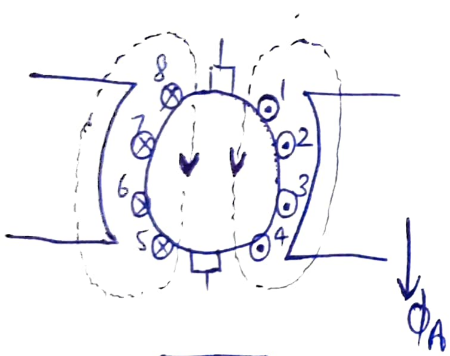
→ **Case I** : When the field get excitation only.



→ MF just generate in main field.

FIG 1.

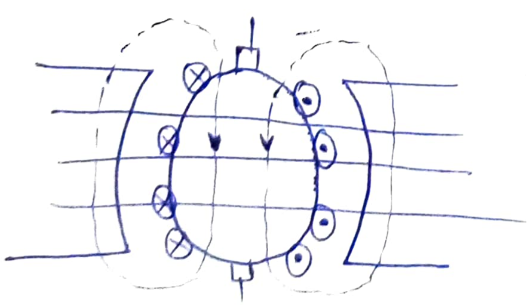
Case 2 : When the armature gets excitation only.



→ MF is always along MNA.

FIG. 2

Case 3 : When both the field & armature get excitation



→ At above (of left) both are add. & downward (sub.) (for right) at above both sub. & down. (add.) so MF change

FIG. 3

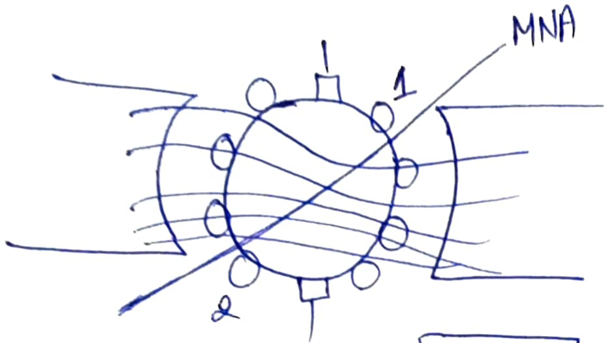
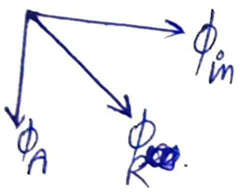


FIG. 4

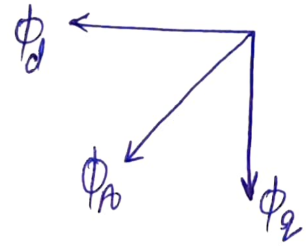
→ As MNA changes so Cross notation changes to dot notation of current.

→ As shape of MF change so MNA changes due to which 'ϕ_A' also changes.



For FIG. 3

⇒



→ Dir^n of ϕ_d is in rev. dir. of main MF. Since its dir^n is in opposition of main MF so it oppose the main mag. flux. (ϕ_m).

Since, ϕ is $\downarrow$ & $E \propto \phi \Rightarrow \therefore E \downarrow$.

→ So, Vol. generation of generator is red. due to Armature rxn & this effect is Demagnetization effect.

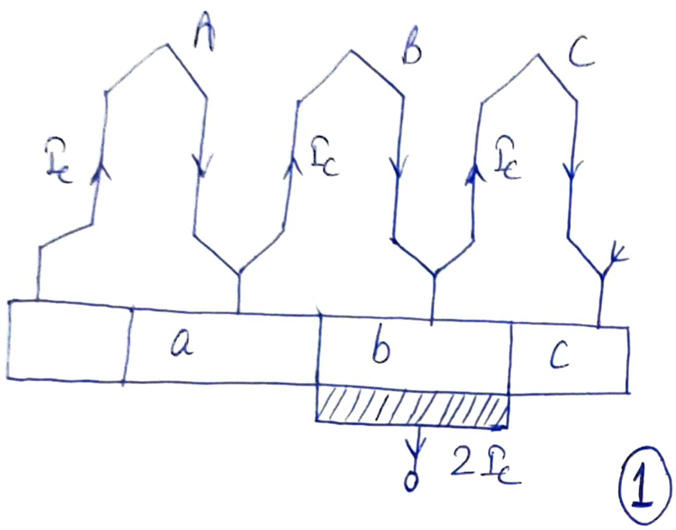
→ Effect of ϕ_q is Cross-magnetization effect. as it is quadrature of main MF. (it Crosses main MF).

Effect of Armature rxn :-

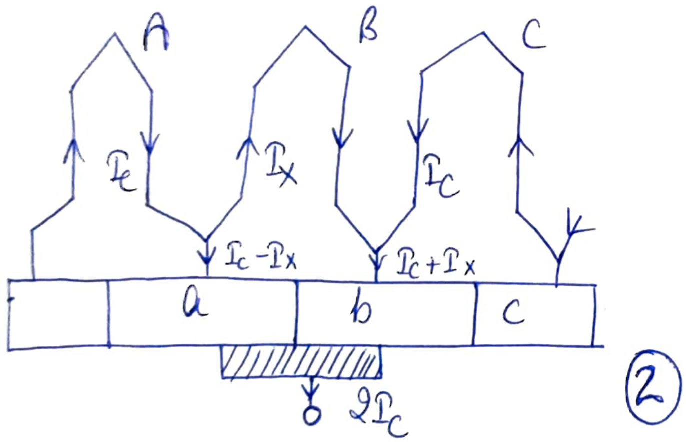
→ Demagnetization effect helps us to drop the voltage.

→ Due to Cross-magnetization effect sparking occurs

Commutation :



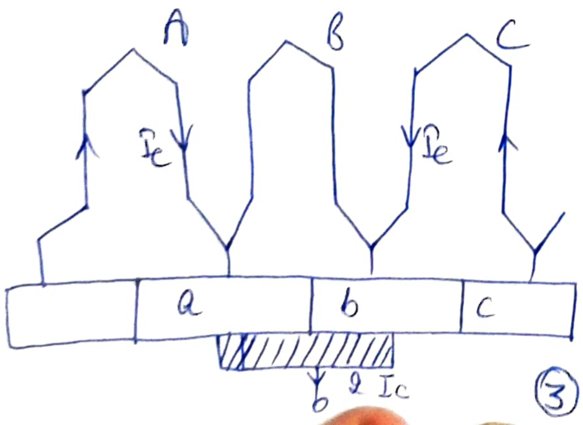
→ Each coil carrying current $= I_c$.

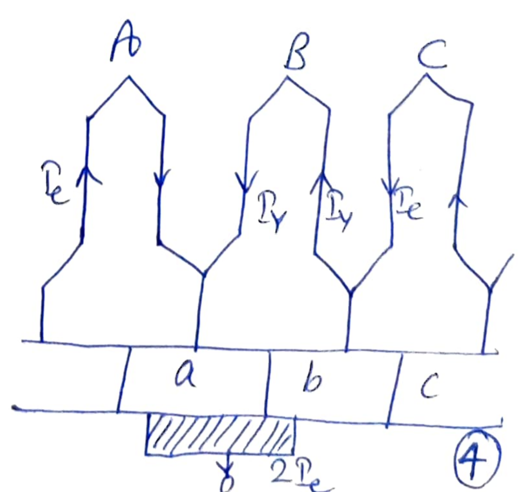


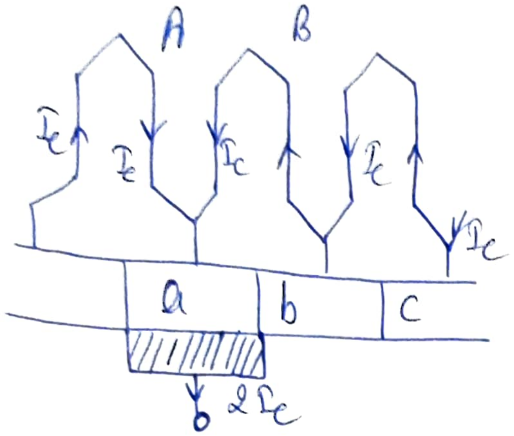
If the Co

→ Brush shifted from b to a.

→ Total current $= I_c - I_x + I_c + I_x$
$= 2I_c$







③ Coil 'B' is perfectly short by brush & Commutator.

→ In ③ brush is at middle of a & b.

→ Commutation is the pr. of reversal of armature Current. due to commutation period sum of armature Coil is short-ckted.

→ If the Commutation is ~~---~~ here then some ~~----~~ sparking occurs ~~---~~ due to reversal of current from cross to dot.

{What is meaning of Commutation, exp.}

Method for Better Commutation :

1). By resistance Commutation
2). Voltage Commutation
3) Compensating winding

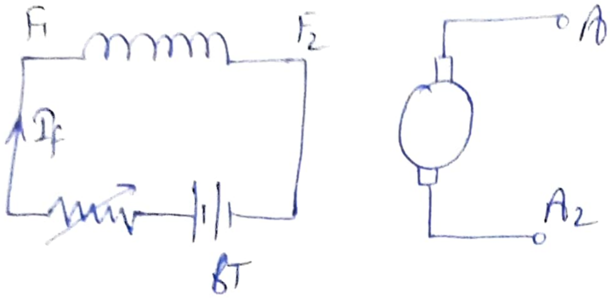
Characteristic of DC Generator :

No load or OCC (open ckt ch.)

Load or External characteristic

Generator → 1) series 2) shunt 3) Compound

1). Separately excited generator :-



→ We know that,

$E = KN\phi$

for const. N,

$E \propto \phi$

But $\phi \propto I_f$

$\therefore \boxed{E \propto I_f}$

OCC or no load ch.

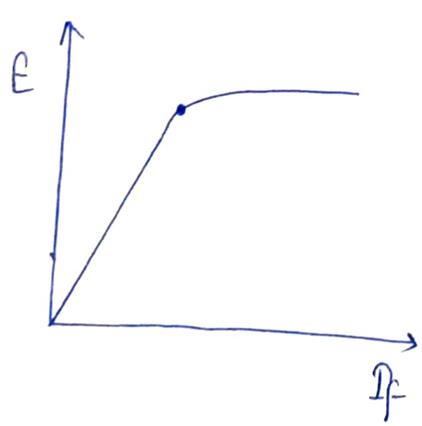
→ as A_1 & A_2 is not connected so open ckt & also no load so no load.

Case I : If $I_f = 0$ ⇒ Induced Emf $\boxed{E = 0}$.

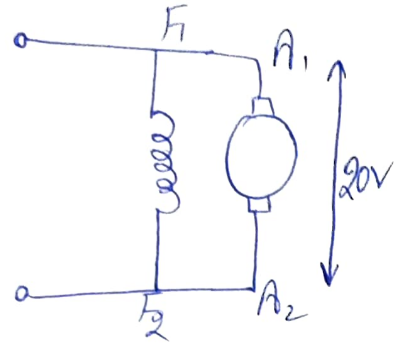
characteristic starts from origin.

Case II : If $I_f \uparrow$ ⇒ Induced Emf $E \uparrow$.

$\therefore$ characteristic of E vs I_f is linear ch.



Shunt Generator :



We know that,

$$E = kN\phi$$

for const. N $\Rightarrow E \propto \phi$

but $\phi \propto I_f \Rightarrow \boxed{E \propto I_f}$

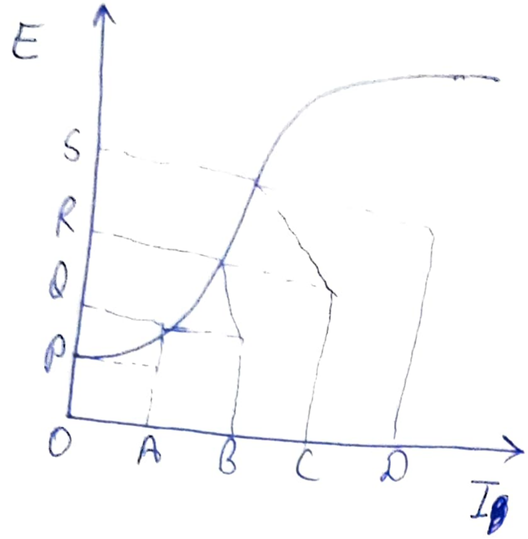
Case I : I_f $I_f = 0$

→ as $I_f = 0$ due to expr. $E = 0 \Rightarrow$ this gen. cannot build up any vol. $\Rightarrow$ To generate some vol. the generator has to develop some volt. & this is poss. for residual magnetism.

∴ Initially gen. has some induced emf at starting.
i.e. graph starts from some value in y.

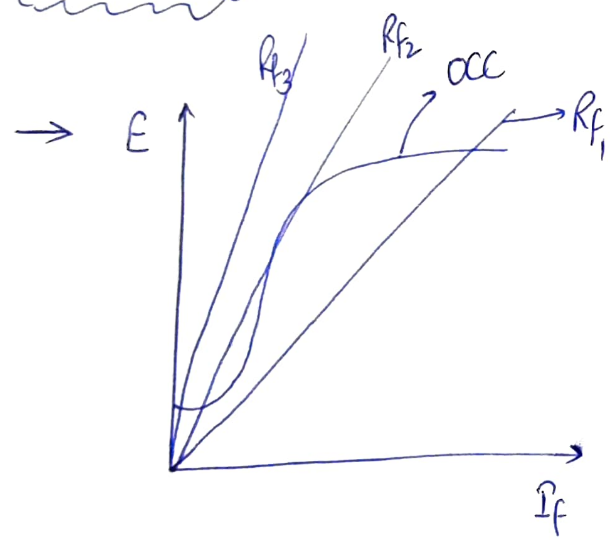
Case II : I_f $I_f \uparrow$

→ I_f is ↑ as $\Rightarrow$ due to residual mag. some vol. is gen. (say 20V) due to which current also start flowing & as current flow through shunt excitation current will generate.



→ Due to residual mag. the current is generated otherwise no current will generate.

Need of residual mag. for generator under OCC or shunt or Exp. pr. of vol. build up for SEG.



$(R_{f_3} > R_{f_2} > R_{f_1})$

$\because E = V + I_a R_a$

$\therefore V = E - I_a R_a$

But at No Load $I_a \approx 0$

$\therefore I_a R_a \approx 0$

$V = E$

$= I_f R_f$

$\Rightarrow \boxed{R_f = \frac{E}{I_f}}$

→ From OCC ch. we can also get idea of field resistance.

→ For a par. generator for the gr. of E vs I_f then R_f should be less than OCC.

→ R_{f_1} & R_{f_2} can be got from OCC ch.

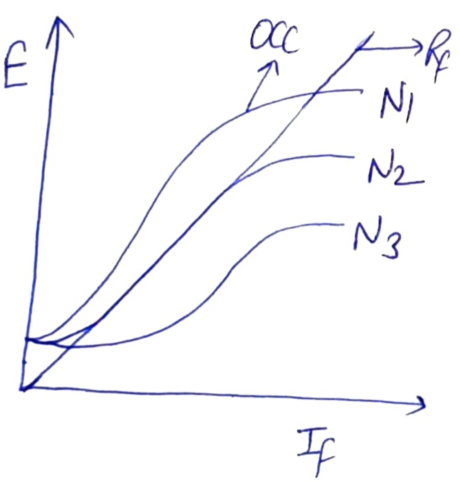
→ If residual mag. is not there then generator Cannot build up the voltage.

→ For R_{f_3} there will not be any OCC then also gen. Cannot build up the vol..

→ Only R_{f_2} (upto) we Can build up the vol.

<u>Critical field resistance</u> : Max. value of feild resistance upto which gen. Can build up the vol.

And it is the tangent on OCC ch..

→ 

(gen. Can be rotate by prime mover or turbine)

$(N_1 > N_2 > N_3)$

$E = KN\phi$

$E \propto \phi$, $E \propto N$

$E \propto I_f$

→ <u>Critical speed</u> : Min. value of rot. of armature upto which gen. Can build up the vol.

→ If the speed of armature < critical speed, the gen. Can't build up any voltage.

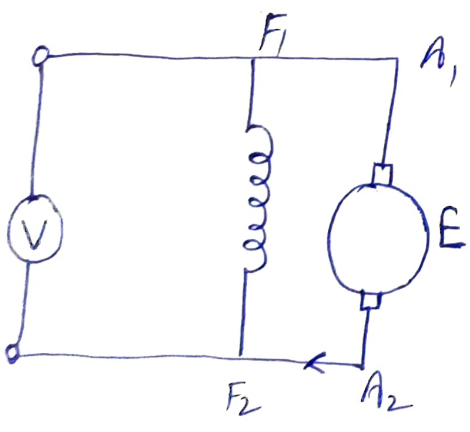
Condition of vol. building:

1) There must be residual magnetism for self-excited gen. or shunt gen.

2) Value of field resistance should be less than critical field resistance.

3) The speed of the armature of gen. must be greater than critical speed.

4) The polarity of the field & rotation of the armature must be in proper sequence.

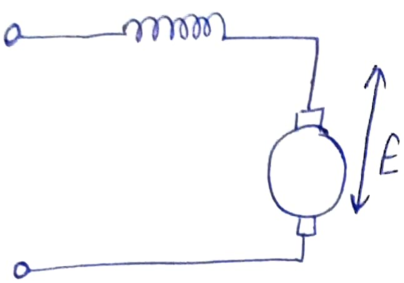


→ res. field will only ↑ if in place of S-pole after is also S-pole.

→ If the vol. is not ↓ i.e. I is also ↓ ⇒ then we have to change the polarity either of feild winding or armature.

→ If above one is correct then only reason is the permanent residual magnetism of gen. is dest.

→ Series Generator :



$$E = kN\phi$$

$E \propto \phi$, $\phi \propto I_f$

$\therefore E \propto I_f$

→ due to Residual mag. ind. emf is gen. but as ckt is open. no current will flow. i.e. no flux is gen. so no ind. emf or no feild current.

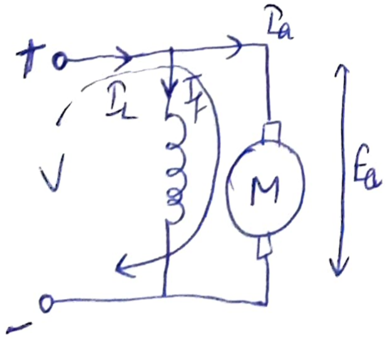
Case 2 → same as that of shunt.

Compound Generator :

→ It ch. is similar as that of shunt gen.

Some other eqn of DC motor :

Shunt Motor :



I_L → load current or line " or supply "

$$I_L = I_a + I_f$$

$$\Rightarrow \boxed{I_a = I_L - I_f} \quad — (1)$$

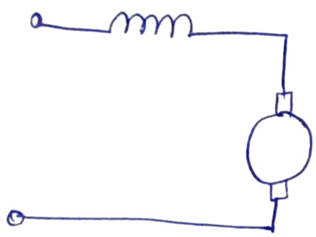
KVL ,

$$V = I_a R_a + E$$

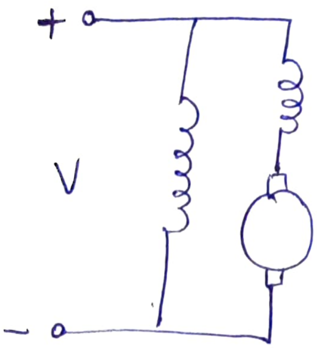
$$\boxed{E = V - I_a R_a} \quad — (2)$$

$$\boxed{V = I_f R_f}$$

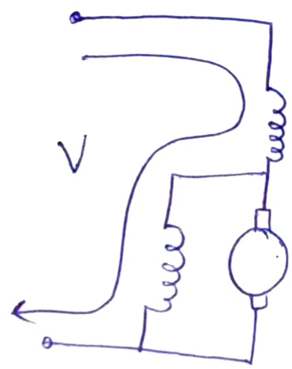
Series Motor :



$\rightarrow E = V - I_a R_a - I_f R_f$



$$\boxed{I_{se} = I_a}$$



$$\boxed{I_L = I_{se}}$$

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

Speed Eq^n :

$\Rightarrow E_b = V - I_a R_a$

$E_b = k N \phi \quad \Rightarrow V - I_a R_a = k N \phi \quad \Rightarrow \boxed{N = \dfrac{V - I_a R_a}{k\phi}}$

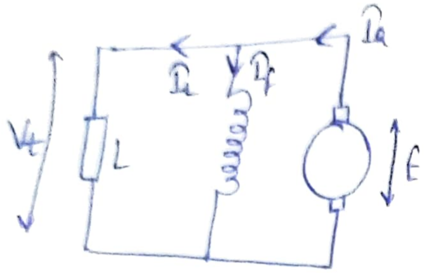
⇒ 1) The speed of motor depends on supply vol.
2) " " " " also depends on $I_a R_a$ drop.
3) " " " " " " " flux of motor.

⇒ Armature Current, $\boxed{I_a = \dfrac{V - E_b}{R_a}}$

Load ch. of DC current :

→ It means change of load results change in terminal voltage

SHUNT GENERATOR :



We know,

$$E = V_t + I_a R_a$$
$$V_t = E - I_a R_a$$

Case-I : At no load cond. →

→ At no load cond. , generator build up vol. process If $I_a \uparrow$, $I_f \uparrow$ and then it becomes generated.

$$I = I_a - I_f$$

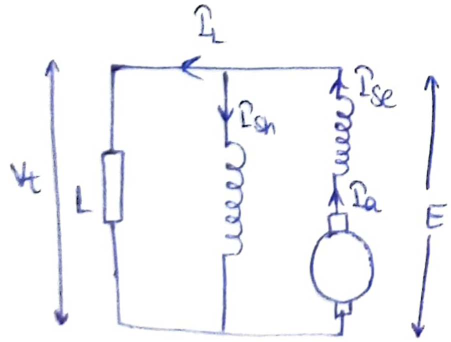
$\Rightarrow$ $I_L \propto I_a$

If $I_L = 0 \Rightarrow I_a \approx 0$

Since, $I_a \to 0 \Rightarrow V_t = E - I_a R_a \Rightarrow \boxed{V_t = E}$

[Continued after 5 pages]

→ Compound Generator :



$$E = V_t + I_a R_a + I_a R_{se}$$
$$= V_t + I_a (R_a + R_{se})$$

$$\Rightarrow \boxed{V_t = E - I_a (R_a + R_{se})}$$

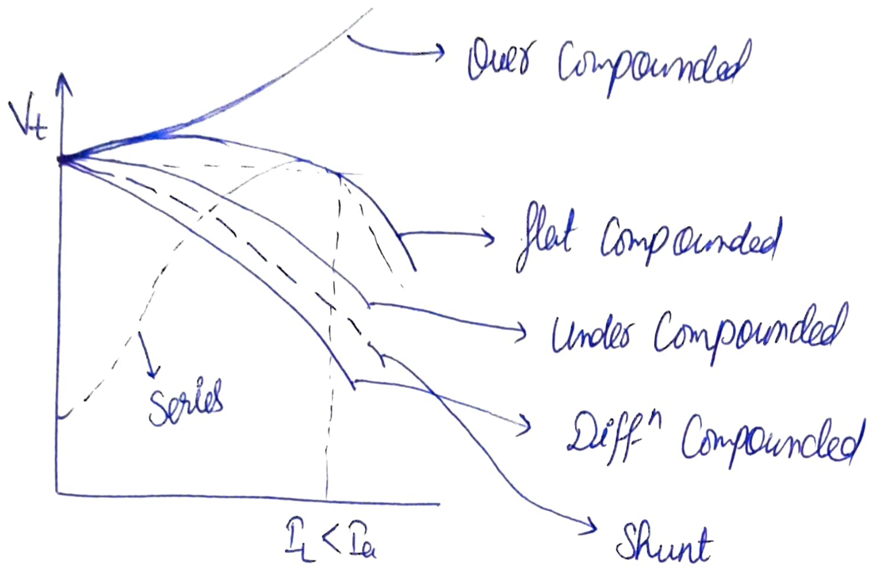
Here $I_a = I_{se}$

[No load cond. is similar as that of shunt generator]

*(at no load, $V_t = E$)

Case 1 : Same as shunt generator.

Case 2 :



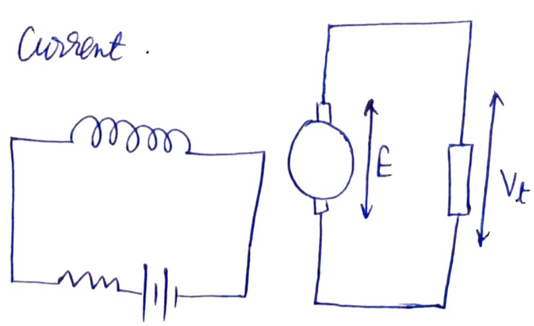
① Cumulative → Over Compounded (always MF ↑ ⇒ ind. EMF ↑)
→ Flat Compounded (No load Vol. = Full load Vol.)
→ Under compounded (change in V_t is neg.)

(Ch. is almost similar as that of Shunt gen. Ch.), (Series feild help shunt field).
(It little bit recovers shunt field).

② Differential → (It opposes i.e. opposition b/w series & shunt).

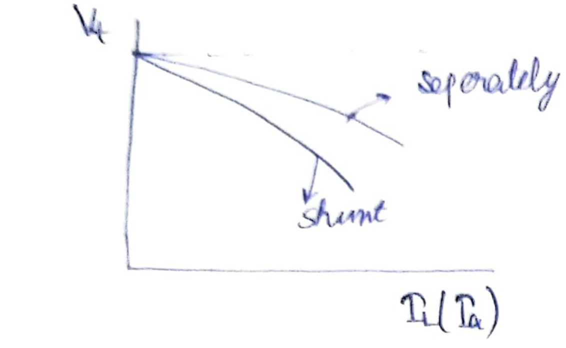
→ Seperately excited Generator :

→ No link b/w arm. Current & feild Current.
i.e. $I_a = I_L$



$\Rightarrow E = V_t + I_a R_a$

$\Rightarrow V_t = E - I_a R_a$ or $E - I_L R_a$



2) Brush contact drop

3) Armature rxn

(feild is excited seperately).

Which gen. is more vol. dropping ⇒ Self excited gen. is more vol. dropping than sep. excited gen.

→ Cause of vol. drop. (1, 2, 3, 4)

→ (1, 2, 3) is valid for both but 4 is not.

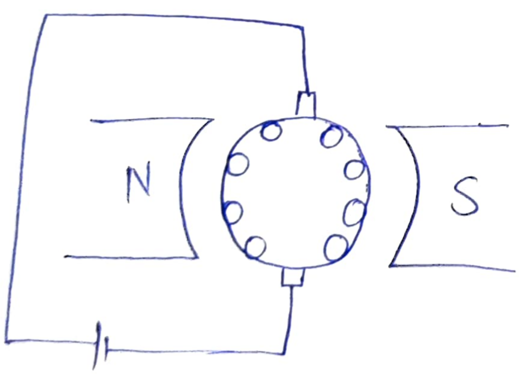
→ Then above graph.

(upto this is of gen.)

DC MOTOR :

[If ques. comes principle of motor. Starts from faradays law i.e. $E = B v l$]

Back Emf →



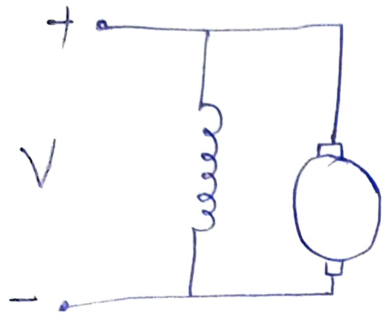
Across rotor cond. of motor we can get induced emf.

As rotor is moving, the mag. line of force is cut by the conductor

Acc to lenz law, induced emf across rotor cond. of motor oppose the ~~[illegible]~~ supply vol. That is why it is called Back emf.

⇒ $E_b = kN\phi$ (expr. of simply ind. emf & back emf are same).

Torque eqⁿ of DC Motor :-



Let E_b = Back emf
I_a = arm. Current
ω = Angular speed
τ = developed torque

$\Rightarrow \quad P_{m\,dev.} = \tau\omega \quad , \quad P_{elec.} = E_b I_a$

$\Rightarrow \quad \tau\omega = E_b I_a \Rightarrow \tau = \frac{E_b I_a}{\omega}$

$\Rightarrow \tau = \frac{P\phi N}{60}\left(\frac{Z}{A}\right) I_a \times \frac{60}{2\pi N} \Rightarrow \boxed{\tau = \frac{PZ}{2\pi A}\phi I_a}$

$\Rightarrow \boxed{\tau = K_t \phi I_a}$ where, $K_t = \frac{PZ}{2\pi A}$ = Const.

1). $\tau \propto \phi$
2) $\tau \propto I_a$

$F = Bli$ $\quad$ i = Current/Cond. , l = length of arm.
$\tau = F \times r$ $\quad$ r = radii of arm. , P = pole ,

Importance of Back Emf :

→ We know that, $I_a = \frac{V - E_b}{R_a}$

Case - I : At no Load Cond. :

(Load torque always oppose the rotation of motor).

→ We have to incorporate loss i.e. no load loss.

→ motor draws very less amount of current

→ It will rotate freely & generate Torque, $\tau = K_t \phi I_a$.

Case - II : When load is ↑.

→ as load torque always opp. rotation of motor.

∴ Speed of motor $N \downarrow$.

and as $E_b \propto N \Rightarrow E_b \downarrow$.

→ Motor will draw more supply of current from load.

Case - III : Now, if load ↓.

⇒ Speed, $N \uparrow$. ⇒ $E_b \uparrow$.

→ How much amount of current drawn by a motor is totally depends on 'Back Emf'.

→ Back Emf work as a Governor of DC Motor.

Characteristics of DC motor :

1) Torque Vs Armature Current (τ Vs I_a).

2) Speed Vs Armature Current (N Vs I_a).

3). Speed Vs Torque (N Vs τ).

DC Shunt motor :

1). τ Vs I_a

We know that, $\tau = K_t \phi I_a$

$\therefore$ for const. ϕ, $\tau \propto I_a$

Now,

Case-I : At no load → Motor will draw slowly.

$E_b \approx$ supply vol. $\Rightarrow I_a \approx 0 . \Rightarrow \tau \approx 0$

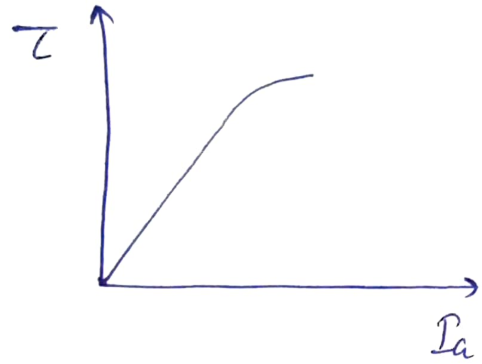
Case-II : When load is ↑.

$I_a \uparrow \Rightarrow \tau \uparrow$ → ch. is linear.

Case-III :

→ Due to prominent arm. rxn the res. mag. flux is ↓.

it is not Const. & hence $\tau \downarrow$.



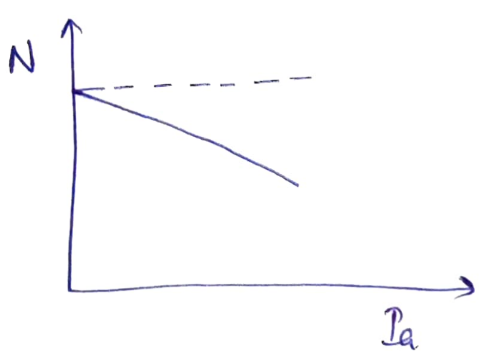
2) N Vs I_a

We know that, $N = \dfrac{V - I_a R_a}{k\phi}$

Case-I : No Load Cond. $\Rightarrow$ $I_a \approx 0$ $\Rightarrow I_a R_a \approx 0$

$\Rightarrow N = \dfrac{V}{k\phi}$ (max. or rated speed of motor).

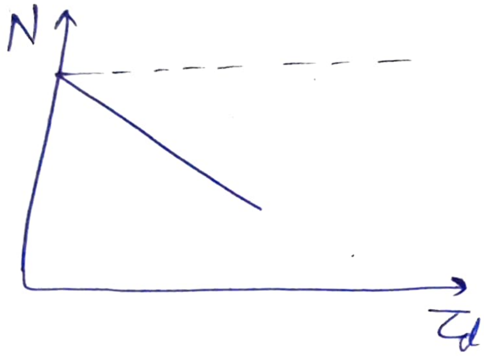
Case-II : Load is $\uparrow$ $\Rightarrow$ $I_a \uparrow$ $\Rightarrow$ $I_a R_a \uparrow$ $\Rightarrow N \downarrow$



3). N Vs τ

1). as $I_a \approx 0 \Rightarrow \tau \approx 0$
$I_a \approx 0 \Rightarrow$ N is max. (some value)

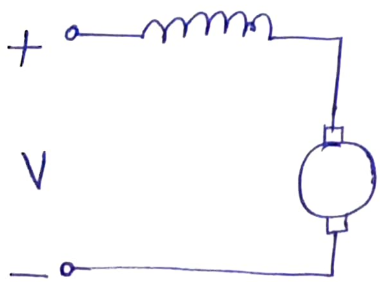
as $I_a \uparrow \Rightarrow \tau \uparrow$
" $\uparrow \Rightarrow N \downarrow$



→ Shunt motor used as a const. speed motor.

Series Motor :

1) τ Vs I_a



$$\tau = K_t \phi I_a$$

$$I_a = I_f = I_L$$

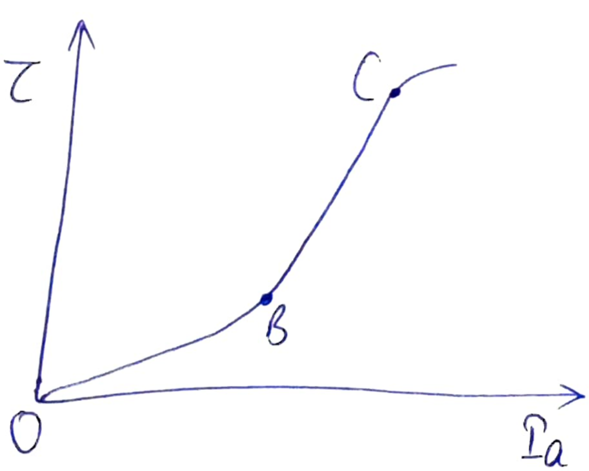
and $\phi \propto I_f$

$$\tau = K_T I_f I_a = K_T I_a^2$$

$$\Rightarrow \tau \propto I_a^2$$

Case-I : Same as of shunt.

Case II :



Upto $O \to B \Rightarrow \tau \propto I_a^2$

$B \to C \Rightarrow \tau \propto I_a$

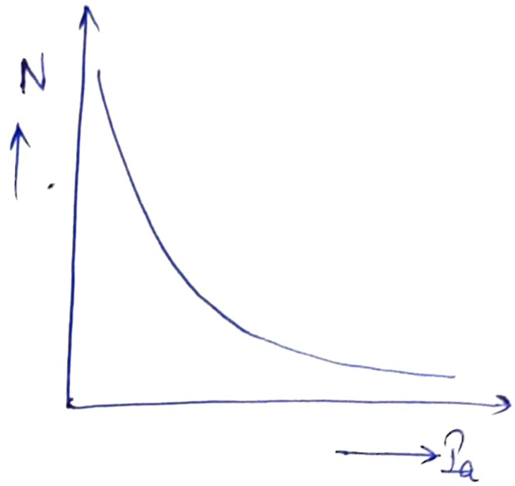
(as that of shunt)

(II) N Vs I_a :

$$N = \frac{V - I_a R_a}{k\phi}$$

$$N = \frac{V - I_a R_a}{k I_f}$$

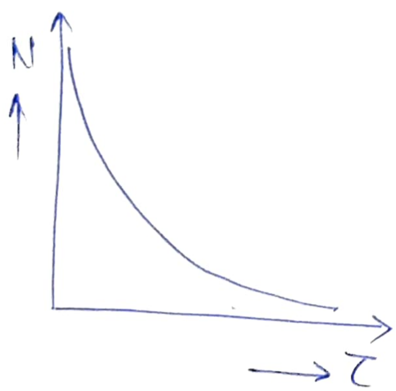
$$N = \frac{V - I_a R_a}{k I_a}$$



→ After field gets saturated then all eqn are similar whether it is series or shunt.

(III) N Vs τ :

→ Same as that of shunt motor.



→ at no load N ↑

→ Series motor used as a traction device?

Shunt motor used as Const. speed motor?

bcoz there are no change of motor to run at ↑ high speed no chance to make motor at no load cond.

Belt pully is not used for motor

bcoz if the belt taught due to high speed the motor will come in noload.

→ The compound motor all 3 ch. are similar as like as shunt motor ch.

Method of Speed Control :

$\because N = \frac{V - I_a R_a}{K\phi}$

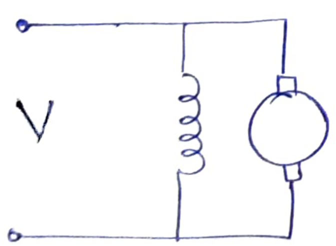
This is not use to control speed of motor.

1). By changing supply vol. (It is always supplied at Const. value)
2) By changing armature current or vol.
3). By changing the I_f.

1). Shunt Motor :

• Armature method ⟹

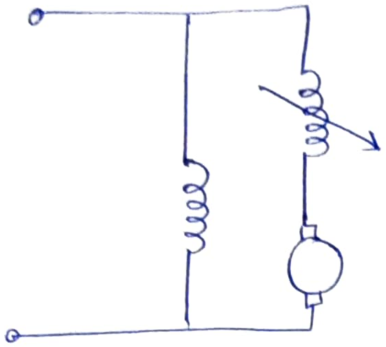
$N = \frac{V - I_a R_a}{K\phi}$ arm. resistance



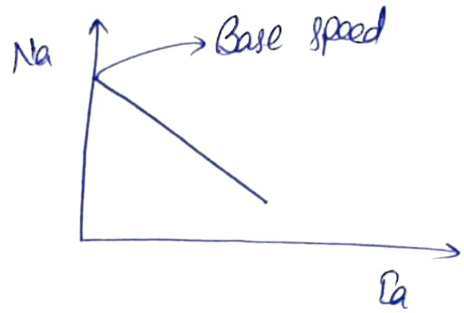
⟹ Supply vol. & field current make it const.

C-I : If $I_f \approx 0$ (No load cond.)
speed of motor max $\left(N = \frac{V}{K\phi}\right)$

⟹ To change I_a ⟹ Change resistor of arm. ckt. ⟹ by conn. ext. resistance in series with arm.



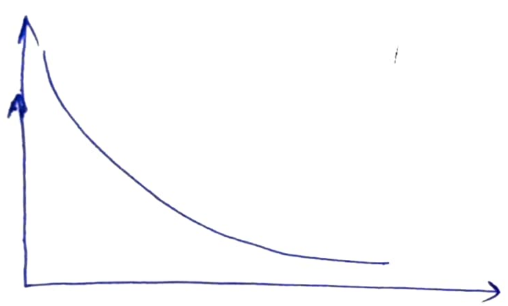
⇒ By arm. Control ⇒ N ↓

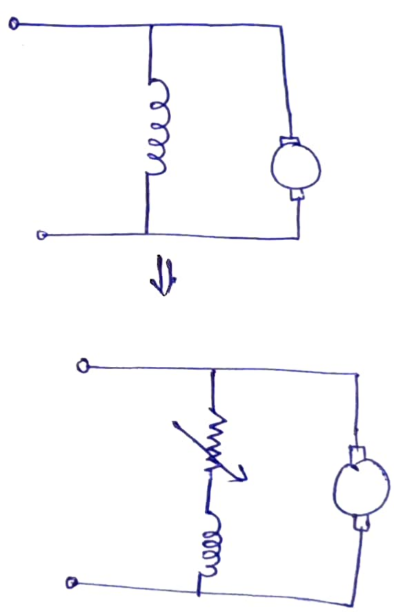


→ By arm. control is used below the base speed ch.

• **Feild control :**

$$N = \frac{V - I_a R_a}{K\phi}$$



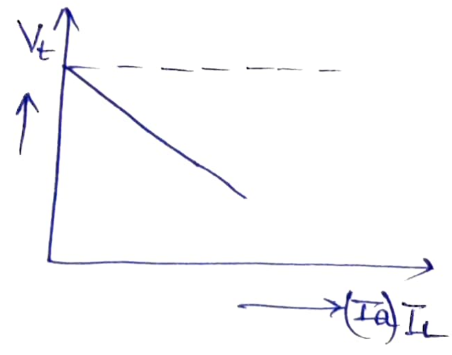


→ Feild control tech. is used above base speed. tech.

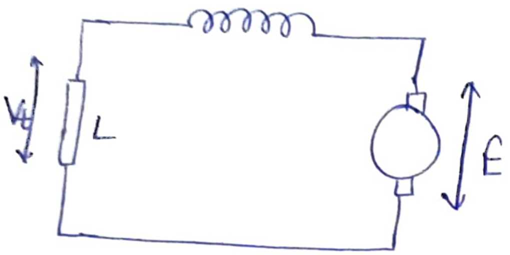
Case - II : If load current ↑ , I_a ↑

$\therefore V_t = E - I_a R_a$

Hence, $V_t = \downarrow$



Series generator :



$I_a = I_L = I_f$

$\Rightarrow E = V_t + I_a R_a + I_{se} R_{se}$

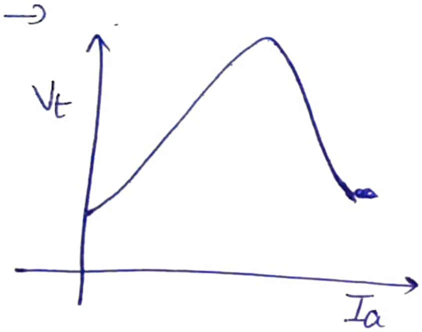
$\Rightarrow V_t = E - I_a (R_a + R_{se})$

→ No vol. buildup process.

→ At no load, the value of E is due to residual magnetism.

Case-I → (No load cond.) OCC ch. → Similar as that of shunt.

Case-II →



⇒ At loaded cond. OCC of shunt & series generation are same upto saturation pt.

Causes of vol. drop :

1). Due to armature vol. drop.

2). Due to brush contact drop.

3). Due to armature rxn.

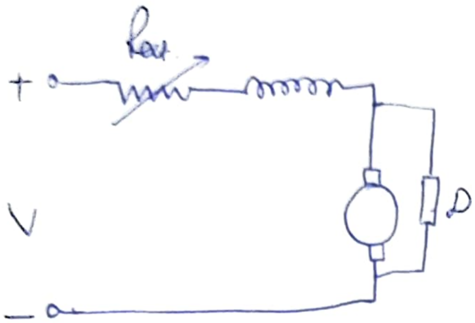
4). Due to dec. of field current for the above 3 effect. (valid for self-excited generator).

** → Explain load ch. of shunt & series generator?
→ Voltage drop causes?

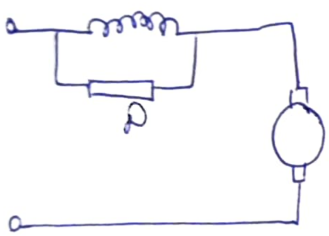
Speed Control for DC series motor :

1) Arm. Control :

for Const. ϕ , N depend on $I_a R_a$ drop.



2) Field Control method :



Field divertor ckt

⇒ field divertor ckt → which has a var. resistance.

⇒ with the help of this we can only change the field current by conn. it in ||.

→ It is reqd if we change only the field current or arm. current

1) How many method for speed control of DC motor. → 3

exp. arm. control & field control.

2) what is field diverter ckt explain its importance.

3) For which motor it is used - series

Ex→1 A 4 pole DC m/c has 144 slot in the arm, with 2 Coil side per slot, each coil has 9 turn. flux/Pole = 20 mWb, the arm. is lap wound, & if rotate at 720 rpm. Determine Ind. EMF.

Soln: We know that, $E = \frac{P\phi N}{60}\left(\frac{Z}{A}\right)$

$P = 4$, $N = 720$, $\phi = 20\ mWb$, $A = 4$, $Z = 144 \times 2 \times 2$

$E = 138.24\ V$.

(ii) E per ‖ path. ⇒ same.

Ex→2. A DC gen. Carry 600 Cond. on its arm. with lap Conn. The gen. has 8 pole with 0.06 Wb useful flux. What will be Ind. EMF at ~~its~~ terminal if it rotated at 1000 rpm? Also, determine the speed at which it should be driven to Ind. same Vol. with wave Conn.

Soln: $E = \frac{P\phi N}{60}\left(\frac{Z}{A}\right)$

$$E = \frac{\cancel{8} \times 0.06 \times 100\cancel{0}}{\cancel{60}}\left(\frac{600}{\cancel{8}}\right) = 600\ V$$

$$\Rightarrow \frac{6\cancel{00} \times \cancel{60} \times \cancel{2} \times 100}{6\cancel{00} \times 8 \cancel{4} \cancel{6}} = N = 250\ rpm$$

Ex-3. A DC m/c running at 750 rpm has an Ind. emf of 200V. Calculate,

i) speed at which ind. emf will be 250 V.
ii) % ↑ in main field flux for an ind. EMF of 250 V at a speed of 700 rpm.

Solⁿ i) $\frac{E_1}{E_2} = \frac{N_1 \phi_1}{N_2 \phi_2} \Rightarrow \frac{E_1}{E_2} = \frac{N_1}{N_2}$ { taking $\phi_1 = \phi_2 = \phi =$ const }

$\Rightarrow \frac{200}{250} = \frac{750}{N_2} \Rightarrow N_2 = \frac{750 \times 5}{4} = 937.5$ rpm

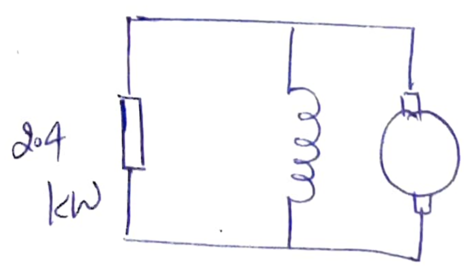
ii) $\frac{E_1}{E_2} = \frac{N_1}{N_2} \frac{\phi_1}{\phi_3}$

$\Rightarrow \frac{\phi_1}{\phi_3} = \frac{200}{250} \times \frac{700}{750} = 1.34$

Q4. A 4 pole shunt gen. with lap conn. arm. has field and arm. resistance of 50 Ω & 0.1 Ω resp. The gen. is suppling a load of 24 kW at 100 V. Calculate the arm. current, current each cond. & gen. EMF.

Solⁿ: $E = V + I_a R_a$

$E = 100 + \frac{I_a \times 1}{10}$.



$I_a = I_L + I_f$

$I_a = 24 + 2 = 26 A$

$I_f = \frac{100}{50} = 2 A$

$I_L = \frac{P}{V} = \frac{2.4 \times 10^3}{10^2} = 24 A$

$E = 102.6$ V

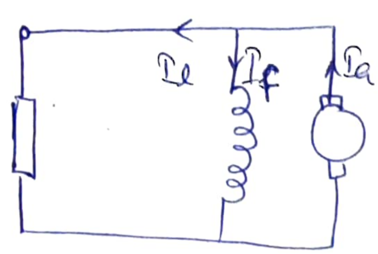
→ Current each cond. $\Rightarrow I_c = \frac{I_a}{A} = \frac{102.6}{4}$ A

Q5 The arm. of 4 pole dc shunt gen. has 378 wave connected cond. The arm. & shunt wind. resistance are 1Ω & 100Ω resp. The flux/pole = 0·02 wb. If load resistance of 10Ω is conn. across arm. terminal & gen. is driven at 1000 rpm, calculate power absorbed by load.

$\Rightarrow E = \frac{P\phi N}{60}\left(\frac{Z}{A}\right) = \frac{4 \times 0.02 \times 4 \times 1000}{60}\left(\frac{378}{2}\right) = 1008$ V

$\Rightarrow E = V + I_a R_a$

$\Rightarrow V = E - I_a R_a$



$\Rightarrow V = 1008 - \left(\frac{V}{10} + \frac{V}{100}\right) \times 1$

$I_a = I_l + I_f \rightarrow \frac{V}{R_f}$

$\Rightarrow 1008 = V + \frac{V}{10}\left(1 + \frac{1}{10}\right)$

$I_a = \frac{V}{10} + \frac{V}{100}$

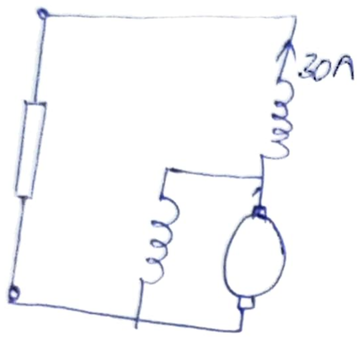
$\Rightarrow 1008 = V\left[1 + 0.1 + 0.01\right]$

$\Rightarrow V = \frac{1008}{1.11} = 908.108$

$\Rightarrow \boxed{P = V I_l} \Rightarrow P = \frac{(908.108)^2}{10} =$

Q) Short shunt Compound gen delivers a load current of 30 A at 220 V. Resistance of arm, series & shunt field 0.05 Ω, 0.3 Ω & 200 Ω. Calculate ind emf & I_a? Allow 1V per brush contact drop?

Soln :



$E = V + I_a R_a + 2 + I_{se} R_{se}$

$I_L = 30A$

$I_a = I_L + I_{sh}$

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

$\boxed{I_{se} = 30A}$

$I_a = 31.145\ A$, $V = 232.56\ V$

Q The Arm. & sh. field resis. of 4 pole lap wound dc shunt motor is 0.05 & 25 Ω resp. If arm. cont 500 conductor. find speed of motor when it takes 120A from a DC main of 100 V supply. flux/pole = 2×10^{-2} wb

$\Rightarrow \quad E = \frac{P \phi N}{60} \left(\frac{Z}{A} \right)$

$E = \frac{4 \times 2 \times 10^{-2} \times 4 \times N}{60} \left(\frac{500}{4} \right)$

$E = V - I_a R_a$

$E = 100 - \frac{5}{100} \times$

$N = 565 \cdot 2$

Q). The electromag. torque develop in DC m/c is 80 Nm. for arm. Current of 30A. what will be the torque for a current of 15A. assume Const. flux. what is the ind. emf at a speed of 900 rpm and a current (I_a) of 15A.

$\Rightarrow \tau = k_t \phi I_a$

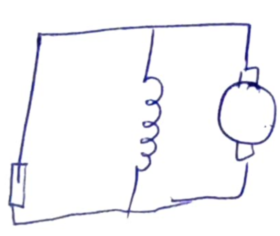
$\Rightarrow \tau \propto I_a \quad \Rightarrow \frac{\tau_1}{\tau_2} = \frac{I_{a_1}}{I_{a_2}} \Rightarrow \frac{80}{\tau_2} = \frac{30}{15} \Rightarrow \tau_2 = 40\ Nm.$

$\Rightarrow E = k_t \phi I_a$

$\Rightarrow P = EI = \omega T$

Q). The arm. resistance of 220V DC gen. is 0.4 Ω. It is delivering a load of 4kW at a rated terminal vol. Now m/c is operated at a motor & draw the same Current at the same terminal vol. In this op. if flux/pole is ↑ by 10%. what will be the ratio of speed from gen. to motor.

Soln:



$P = 4kW = EI \Rightarrow 4 \times 10^3 = 220 + 0 \cdot 4 I_a$

$I_a = I_L$

$0 \cdot 4 I_a = 3780$

$E = V + I_a R_a$

$I_a =$

$E = 220 + \frac{4}{10} \times I_a$

$$\frac{N_1}{N_2} = 1.17$$

Q) A DC shunt motor run at 1000 rpm, 220 V supply. Its arm & feild resistance are 0.5 Ω & 100 Ω resp. & total Current taken from supply is 26 A. It is desired to reduce the speed to 750 rpm. Keeping the arm. & feild Current same. What res. should be inserted in arm. ckt.

{ Motor taking current → I_L
gen. delivering " → I_L }

$$\Rightarrow \quad \frac{E_1}{E_2} = \frac{N_1}{N_2}\frac{\phi_1}{\phi_2}$$

$$\Rightarrow \quad \frac{E_1}{220} = \frac{3\cancel{750}}{4\cancel{1000}} \Rightarrow E_1 = 55 \times 3 =$$

$E_1 = 208$ V

$$\Rightarrow E = V - I_a R_a \quad \Rightarrow \quad E_2 = V - I_a (R_a + r)$$

Q). The field winding res. & arm. res. of 240 V DC shunt motor is 120 Ω & 0.1 Ω resp. If draw 24 A at rated Vol. to run at 1000 rpm. find the value of addl. resistance req. in arm. ckt to reduce the speed to 800 rpm. when,

i) Load torque ∝ speed
ii) Load torque ∝ $(\text{speed})^2$

$\boxed{r = 3.434\ \Omega}$

Soln $I_{a_1} \rightarrow E_1 = \checkmark$ then E_2 for that I_2 have to found.

$T_1 \propto N_1$
$T_2 \propto N_2 \Rightarrow \frac{T_1}{T_2} = \frac{N_1}{N_2} \Rightarrow$

Q). The field & arm. resistance of a 500 V dc series motor are 0.2 Ω & 0.3 Ω resp. Motor run at 500 rpm. when drawing a current of 49 A. If load torque vary as sq. of speed. Determine value of ext. resis. to be added to series with arm. for motor to run at 450 rpm.

$$\boxed{r = 3.017 \Omega}$$

⇒ Linear magnetisation ⇒ $\phi_1 = \phi_2$

Starter (DC Motor):

We know that,

$E_b = V - I_a R_a$

$\Rightarrow I_a = \frac{V - E_b}{R_a}$

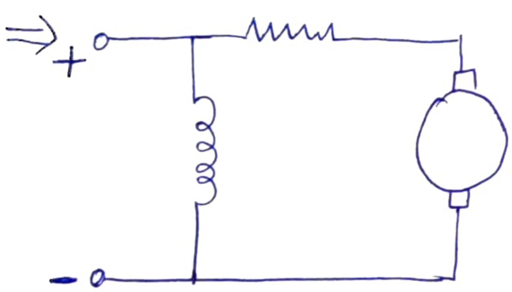
Now at starting,

$E_b = 0$ (as $N = 0$ & $E_b \propto N$)

$\therefore I_a = \frac{V}{R_a}$

$\Rightarrow$ But $V \approx 220\,V$ & $R_a = 1\,\Omega$

$\Rightarrow I_a = \frac{220}{1} = 220\,A$



Due to high current arm. may burn out $\Rightarrow$ Protect arm. at starting period $\Rightarrow \downarrow$ the I

$\Rightarrow$ Connect resistance (var.) in series with arm.

Now, $I_a = \frac{V}{R_a + R}$

$\Rightarrow$ We have to remove the ext. resistance after starting so that the extra I^2R loss does not happen. and the eff. of motor not $\downarrow$.

→ Starter is a starting device by which we start the motor.

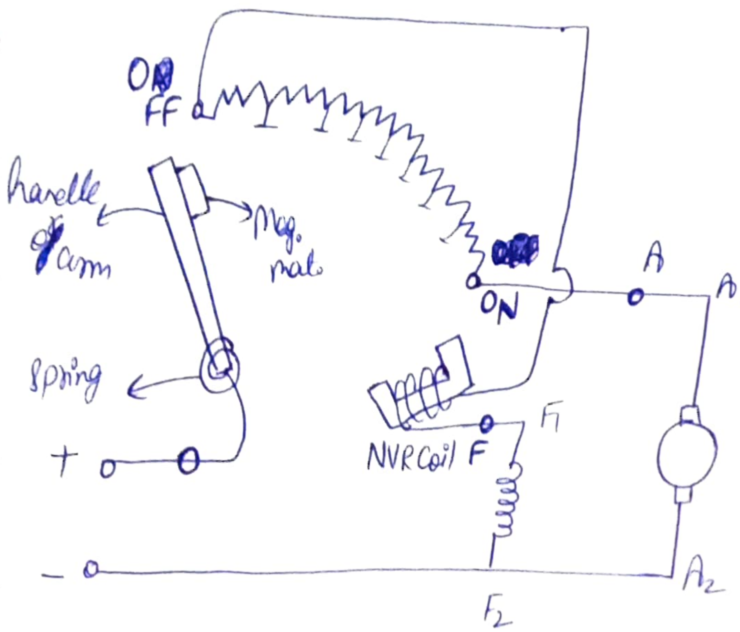
→ has a var. resistance.

→ connect series with arm. ckt.

→ The nature of ext. resistance is var. in nature.

Starter → Two point, Three point, Four point

Operating pr. of 3-point starter :



⇒ NVR → No vol. released
coil coil

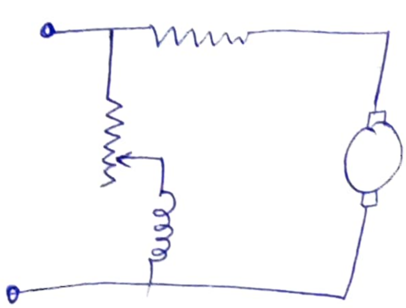
→ when starter arm is in ON pos.

total ext. resist. in series with arm. ⇒ motor start rotating ⇒ motor current ↓.

→ when starter arm is on 'ON' pos. ⇒ resis. is by passed.

→ It is always on that pos. ⇒ due to NVR Coil

→



As rheostat is also used to generate current

→ If vol. is disconnect & again connect then huge amount of current will flow which should damage the arm.

Advantages :

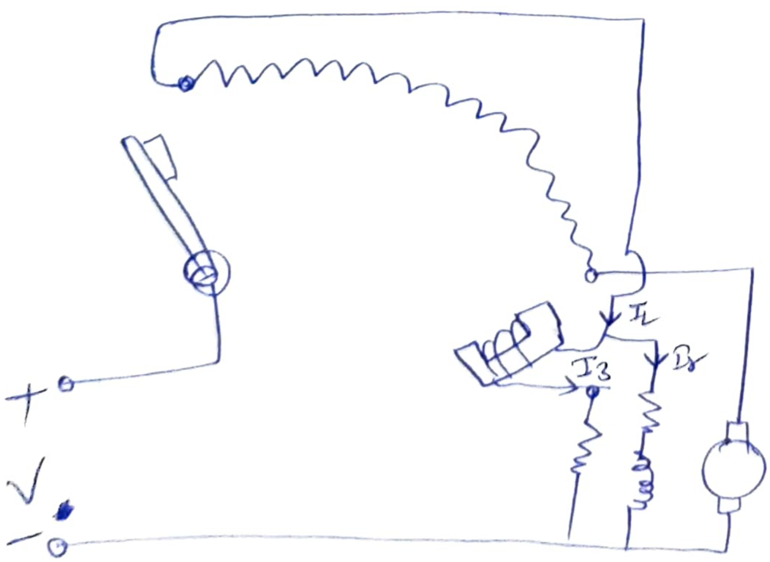
1) Hold the starter pt. at ON pos.
2) NVR Coil gives prot. to the coil
   provides no vol. prot. to motor.
3) overload protection also provided by startor.

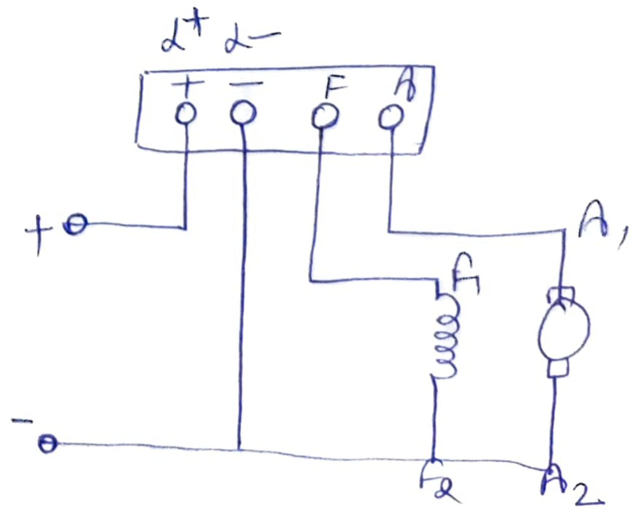
Starter (Now better than stator)
Necessity of starter
oper. prin. of 3pt. starter.

Disadvantage :

→ when we control speed of motor by field control
by conn. ext. resis. ⇒ $I_f \downarrow$ ⇒

→ It can be over come by using 4 pt. starter.





Losses of DC M/C

- Constant Loss
  - Core Loss OR Iron Loss
    - Hysterisis
    - Eddy Current
  - Mechanical loss
    - Windage Loss
    - Friction Loss
- Variable Loss
  - Copper Loss
    - Arm. Copper Loss
    - Field Copper Loss
    - Brush Contact
  - Stray Load Loss
    - Copper stray load Loss
    - Core stray Load Loss

Efficiency of DC M/C :

$$\Rightarrow \eta = \frac{Output}{Input}$$

$$\Rightarrow \eta = \frac{Output}{Output + Loss} = \frac{Output}{Output + P_i + P_c} = \frac{Output}{Output + P_i + I_a^2 R_a}$$

$P_i \rightarrow$ Iron Loss

$P_c \rightarrow$ Copper Loss

$$\Rightarrow \eta_G = \frac{V \times I_L}{V I_L + P_i + I_a^2 R_a}$$

(Output for gen. $= V \times I_L$)

$$\Rightarrow \eta_G = \frac{V I_a}{V I_a + P_i + I_a^2 R_a} = \frac{V}{V + \frac{P_i}{I_a} + I_a R_a}$$

$$\Rightarrow R_a - \frac{P_i}{I_a^2} = 0 \Rightarrow I_a = \sqrt{\frac{P_i}{R_a}}$$

$$\Rightarrow \boxed{P_i = I_a^2 R_a}$$

→ M/c runs at max. eff. when var. loss = const. loss.

$$\Rightarrow \eta_m = \frac{VI_L - P_i - I_a^2 R_a}{VI_L}$$

Q1). A DC shunt gen. supply 195 A at 220 V. Arm. resis. is 0.02 Ω & shunt field resis. is 44 Ω. If Iron & fric. loss is 1600 W, find

⟨i⟩ Emf generated

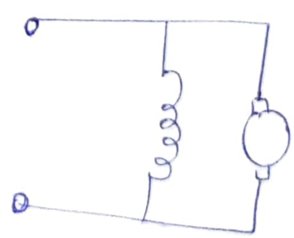
⟨ii⟩ Cu loss

⟨iii⟩ b.h.p. of the engine driving the gen.

(iv) Commercial, elect. & mech. eff.

Solⁿ:

$$E = V + I_a R_a$$
$$= 220 + \frac{2}{100} \times$$



$$I_a = I_f + I_L = 200$$

$$I_f = \frac{220}{44} = 5 \text{ A}$$

$$E = 220 + 4 = 224 \text{ V}$$

→ Cu loss due to arm. $= I_a^2 R_a$

$$= 2/100 \times (200)^2 = 800 \text{ W}$$

$\Rightarrow$ $\boxed{\text{Input} = \text{Output} + \text{loss}}$

$\Rightarrow$ Cu loss due to field $= 25 \times 44 = 1100$

$\Rightarrow$ Total Cu loss $= 1100 + 800 = 1900$ W

$\Rightarrow$ ** $\boxed{1 \text{ bhp} = 735.5 \text{ W}}$

$\Rightarrow$ $P_I = I_a^2 R_L = 4 \times 10^4 \times$ 42900 $= \frac{46400}{735.5}$

$= V \times I_L = 224 \times 220 =$ $=$ $= \boxed{63.08}$

Input power

$+$ frc. loss $+1600$

$+$ Cu loss $+1900$

(iv)

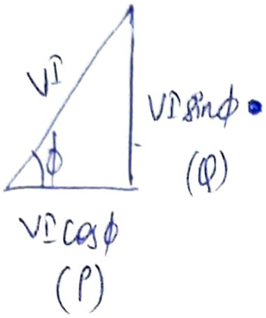
$\rightarrow$ Mech. eff. $= \frac{\text{Power developed}}{\text{elect. power dev.}} = \frac{E_g I_a}{P_I} = 96.4$

Elect. eff. $= \frac{\text{Power Output}}{\text{Power dev.}} = \frac{V \times I_L}{E \times I_a} = 95.76\%$

$\rightarrow$ Commercial $= \frac{\text{elect.}}{\text{Mech.}} = 92.45\%$

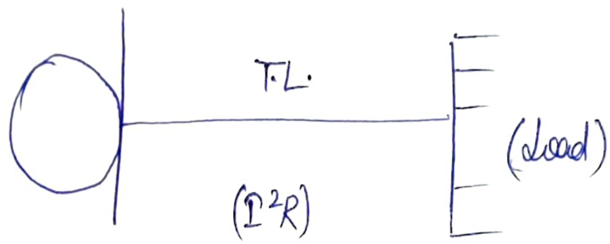
Transformer :

$VI \rightarrow$ apparant power



$P = VI\cos\phi \rightarrow$ Active power

$Q = VI \sin\phi \rightarrow$ Reactive power



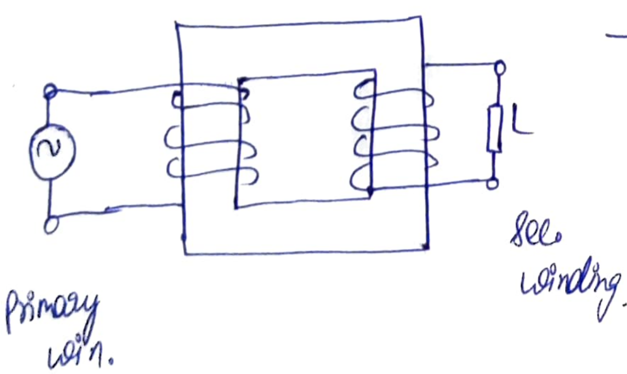
$\Rightarrow V_1 I_1 = V_2 I_2$

$\Rightarrow \frac{V_1}{V_2} = \frac{I_2}{I_1}$

→ electromag. static dev.

→ used to tr. elec. energy to one elec. ckt to another with const.

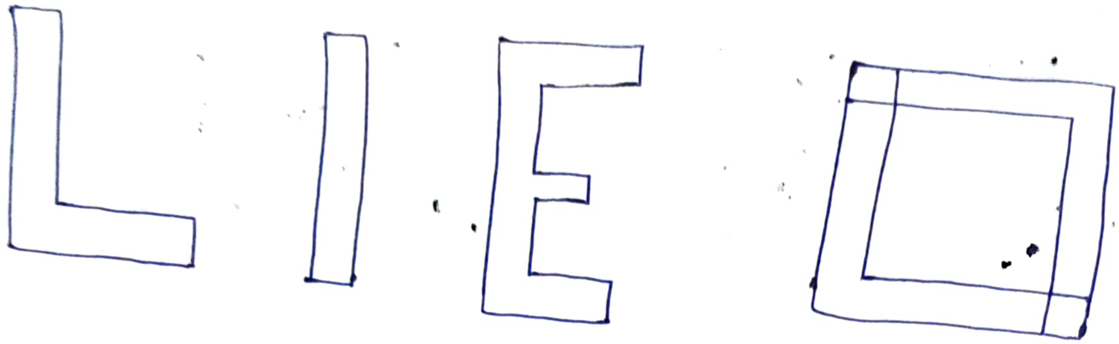
→ Two winding does not have any elec. Con.



→ When we apply voltage to pr. win. acc. to mutual ind. across sec. win. we get vol.

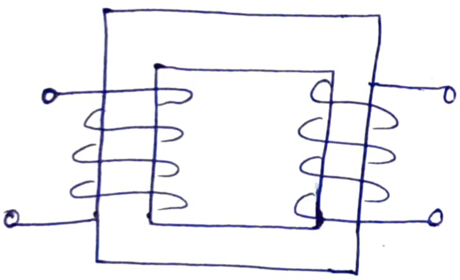
Construction :

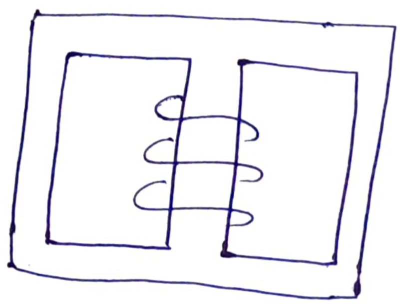
→ designed by ferromag. mat. → also by lam. sheets.

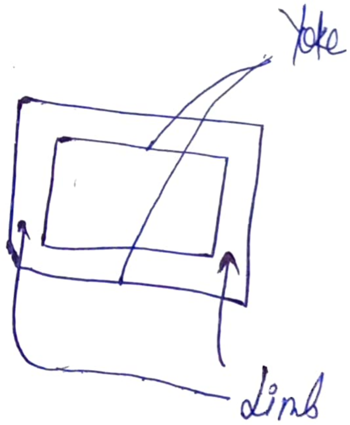


TYPE

- Core
- Shell







Core

→ Winding surround the core.

→ Windings are placed on left & right limb of core of tr.

→ Dim. of left & right lim is less.

Shell

→ Core surround the wind.

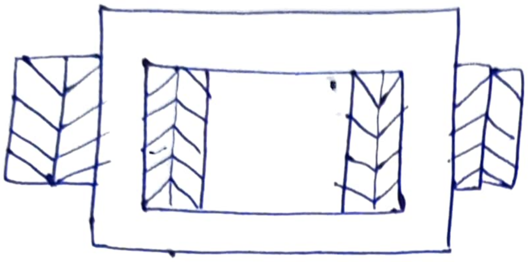
→ Both the win. are placed at centre limb.

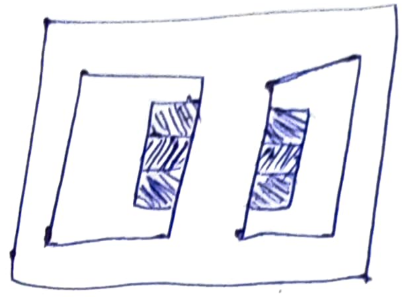
→ Dim. of centre limb is more.

Yoke / Limb

→ hold the coil.

→ also known as 'Core' of tr.





→ Win. is Concentric patt.

→ Win. is Sandwich Patt.

TYPE

- Step-up
- Step-down

→ If sec. vol. is gr. than. pr. i.e.

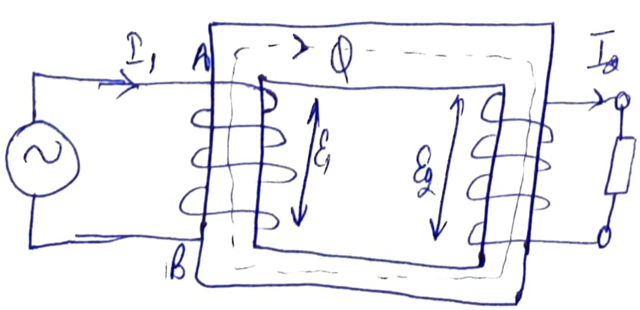
$V_2 > V_1$

→ $V_1 > V_2$

→ 1) Low vol. winding

2) High vol. wind.

Operating Principle of Transformer :



App. :-

1) Used to step-up & step down vol.

2) Only dev. by which isolate the two ckt. or used as a isolator.

3) Tr. also used as a measuring inst, PT (Potential tr) & CT (Current tr)

4) Only dev. to do impedance matching.

5) Impulse generation.

6) also used as welding m/c.

Ideal Transformer :

→ If both the winding are purely inductive i.e zero res.

→ Leakage flux of tr. is zero.

→ The loss of tr. is zero.

→ Eff. of tr. is 100%.

→ Coeff. of Coupling of tr. is '1'.

EMF eq^n :

⇒ Let $\phi = \phi_m \sin \omega t$

Since supp vol. is sinu. → core is mag. → MF is gen.

Now, Induced emf for a single turn coil,

$$e = -\frac{d\phi}{dt} = -\frac{d}{dt}(\phi_m \sin\omega t)$$

$$= -\phi_m \omega \cos(\omega t) = -\phi_m (2\pi f) \cos(\omega t)$$

$$\boxed{e = \phi_m (2\pi f) \sin(\omega t - \pi/2)}$$

$$\boxed{e = E_m \sin(\omega t - \pi/2)}$$ where, $E_m = (2\pi f)\phi_m$ (max. value)

$\Rightarrow E_{rms} = \frac{E_m}{\sqrt{2}}$

$$E_{rms} = \frac{2\pi f \phi_m}{\sqrt{2}} \Rightarrow \boxed{E_{rms} = 4.44 f \phi_m}$$

$\therefore$ Induced emf for 'N_1' no. of turn,

$$E_1 = 4.44 f \phi_m N_1$$

Induced emf for 'N_2' no. of turn, $E_2 = 4.44 \phi f N_2$

N_1 = No. of turn of pr. coil
N_2 = " " " " sec. coil.

$\Rightarrow$ In general, emf eqn is, $\boxed{E = 4.44 f \phi_m N}$

$\Rightarrow \quad \frac{E_1}{E_2} = \frac{N_1}{N_2}$

$\rightarrow$ But for Ideal tr. $V_1 \approx E_1$ & $V_2 \approx E_2$

$\therefore \quad \boxed{\frac{E_1}{E_2} = \frac{V_1}{V_2}}$

$V_1 \rightarrow$ primary vol.

$V_2 \rightarrow$ sec. vol.

$$\boxed{\frac{V_1}{V_2} = \frac{N_1}{N_2}}$$

$\Rightarrow \quad V_2 = \left(\frac{N_2}{N_1}\right) V_1 \quad \Rightarrow \quad \boxed{V_2 = \frac{1}{k} V_1}$ where, $k = \frac{N_1}{N_2}$

"turn ratio"

$\rightarrow$ If $k > 1 \Rightarrow V_2 < V_1 \Rightarrow$ step down tr.

$\rightarrow$ If $k < 1 \Rightarrow V_2 > V_1 \rightarrow$ step up tr.

$\Rightarrow$ If $k = 1 \Rightarrow V_2 = V_1 \Rightarrow$ Isolator or 1:1 transformer

$\Rightarrow$ If want to isolate the ckt $\Rightarrow$ use 1:1 tr.

$\rightarrow$ For an Ideal tr.,

$\Rightarrow$ VA in primary = VA in sec.

i.e. $\boxed{V_1 I_1 = V_2 I_2}$

$$\Rightarrow \quad \frac{V_1}{V_2} = \frac{I_2}{I_1}$$

But $\frac{V_1}{V_2} = \frac{N_1}{N_2} \quad \Rightarrow \quad \therefore \boxed{\frac{I_2}{I_1} = \frac{N_1}{N_2}}$

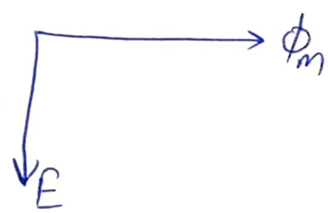
or $\boxed{\frac{I_1}{I_2} = \frac{N_2}{N_1}}$

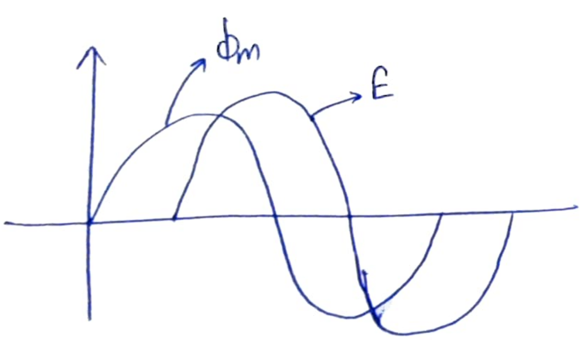
$$\Rightarrow \quad \phi = \phi_m \sin(\omega t) \quad \text{--- (1)}$$

$$E = 4.44\, f\, \phi_m\, N_1$$

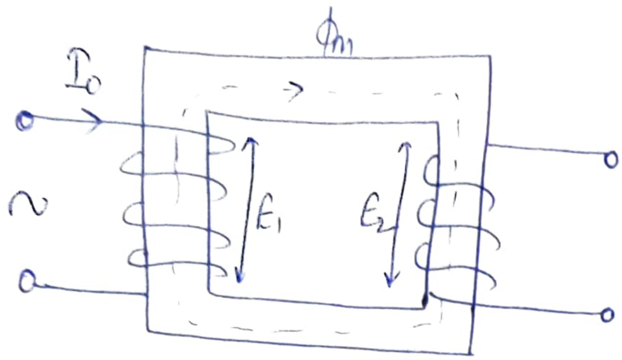
$$\Rightarrow \quad E = E_m \sin\left(\omega t - \pi/2\right) \quad \text{--- (2)}$$

$\Rightarrow$ E lags the ϕ by "$\pi/2$".





$\rightarrow$ <u>Tr. at No Load Cond.</u> :



⇒ when secondary is at no load i.e. nothing is connected (no load) i.e. tr. is at no load.

⇒ when apply vol. at pri. at no load a pri. current gen. (I_0).

(I)
⇒ Purpose of I_0 current is to magnetize the core of the tr.

⇒ At no load ⇒ 'Cu' loss is very less to 'core' loss. so we neglect 'Cu' loss. [$I_0 <<< I_{rated}$]

(II)
⇒ Overcome the core loss of the tr.

→ I_0 has two component → (I) & (II)

⇒ $I_\mu = I_m$ (magnetize component)

⇒ I_w = Loss component

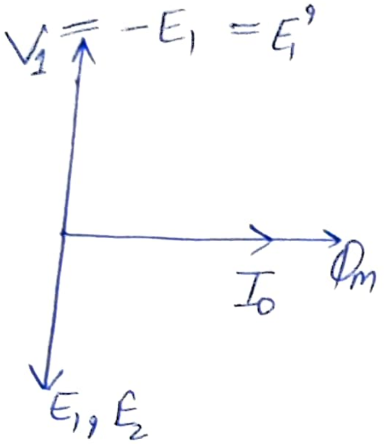
⇒ at no load $I_w = 0$ ⇒ $\boxed{I_0 = I_m = I_\mu}$

⇒ In tr. ⇒ ϕ_m is common (it is drawn hor. in phasor)

⇒ Both E_1 & E_2 are of same phase.

⇒ Ind. emf E_1 is dev. due to supply vol. V_1

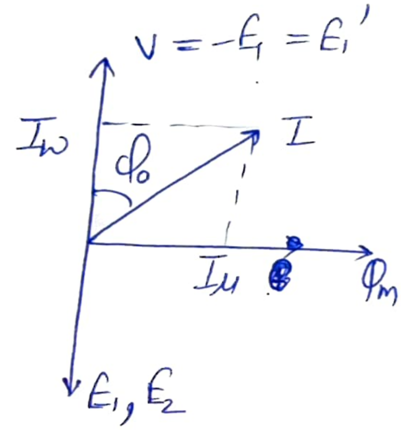
⇒ V_1 & E_1 are 180° part acc. to Lenz law.



$\Rightarrow$ for Ideal tr., $\boxed{V_1 = E_1}$

(only mag. but not dir^n)

$\rightarrow$ for practical tr. I_w will also be there. $\longrightarrow$

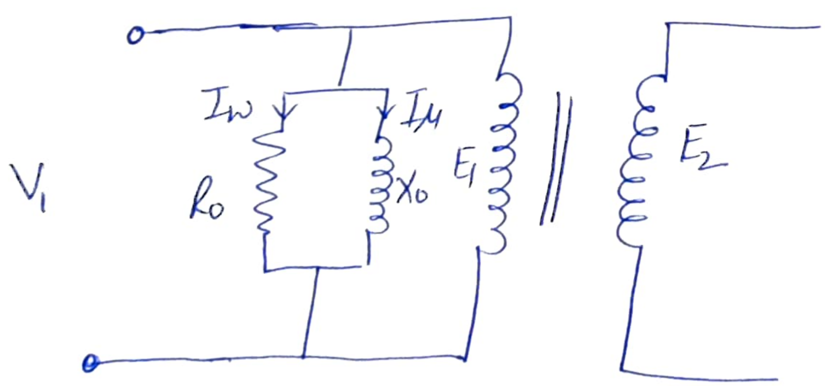


No load equivalent ckt of Tr. :

$\Rightarrow \quad \vec{I_0} = \vec{I_\mu} + \vec{I_w}$

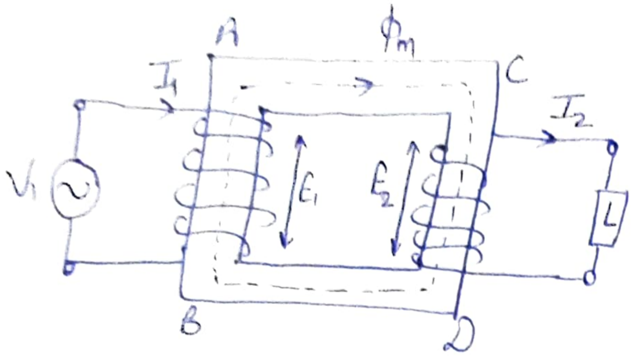
$\Rightarrow$ how much MF is gen. or dev. $\Rightarrow$ depends on reactance (X_0) value

$\Rightarrow$ how much loss is there $\Rightarrow$ depends on resistance value (R_0)



op. pr. of tr. at no load do upto this ckt.

Transformer on loaded Condition :



$\Rightarrow$ Across sec. E_2 is ind. Current I_2 starts flowing. ϕ_2 is also induced.

$\Rightarrow$ ϕ_2 opposes main flux or MF.

$\Rightarrow$ $\phi\downarrow$ $\Rightarrow$ $E_1\downarrow$

$\Rightarrow$ Tr. will draw more current from supply.

$\Rightarrow$ Value of more current is (I_1').

$\Rightarrow$ Due to which extra mmf $\overset{dev.}{\wedge}$ = $N_1 I_1'$

$\Rightarrow$ Nature of $N_1 I_1'$ is such that it neutralize $N_2 I_2$.

$\Rightarrow$ i.e. current from pr. goes to sec. ckt.

$\rightarrow$ $I_1 = I_0 + I_1'$

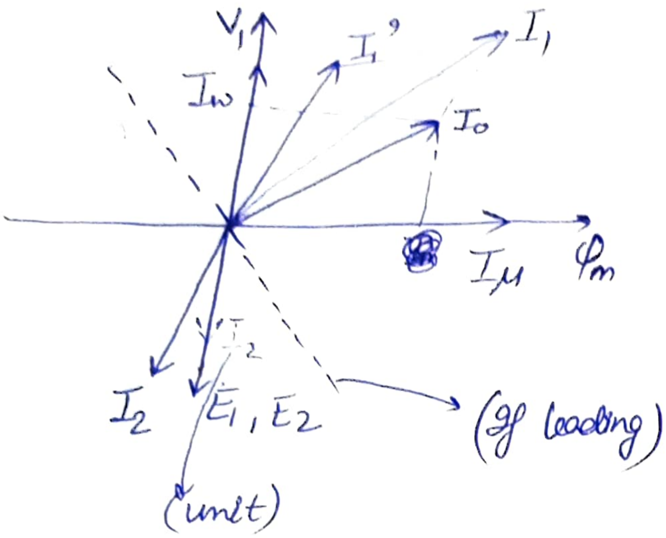
$\Rightarrow$ I_2 & I_1' are in opposition.

$\Rightarrow$ Nature of Load
- Unit pf. (Resistive)
- Lagging pf. (Inductive)
- Leading pf. (Capacitive)

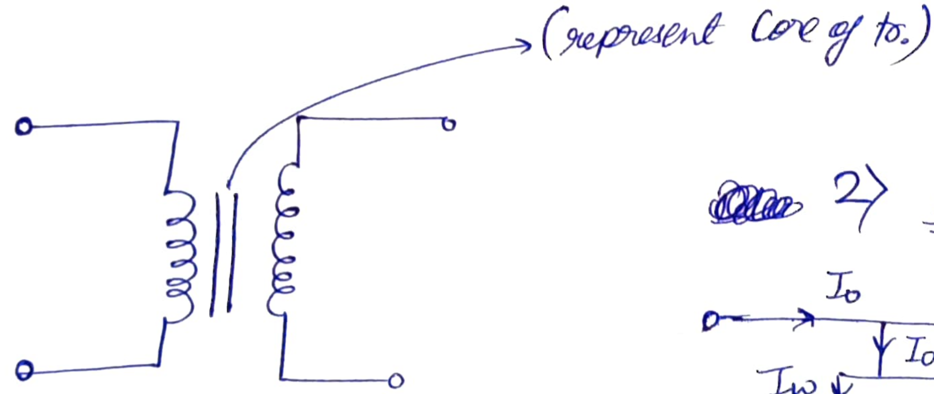
Lagging pf :

(Lag → clockwise dir^n)

** [Qn. pr. of loaded tr. & to draw phase dia.]

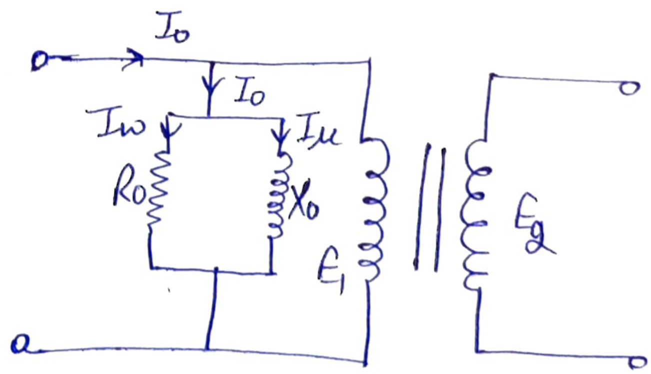


Equivalent ckt :



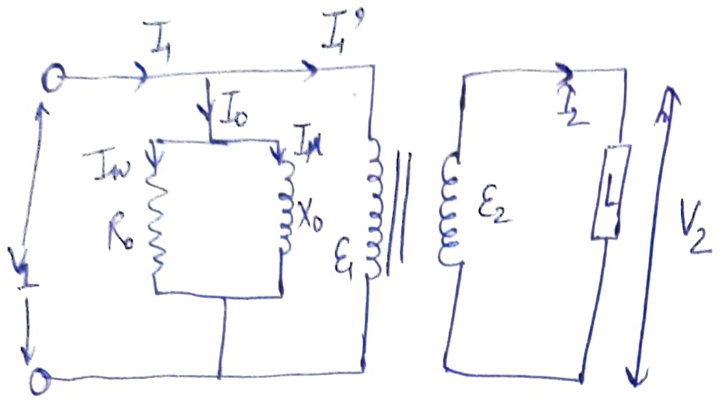
1) Ideal tr.

2) At No Load Cond.

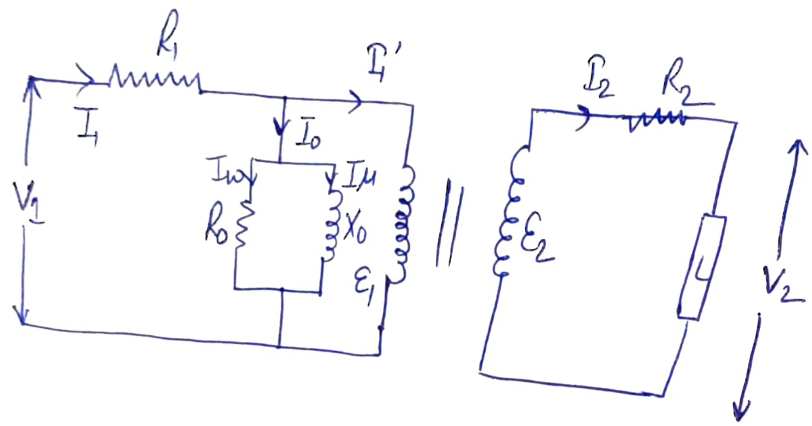


X_0 depend on how much MF is dev.

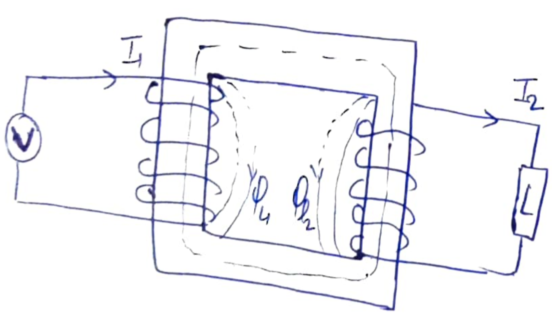
3) At Loaded Cond. :



4) <u>Considering Winding resistance</u> :



5) <u>Leakage Reactance</u> :



Due to ϕ_{l_1} & ϕ_{l_2}

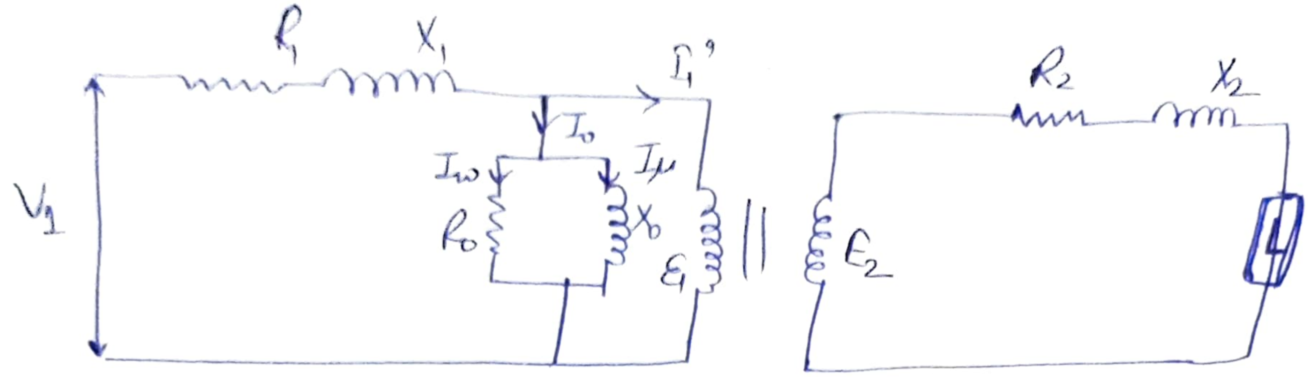
$\phi_{l_1} \rightarrow$ leakage flux in pr.

$\phi_{l_2} \rightarrow$ leakage flux in sec.

$\Rightarrow$ for ϕ_{l_1} & ϕ_{l_2} some leake reactance has to consider.

$\Rightarrow$ $X_1 \rightarrow$ prim. leakage reactance.

$\Rightarrow$ $X_2 \rightarrow$ sec. leakage reactance



⇒ Reactance of coil helps us to magnetize or generate MF.

⇒ No. of turn of coil = Reactance value.

⇒ Coil Reactance value in eq. ckt is "I_0".

Refferred Value :

→ Now referred to pr. side : i.e. all the sec. side component transfer to pr. side.

Let R_2' = sec. side res. in pr. side

and X_2' , $\boxed{I_2' = I_1'}$

$$\Rightarrow I_2^2 R_2 = I_2'^2 R_2'$$

$$\Rightarrow R_2' = \left(\frac{I_2}{I_2'}\right)^2 R_2 = \left(\frac{I_2}{I_1'}\right)^2 R_2 = \left(\frac{N_1}{N_2}\right)^2 R_2$$

$$\Rightarrow \boxed{R_2' = \left(\frac{N_1}{N_2}\right)^2 R_2}$$

Similarly,

$$\boxed{X_2' = \left(\frac{N_1}{N_2}\right)^2 X_2}$$

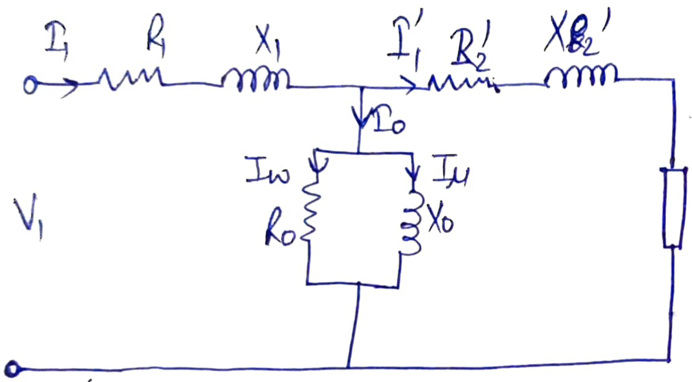
→ Now, referred to sec. side :

R_1' = referred value of R_1 in sec. side
X_1' = " " " X_1 " " "

$\Rightarrow \quad I_1^2 R_1 = I_1'^2 R_1' \quad \Rightarrow \quad R_1' = \left(\frac{I_1}{I_1'}\right)^2 R_1 = \left(\frac{I_1}{I_2}\right)^2 R_1$

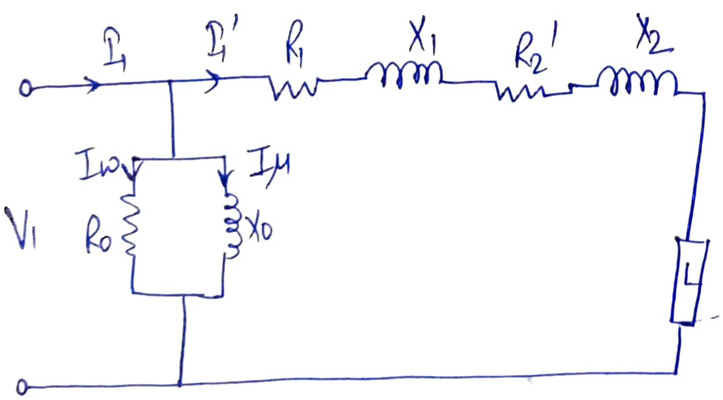
$\Rightarrow \boxed{R_1' = \left(\frac{N_2}{N_1}\right)^2 R_1}$

Equivalent ckt referred to pr.



(Exact eq. ckt)

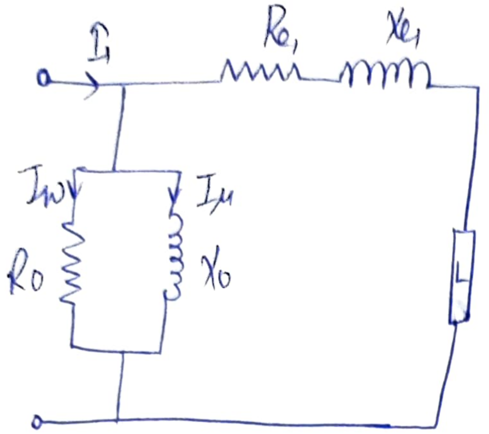
when $I_0 << I_1$ then $I_0 R_1$ or $I_0 X_1$ drop is also very less so the ckt further redrawn as,



(approximation eq. ckt)

→ Helps us to find out the expr. of voltage regulation of tr.

→ Other adv. is that all quan. is add up but at above it is not.



R_{e_1} = eq. resis. referred to pr.

$R_{e_1} = R_1 + R_2'$
$= R_1 + \left(\frac{N_2}{N_1}\right)^2 R_2$

** [Draw, expl. eq^n ckt of tr.
starts from ideal tr. & ends at the eq^n. ckt]

→ KVL

⇒ KVL in pr. side,

$V_1 = I_1 R_1 + I_1 X_1 + E_1$

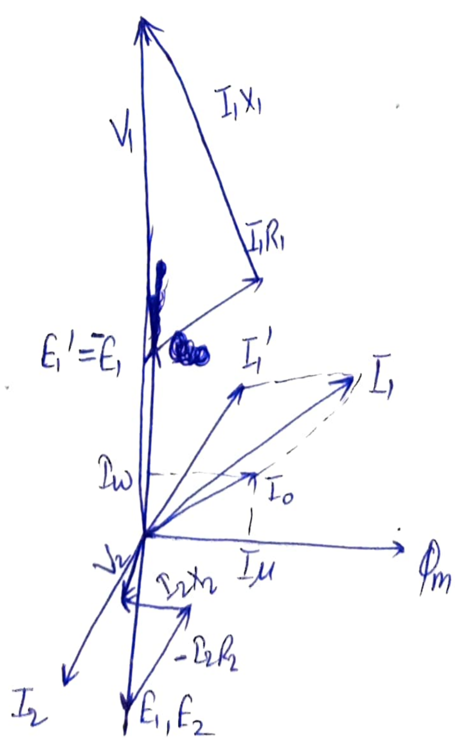
⇒ KVL in sec., $V_2 = E_2 - I_2 R_2 - I_2 X_2$

⇒ $E_2 = V_2 + I_2 R_2 + I_2 X_2$

At full load, $\boxed{E_1 = E_1'}$

⇒ $V_1 = E_1' + I_1 R_1 + I_1 X_1$

Full load phasor diag. :-



→ $I_1R_1 \parallel I_1$

⇒ $I_1X_1 \perp I_1$

⇒ $I_2R_2 \parallel I_2$

→ V_2 shouldn't be in IV Quad. as V_2 lags E_2.

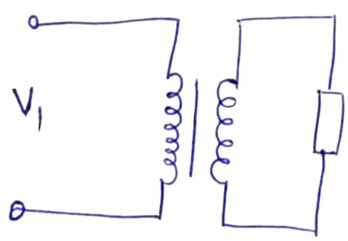
Voltage Regulation :

⇒ $$VR = \frac{V_{NL} - V_{FL}}{V_{FL}}$$

NL → No Load
FL → full "

⇒ V_{NL} → sec. side terminal vol. (no Load)
⇒ V_{FL} → sec. side ter. vol. (full Load)

→ At Const. pf & load diff. of no load & full load ter. vol. of sec. wrt full load vol. of sec.



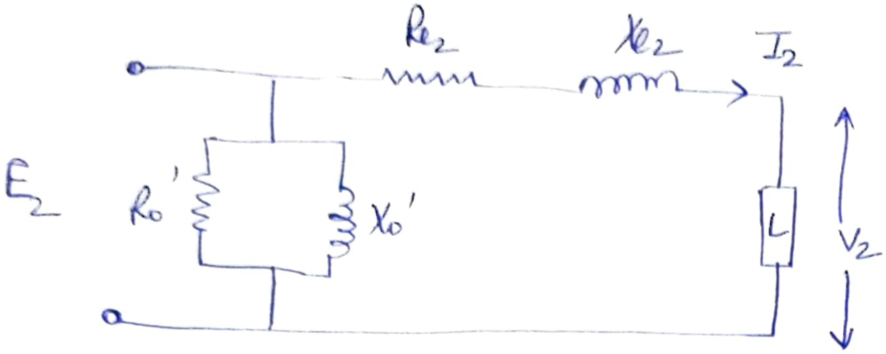
Need of Vol. regulation :

→ ① Consumer should be satisfied or Consumer satisfaction.

→ Tolerance is ±5%.

② Hooking Phenomena.

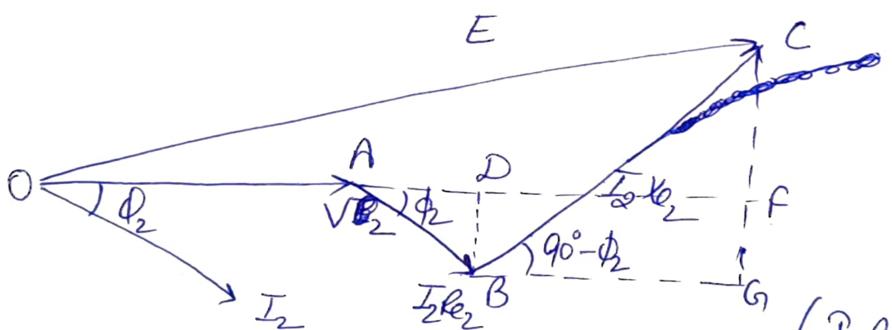
③. Over loading



$$E_2 = I_2 R_{e_2} + I_2 X_{e_2} + V_2$$

$$= V_2 + I_2 R_{e_2} + I_2 X_{e_2} = V_2 + I_2 (R_{e_2} + j X_{e_2})$$

Phasor :



$(I_2 R_{e_2} \parallel I_2)$

$$\left[OC^2 = OF^2 + CF^2 \right.$$
$$OF = OA + AD + DF$$
$$\left. CF = CG - FG \right]$$

Let, $V_2 = V_2 \angle 0°$

$I_2 = I_2 \angle \phi_2$

$$\Rightarrow E_2 = V_2 \angle 0 + I_2 \angle \phi_2 (R_{e_2} + j X_{e_2})$$

$$= V_2 + (I_2 \cos\phi_2 - j I_2 \sin\phi_2)(R_{e_2} + j X_{e_2})$$

$$= V_2 + I_2 R_{e_2} \cos\phi_2 + I_2 X_{e_2} \sin\phi_2 + j(I_2 X_{e_2} \cos\phi_2 - I_2 R_{e_2} \sin\phi_2)$$

$\Rightarrow E_2 = V_2 + I_2 R_{e_2} \cos\phi_2 + I_2 X_{e_2} \sin\phi_2$

$\Rightarrow E_2 - V_2 = I_2 R_{e_2} \cos\phi_2 + I_2 X_{e_2} \sin\phi_2$

$\Rightarrow VR = \dfrac{I_2 R_e \cos\phi_2 + I_2 X_{e_2} \sin\phi_2}{V_2}$ (for Lagging P.f.)

$\Rightarrow VR = \dfrac{I_2 R_e \cos\phi_2 - I_2 X_{e_2} \sin\phi_2}{V_2}$ (for leading P.f.)

→ Cond. of Zero vol. reg.:

→ for zero vol. reg $\Rightarrow I_2 R_{e_2} \cos\phi_2 + I_2 X_{e_2} \sin\phi_2 = 0$

$\Rightarrow \boxed{\tan\phi_2 = -\dfrac{R_{e_2}}{X_{e_2}}}$ [(−ve) side indicate leading Pf of tos]

→ Vol. reg. is zero for leading P.f. of Load.
→ Vol. reg. is also (−ve) for leading P.f. of Load.

→ Cond. of max. vol. regulation:

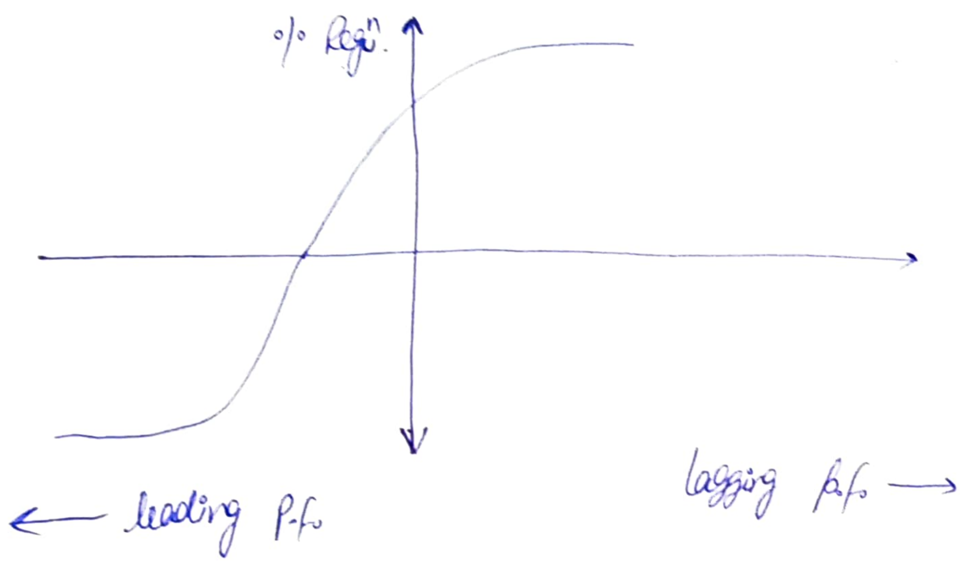
$\Rightarrow \dfrac{d}{d\phi_2}\left(I_2 R_{e_2} \cos\phi_2 + I_2 X_{e_2} \sin\phi_2\right) = 0$

$\Rightarrow I_2 R_{e_2}(-\sin\phi_2) + I_2 X_{e_2} \cos\phi_2 = 0$

$$\Rightarrow \boxed{\tan\phi_2 = \frac{X_{e_2}}{R_{e_2}}} \quad \text{(lagging p.f.)}$$

→ Vol. reg. is max. for lagging P.f. of load.

⇒ <u>% Vol. reg. Vs Peretation</u> :



[Expr. of vol. reg.
If you change P.f. % reg changes.? starts from exp of vol. reg.]

Loss of Transformer

- Iron Loss or Core Loss
  - Hysteresis Loss
  - Eddy Current Loss
- Copper Loss

→ **Eff. of Tr.** :

$$\eta = \frac{O/P}{I/P}$$

$$\Rightarrow \eta = \frac{O/P}{O/P + loss} = \frac{O/P}{O/P + P_i + P_c} = \frac{V_2 I_2 \cos\phi_2}{V_2 I_2 \cos\phi_2 + P_i + I_2^2 R_{e_2}}$$

$$\Rightarrow \eta_{max.} \rightarrow P_i = P_c \quad (\text{Iron Loss} = \text{Core Loss})$$

$$\Rightarrow \eta_{max.} = \frac{I_2 V_2 \cos\phi_2}{V_2 I_2 \cos\phi_2 + 2P_i}$$

→ Cu loss depend on current so as I changes Cu loss changes.

→ If x is the fraction of full load, the eff. of tr. at this fraction is given by the relation,

$$\eta_x = \frac{x \times (V_2 I_2 \cos\phi_2)}{x(V_2 I_2 \cos\phi_2) + P_i + x^2 P_c}$$

again, $\eta_x = \dfrac{x S \cos\phi_2}{x S \cos\phi_2 + P_i + x^2 P_c}$ (where, $S = V_2 I_2$)

OR

→ $\eta_x = \dfrac{x S_{fl} \cos\phi_2}{x S_{fl} \cos\phi_2 + P_i + x^2 P_c}$

where, V_2 = full load sec. Vol. or V_{2fl}

I_2 = full load sec. Current or I_{2fl}

Again, at $\eta_{max.} \Rightarrow P_i = P_c$

$\Rightarrow P_i = I_2^2 R_2 \Rightarrow \boxed{I_2 = \sqrt{\dfrac{P_i}{R_2}}}$

⇒ But at fractional load 'x' the Cu loss $= x^2 P_c$

$\therefore$ at $\eta_{max.} \Rightarrow \boxed{P_i = x^2 P_c}$

that means fractional load is calculated by

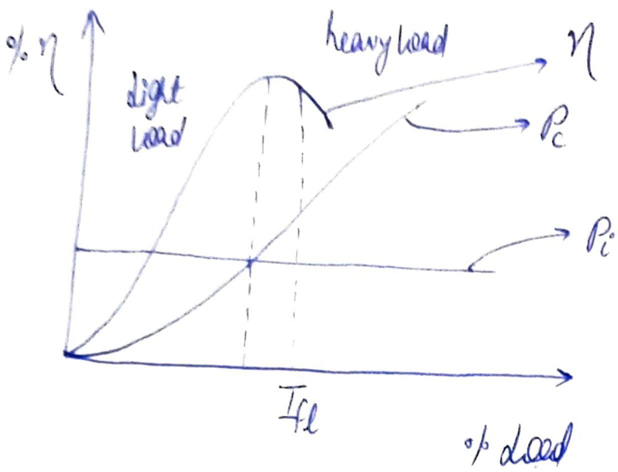
$$\boxed{x = \sqrt{P_i / P_c}}$$

→ Output KVA corresponding to max. eff.,

$= x \times$ full load KVA

$=$ full load KVA $\times \sqrt{(P_i/P_c)} = \boxed{S_{fl} \sqrt{P_i/P_c}}$

Efficiency Vs Load : (Iron Loss is Constant Loss)



⇒ Eff. of tr. is max. near the full load current.

⇒ Or where $P_i = P_c$.

⇒ Eff. is ↓ for heavy load.

→ Loss in tr. is less than DC M/C.

⇒ Eff. of tr. > eff. of D/C max.

⇒ Eff. of tr. is more than 90%.

Efficiency Vs Power factor :

⇒ We know that, $\eta = \frac{O/P}{O/P + Loss}$

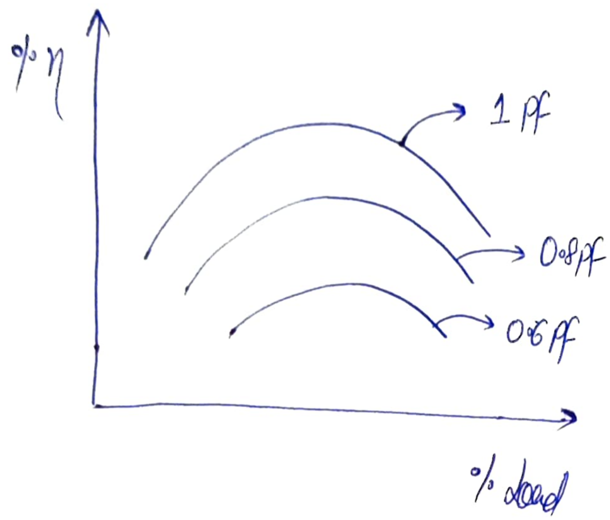
$$\Rightarrow \eta = 1 - \frac{Loss}{O/P + Loss} = 1 - \frac{Loss}{V_2 I_2 \cos\phi_2 + Loss}$$

$$= 1 - \frac{Loss/V_2 I_2}{\cos\phi_2 + Loss/I_2 V_2} = \boxed{1 - \frac{m}{\cos\phi_2 + m}}$$

$\left[\text{where, } m = \frac{Loss}{V_2 I_2}\right]$

$$= 1 - \frac{m/\cos\phi_2}{1+m/\cos\phi_2}$$

$\Rightarrow$



→ <u>All day Eff.</u> :-

$\Rightarrow \eta = \frac{O/P}{I/P}$

→ Since the eff. of tr. is defined as (output power) / I/p power but the load on a certain tr. fluctuate throughout the day.

Types
- Power tr. >250 mVA
- distribution tr. 0-250 mVA

$\Rightarrow$ Vol. reg. is better in distribution than Power tr. bcoz Consumer get power from distr. at that time vol. is maintained at Const.

The distr. tr. are energized ~~for~~ 24 hr., But they deliver very light load for major portion of day. Thus, Iron loss occur for whole day is constant. But the Cu loss occur only when the tr. is in loaded cond. and is not const. Hence, performance of tr. cannot be judged by the power eff., but it can be judged by "all day eff." also known as "operational eff." or "Energy eff." which is calculated on the basis of energy consumed during a period of 24 hr.

$\therefore$ all day eff. is defined as ratio of O/P in kwh by I/P kwh for a period of 24 hr.

$$\boxed{\eta = \frac{O/P\ kwh}{I/P\ kwh}}$$

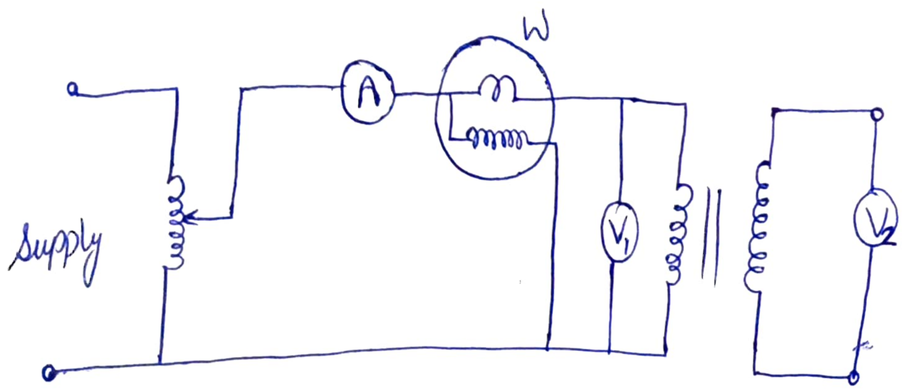
or

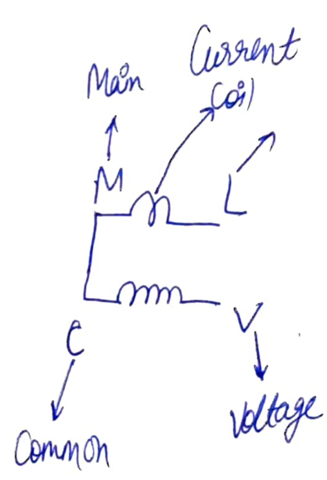
$$\eta = \frac{O/P\ energy}{I/P\ energy}$$

$\Rightarrow$ all day eff. is used by distribution tr.

Test on Transformer : $\rightarrow$ open ckt test, short ckt test

1). Open ckt test $\rightarrow$





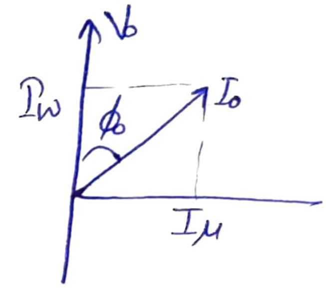
→ For open ckt test ⇒ we have to do on high vol. side.

→ $I_0 <<$ No load Current

→ We do open ckt test to determine Core Loss of trans.

→ Wattmeter reading, $P_0 = V_0 I_0 \cos\phi_0$

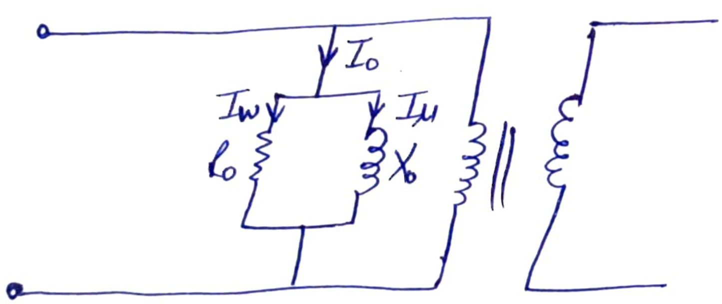
V_0 → Vol. at no load



$$\Rightarrow \cos\phi_0 = \frac{P_0}{V_0 I_0}$$

$$\Rightarrow I_w = I_0 \cos\phi_0 \quad \& \quad I_\mu = I_0 \sin\phi_0$$

<u>Eq. ckt</u> : (No Load)



R_0 → No load eqn resistance

X_0 → No load eqn reactance.

⇒ By open ckt test we can also find the equivalent ckt at no load cond.

Short ckt Test :

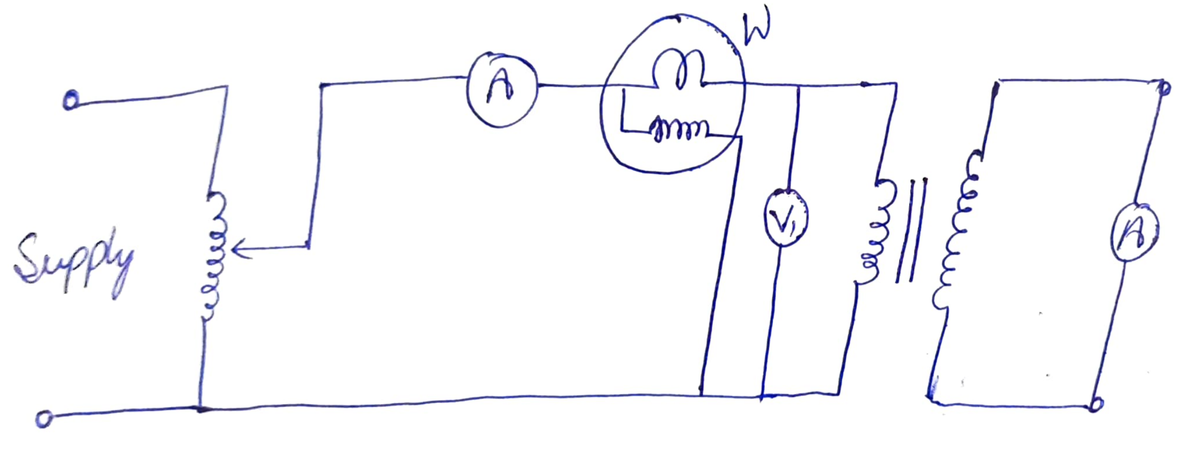
→ Trf. draw huge amount of Current.

→ By Conducting short ckt we can calculate "Cu Loss".

→ Apply vol. in such a way that rated Current flow through trf.

→ Low vol. is applied. How much ?

→ We have to Conduct the test at High Vol. Side & Low vol. side short ckt.



⇒ $P_{sc} = I_{2sc}^2 R_{e_2}$

→ Voltmeter reading, $V = I_{sc} Z_{es}$ ⇒ $Z_{es} = V/I_{sc}$

⇒ $X_{es} = \sqrt{Z_{es}^2 - R_{e_2}^2}$

→ By cond. short ckt test we can determine full load equi. ckt of the trf.

Purpose of Test :

1) To measure Core loss and Cu Loss.

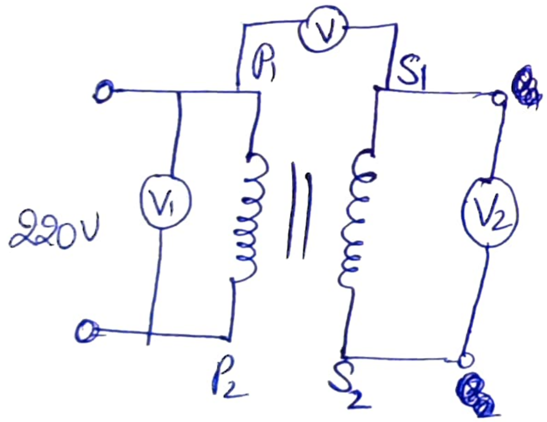
2) Can Measure the eqn ckt parametres of tf.

3). Eff. Can be Calculated of tf.

4) Vol. regulation of the tf. Can also be Calculated by Conducting open ckt and short ckt test.

Polarity test :

→ Two battery Can never be Connected in || unless until there value are same.

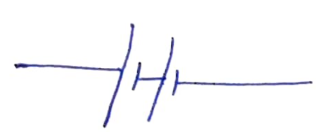


$V_1 = 220\,V$

$V_2 = 110\,V$

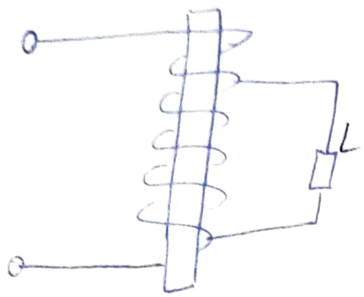
$V_3 = V_1 + V_2$ = additive

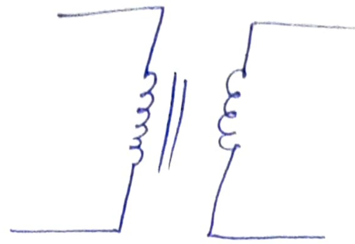
$= V_1 - V_2$ = subtractive



opp. polarity → additive

Auto Transformer : (Variac)



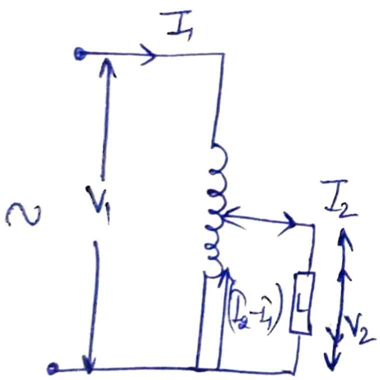


Two-winding Tr.

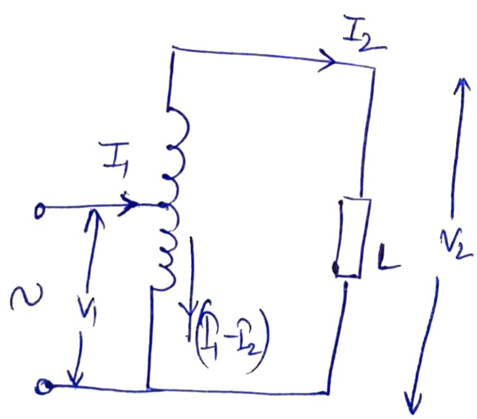
⇒ Single coil ~~coil~~ is present in Core of tr.

⇒ Single coil is treated as both Pr. & sec.

⇒ It can be step-up or step-down as two winding tr.



Step down auto tr.



Step up auto tr.

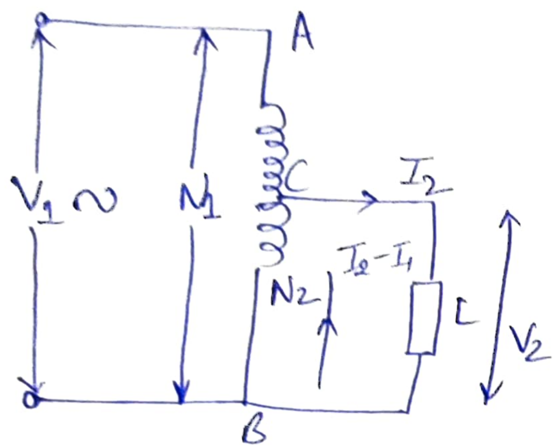
⇒ $V_2 < V_1$

⇒ $I_2 > I_1$

⇒ $V_1 < V_2$

⇒ $I_1 > I_2$

Working Pr. of Auto tr. :



$V_1 \rightarrow$ Vol. across A & B. (pr. vol.)

$N_1 \rightarrow$ No. of turns of AB part

$V_2 \rightarrow$ Vol. of C & D (sec. vol.)

$N_2 \rightarrow$ No. of turns of CB parts

$\Rightarrow (N_1 - N_2)$ = No. of turns of AC part

$\Rightarrow V_1 - V_2$ = Vol. of AC part.

→ AC is series winding of auto tr.
→ CB is common winding of auto tr.

Now, I/P power = O/P power

$$V_1 I_1 \cos\phi_1 = V_2 I_2 \cos\phi_2$$

now, neglecting internal leakage part & loss of tr.,

$$\cos\phi_1 = \cos\phi_2$$

$\Rightarrow V_1 I_1 = V_2 I_2$ or $\boxed{\frac{V_1}{V_2} = \frac{I_2}{I_1}}$ or $\boxed{\frac{V_2}{V_1} = \frac{I_1}{I_2} = \frac{N_2}{N_1} = K}$

$\left(\frac{N_1}{N_2} = K = \text{Turn ratio}\right)$ (K = Transformation ratio)

$\Rightarrow$ Power tr. from I/p to o/p is done by 2 ways.

1). Due to Conductive effect.

2) Due to Inductive effect. (due to tf action).

$\Rightarrow$ mmf of AC $= I_1(N_1 - N_2)$

$$= I_1N_1 - I_1N_2 = I_2N_2 - I_1N_2 \quad [\because I_1N_1 = I_2N_2]$$

$$= (I_2 - I_1)N_2 = \text{mmf of } BC$$

$\rightarrow$ Output:

Power transformed Inductively in VA $= V_{AC} I_{AC}$

$$= (V_1 - V_2) I_1$$

$\rightarrow$ Total I/p power $= V_1 I_1$

$\rightarrow \therefore$

$$\frac{\text{Power transformed Inductively}}{\text{I/p power}} = \frac{(V_1 - V_2) I_1}{V_1 I_1} = 1 - \frac{V_2}{V_1}$$

$$= 1 - \frac{N_2}{N_1} = (1 - K)$$

$\Rightarrow$ Power tr. Inductively $= (1-K) \times [\text{I/p power}]$

$\Rightarrow$ Power tr. Conductively $=$ I/p power $-$ Power tr. Inductively

→ Power tr. Conductivity $= k$ [I/p power]

[Short notes upto this]

[adv. disadv. Saving.]

Saving in Copper :

⇒ Current value depend on Cross-sec.

⇒ Length of Copper depend on No. of turns.

⇒ Wattage of Copper $\propto$ (No. of turns)(Current

⇒ Weight of autotr. = Weight of AC part + Weight of BC part

$$= I_1(N_1 - N_2) + (I_2 - I_1)N_2$$

$$= I_1 N_1 + I_2 N_2 - 2 I_1 N_2$$

⇒ Weight of Two winding Trf. $= I_1 N_1 + I_2 N_2$

$$\Rightarrow \frac{W_{auto}}{W_{Twowinding}} = \frac{I_1 N_1 + I_2 N_2 - 2 I_1 N_2}{I_1 N_1 + I_2 N_2}$$

$$= 1 - \frac{2 I_1 N_2}{I_1 N_1 + I_2 N_2}$$

$$= 1 - \frac{2\left(\frac{N_2}{N_1}\right)}{1 + \left(\frac{I_2 N_2}{I_1 N_1}\right)} = 1 - K$$

$\Rightarrow W_{auto} = (1-k) W_{Two\text{-}winding}$

$\Rightarrow \therefore$ Saving in Copper in auto to $= k W_{Two\text{-}winding}$

<u>adv.</u> :-

→ Less Cost
→ Less Core Loss (Cu loss)
→ eff. > two winding
→ change Vol. value from 0 to higher.

<u>disadv.</u> :-

→ It cannot be used as an Isolator.

⇒ Tf. rating is always KVA. or VA.
⇒ bcoz it has 2 loss Cu & Fe.
⇒ Fe loss depends on Vol.
⇒ Cu loss depends on current.
⇒ ∴ Total loss depend on V & I.

If we use 220 DC instead of AC ⇒ at Instant the Tf burn out.
as I ↑ reactance ≈ 0.

Q. 6600/230 V, 50 Hz single phase core type t/f as core sec. 25 cm x 25 cm. Calculate the approximate no. of primary and secondary turn if the flux density = 1.1 wb/m².

Sol^n. We know that, $E = 4.44 f \phi_m N$

$\therefore \quad E_1 = 4.44 f \phi_m N_1$

But $\quad E_1 = V_1 \Rightarrow V_1 = 4.44 f \phi_m N_1$

$\Rightarrow \quad 6600 = 4.44 \times 50 \times 1.1 \times N_1 \Rightarrow N_1 = 432$

$\Rightarrow E_2 = 4.44 f B_m A_1 N_2$

Or $V_2 = 4.44 f B_m A_1 N_2 \Rightarrow \quad N_2 = 15$

Or $\quad \frac{V_1}{V_2} = \frac{N_1}{N_2}$

Q2. A 40 kVA, 2000/250 V t/f as a pr. resistance of 1.15 & sec. resistance of 0.0155 Ω. Calculate,

(i) total resistance in terms of sec. winding.

(ii) total resistance drop on full load.

(iii) total 'Cu' loss on full load.

Sol^n: $R_{e_2} = R_2 + R_1'$

$\Rightarrow R_{e_2} = R_2 + \left(\frac{N_2}{N_1}\right)^2 R_1$

$\Rightarrow R_{e_2} = 0.0155 + \left(\frac{250}{2000}\right) \times 1.15 = 0.03346\ \Omega$

$\Rightarrow I_2 = \frac{40 \times 10^3}{250} = 160\ A$

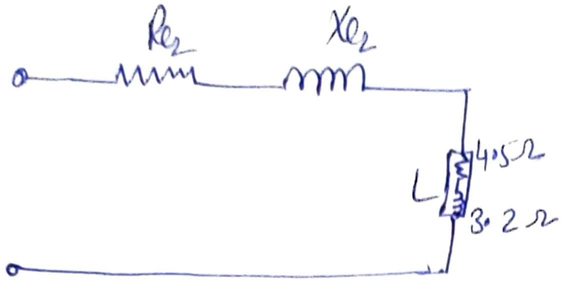
$\Rightarrow$

(iii) $I_2^2 R_{e_2} =$

Q3. A single phase 3300/400 V trf. has the foll. winding resistance & reactance. $R_1 = 0.7\Omega$, $R_2 = 0.011\Omega$

$X_1 = 3.6\Omega$, $X_2 = 0.045\Omega$

The sec. is connected to a coil having a resistance of 4.5Ω and inductive reactance of 3.2Ω. Calculate the sec. terminal voltage & power consumed by the coil.



$$\Rightarrow R_{e_2} = R_2 + R_1' = R_2 + \left(\frac{N_2}{N_1}\right)^2 R_1$$

$$= 0.011 + \left(\frac{400}{3300}\right)^2 \times 0.7 = 0.0213\ \Omega$$

$$\Rightarrow X_{e_2} = X_2 + \left(\frac{N_2}{N_1}\right)^2 X_1 = 0.045 + \left(\frac{400}{3300}\right)^2 \times 3.6 = 0.0979\ \Omega$$

$$\Rightarrow \text{Total Impedance} = 0.0213 + 4.5 + j(0.0979 + 8.2)$$

$$= 4.5213 + j\,(3.2979)$$

$$\Rightarrow I_2 = \frac{V}{Z_{Total}} = \frac{400}{5.596} = 71.48 \angle -36.1\ A$$

$$\Rightarrow V_2 = I_L \times Z_{coil} = I_L(4.5213 + j\,3.2979)$$

$$= 71.48 \angle -36.1 \cdot \sqrt{(4.5)^2 + (3.2)^2}\ \angle \tan^{-1}(3/4)$$

$$= 394.7 \angle -0.68$$

$$\Rightarrow \text{Power Consumed} = I_2^2 R_{coil}$$

$= (71.48)^2 \times 4.5 = 22\,99.2 \text{ W}$

Q A single phase tf has 1200 turn on pr. & 300 turn on sec. The no load current is 2.5 A and no load power factor is 0.2 lagging. Calculate current & pf of pr. ckt when sec. draw a current of 300 A at a pf of 0.8 lagging.

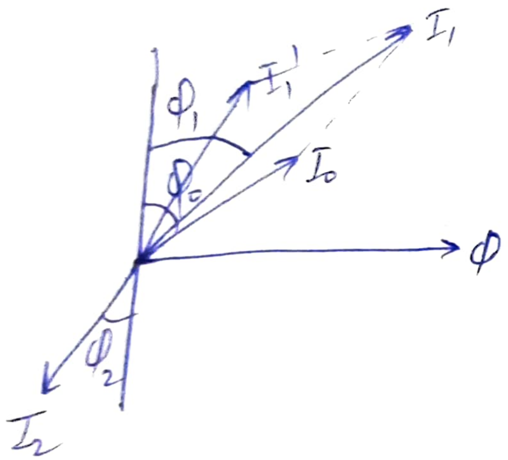
Sol^n: $I_0 = 2.5A$

$I_2 = 300A$

$\Rightarrow \vec{I_1} = \vec{I_0} + \vec{I_1'}$

$\Rightarrow \frac{I_1'}{I_2} = \frac{N_2}{N_1}$

$\Rightarrow I_1' = I_2\left(\frac{N_2}{N_1}\right)$



$\Rightarrow I_1' = 300\left(\frac{300}{1200}\right) = 75A$

$\Rightarrow$ Q

$$I_1 = I_0(\sin\phi_0 + \cos\phi_0) + I_1'(\sin\phi_1 + \cos\phi_1)$$

$$I_1 = (I_0\sin\phi_0 + I_1'\sin\phi_1)\hat{i} + (I_0\cos\phi_0 + I_1'\cos\phi_1)\hat{j}$$

$$= (47.45)\hat{i} + (60.5)$$

$\Rightarrow \cos\phi_0 = 0.2$

$\cos\phi_1 = 0.8$

$\sin\phi_0 = 0.979$

$\sin\phi_1 = 0.6$

$$\boxed{I_1 = 76.88A}$$

Q. A 10 kVA single phase t/f, rated for 2000/400V has pr. resistance & reactance 5.5Ω & 12Ω resp. & sec. resistance & reactance are 0.2Ω & 0.45Ω. determine the appr. value of the sec. vol. at full load at 0.8 pf lagging when pr. vol. is 2000 V. and also calculate vol. reg. at this load.

Sol^n:

$R_1 = 5.5\Omega$, $R_2 = 0.2\Omega$

$X_1 = 12\Omega$, $X_2 = 0.45\Omega$

$\Rightarrow R_{e2} = R_2 + R_1' = R_2 + \left(\frac{N_2}{N_1}\right)^2 R_1 = 1.3\Omega$

$\Rightarrow X_{e2} = X_2 + X_1' = X_2 + \left(\frac{N_2}{N_1}\right)^2 X_1 = 2.85\Omega$

$\Rightarrow V_2 = 400 - I_2 (R_{e2} + j X_{e2}) = 400 - 25[1.3 + j2.85]$

$= 374.5$

$\Rightarrow VR = 6.8$

Q. A 250/500 V tr. has foll. result

open ckt test : 250 V, 1A, 80 W on low Vol. side.

short ckt test : 20 V, 12 A, 100 W on h.v. side

Calculate the ckt Constant & show them on eqn ckt.

Soln: from open ckt → R_0, X_0

From open ckt test, $P_0 = 80\,W$

$V_0 = 250\,V$, $I_0 = 1\,A$

$$\Rightarrow R_0 = \frac{V^2}{P} = \frac{(250)^2}{80} = 781.25\,\Omega$$

$$\Rightarrow I_W = I_0 \cos\phi_0 =$$

from short ckt test,

$V_{sc} = 20\,V$

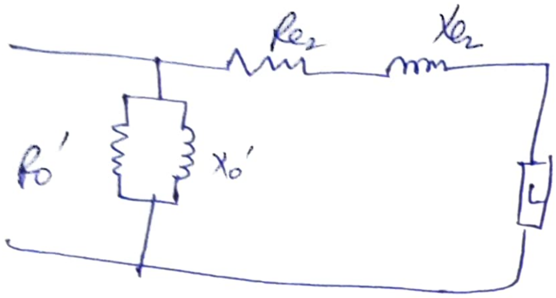
$I_{sc} = 12$

$P_{sc} = 100\,W$

$$\Rightarrow P_{sc} = I_{sc}^2 R_2$$

Z_{eq}

X_{eq}



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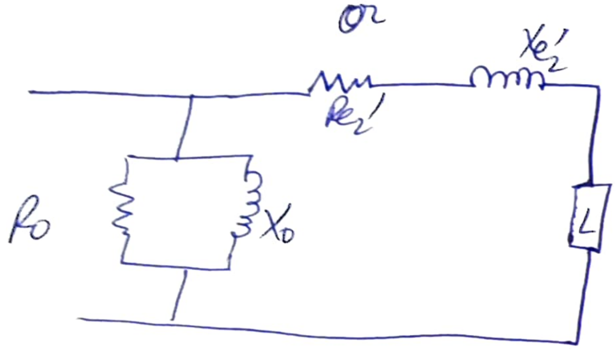


Q. The pri. & sec. winding of 40 kVA, 6600/250 V single phase tr. has resistance of 10 Ω, 0.02 Ω resp. The leakage reactance is 35 Ω as reffered to pri. winding. Find full load V.R. at a p.f. of 0.8 lagging.

__Soln__:
$$VR = \frac{I_2 R_{e_2} \cos\phi_2 + I_2 X_{e_2} \sin\phi_2}{V_2}$$

$\Rightarrow$

$X_{e_1} = 35\,\Omega$

$R_1 = 10\,\Omega$

$R_2 = 0.02\,\Omega$

$$R_{e_2} = R_2 + R_1' = R_2 + \left(\frac{N_2}{N_1}\right)^2 R_1$$
$$= 0.02 + \left(\frac{250}{6600}\right)^2 \times 10$$
$$= 0.0343\,\Omega$$

$$X_{02} = X_2 + \left(\frac{N_2}{N_1}\right)^2 X_1$$

$$= 0.05022$$

$$\Rightarrow I_2 = \frac{40 \times 10^3}{250} = 160 \text{ A}$$

$$VR = \frac{160 \times 0.0343 \times 0.8 + 160 \times 0.05022 \times 0.6}{250}$$

$$VR = \frac{43.904 + 4.82112}{250} = 3.684\%$$

Q. A Trf. is rated as 100 kVA. At full load if Cu loss is 1200 W & Iron loss is 960 W. Calculate, (i) The eff. at full load, unity P.f.

(ii) The eff. at half load, 0.8 pf.

(iii) Eff. at 75% of load, 0.7 pf.

(iv) The load kVA at which max. eff. will occur.

(v) The max. eff. at 0.85 P.f.

Soln: $$\eta = \frac{mS\cos\phi_2}{mS\cos\phi_2 + P_i + m^2 R_{ep}}$$

(i) $m = 1$ $\Rightarrow \eta = \dfrac{100 \times 1}{100 + 960 +}$

(i) 97.88 (ii) 96.94 (iii) 96.98

(iv)

$$S_m = S_{fl} \sqrt{P_i / P_{fl}}$$

$$= 89.44 \text{ kVA} \Rightarrow \eta_{max.} = \frac{S_m \cos\phi_2}{S_m \cos\phi_2 + 2P_i} = 97.53\%$$

Q. Find all day power of trf. having max. eff. 98% at 15 kVA at unity p.f.

Soln:

12 hr $\rightarrow$ 2 kW at 0.5 pf lagging

6 hr $\rightarrow$ 12 kW " 0.8 " "

6 hr $\rightarrow$ at No load (no power delivered)

Soln:

$$P_{out} = 15k \times 1 = 15 \text{ kW}$$

$$\Rightarrow \frac{15 \times 10^3}{I} \times 100 = 98 \Rightarrow P_{Input} = 15.306 \text{ kW}$$

$$\text{Total Loss} = 306 \text{ W} = (15.306 - 15) \text{ kW}$$

$\Rightarrow \quad P_i = \frac{306}{2} = 153\ W = P_c$

$\Rightarrow$ All day output $= (12 \times 2) + (6 \times 12) + (6 \times 0)$

$= 24 + 72 = 96\ kW/hr$

$\Rightarrow$ Iron loss for 24 hr $= 24 \times 153 = 3.672\ kW\,hr$

$\Rightarrow \quad P_c = \left(\frac{O/P\ kVA}{rated\ kVA}\right)^2 \times time \times (Cu_{Loss})_{max.\ eff.}$

$\Rightarrow$ Total copper loss for 24 hr $= \left(\frac{2/0.5}{15}\right)^2 \times 12 \times 0.153$

$+ \left(\frac{12/0.8}{15}\right)^2 \times 6 \times 0.153 + 0$

$= 0.13056 + 0.918 = 1.04856\ kW$

$\Rightarrow$ All day eff. $= \frac{O/P}{O/P + \text{loss}} = \frac{96}{96 + 1.04856 + 3.672}$

$= 95.313\%$

1) $E = 4.44 f \phi_m N$

2) Eqn ckt

3) Test of tsf (open ckt, short ckt) [VR, η]

4) Phasor diag.

5) Eff. [Normal eff., All day eff.]

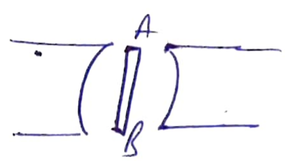
Three-phase Induction Motor :-

1) DC M/C
2) 1-ϕ Tsf.
3) 3-ϕ Ind. motor
4) Synch. motor

Construction :

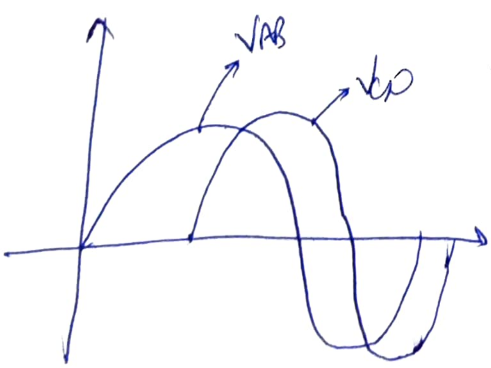
Stator — Rotor

1ϕ-gen.



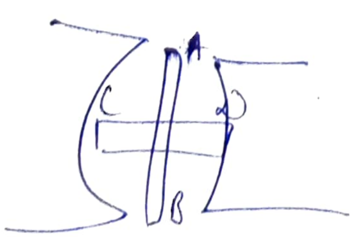
If there is no Commutator.

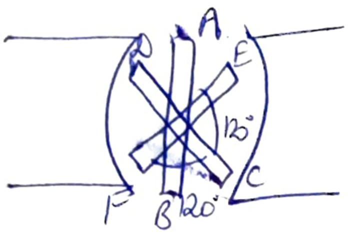
⇒ DC has Commutator while AC does not have.

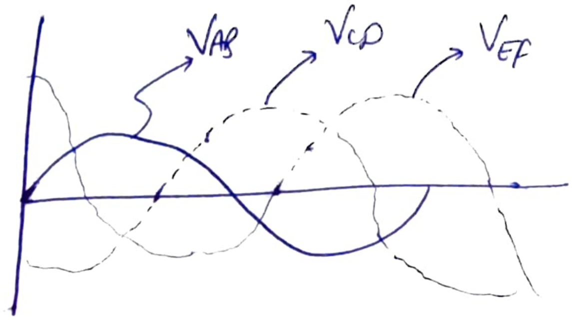


→ 2-ϕ Vol. generation.

→ as 2 waves are there and 90° apart.







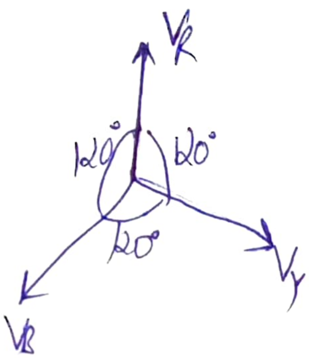
→ To generate 3-ϕ vol. ⇒ 3 winding are req. & will be 120° apart.

⇒ $V_R = V_m \sin(\omega t)$

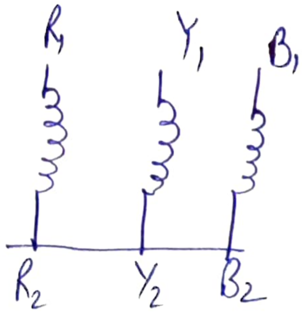
⇒ $V_Y = V_m \sin(\omega t - 120°)$

⇒ $V_B = V_m \sin(\omega t - 240°)$

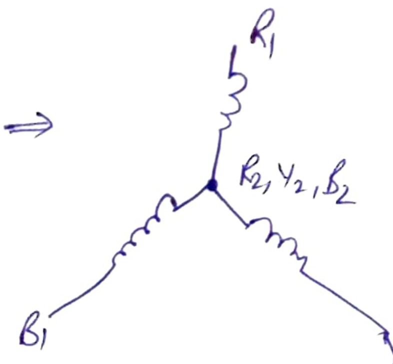
$= V_m \sin(\omega t + 120°)$



⇒

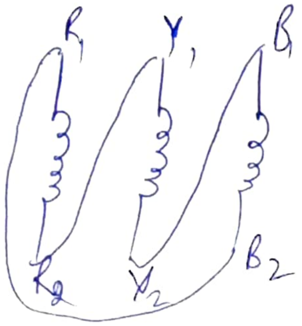


⇒



(We can also short B_1, Y_1 & R_1).

⇒

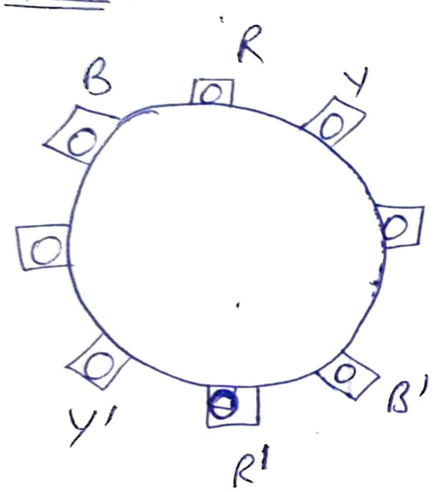


⇒

⇒ __Balance Vol.__ → Each and every phase has same mag. & every two phase has diff. of 120°.

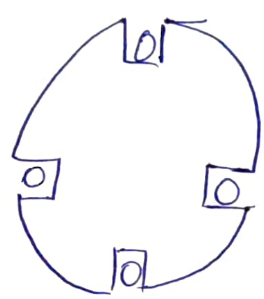
⇒ Potential diff. change → 1) Due to phase diff.
2) Due to freq. diff.

__Stator__ :



⇒ Cut in inner periphery.

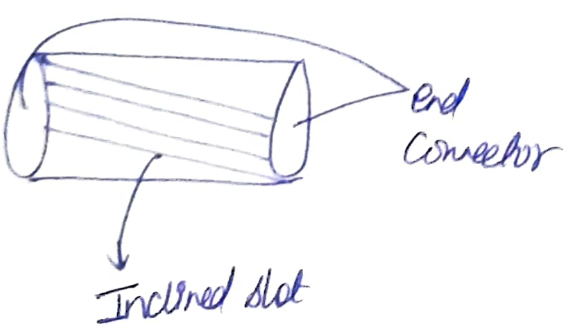
__Armature__



⇒ Cut in Outer periphery

→ __ROTOR__

- Cage Rotor
  Squirrel Cage
- Wound Rotor
  Slip - ring



⇒ The rotor constr. is same as that of AC DC motor rotor.

→ Instead of Coil 'Cu' bar mat. is used.

→ rotor is dumbled shape

→ slot is skewed

→ All the 'Cu' bar mat are short ckted by end connector

<u>Adv</u>:

→ It helps us to develop uniform torque of motor.

→ Helps us to avoid magnetic locking.

→ Cage rotor is more robust than wound rotor.

→ Less maintenance is req. in Cage rotor.

→ Effeciency is more in Cage rotor.

→ Nothing brush are req. in " "

→ Less cost.

⇒ $\tau \propto R_2$

τ → starting torque

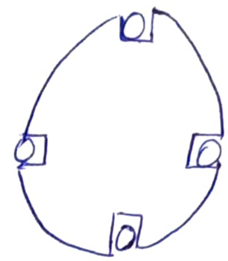
R_2 → rotor resistance.

⇒ τ is more ⇒ reach to rated speed quickly.

→ Not extra resistance should be connected

No starting torque is there

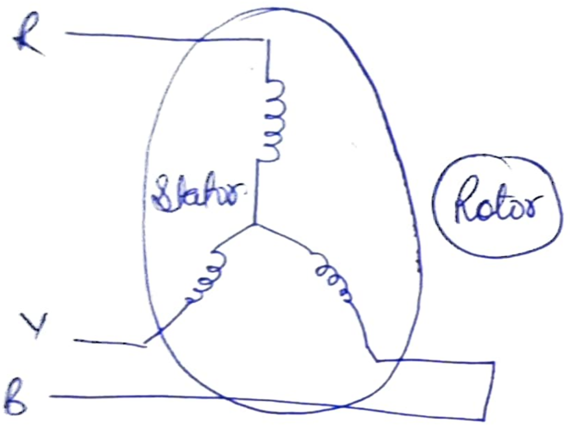
⇒ Only diff. is instead of single phase it is 3-ϕ winding.



⇒ Ultimately the 3ϕ winding are short ckted by slip ring.

⇒ By connecting extra resistance in series helps to control speed of slip ring motor.

SYMBOL :



Q. What happens when a 3ϕ supply applied to stator of 3ϕ Induction Motor ?

$\Rightarrow V_R = V_m \sin(\omega t)$

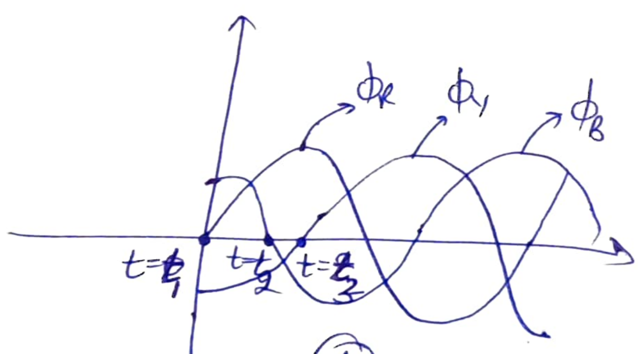
$V_Y = V_m \sin(\omega t - 120^\circ)$

$V_B = V_m \sin(\omega t - 240^\circ)$

$\Rightarrow \phi_R = \phi_m \sin\omega t$

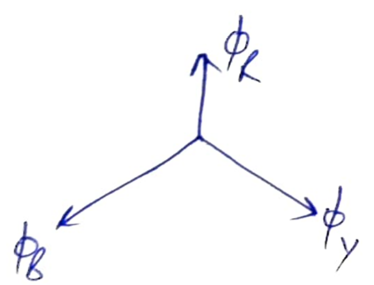
$\Rightarrow \phi_Y = \phi_m \sin(\omega t - 120^\circ)$

$\Rightarrow \phi_B = \phi_m \sin(\omega t - 240^\circ)$



1

As a vector ⇒



2

⇒ 3ϕ vol. ⇒ I will flow ⇒ 3 types of MF gen. ϕ_R, ϕ_Y, ϕ_B.

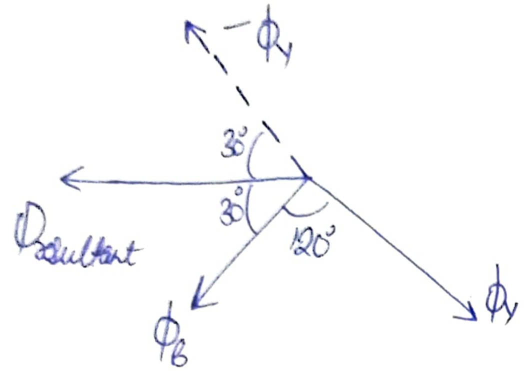
It can be shown as wave form in fig. 1.

and vector form in fig. 2.

Now, Case I → At $t = t_1$

$\Rightarrow \omega t = 0$

$\Rightarrow \phi_R = 0$, $\phi_Y = -\frac{\sqrt{3}}{2}\phi_m$, $\phi_B = \frac{\sqrt{3}}{2}\phi_m$



$\Rightarrow \phi_{resultant} = \sqrt{\phi_Y^2 + \phi_B^2 + 2\phi_Y\phi_B \cos 60^\circ}$

$= \sqrt{2\left(\frac{\sqrt{3}}{2}\phi_m\right)^2 + 2\left(\frac{\sqrt{3}}{2}\phi_m\right)^2\left(\frac{1}{2}\right)}$

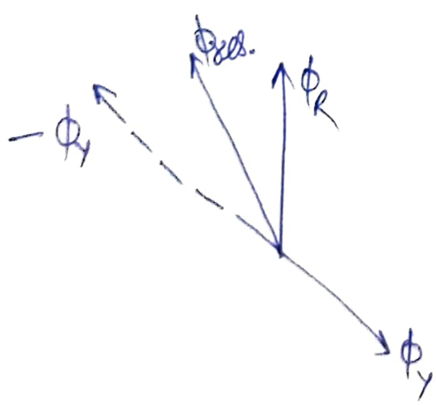
$= \sqrt{2}\left(\frac{\sqrt{3}}{2}\right)\phi_m \frac{\sqrt{3}}{\sqrt{2}} = 1.5\phi_m$

$\Rightarrow \boxed{\phi_{res.} = 1.5\phi_m}$

Case-II: At $t = t_2$

$\Rightarrow \omega t = 60^\circ$

$\Rightarrow \phi_R = \frac{\sqrt{3}}{2}\phi_m$, $\phi_Y = -\frac{\sqrt{3}}{2}\phi_m$, $\phi_B = 0^\circ$

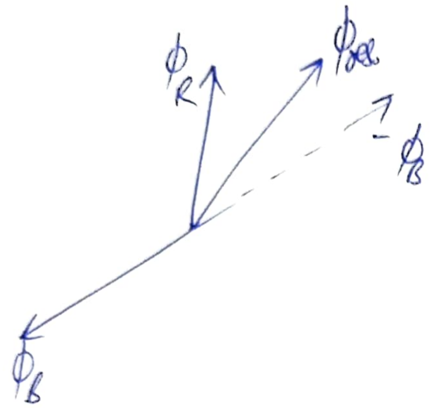


$\boxed{\phi_{res.} = 1.5\phi_m}$

Case-3 : At $t = t_3$

$\Rightarrow \omega t = 120°$

$\Rightarrow \phi_R = +\frac{\sqrt{3}}{2}\phi_m$, $\phi_Y = 0$, $\phi_B = -\frac{\sqrt{3}}{2}\phi_m$



$$\boxed{\phi_{res.} = 1.5\,\phi_m}$$

→ Resultant mag. feild after application of three is Constant ($1.5\phi_m$).

→ Resultant feild is rotating i.e. nature of res. mag. field is rotating.

Defin. Rotating MF. How it is devd. in 3ϕ Ind. motor

OR

Exp. reason of development of rotating MF.

SYNCHRONOUS SPEED :-

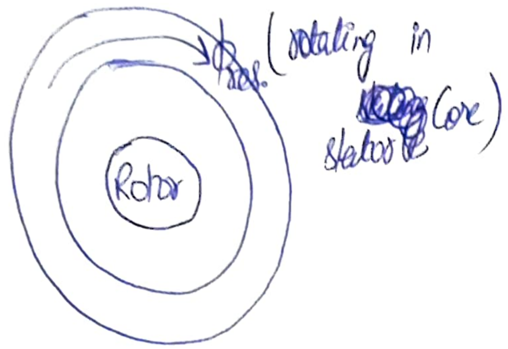
→ The speed of rotating MF is denoted as Synchronous speed.

$$\boxed{N_s = \frac{120 f}{P}}$$

$f \rightarrow$ freq. , $P \rightarrow$ No. of Pole

Operating Principle :

→



Due to rotating MF ⇒ Some flux pass through rotor Cond. ⇒ acc. to Faraday Law,

⇒ Some Ind. Emf get across rotor Cond.

⇒ By Constr. rotor is short ckted, due to that Current is Induced in rotor Cond.

⇒ Since Current is flowing ⇒ rotor is Current Carrying Cond. placed in MF. ⇒ Due to which Torque or Couple generate

→ In b/w rotating MF and rotor (rest) a rel. speed exist. Due to this flux Cutting rotor Cond → we get Ind. emf. → Current will flow.

→ To destroy rel. speed rotor start to rotate.

DIRN OF ROTOR : Same as that of dirn of rotation of MF. (due to Lenz. law)

Let Rotor speed $= N_r$.

⇒ $\boxed{N_r < N_s}$ (always)

⇒ If $N_r = N_s$ ⇒ Motor will not rotate as rel. speed is zero.

→ 'N_r' always less than Synch. ~~rotor~~ speed

→ Asynchronous speed → whose speed is always less than the Synch. speed.

⇒ $\boxed{\text{Slip}, \; S = \dfrac{N_s - N_r}{N_s}}$

Frequency of Rotor Current or Induced EMF :

⇒ $N_s = \dfrac{120f}{P}$ ⇒ $f = \dfrac{P \times N_s}{120}$

Let rotor freq. $= f_r$.

$\therefore \quad f_r = \dfrac{P(N_s - N_r)}{120}$

So, $\dfrac{f_r}{f} = \dfrac{\dfrac{P(N_s - N_r)}{120}}{\dfrac{P \times N_s}{120}} = \dfrac{N_s - N_r}{N_s}$

⇒ $\dfrac{f_r}{f} = S$ ⇒ $\boxed{f_r = S \times f}$

→ If $S = 1$ ⇒ Motor at rest (does not rotate)

For motor gen. → value of $\boxed{S < 1}$

⇒ At $S = 1$ → $\boxed{f_r = f}$

→ Applied the vol. at stator winding.
→ Get the vol. at rotor

→ Stator ⇒ Primary side of Tsf.
→ Rotor ⇒ Secondary side of Tsf.
→ Induction Motor is also termed as Rotating Transformer

Rotor Current and p.f. :

Let R_2 = rotor resistance
X_{20} = Rotor reactance at standstill cond.
X_{2S} = Rotor reactance at Slip S,

$$\Rightarrow X = \omega l = 2\pi f l$$

$$X_2 = 2\pi f_r l$$
$$= 2\pi s f l \quad , \quad \text{At } S = 1 \Rightarrow X_2 = 2\pi f l$$

$$X_{20} = 2\pi f l$$
$$X_{2S} = 2\pi f S l \quad \Rightarrow \quad \boxed{X_{2S} = S X_{20}}$$

E_{20} - Rotor Induced emf at stand still
E_{2S} = Rotor Ind. emf at any value of slip.

$\Rightarrow$ $\boxed{E = 4.44 f \phi_m N}$ (As Induction motor is same as Tf)

$\Rightarrow$ $\boxed{E_{2S} = S E_{20}}$ as $f_r = Sf$,
$X_{2S} = S X_{20}$

$\therefore$ Rotor Current at stand still cond., $I_{20} = \dfrac{E_{20}}{R_2 + jX_2} = \dfrac{E_{20}}{\sqrt{R_2^2 + X_{20}^2}} = \dfrac{E_{20}}{Z_{20}}$

$\Rightarrow$ Rotor pf at standstill cond., $\boxed{\cos\phi_{20} = \dfrac{R_2}{Z_{20}}}$ $Z_{20} \rightarrow$ rotor Impedance at stand still cond.

$\rightarrow$ Rotor Current at any slip, S $\Rightarrow I_{2S} = \dfrac{E_{2S}}{R_2 + jX_2} = \dfrac{S E_{20}}{R_2 + jSX_{20}}$

$= \dfrac{SE_{20}}{\sqrt{R_2^2 + (SX_{20})^2}} = \dfrac{S E_{20}}{Z_{2S}}$

$\rightarrow$ Rotor P.f. at ~~stand still~~ Condo, any slip S, $\boxed{\cos\phi_{2S} = \dfrac{R}{Z_{2S}}}$

Torque of Motor :

→ Torque of motor depends on:

1) Rotor Current.

2) Rotor induced EMF $[E_{2S} \propto \phi]$

3) Rotor P.f.

Starting Torque → $T_{st} \propto \phi I_{20} \cos\phi_{20}$

$$\Rightarrow T_{st} = K\phi I_{20} \cos\phi_{20}$$

$$= K\phi \frac{E_{20}}{\sqrt{R_2^2 + X_{20}^2}} \cdot \frac{R_2}{\sqrt{R_2^2 + X_{20}^2}}$$

$$\boxed{T_{st} = \frac{K E_{20}^2 R_2}{R_2^2 + X_{20}^2}}$$ (as $\phi \propto E_{20}$)

→ **Effect of supply vol.** → $E_{2S} \propto \phi$

$$\Rightarrow \therefore T_{st} = \frac{K E_{20}^2 R_2}{R_2^2 + X_{20}^2}$$

$\Rightarrow T_{st} \propto E_{20}^2$ but $E_{20} \propto \phi$ & $\phi \propto V$ $\Rightarrow$ $\boxed{T_{st} \propto V^2}$

→ **Cond. of max. Torque :**

$\Rightarrow$ We know that $T_{st} = \dfrac{K E_{20}^2 R_2}{R_2^2 + X_{20}^2}$

$$\Rightarrow \frac{dT_{st}}{dR_2} = \frac{(R_2^2 + X_{20}^2) K E_{20}^2 - 2K E_{20}^2 R_2^2}{(R_2^2 + X_{20}^2)^2} = 0 \Rightarrow \cancel{K}\cancel{E_{20}^2} R_2^2 = \cancel{K} X_{20}^2 \cancel{E_{20}^2}$$

$\Rightarrow$ $\boxed{R_2 = X_{20}}$, Now, $\tau_{st_{max}} = \dfrac{k E_{20}^2 R_2}{(R_2^2 + R_2^2)}$

→ Torque of Motor :

At running Cond. → $\tau \propto \phi \, I_{2s} \cos\phi_{2s}$

$$\Rightarrow \tau = k\phi \frac{E_{2s}}{\sqrt{R_2^2 + (SX_{20})^2}} \cdot \frac{R_2}{\sqrt{R_2^2 + (SX_{20})^2}}$$

$$\Rightarrow \tau = \frac{kE_{20} \; S E_{20} R_2}{(R^2 + SX_{20})^2} \Rightarrow \boxed{\tau = \frac{k \, S E_{20}^2 R_2}{R_2^2 + (SX_{20})^2}}$$

$\boxed{E_{2s} < E_{20}}$

[Derive Torque eq^n of Ind. motor

$$\Rightarrow \tau_{st} = \frac{k \, E_{20}^2 R_2}{R_2^2 + (X_{20})^2} \quad [S=1]$$

Derive Torque eq^n of Ind. motor at st. pt. $\Rightarrow \tau_{st}$]

$$\Rightarrow \boxed{\tau \propto V^2}$$

Cond. of max. Torque $\Rightarrow \dfrac{d\tau_s}{dR_2} = \cancel{K}\cancel{S}\cancel{E_{20}^2}[R_2^2 + (SX_{20})^2] - 2\cancel{K}\cancel{S}\cancel{E_{20}^2} R_2^2 = 0$

$$\Rightarrow \boxed{R_2 = SX_{20}}$$

$$\Rightarrow \tau_{max.} = \frac{KSE_{20}^2(SX_{20})}{(SX_{20})^2 + (SX_{20})^2} \Rightarrow \boxed{\tau_{max.} = \frac{KE_{20}^2}{2X_{20}}}$$

→ Value of max. Torque of Ind. motor is Independent of rotor resistance (R_2).

→ Cond. of max. Torque :

$\Rightarrow$ $R_2 = SX_{20}$

$\therefore$ $R_2 = SX_{20}$

$\therefore$ At $\tau_{max.}$, slip will be max. $\Rightarrow$ $S_{max.}$, $\boxed{S_m = \frac{R_2}{X_{20}}}$

$\Rightarrow$ By Inc. R_2 value, the max. slip also Inc. but max. Torque cannot be Inc.

→ Max. Torque should retain same max. value.

[Effect of rotor resistance in Ind. motor]

[start with τ_{st} depend on R_2]

Torque Vs slip :

$$\Rightarrow \tau = K \frac{SE_{20}^2 R_2}{R_2 + (SX_{20})^2}$$

Case - I : when slip, $S = 0$

$\therefore$ $\tau = 0$

$\Rightarrow$ Torque slip ch. start from origin

Case - II : When N_r is very near to N_s (Synchronous speed).

$\Rightarrow$ $\therefore$ Slip, S is very low value.

then term $(SX_{20})^2$ is very less and neglected.

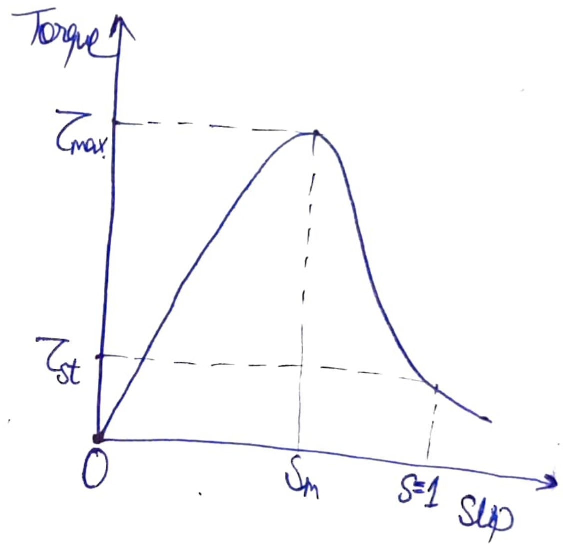
$\Rightarrow \quad \tau = K \dfrac{S E_{20}^2 R_2}{R_2^2} \quad \Rightarrow \quad \boxed{\tau \propto S}$

$\Rightarrow$ τ, slip ch. start from origin & has linear ch.

Case-III : When speed of motor ↑ $\Rightarrow$ τ of motor also ↑ upto max. Torque of motor.

$\Rightarrow \quad \boxed{S_m = \dfrac{R_2}{X_{20}}}$

$\Rightarrow$ If we ↑ upto S_m Value τ also ↑.

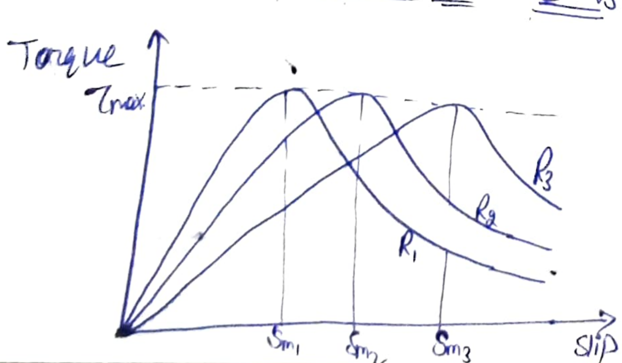


Case-IV : When slip of motor is high (i.e. motor at full Load Cond.)

$\Rightarrow \quad (N_r <<< N_s) \Rightarrow \cdot R_2^2 << (S X_{20})^2$

$\Rightarrow \tau = K \dfrac{S E_{20}^2 R_2}{S^2 X_{20}^2} \quad \Rightarrow \quad \boxed{\tau \propto \dfrac{1}{S}}$

Effect of rotor Resistance in τ Vs Slip ch. :-



$\therefore \quad S_m = \dfrac{R_2}{X_{20}}$

and from graph $\quad S_{m_3} > S_{m_2} > S_{m_1} \quad \Rightarrow \quad \boxed{R_3 > R_2 > R_1}$

[Effect of rotor resistance in Ind. motor]

$\Rightarrow$ By $\uparrow$ rotor resistance the starting torque of motor $\uparrow$ accordingly but there is no change of max. Torque bcoz max. Torque does not depend upon rotor resistance.

Effect of Supply voltage in τ Vs Slip ch. :-

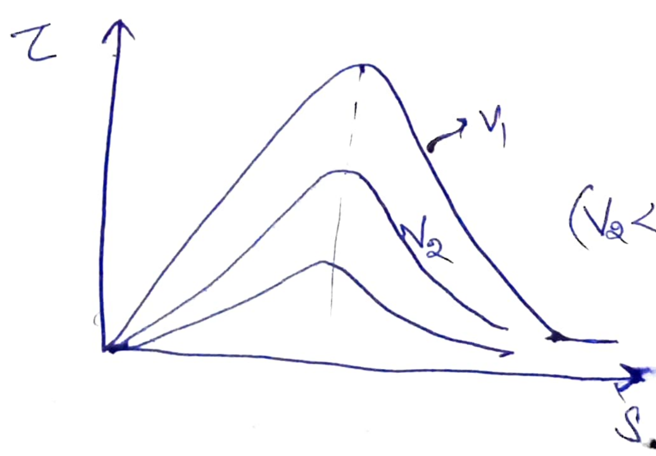
$$\Rightarrow \quad \tau = \frac{K S E_{20}^2 R_2}{R_2^2 + (SX_2)^2}$$

$\Rightarrow$ For a particular torque $\Rightarrow \tau \propto E_{20}^2$ [$E_{20} \rightarrow$ rotor Ind. emf]

But E_{20} depend on supply vol. as Ind. principle.

$\therefore \quad \boxed{\tau \propto V^2}$

$\Rightarrow$ If we change supply vol. $\Rightarrow$ τ_{st} also change.



$\Rightarrow$ If we $\uparrow$ V $\Rightarrow$ $T_{st}\uparrow$ and $T_{max.}$ also $\uparrow$. & vice versa.

\# Relation in b/w T_{fl} (full Load) & $T_{max.}$:

$\rightarrow$ We know that, $T = k \dfrac{S E_{20}^2 R_2}{R_2^2 + (SX_0)^2}$

$$\therefore \quad T_{fl} = k \frac{S_{fl} E_{20}^2 R_2}{R_2^2 + (S_{fl} X_{20})^2}$$

and $$T_{max.} = k \frac{E_{20}^2}{2X_{20}}$$

Now, $$\frac{T_{max.}}{T_{fl}} = \frac{k \frac{E_{20}^2}{2X_{20}}}{k \frac{S_{fl} E_{20}^2 R_2}{R_2^2 + (S_{fl} X_{20})^2}} = \frac{R_2^2 + (S_{fl} X_{20})^2}{2 S_{fl} R_2 X_{20}}$$

$\rightarrow$ Div. Nr & Dr by $(X_{20})^2$ $\Rightarrow$ $$\frac{\left(\frac{R_2}{X_{20}}\right)^2 + (S_{fl})^2}{2 S_{fl} \left(\frac{R_2}{X_{20}}\right)} = \frac{S_m^2 + (S_{fl})^2}{2 S_m S_{fl}}$$

$\therefore$

$$\Rightarrow \boxed{\frac{T_{max.}}{T_{fl}} = \frac{S_m^2 + (S_{fl})^2}{2 S_m S_{fl}}}$$

(Try, $T_{max.}$ & T_{st})

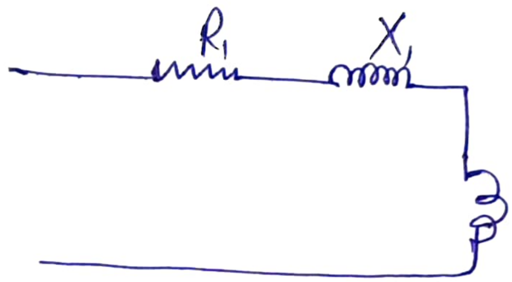
Eqn ckt of 3-ϕ Ind. motor : (per phase)

Stator model :

→ Since stator of Ind. motor is similar to pr. of Xmf.

R_1 → stator winding resistance.
X_1 → stator leakage reactance.

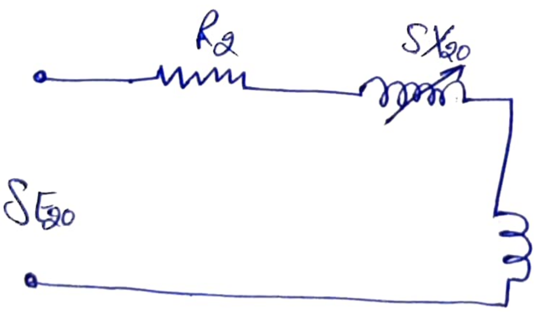
∴ Stator eqn ckt is,



Rotor Model :

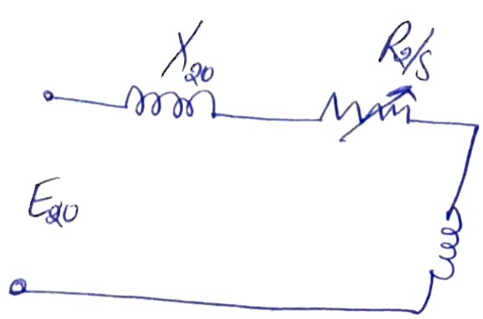
Since, $I_{2S} = \dfrac{E_{2S}}{R_2 + X_{2S}} = \dfrac{SE_{20}}{R_2 + SX_{20}}$

∴ the ckt is,



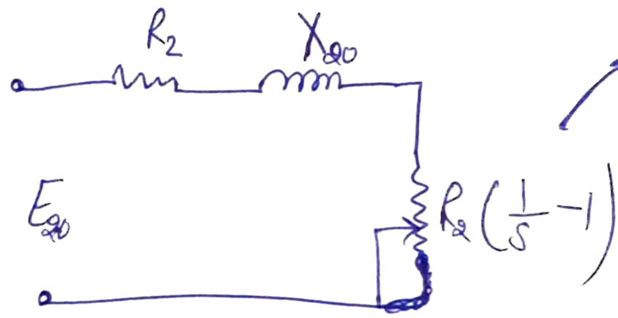
Again, $I_{2S} = \dfrac{SE_{20}}{R_2 + SX_{20}}$

$= \dfrac{E_{20}}{\frac{R_2}{S} + X_{20}}$ ⇒ ckt :



Now, $\frac{R_2}{S} = R_2 + R_2\left(\frac{1}{S} - 1\right)$

$\Rightarrow$ The ckt is,

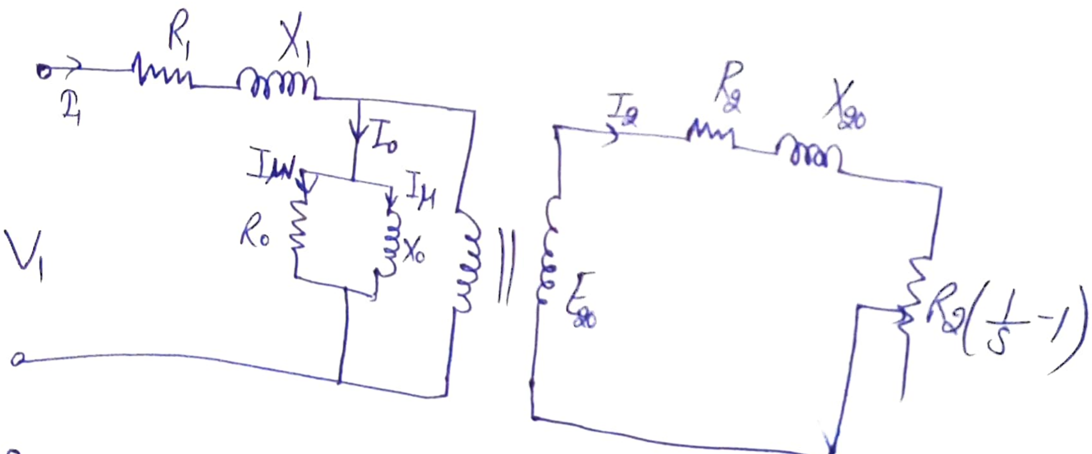


electr. load eq^n to mech. power.

→ **At No load Cond.** :

$\Rightarrow I_0 = I_\mu + I_W$

$I_\mu \rightarrow X_0$, $I_W \rightarrow R_0$



[Diff. of eq^n ckt in b/w tf. & Ind. motor]

$\Rightarrow$ In tf $\Rightarrow$ Out is electr.

$\Rightarrow$ In above ckt output is mech. power so to take output electr. assess. is applied.

→ Component of X_0, R_0 is

No load current of Ind. motor > Current of tf.

→ In Tf there is no air gap b/w pri. & sec.

→ flux is directly passing.

→ And in Ind. motor flux is also passing through air gap.

→ So to incorporate same flux more current is taken in Ind. motor.

Relation of rotor input, rotor output & rotor copper loss:

Let τ = developed Torque

N_s = Synchronous Speed

N_r = rotor Speed

$\therefore$ Rotor Input $= \dfrac{2\pi N_s \tau}{60}$

Rotor Output $= \dfrac{2\pi N_r \tau}{60}$

Hence, Rotor I/p − Rotor o/p = Rotor Copper Loss

$\therefore$ Rotor Copper Loss $= \dfrac{2\pi N_s \tau}{60} - \dfrac{2\pi N_r \tau}{60}$

$= \dfrac{2\pi \tau}{60}(N_s - N_r)$

Now, $\dfrac{\text{Rotor Copper Loss}}{\text{Rotor I/p}} = \dfrac{\frac{2\pi\tau}{60}(N_s - N_r)}{\frac{2\pi\tau}{60} N_s} = \dfrac{N_s - N_r}{N_s} = S$

$\Rightarrow$ $\boxed{\text{Rotor Copper Loss} = S \times \text{Rotor I/P}}$

$\Rightarrow$ Again, Gross Rotor O/P = Rotor I/p − Rotor Cu Loss

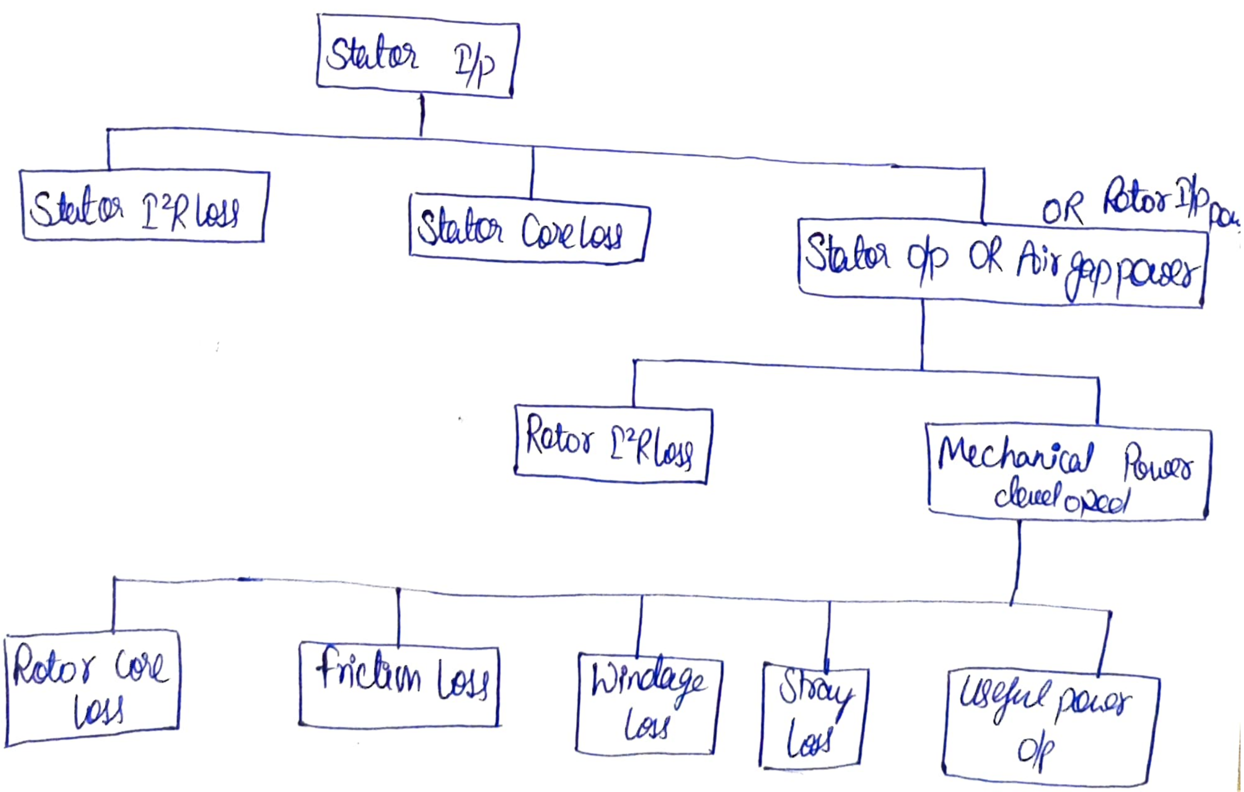
= Rotor I/p − S Rotor I/p

= (1−S) Rotor I/p

Again, $\boxed{\dfrac{\text{Rotor O/p}}{\text{Rotor I/p}} = 1 - S}$

or $\boxed{\dfrac{\text{Rotor Cu Loss}}{\text{Rotor o/p}} = \dfrac{S}{1-S}}$

→ Power Flow Diagram :



Loss of Ind. motor

→ I^2R loss, Cu loss than core loss etc.

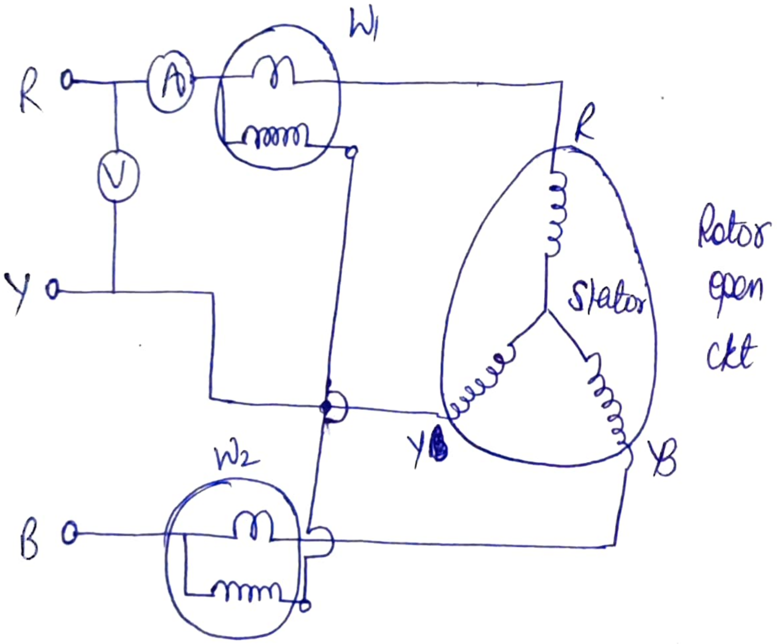
Core loss depend on supply vol.

Test on I/M

No Load

Blocked Rotor

Ckt diag.



→ By single phase wattmeter connect 3-ϕ wattmeter

→ 3-ϕ Power = $W_1 \pm W_2$

→ By cond. No load test we can calculate core loss of I/M.

$\Rightarrow P_0 = W_1 - W_2 = 3V_{ph} I_{ph} \cos\phi_0$

$= \sqrt{3} V_L I_L \cos\phi_0$

→ motor draw more current from supply.

to overcome the obstacle as motor is blocked by some obstacle.

→ Since motor draw more current then it can be treated as short ckt of t/f.

⇒ Theory No load test is similar to open test of t/f.

⇒

Stator of 3-ϕ I/M :

For Cage Rotor I/p

- D.O.L (Direct ON Line)
- Auto T/f
- Star - Delta

D.O.L

⇒ NO red. of starting Current by using D.O.L but instead use as of 2 adv.

1). Over Load ~~protection~~ protection.

2). Under Voltage Protection.

Auto T/f

⇒ Slowly ↑ the value from 0 to High value.

Star - Delta

→ Initially motor starts by star Connection.

→ When speed of motor reach 75% of rated value it goes to Delta Connection. due to Relay.

Method of Speed Control :

$$\because \quad N_s = \frac{120f}{P}$$

1). By changing supply vol ⇒ τ changes. ⇒ speed also change.

2) By changing supply freq.

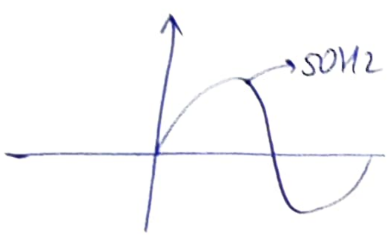
3). By changing Pole.

4) By inserting resistance in series with slip ring I/m (Var. res.)
5) By injecting voltage to the motor.

Cogging: magnetic locking.

→ If no. of slot of rotor & stator are equal then there is a tendency of mag. locking.

Crawling: Harmonic effect



Due to 5th harmonic & 7th harmonic, some torque is dev.

Due to effect of 5th & 7th harmonic the speed of I/m dec. as $\left(\frac{N_s}{5}\right)$ or $\left(\frac{N_s}{7}\right)$.

→ Since speed is red. motor treated as over load i.e. motor can burn out. This is treated as Crawling effect.

Q. A 3-ϕ, 4 pole I/M is connected 400 V, 50 Hz.
Determine, (i) Synchronous speed
(ii) Actual speed of motor when running at 4% slip.
(iii) Freq. of ind. emf in rotor.

Soln: $N_s = \frac{120f}{P} = \frac{120 \times 50}{4} = 1500$

$\Rightarrow N_r = (1-s) N_s$

$N_r = (1-0.04) \times 1500 = 1500 \times 0.96 = 1440$

freq. $= sf = \frac{4}{100} \times 50 = 2$ Hz

Q* Power to an induction motor is supplied by a 12 Pole alternator, 500 rpm.
The full load speed of motor is $N_r = 1440$ rpm.
Find % slip & no. of pole of ind. motor.

Sol^n:

$\cancel{N_s = \frac{120 f}{P} = \frac{120 \times 12}{12}}$ Supply freq., $f = \frac{P N_s}{120} = 50$

$\Rightarrow \cancel{S = 1 - \frac{N_r}{N_s}}$ & $N_r = 1440$ rpm

as $(N_r < N_s) \Rightarrow N_s = 1500$ rpm

Q. A 8hP 3-ϕ, 4 Pole Cage I/m is Connected to 400V, 50 Hz supply, the motor is operated at full load at 5% rated speed.

Calculate, (i) The speed of revolving field rel. to stator str.

(ii) The freq. of rotor current.

(iii) The speed of rotor mmf. rel. to rotor str.

(iv) The speed of rotor mmf rel. to stator str.

(v) The speed of rotor mmf rel. to stator field distribution.

(Vi) for Write for the dev. of Uni-directional Torque.

⇒ (i) $N_s = \frac{120f}{P} = \frac{120 \times 50}{400} = 15$

(ii) $f_r = sf = \frac{5}{100} \times 50 = 2.5$ Hz

(iii) $N_r = (1-s)N_s = \left(1-\frac{5}{100}\right) \times 15 = \frac{95 \times 15}{100} = 1425$

or $N_r = \frac{120 f_r}{P}$ = speed of rotor mmf.

(iv) ~~speed of~~ rotor mmf + N_r = 1500

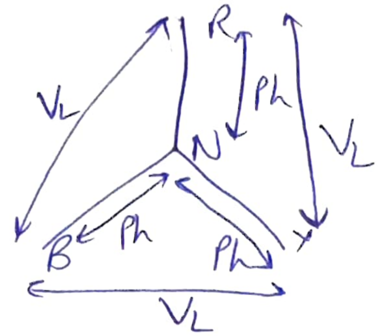
(v) 1500 − 1500 = 0

(vi) Yes it is valid

Q. The resistance & ~~standstill~~ standstill reactance per phase of 3-ϕ 4 pole 50 Hz I/m is 0.2 Ω & 2 Ω resp. The rotor is connected in star and emf induced b/w slip ring at start is 80V. If at full load the motor is running at a speed of 1440 rpm. Calculate,

(i) Slip
(ii) Rotor Ind emf per phase
(iii) Rotor current & pf. under running cond.
(iv) Rotor current & pf at standstill when slip ring is short ckted.

$\underline{\text{soln}}$: (i) $R_2 = 0.2\Omega$, $X_{20} = 2$



$\Rightarrow$ ~~[illegible]~~

$\Rightarrow N_r = 1440$, $N_s = \frac{120f}{P} = 1500$ $\Rightarrow$ $S = \frac{N_s - N_r}{N_s}$
$= 4\%$

$\Rightarrow$ $Z_{2s} = \sqrt{R_2^2 + (SX_{20})^2} =$

(iii) $\Rightarrow$ $\cos\phi_s = \frac{R_2}{Z_{2s}} = 0.928$

$\Rightarrow$ $I_{2s} = \frac{SE_{20}}{\sqrt{R_2^2 + (SX_{20})^2}} = 8.58\,A$

(iv) $I_2 = 22.98A$

$\cos\phi_2 = 0.0995$

(ii) $E = 80/\sqrt{3} = 46.18V$

Q A 20 Hp , 4 pole 25 Hz, 3ϕ wound rotor I/m is taken 9100W from the line. Core loss is 290 W, stator Cu loss 568 W , rotor Cu loss is 445 W & fr. windage loss is 100 W . Determine,

(a) power tr. across air gap

(b) Mech. power dev. by motor

(c) Mech. power o/p ,

(d) Eff. of motor.

(e) Slip of motor.

I/p power = 9100 W [10hp → at full load is delivered]

⇒ (a) Stator o/p − core loss − Cu loss = air gap power (I/p power to rotor)
= 8242 W

⇒ (b) Mech. power dev. = rotor I/p − rotor Cu loss
= 8247 − 445 = 7796 W

→ (c) Mech. power o/p = 7796 − 100 = 7696 W

⇒ (d) $\eta = \frac{O/p}{I/p} = 84.57$

(e) rotor Cu loss = s (rotor I/p)

$\Rightarrow s = \frac{445}{8242} = 0.054$ or 5.4%.

Q The impedance of rotor ckt of a 3φ 16 pole I/m is $(0.02 + j0.15)\,\Omega$ at standstill. If dev. full load torque at 360 rpm then what would be the,

i) ratio of max to full load torque.

ii) The speed at max Torque.

iii) The rotor resistance to be added to get max. st. torque

⇒ $N_s = \frac{120f}{P} = \frac{120 \times 50}{6} = 375$

s = 0.04

$\Rightarrow s = \frac{N_s - N_r}{N_s} = \frac{375 - 360}{375} = 0.04$

$\Rightarrow \tau_{fl} = \dfrac{K S_{fl} E_{20}^2 R_2}{R_2^2 + (S X_{20})^2}$, $\tau_{max.} = \dfrac{K E_{20}^2}{2 X_{20}}$

$\Rightarrow \dfrac{\tau_{max.}}{\tau_{fl}} = \dfrac{R_2^2 + (S_{fl} X_{20})^2}{2 S_{fl} X_{20} R_2} = 1.81$

(ii) $\Rightarrow$ At $\tau_{max.}$, slip is $S_{max.}$, $S_m = \dfrac{R_2}{X_{20}} = 2/15$

$\Rightarrow N_r = (1 - S_m) N_s = 325$

(iii) $R = 0.13 = R_2\left(\dfrac{1}{S} - 1\right) = 0.02\left(\dfrac{1}{2/15} - 1\right)$

Q. A 4-pole 3ϕ 50 Hz i/m has resistance and reactance of 0.03 Ω & 0.12 Ω. Find the amount of rotor resistance per phase to be inserted to obt. 75% of max. torque at start.

Solⁿ: $\dfrac{\tau_{st}}{\tau_{max.}} = 0.75 = \dfrac{2a}{a^2+1}$

$a = \dfrac{R_2}{X_2}$ $\Rightarrow a = 2.215$ or $a = 0.4517$

$\times$ ✓ (as $S<1$)

$\Rightarrow$ Amount of rotor $= R_{2i} - R_2$

$= 0.03 - R_2 = 0.0242\ \Omega$

Q.

400 V, 3ϕ Delta Connected I/m as the foll. result

No load test = 400V, 2.5A, 600 W

Blocked rotor test : 200V, 12.5 A, 1500W

Determine the energy (or working) Components and magnetising Component of No load Current (I_w, I_μ)

No load p.f., exciting resistance & reactance per phase (R_0, X_0). Refer to stator side assumed ~~stator~~ friction and windage Loss are 40

Also determine

Soln:

$V_L = 400$ [$V_L = V_{ph}$ as delta Conn.]

$I_L = 2.5A$

$\Rightarrow$ No load Current per phase $= 1.44$ A

Stator Cu Loss $= 3 I_0^2 R_1$

$= 31.25$ W

$\Rightarrow$ Stator Iron Loss = 600 − fr. ~~wind~~ Wind Loss − Stator Cu Loss

$\Rightarrow$ Stator Iron Loss = 388.75

$\Rightarrow$ Stator Iron Loss, $P_0 = 3 V_{ph} I_{ph} \cos\phi_0$

$\cos\phi_0 = 0.22$

$\sin\phi_0$, I_w, I_μ, R_0 & X_0.

$\Rightarrow \quad 3 I_{se}^2 R_{es} = P_{se}$

3ϕ Synchronous M/c

→ The M/c which always run at Synchronous speed.

→ $N_s = \frac{120f}{P}$

Synchronous Generator (Alternator) | Synchronous Motor

Synchronous Generator (Alternator)

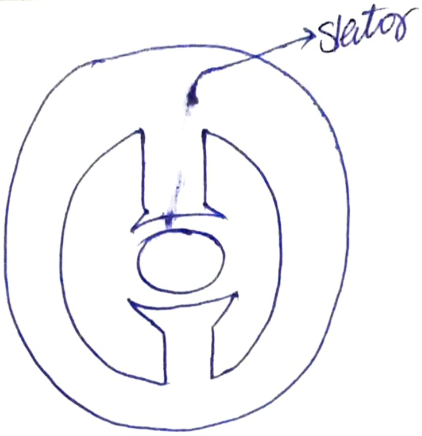
→ is design in such a way that speed should not be ↓. It is maintained Const. Speed is Invarient quantity.

→ Freq. is always maintained at 50 HZ

→ that's y speed is Const. bcoz if speed is not at Const. value then acc. to $f = \frac{PN_s}{120}$ f is also not const.

Construction

Stator | Rotor (Vol. is dec.)

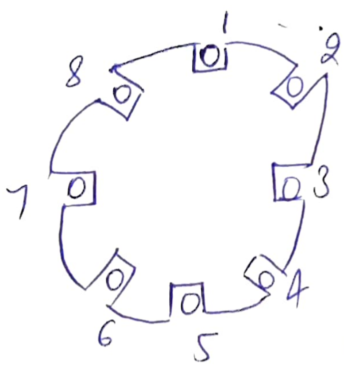


⇒ For syn. → field win. placed on rotor
and arm. win. placed at stator.

⇒ for DC → field win. at stator
arm. win. placed at rotor.

⇒ The field of syn. motor is rotating..

⇒ DC motor arm. $(1-\phi)$ ⇒ for 3ϕ ⇒ $3 \times 8 = 24$ slot are req.



→ for this ckt

⇒ If we placed field win. in rotor instead of stator then there is no change in size.

(1) ⇒ Avoid the size of roto or motor or bulkiness of motor or size of m/c.

(2) If we placed arm. win. in outer part.

(3) No slip ring is req.

adv. of rotating MF :-

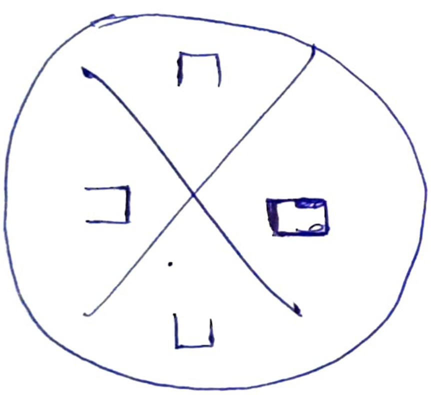
1) size of m/c is reduced
2) terminal of stationary arm. is easily avai. if we placed arm. win. in stator.
3) Insulation is easily provide if arm. wind. is placed in outer part (stator part).

4) If we placed arm. wind. at stator part (Outer part) Cooling ps. or mech. is easy.

5) Stationary arm. does not req. any slip ring.

6) As weight of m/c is req ⇒ Cost is also ↓ i.e. it is cost effective.

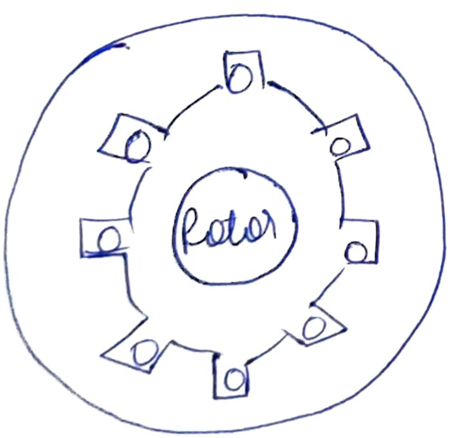
→ Ind. motor stator & alternator both have 3-ϕ i.e. designed is same.



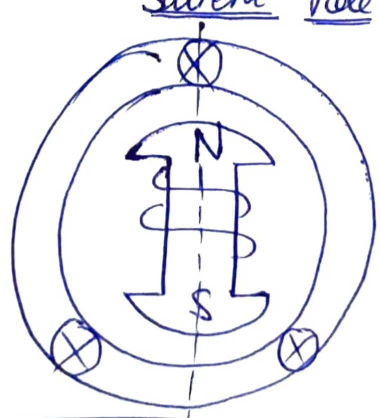
⇒ As consts. of motor syn. m/c are of two type:-

1) Salient Pole

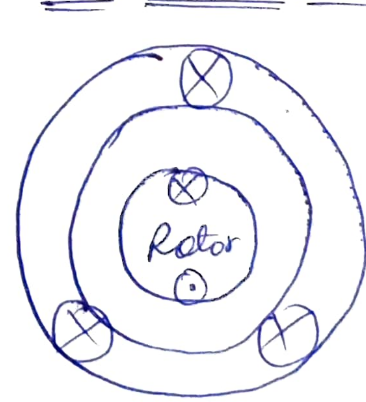
2) Non-salient Pole (Cylindrical)



Salient Pole



Non-Salient Pole



(Direct axis)

⇒ air of salient pole is non uniform.

⇒ ~~air gap along quadrature axis is max.~~

⇒ air gap is uniform.

⇒ Air gap along quadrature axis is max.
⇒ " " " Direct " " min.

In salient pole ↑

→ Salient pole used for → Hydel station (Low speed)

⇒ Non-Salient pole used for ⇒ Thermal st. (High speed)

⇒ Non Salient Pole is also Called Turbo alternator or gen.

Some special features of Salient Pole M/C :-

1) The Pole of the m/c are projected in nature
2) The air gap of m/c are non-uniform.
3) The mag. flux is also non-uniform due to non-uniform of air gap.
4) It has large dia. & small axial length.
5) The m/c is Generally a low speed m/c.
6) It is used in hydraulic turbine or diesel engine.

Some special feature of Non-Salient Pole m/c :-

1) The air gap of m/c are uniform.
2) Pole of m/c are not projected in nature.
3) Due to uniform air gap, mag. flux is also uniform.

4) It has smaller dia. & large axial length.

5) It is a robust constr. & noise less operation.

6) Dynamic balance of m/c is better.

7) High speed operation.

8) Used in steam turbine.

Freq. of Induced EMF :

⇒ Let P = total no. of pole

$\therefore$ p = pair of pole

N = speed in rpm

n = speed in rps

f = freq. of generated vol.

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

⇒ Now, in one rev. /rotation of rotor the arm. coil cut by

$\left(\frac{P}{2}\right)$ North-pole & $\left(\frac{P}{2}\right)$ S-pole.

Since one cycle is generated in arm. coil when a pair of field pole passes over the coil, the no. of cycle gen. in one revolution of the rotor will be = No. of pair of pole.

$\therefore$ No. of Cycle per rev. $= p$

also no. of rev. per sec. $= n$

Now, freq. $=$ $\dfrac{\text{No. of Cycle}}{\text{per sec.}}$ $= \dfrac{\text{No. of Cycle}}{\text{revolution}} \times \dfrac{\text{revolution}}{\text{sec.}}$

$$= p \times n$$

Emf eqn :

Let $\phi =$ useful flux/pole

$p =$ total no. of pole

$Z_p =$ Total no. of Cond.

$T_p =$ No. of turns

$n =$ rps

Since, flux/pole $= \phi$

$\therefore$ each stator Cond. Cut a flux i.e. '$p\phi$' for 1 rev.

$\therefore$ Avg. value of gen. vol. per Conductor $= \left(\dfrac{p\phi}{1/n}\right) = pn\phi$

$\therefore$ Ind. emf per phase, $\boxed{E_{avg.} = pn\phi = 2f\phi}$

for Z no. of Cond. ind. emf. $= 2\phi f Z_p$

Ind. emf per phase $= 4\phi f T_p$

$\Rightarrow \dfrac{Rms}{avg} = 1.11$

$\Rightarrow$ Ind. emf in rms, $E_{rms} = 4.4 ff \phi T_P$

$$E_{rms} = 4.44 f \phi T_P K_d K_p$$

$K_d \rightarrow$ distribution factor

$K_p \rightarrow$ pitch factor

Since arm. win. of alt. is distributed & short pitched.

Adv. of Distributed wind. :-

1). Harmonic emf are red.

Waveform also improved (near to sinusoidal).

2). Some harmonic can be eliminated directly for the distributed winding.

3). The distributed win. also reduce the arm. rxn.

4). The core of motor is better utilized.

Adv. of Short pitched win. :-

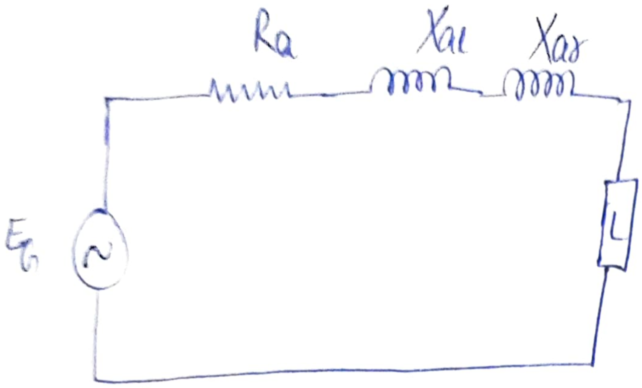
1) The waveform of ind. emf is improved and harmonic can be reduced

2) The less Cu is req. due to short pitched wind.

3) The inductance of win. also red.

4). The mechanical strength of coil is also incr

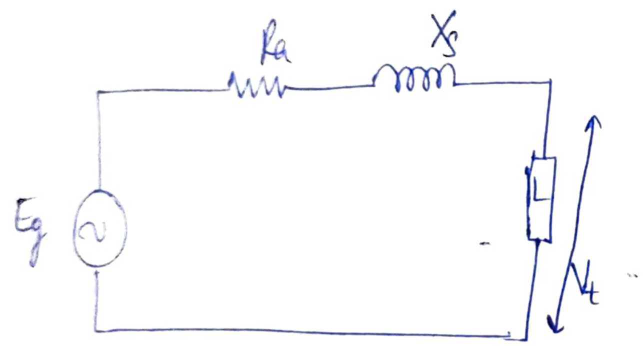
Ckt Model: (Alternator)



$X \propto f$

$X_{al} \rightarrow$ leakage reactance of alto

$X_{ar} \rightarrow$ fictitious resistance



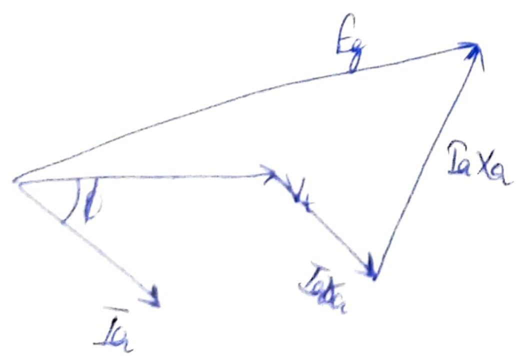
Synchronous reactance

$$X_s = X_{al} + X_{ar}$$

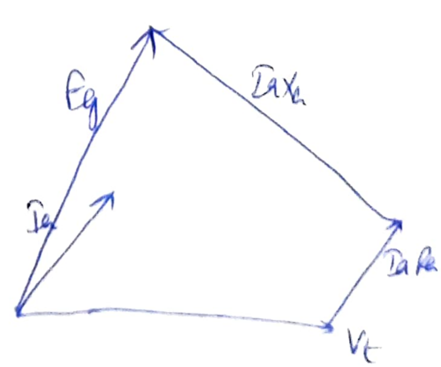
$$E_g = V_t + \bar{I}_a R_a + \bar{I}_a X_s$$

Phasor diag. :-

1) Lagging p.f. load

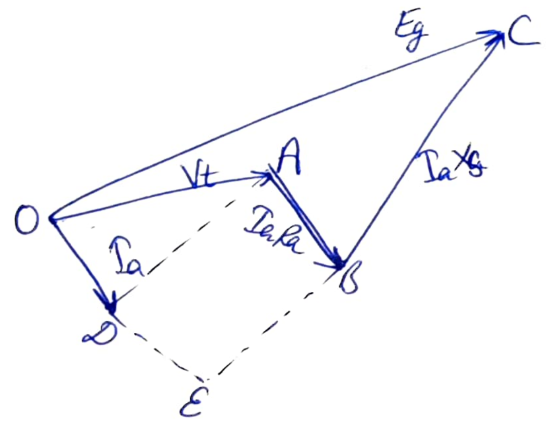


2) Leading Pf. load



Express. of emf from phasor diag. :-

For lagging p.f.



Consider right angle Δ OCE

$\Rightarrow OC^2 = OE^2 + EC^2$

~~O — $OD^2 + DE^2$ + $EB^2 + BC$~~

~~$PB + BC$~~

$\Rightarrow OC^2 = (OD + DE)^2 + (EB + BC)^2$

$OD = V_t \cos\phi$

$DE = I_a R_a$

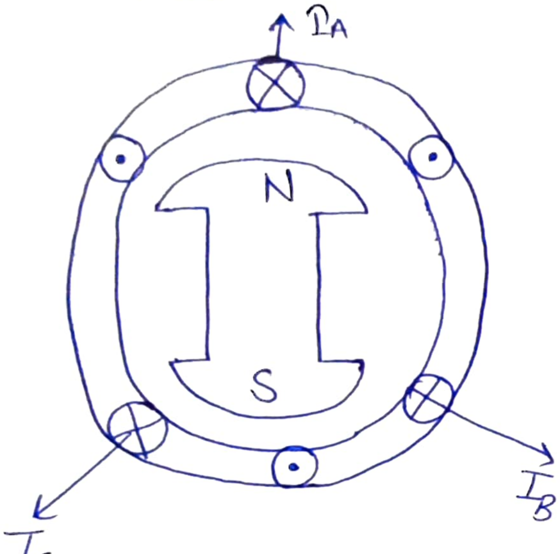
$\Rightarrow OC^2 = (V_t \cos\phi + I_a R_a)^2 + (V_t \sin\phi + I_a X_s)^2$

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

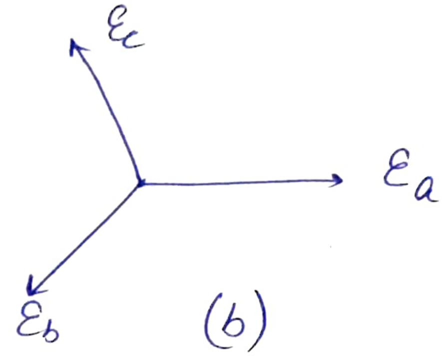
(For lagging p.f.) $\rightarrow$ (+ve)

(for leading p.f. $\rightarrow$ (−ve)

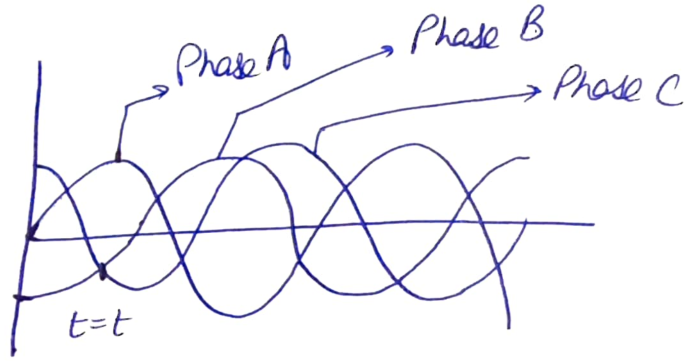
Armature Rxn :



(a)



(b)



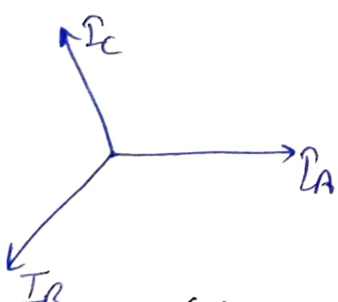
(c)

→ Depends not only load but also nature of load.

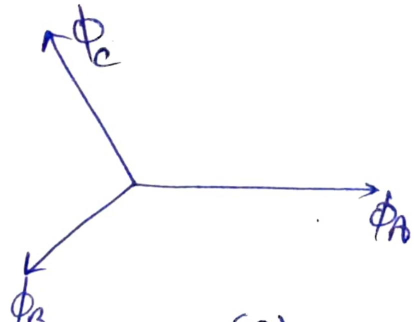
→ Dirn of MF is always upward dirn in (a).

Case - I Unity p.f. of Load :-

⇒ The Current I_A, I_B & I_C is same phase as of E_a, E_b, E_c.



(A)

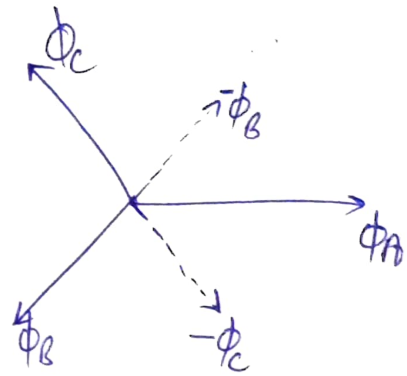


(B)

Now, from fig. (C), at $t = t$

$\Rightarrow \phi_A$ is max.

$\phi_B, \phi_C \equiv$ (-ve) and less than ϕ_A.



→ Res. MF along ϕ_A dirⁿ & main. MF is upward so both are at 90°.

"$\phi_{res.}$ is along ϕ_A".

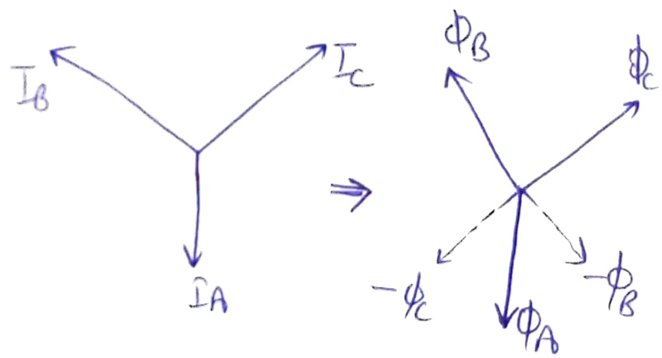
∴ "Cross magnetisation effect".

<u>Case 2</u> : Lagging pf of load :

At $t = t$,

$\Rightarrow \phi_A = max$ & $\phi_B, \phi_C \equiv -ve$

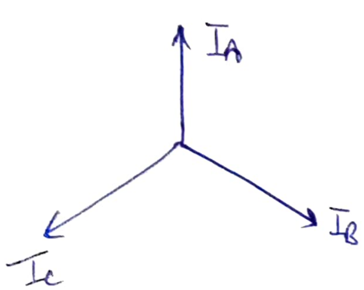
$\Rightarrow \phi_{res.}$ along ϕ_A i.e. downward dirⁿ.

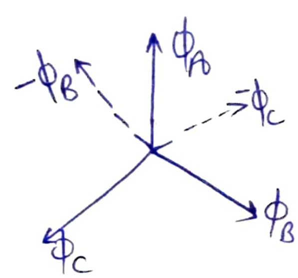


But main. mag. field is in upward dirⁿ. (i.e. 180° part)

∴ effect of arm. rxn is demagnetisation effect.

<u>Case 3</u> : Leading pf of load :





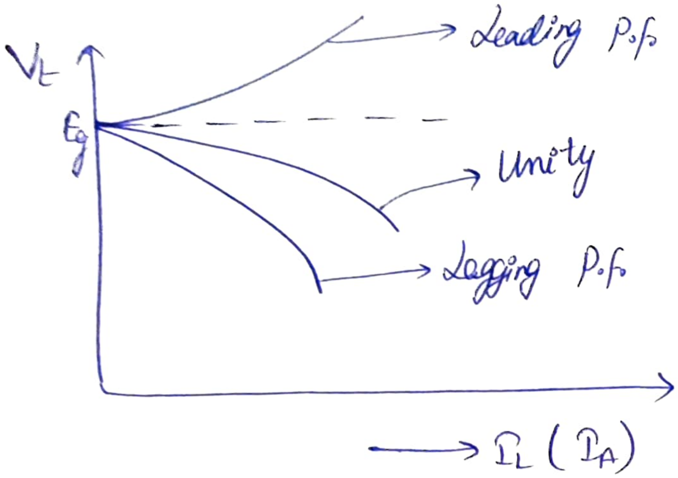
⟹ ϕ_{res} is along ϕ_R.

⟹ i.e. Both are in upward dirn i.e. ↑ mag. field.

⟹ This effect is known as "Re magnetising effect".

⟹ Supply vol. is ↑.

Load ch. of Alternator :



$$E_g = V_t + I_a R_a + I_a X_s$$

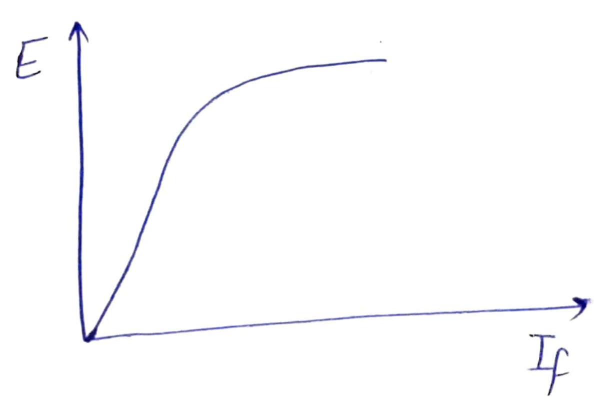
$$V_t = E_g - I_a R_a - I_a X_s$$

$$V_t = E_g - I_a (R_a + jX_s)$$

$$V_t = E_g - I_a Z_s$$

O.C.C : (Magnetisation characteristic) :

E Vs I_f →



Voltage Regulation :

⟹ Vol. can be measured by 3 method without loading Alternator, 1). Synchronous Impedance Method : [If we do not use this method then we have to drive gen. in full load]

1) No load test [E Vs I_f]
2) Short ckt test [$I_{A(sc)}$ Vs I_f]

$$Z_s \text{(Syn. Impedance)} = \frac{\text{open ckt Vol.}}{\text{short ckt Current}}$$

⇒ By this method we can calculate syn. impedance.

⇒ $\boxed{R_{ac} = 1.5 R_{dc}}$ Due to screen effect AC resistance is more.

Parallel operation :

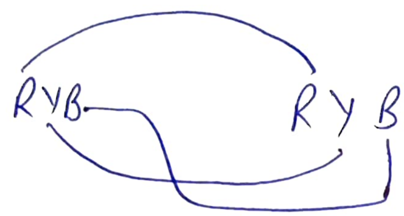
Need of ll ops →

1) More alternator can supply a bigger load than a single alt.
2). During a period of light load one or more alternator may be shut down to run rest of alt. at max. eff.
3) If there is breakdown of gen., there is no Interruption of power supply.
4). When one m/c is taken out for servicing, the remo. m/c maintain the
5). For ↑ the future demand of load more m/c can be added without dist. the

6) The operating cost & cost of energy generated are reduced for ∥ opr.

Cond. of ∥ opr. :-

⇒ The phase sequence of the bus bar vol. & incoming m/c vol. must be same.



2). The bus bar vol. & o/c m/c ter. vol. must be same.

3) The freq. of bus bar vol. & I/c m/c vol. must be same.