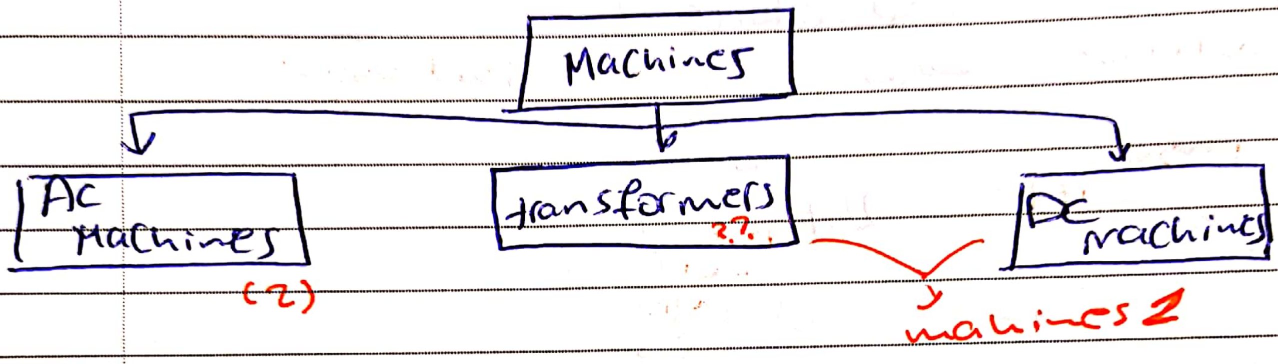
No.

* electrical machines 2 :-

- This includes :-
- electromagnatic principles (to review)
- power transformers.
- Direct Current Machines.



* Review of electromagnatics

electrial : voltage (EMF), current, power, resistance (Impedence), capacitance.

magnatic : MMF (magnetomotive force.)

$F = i \cdot N$

* no magnatic structure with out current except its a permenent magnet } to make a machine from a permenent magnet it will be very expensive.

$\boxed{i = \text{in (electrial)}}$ → responce.

$\boxed{i = \text{(magnatic)}}$ → ϕ (flux) Wb (forcing function)

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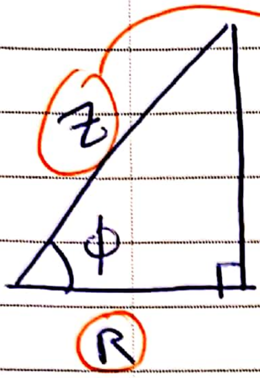
* between the forcing function & the responce in electric structures,

The resistance. No.



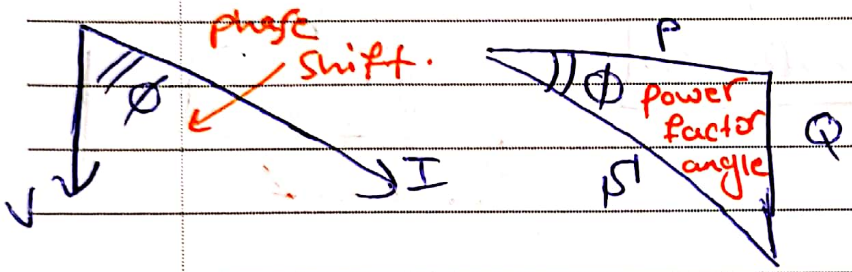
combination of real element & Imaginery (reactance).

(Reactance)

resistance.

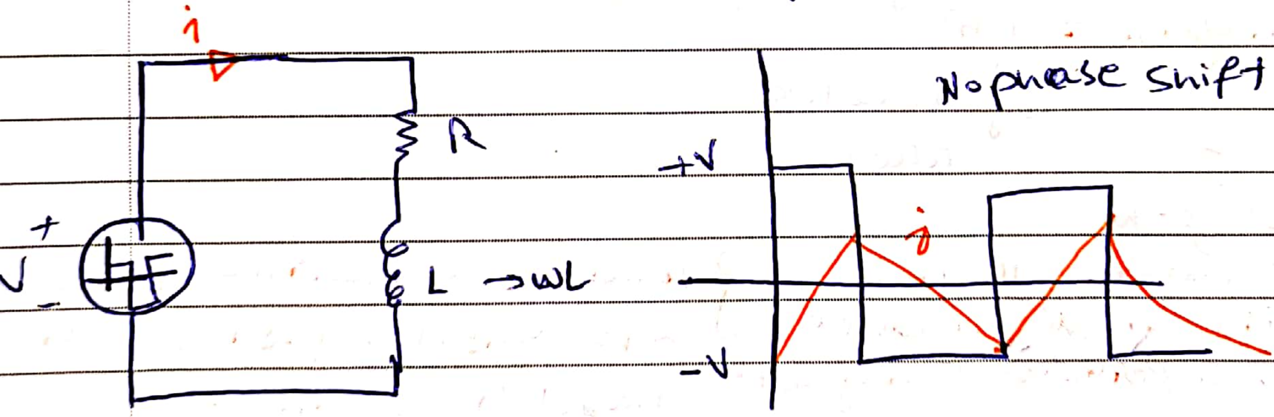
capacitance

بتكون سالب ϕ → load angle.



ϕ : PF angle & phase shift and lead phase

→ same if v and i are pure sinusoidal.



$$V(t) = \begin{cases} +V, & 0 \le \omega t \le \pi \\ -V, & \pi < \omega t < 2\pi \end{cases}$$

$$v(t) = \sum V_m(n) \sin(n\omega t + \psi(n))$$

$$V_m(n) = \sqrt{A^2(n) + B^2(n)}$$

$$\psi(n) = \tan^{-1}\left(\frac{A(n)}{B(n)}\right)$$

smile for life

$PF = x \cos\phi$

non sinusoidal $= DTF * DPF$ No.

Distoration factor

$$\frac{I_{fund}}{I_{total}}$$

Displacement angle.

$$\cos(\psi_{v(1)} - \psi_{i(1)})$$

fund n=1

fund n=1

lec(2):-

	forcing function	Responce	factor of responce.
electric	V	i	Resistance (Impedence) $R = \frac{\rho \ell}{A} = \frac{\ell}{\sigma A}$
Magnatic	F, i	ϕ	Relectance. (Rm) $R_m = \frac{\ell}{\mu A}$

ℓ → طول لما، طول بيمشي فيه flux

A → cross sectional area.

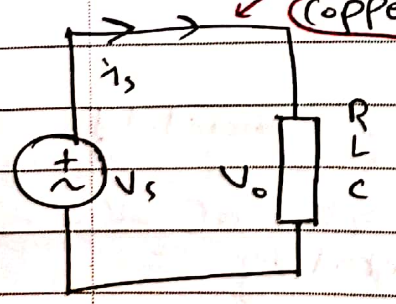
$\sigma \equiv$ conductivity (eletric)

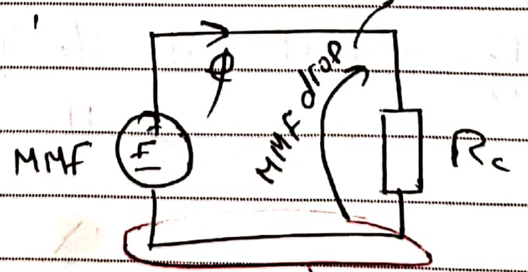
$\mu \equiv$ Magnatic conductivity

* Resistance (Impedence) → complex (imag + Real)
* Reldctance → (only real)

copper conductors

or requirement.





iron ferromagnatic

* series & parallel connections [same Rules]

Laws, Theorms, priciples, Techniques, ... [same]

No.

Laws

Ohm's law $i = \frac{V}{R} \longrightarrow \phi = \frac{F}{R_e}$

Node

KCL : $i_{node} = \sum_{n=1}^{k} i(n)$ branches $\rightarrow$ Kirchhoff's flux law.

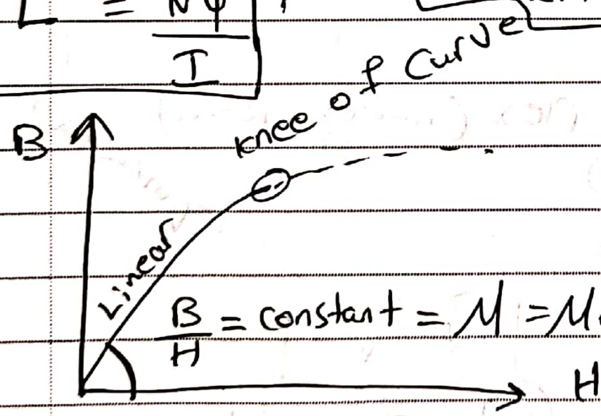
$\sum_{n=1,2,3,\dots} \phi(n) = 0$

KVL : $\sum V$ in a closed path $= 0 \longrightarrow \sum F$ in a closed path $= 0$

Amper's law : $N \cdot i = \oint \bar{H} \cdot \bar{dl}$

then $\boxed{F = NI = H\ell = \phi R_m}$

$\boxed{L = \frac{N\phi}{I}} \rightarrow \boxed{L = \frac{N^2}{R_m}} \rightarrow \frac{N \cdot A \cdot B}{\frac{H\ell}{N}} = \frac{N^2 \mu A}{\ell} = \boxed{\frac{N^2}{R_m}}$



$\frac{B}{H} = \text{constant} = \mu = \mu_0 \mu_r$ $\rightarrow$ relative permebility

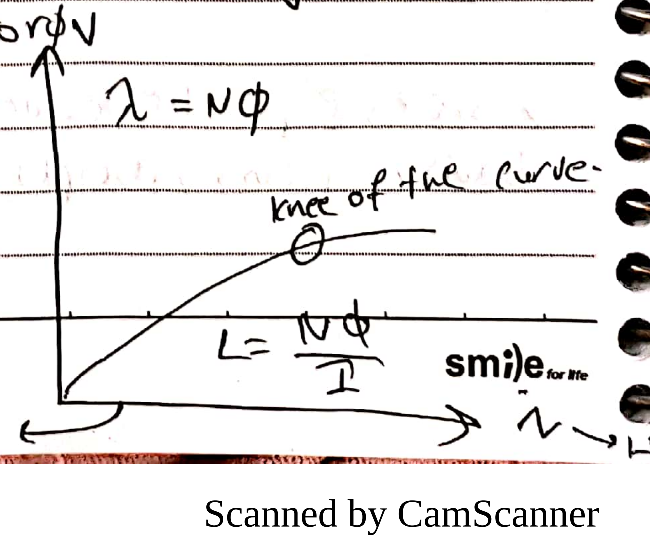
μ_0 : free space or air permebility

$1 \leq \mu_0 \leq \longrightarrow$ (up to) 400,000

$V = k \cdot \omega_m \cdot \phi$

$B = \frac{\phi}{A}$

$i = \frac{H\ell}{N}$



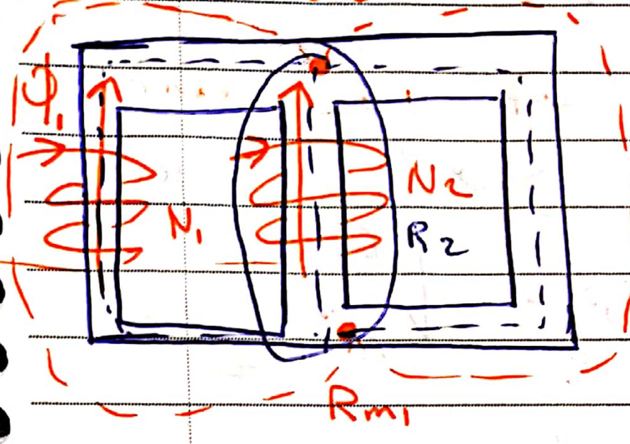
$\lambda = N\phi$

$L = \frac{N\phi}{I}$

smile for life

No. lecture (3)

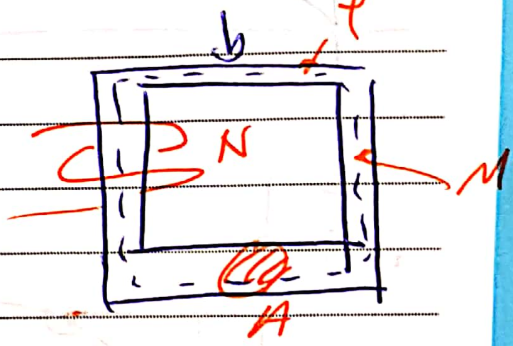
* Inductance:-



• self inductance $L = \dfrac{N^2}{R_m}$

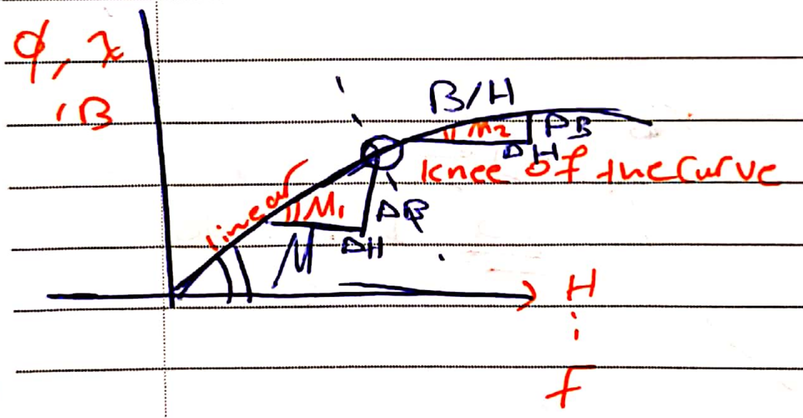
$R_m = \dfrac{l}{\mu A}$

$= \dfrac{N^2 \mu A}{l}$ → I can use it only whe I have one coil



$L = \dfrac{\lambda}{I}$ (for linear)

or $\dfrac{\Delta\lambda}{\Delta i}$ (for non-linear)



$\mu_1 > \mu_2$

when saturation increases $\dfrac{\Delta B}{\Delta H} = \mu$

↳ derease.

** Saturation of magnatic core leads to (almost short-circuit)

↓ electric

→ why? ① $\boxed{\mu}$ ~~increase~~ decrease then from ② $L = \dfrac{N^2 \mu A}{l}$

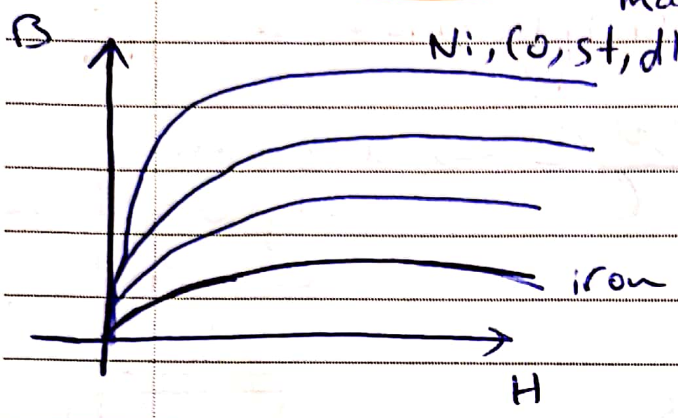
then ~~[illegible]~~

↳ ③ low $\omega L = X$ → ④ leads to short circuit.

smile for life

$B_m * A$

$$E \equiv V \equiv 4.44 * N_{ph} * \phi_{max}\, f \rightarrow V = K \cdot B_m * f$$



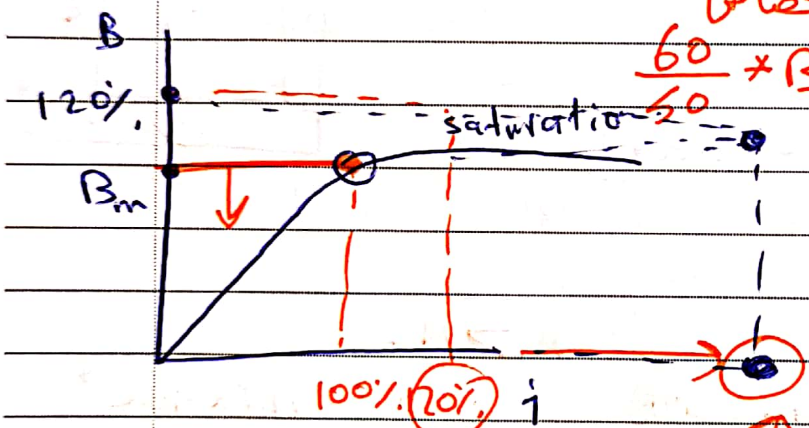
If V = constant

$B_m * f$ = constant

60Hz ↓ 50Hz

بترتفع بنفس النسبة للانخفاض

$\frac{60}{50} * B_m$



بتصير هون

so I'll have losses

linear هادا لو كان

بس لأنه في saturation

أما

f 50 ⟶ 60

then $B = B_m * \frac{50}{60} \rightarrow B \rightarrow 80\%$ (linear)

then I will decrease.

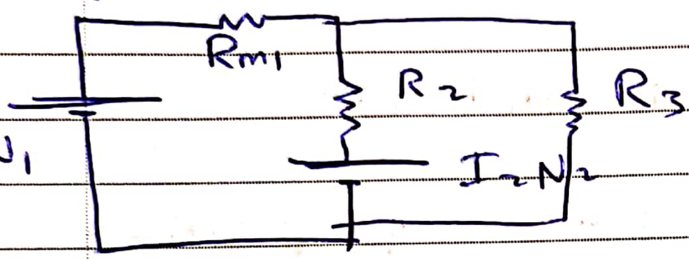
* Back to the (self inductance)

to calculate $L_1 = \dfrac{N^2}{R_m} \rightarrow$ Rm: as see

don't use $\dfrac{N^2 \mu A}{\ell}$

- eq clct.

$$R_m = \frac{\ell}{\mu A}$$



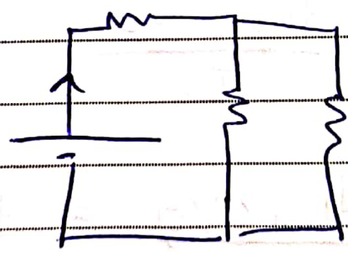
R_m (seen by N_1) $= R_{m1} + (R_{m2} // R_{m3})$

بعتبر N_2 مش موجود

then $L_{11} = \dfrac{N_1^2}{R_{meq}} = \dfrac{\lambda_{11}}{I_1} = \dfrac{N_1 \phi_{11}}{I_1}$

* to find $\phi_{11} \equiv$ flux due to coil (1)

while or other sources are killed



$$\phi_{11} = \frac{I_1 N_1}{R(\text{seen by coil } (1))}$$

killing $\equiv$ super position theorm is applied.

in linear clct

$L_{11} = \dfrac{N_1^2}{R_m(eq)}$ $\boxed{\text{must equal}}$ $\dfrac{N_1 \phi_{11}}{I_1}$

~~$\dfrac{N_1^2}{R_m}$~~

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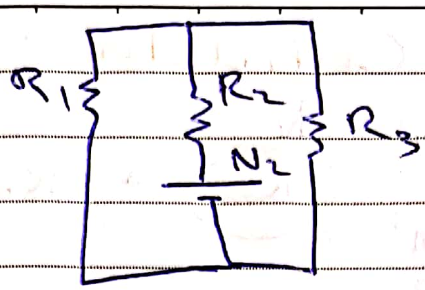
No.

$$L_{22} = \frac{N_2^2}{R_{m\,eq}^{(2)}}$$

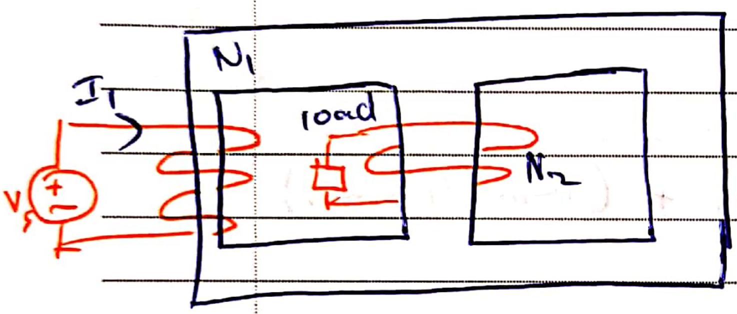
coil No

coil current



$$R_{eq}^{(2)} = R_{m2} + (R_1 // R_3)$$

** Mutual Inductance / coil coupling :-



(also super position is applied)

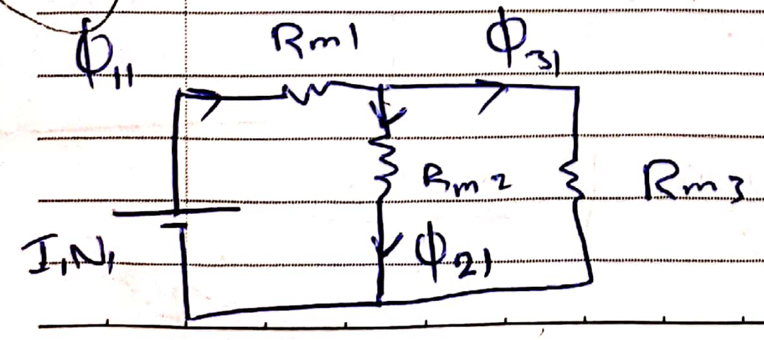
$M_{21} \rightarrow$ mutual inductance of coil (2) due to current (1)

$M_{12} \rightarrow$ " " " " (1) " " " (2)

$$M_{21} = \frac{\lambda_{21}}{I_1} = \frac{\phi_{21} * N_2}{I_1}$$

$$M_{12} = \frac{\lambda_{12}}{I_2} = \cancel{\phi_{12} * N_2} = \frac{\phi_{12} * N_1}{I_2}$$

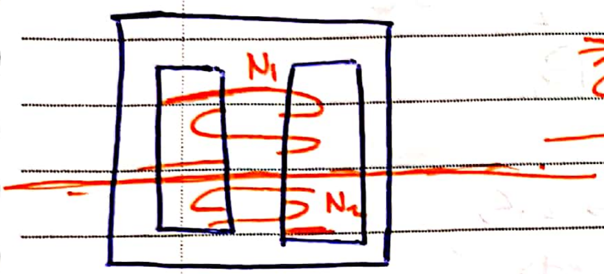
$\phi_{21} N_2 / I_1$

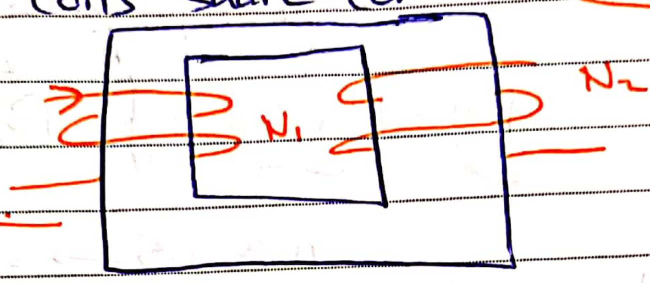


No. lecture (4)

$M_{12} \overset{?}{=} M_{21}$

↑ if both coils share common homogeneous core → if the





core type

shell type.

$M = K\sqrt{L_{11} L_{22}}$

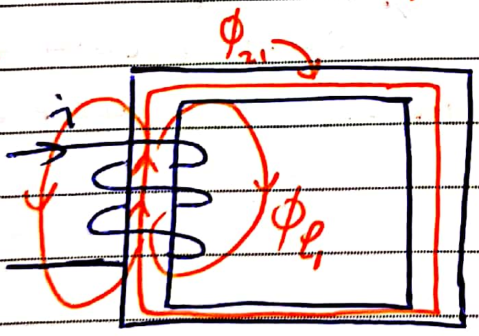
k : coupling coefficient

$1 \leq K \leq \ldots \longrightarrow$ small value.

poor coupling. (high lealcage flux)

tight coupling → ≈ zero leakage flux

then $\phi_{11} = \phi_{21} + \phi_{\ell_1}$



** core losses

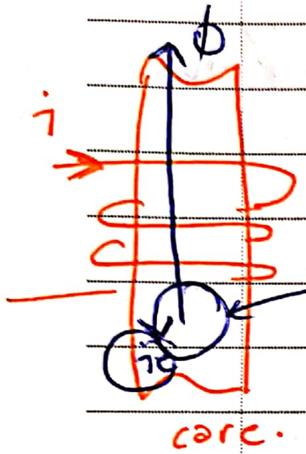
copper loss $\longrightarrow P_{cu} = I^2 R_{elect}$

Core loss is due to flux ϕ in the core.

$P_{core} = P_{magnatic} = P_{iron} = P_{eddy\text{-}current} + P_{hysteries}$

Eddy current loss → ϕ should be time varying.

$\phi \rightarrow \frac{d\phi}{dt} \neq 0$ ↳ $\frac{d\phi}{dt} \neq 0$



volume of the core.

$$P_e = K * Vol * f^{n} \cdot B_m^{2}$$

$n \simeq 1.5 \rightarrow 2.5$

$n \equiv$ stiemets factor

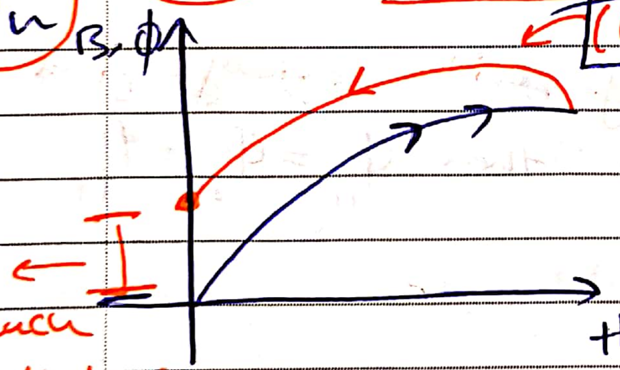
$$P_e = K_n \cdot f^{n} \cdot B_m^{2}$$

voltage dependent.

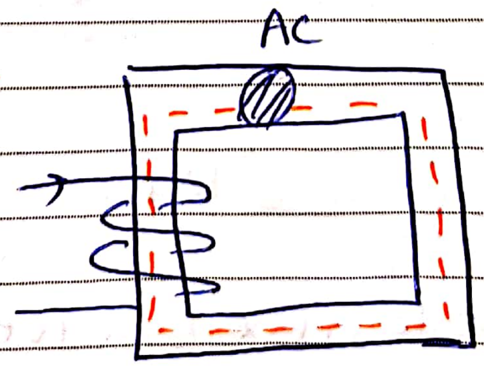
P_h (AC) because as shown the (back current) is not the same of the first in direction & amount.

(hard material)

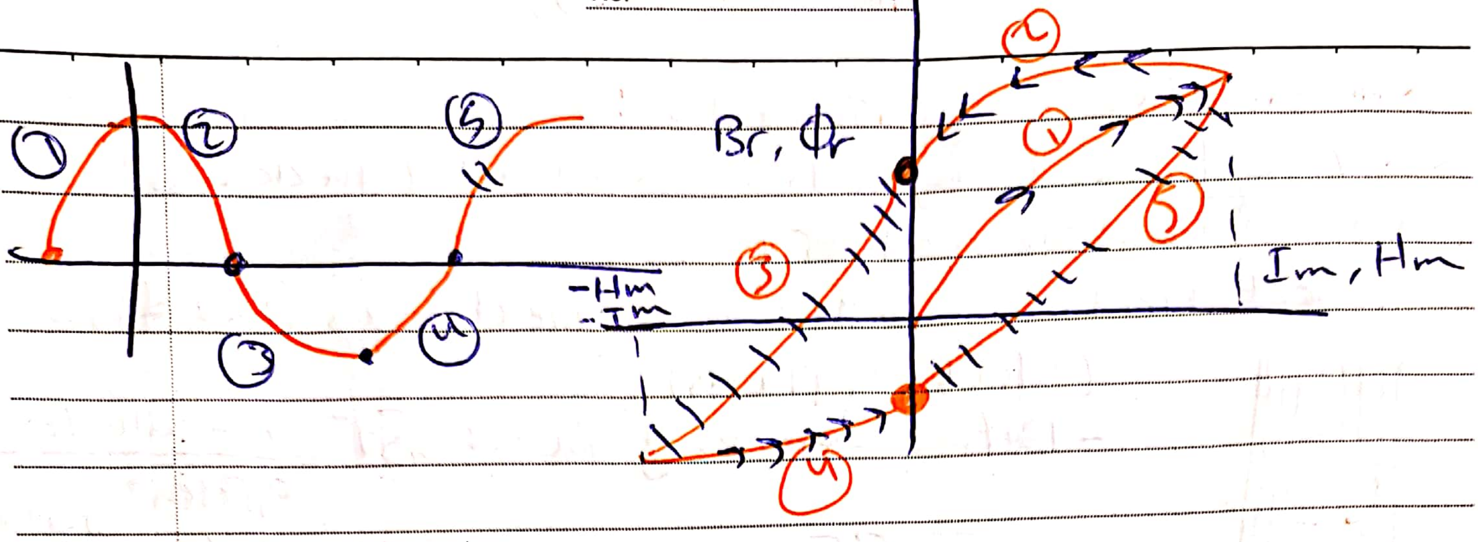
↳ but if the line went back to zero the its a soft material



as much this distance is bigger the material is harder.



No.



Δ Area $= \Delta B * \Delta H$

$= \frac{\phi}{A} * \frac{NI}{\ell} = \frac{V.I.\,sec}{vol} = \frac{Joule}{vol}$

* This impies that the area of the hystersis loop repr the hytersies loss per volume unit.

$P_h = Area * vol * f$

$P_h = k \cdot volume \cdot f \cdot B_m^2$

$= K_h \cdot f^2 \cdot B_m^2$

$\boxed{P_{core} = P_h + P_e}$

Pcore → fixed losses as for as the voltage is fixed.

P_h is usually less than P_{cu} P_{cu} = variable losses.

when $P_h = P_{cu}$

↓ leads to

Max. efficiency of the machines.

smile for life

No. lecture (5)

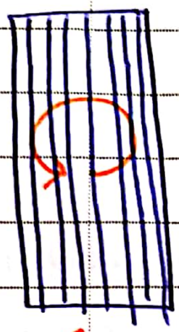
* How to reduce eddy current loss?

** Core limination: (thin sheets of I thickness isolated from each other).

Sheet direction is in the same direction as flux flow.

(Stacking process)

- Define stacking factor $SF = \dfrac{\text{Actual core vol}}{\text{apperent core vol.}}$

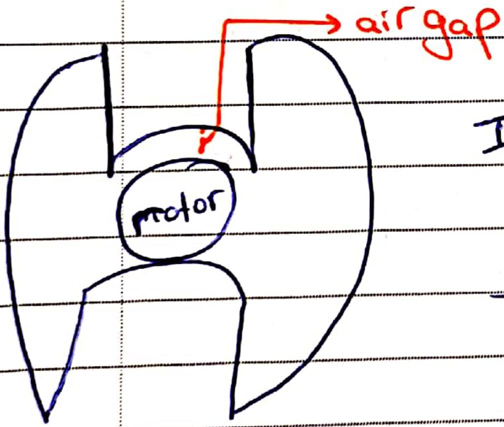


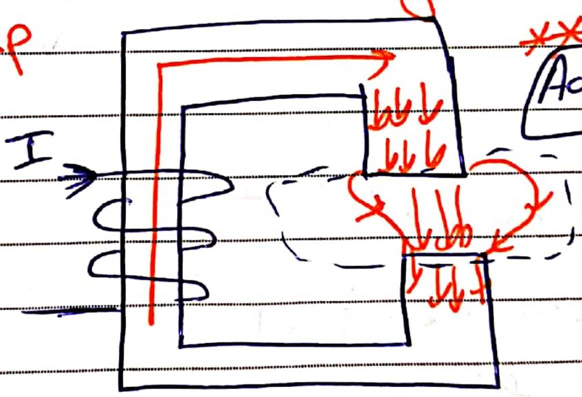
$SF < 1$

$SF = 1 \rightarrow$ No sheets

$\uparrow \phi$ (time varying)

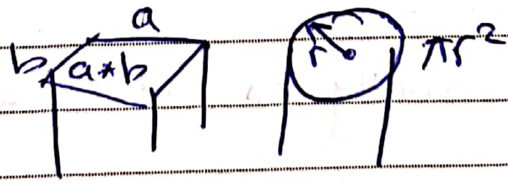
* if not AC no need for laminating.





** A airgap correction (fringing)

* flux distribution in the airgap area is not uniform as that inside core



$$B_c = \frac{\phi}{A_c}$$

$$B_g = \frac{\phi}{A_{g(App)}}$$ if no fringing

$$B_g = \frac{\phi}{A_{g}(eff)}$$

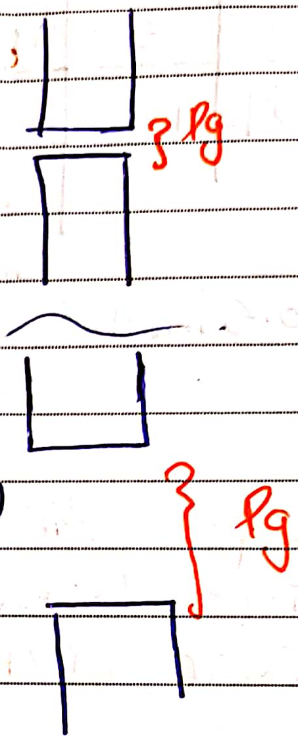
$A_g(eff) > A_g(app)$

fringing factor

$$A_g(eff) = \underset{\sim}{F.F} * A_g(app)$$

$$FF \geq 1$$

$$FF = \frac{A_g(eff)}{A_g(app)}$$

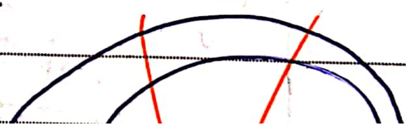


$$= \frac{(a+l_g) * (b+l_g)}{a * b}$$ (rectangular)

(circular section)

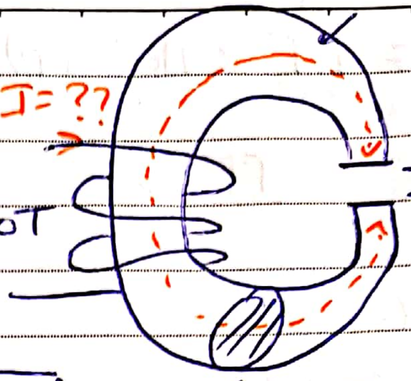
$$FF = \frac{\pi(r+l_g)^2}{\pi r^2}$$

$$B_g = \frac{\phi_g}{A_g(eff)} = \frac{\phi_g}{FF * (A_g app)}$$



(B/H)

H	2500	3000	3500	4000
B T/(wb/m²)	1.55	1.59	1.6	1.615



$\phi = 0.5\,mwb$

$\boxed{D = 2cm}$ $\leftarrow A_c = \pi \times 10^{-4}\ m^2$

$A_c = \pi r^2$

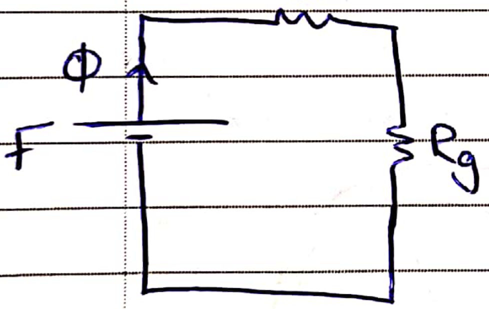
$\mu_r = 4000$

I = ?

a) No airgap . $\mu_r = 4000$ (linear)

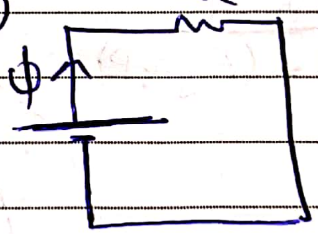
b) $\mu_r = 4000$ (linear) with air gap

c) non linear (B/H) curve given. (جدول أو رسم)



in a) $R_g = 0$ because $R_g = \dfrac{l_g}{\mu_\circ A}$

a)



$R_c = \dfrac{l_c}{\mu_\circ \mu_r * A_c}$

$= \dfrac{30 \times 10^{-2}}{4\pi \times 10^{-7} * 4000 * \pi}$

$A_c = \pi r^2 = (1 \times 10^{-2})^2 *$

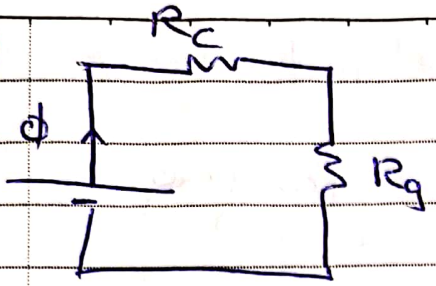
$R_c = 190 \times 10^{3}\ \left(\frac{1}{H}\right)$

$F = IN = \phi * R_m$

$I = \dfrac{\phi * R_m}{N} = \dfrac{0.5 \times 10^{-3} * 190 \times 10^{3}}{500} = 0.19\ A$

stacking بال Ac ال نضرب correct the lamination factor. لو قال *

b)



$$R_g = \frac{l_g}{\mu_0 A_g} = \frac{1\times10^{-3}}{4\pi\times10^{-7}\times4000\times\pi\times10^{-4}} = 2.5\times10^{6}\ \frac{1}{H}$$

*لو حكى خيال fringing بضرب
اهمام بال fringing
factor.

$\boxed{A_g = A_c} \rightarrow$ No fringing.

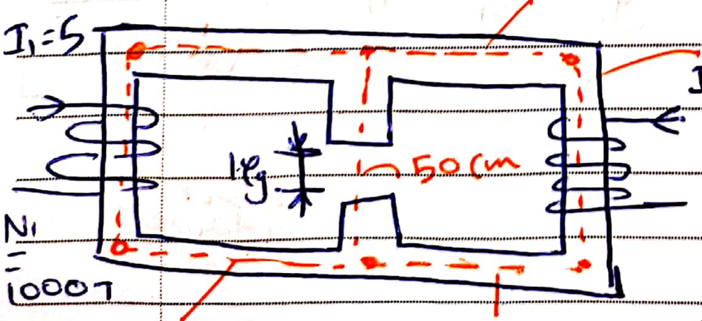
$$I\cancel{N} = \frac{\phi(R_c+R_g)}{N} = \frac{0.5\times10^{-3}(2.5+0.19)\times10^{6}}{500} = 2.7\ A$$

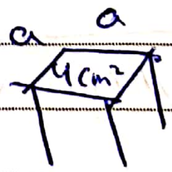
c) $H_g = \frac{B_g}{\mu_0} = \frac{\phi}{A_g\mu_0}$

$B_c = \frac{\phi}{A_c} \rightarrow$ from curve $\rightarrow$ find H_c

$IN = H_c l_c + H_g l_g$

lecture (6):-





$\mu = 1000\mu_0$

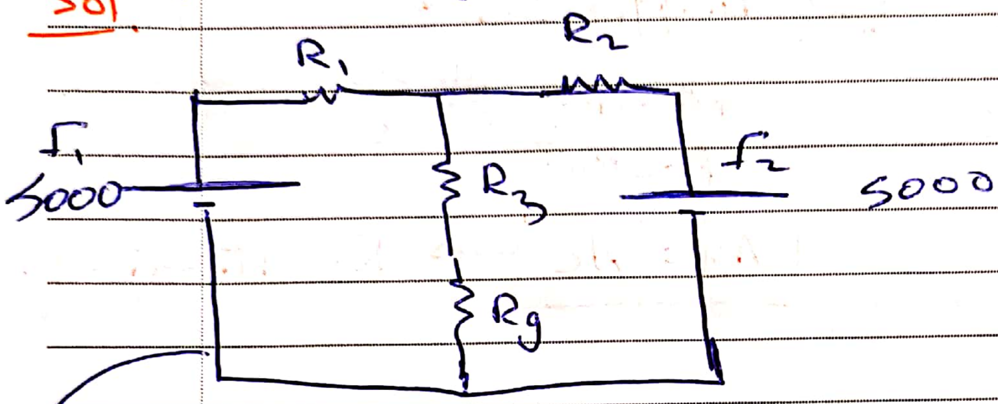
$l_g = 0.5cm$

No.

$\phi_g , B_g , H_g = ??$ self & Mutual inductance.

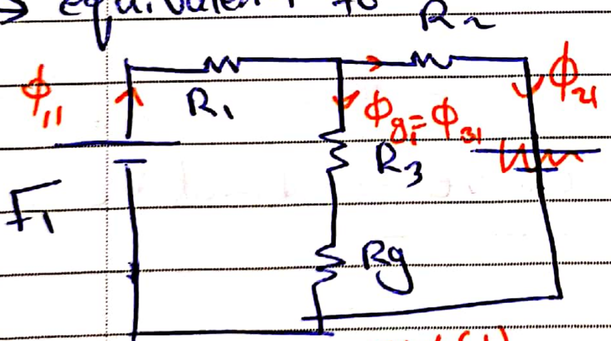
Neglect leakage but correct for fringing.

sol.

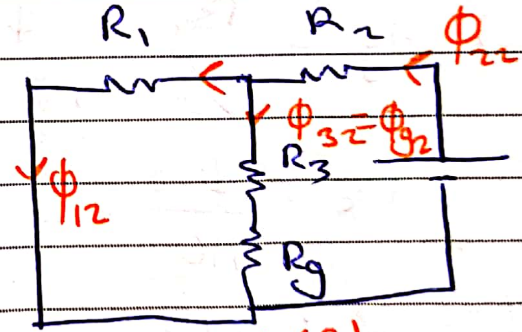


- since $L_{11}, L_{22}, M_{21}, M_{12}$ are req, super position is to be applied.

→ equivalent to



$+$



ckt(1) ckt(2)

$$\phi_{11} = \frac{F_1}{[R_2 // (R_3+R_g)+R_1]} , \quad \phi_{g_1} = \phi_{31} = \phi_{11} * \frac{R_2}{[R_2 + (R_3+R_g)]}$$

current devider rule.

$$\phi_{21} = \phi_{11} - \phi_{31}$$

or $\phi_{11} * \dfrac{(R_3+R_g)}{R_2+R_3+R_g}$

smile for life

No.

$$\phi_{22} = \frac{F_2}{R_2 + [R_1 // (R_3 + R_g)]} = \phi_{11} \quad \text{only in this } \underline{\underline{\text{case}}}$$

- مش دائماً

$$\phi_{g2} = \phi_{32} = \phi_{22} * \frac{R_1}{R_1 + R_3 + R_g}$$

$$\phi_{12} = \phi_{22} - \phi_{32}$$

$$* \boxed{\phi_g = \phi_{g_1} + \phi_{g_2}}$$

$$B_g = \frac{\phi_g}{A_{eff}}$$

$A_{eff} \rightarrow$ (correct for fringing).

$$-A_{eff} = (2+0.5) * (2+0.5) = 6.25\ cm^2 = 6.25 \times 10^{-4}\ m^2$$

$$* \boxed{B_g = \frac{\phi_g}{6.25 \times 10^{-4}}}$$

$$\boxed{H_g = \frac{B_g}{\mu}}$$

$$\boxed{R_1 = R_2 = \frac{\cancel{0.5}\ 1.5}{4 \times 10^{-4} \times 1000 \times 4\pi \times 10^{-7}}}$$

$$R_3 = \frac{0.495}{[\quad]}$$

$$R_g = \frac{0.5 * 10^{-2}}{6.25 \times 10^{-4} \times 4\pi \times 10^{-7}}$$

$$L_{11} = \frac{\overset{N_1}{1000} \times \phi_{11}}{\cancel{N_2}\ I_1}, \quad M_{12} = \frac{N_1 \phi_{12}}{I_2}$$

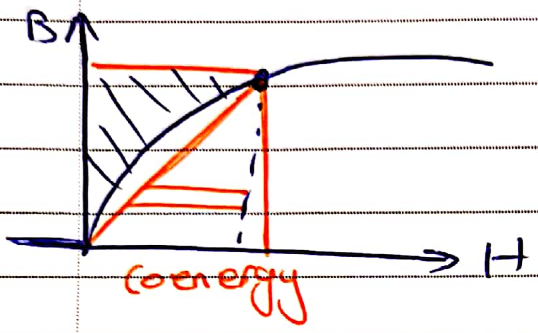
$$L_{22} = \frac{N_2 \phi_{22}}{I_2} \qquad M_{21} = \frac{N_2 \phi_{21}}{I_1}$$

if $M_{12} = M_{21}$ then its homogeneous.

$$w_e = \int P\,dt = \int e\,i\,dt = \int N\frac{d\phi}{dt}\,\frac{H\ell}{N}\,dt$$

$IN = H\ell$

$$\ell A\int H\,dB \rightarrow \boxed{Vol.\ \mu\int H\,dH}$$



$w_f = \int H\,dB$

if the integration is complicated we can calculate the coenergy & then subtract it from the rectangle.

(electrically isolated).

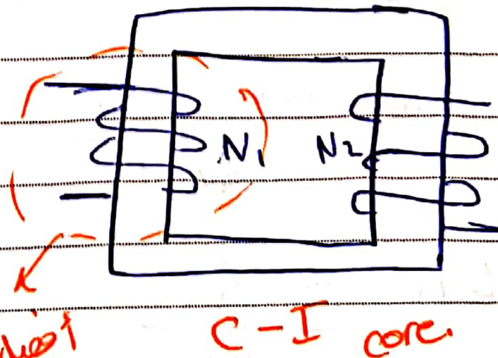
** Transformers:-

a Transformer:- static, Electromagnetic device, where at two coils are electromagnetically coupled by a core that is usually ferromagnetic. & this is a pure AC ~~machine~~/device, (flux should be time varying → $\frac{d\phi}{dt} \neq 0$).

* core: two major forms:

① * core type C-I

* shell type E-I



أفضل شي يكون ال coils فوق بعض (tite coupling).

E-I core.

No.

→ Could be vertical or Horizantal

→ best coupling (tite) when the two coils are put here.

E-I core.

No.

→ Could be vertical or Horizantal

→ best coupling (tite) when the two coils are put here.

*lecture (7):-

$\tau \approx 0.1 \sim 0.5$

↳ in power applications.

$\tau \approx 0.05 - 0.01$

↳ communication

Stacking factor = $\dfrac{\text{vol (actual)}}{\text{vol (app)}}$

(تأثر)

تقريباً

(unity

$\boxed{\tau \longrightarrow \text{قلّت}}$

eddy current loss will decrease.

Homework (1)

$$W_g = \frac{1}{2} \text{vol} * B_g * H_g$$

$$= \frac{1}{2} \text{vol} \frac{B_g^2}{\mu}$$

$$= \frac{1}{2} \phi^2 R_{mg}$$

$$= \frac{1}{2} \text{Vol} * H_{gm}$$

$$W_c = \frac{1}{2} \phi^2 R_m^c$$

$$= \frac{1}{2} B_c * H_c$$

$$= \frac{1}{2} B * A * \frac{l}{\mu A}$$

Q2:- $P_h = k_h * f * B_m^n$

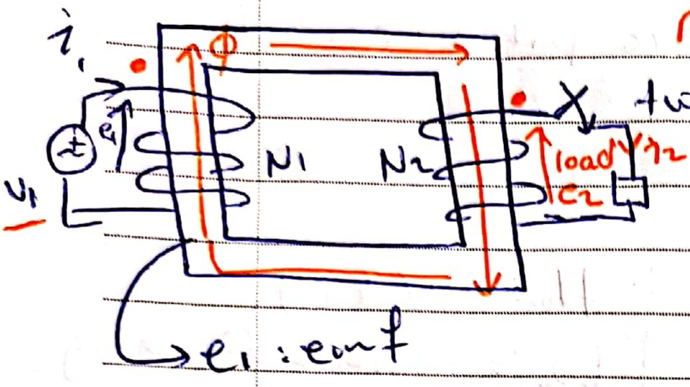
$$P_e = f^2 * k_e * B_m^2 * \tau^2$$

τ: lamination thickness

No.

lecture (8) :-

Back to transformers:-



Basic Tr :- Common core + atleast two coils or windings.

$\boxed{\text{one coil}}$ is excited by an AC Current. This coil is refered as the primary coil.

$\boxed{\text{The second}}$ coil is usually connected to the load, to supply it by power (indirect), is refered to the secondary coil.

$i_1 \to$ flux (ϕ) $\to$ emf against the supply.

$$e_1 = -N_1 \frac{d\phi}{dt} \quad \text{(counter emf)}$$, usually $e_1 < V_1$

because of the leakage.

** due to ϕ link coil ② e_2 is created according to Faraday's law.

$$e_2 = -N_2 \frac{d\phi}{dt}$$

** The direction of e_2 is such that when a current flows into the load, it should create a flux that opposes the original flux.

$$\frac{e_1}{e_2} = \frac{-N_1 \frac{d\phi}{dt}}{-N_2 \frac{d\phi}{dt}} = \frac{N_1}{N_2}$$ $\Longrightarrow$ e_1 and e_2 are Inphase (if no losses).

$$= \frac{E_{m1}}{E_{m2}} = \frac{N_1}{N_2} \longrightarrow \frac{E_1 (rms)}{E_2 (rms)} = \frac{N_1}{N_2}$$

No.

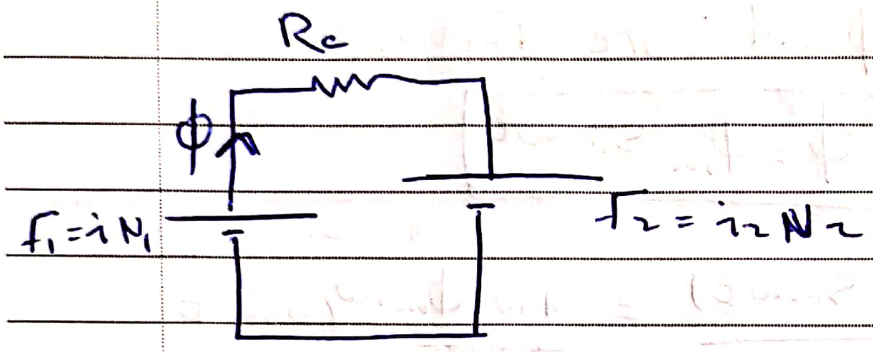
Since $V_1 \approx E_1$, $V_2 \approx E_2$ ∴ $\frac{V_1(rms)}{V_2(rms)} = \frac{N_1}{N_2} = \boxed{a}$

Trans ration

or

Transformation ratio.

Magnatic eq Circuit



Assuming ideal core.

→ $\mu_r \to \infty$

$R_c = \frac{l}{\mu A} = 0 \to \phi * R_c \to 0$

$\mu = \frac{B}{H} \to H = \frac{B}{\mu} \to \frac{B}{\infty} \to \boxed{H \sim 0}$

$i_1 N_1 - \cancel{Hl}$ (or) $\cancel{\phi . R_c}$ $- i_2 N_2 = 0 \to i_1 N_1 = i_2 N_2$

zero (ideal)

$\boxed{\frac{i_1}{i_2} = \frac{N_2}{N_1} = \frac{1}{a}}$

$a = \frac{i_2}{i_1} = \frac{V_1}{V_2}$

$i_1 V_1 = i_2 V_2$

$\boxed{S_1 = S_2}$

$E_{(capital)} \equiv$ rms value

No.

$$\boxed{e_1 = N_1 \frac{d\phi}{dt}}$$

$i_1 = I_m \sin \omega t$

$i_1 N_1 = H\ell = \frac{B}{\mu}\ell = \frac{\phi \ell}{A\mu}$

$$\boxed{i = \frac{\ell}{\mu A N_1}\phi}$$ → ϕ and i are Inphase

$$\boxed{\phi = \phi_m \sin \omega t}$$

$= N_1 \frac{d(\phi_m \sin \omega t)}{dt} = \frac{+N_1 \phi_m \cdot \omega \cos \omega t}{\cancel{\quad}}$

$= N_1 \phi_m \, \omega \sin(\omega t - \frac{\pi}{2})$

$E_{m(1)} = N_1 \phi_m \omega = N_1 \phi_m (2\pi f)$

$\boxed{E(1)} = \frac{E_{m(1)}}{} = \frac{2\pi}{\sqrt{2}} N_1 \cdot f \, \phi_m = \boxed{4.44 N_1 f \phi_m}$

similarity

$E_2 = 4.44 N_2 f \phi_m$

*The effect of running a transformer at lower freq than the rated value
(Assuming V & E is same)

original f

$E_1 \approx V_1 = 4.44 * N_1 * f_1 * \phi_m$

f_2 (new freq)

$E_1 \approx V_1 = 4.44 * N_1 * f * \phi_m'$

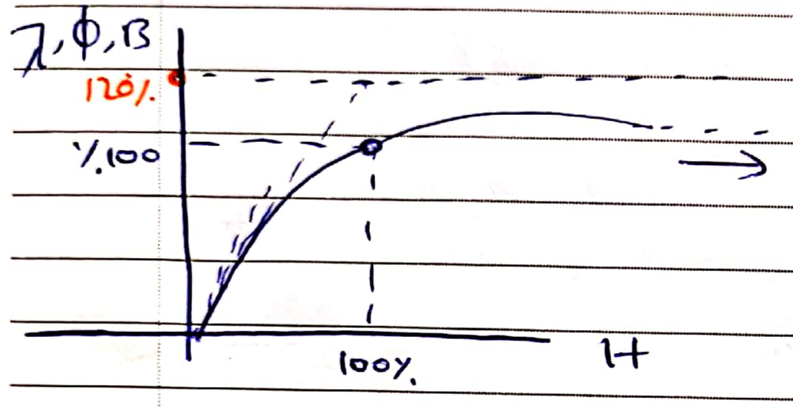
smile for life

** Reduction of f to f' → leads to increase of ϕ_m to ϕ_m' (since V = constant)

* Increasing ϕ_m to ϕ_m' → leads to core saturation.

f 60Hz → 50Hz

ex: $\frac{\phi_m'}{\phi_m} = \frac{f}{f'} = \frac{60}{50} = 1.2$



* which mean very much current is required to match the new flux.

* This current may be in the range of hundreds of the original value leading to transformer destraction.

** If $f' > f$ No danger. but bad design from the economic point of view.

lecture(8): -

* If freq is to be changed then:-

a) If $f' < f_r$ to keep ϕ_m = constant → $\frac{V'}{f'} = \frac{V_r}{f}$

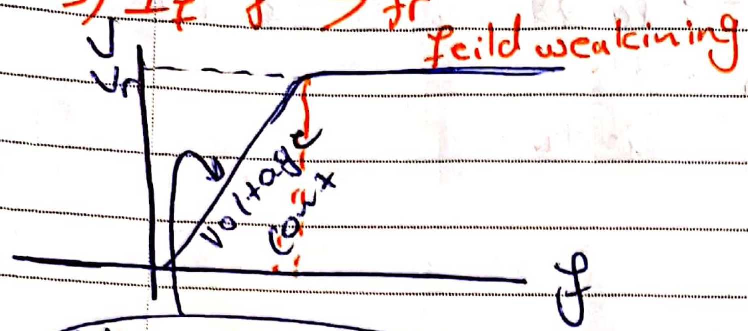
$$\boxed{\phi_m = \frac{V_r}{4.44 N f_r} = \text{Const} = \frac{V'}{4.44 N f'}}$$

$\frac{V_r}{f_r} = \frac{V'}{f'}$ if ϕ_m is to be constant and to avoid any saturation problems

(VVVF control)

No.

b) If $f > f_r$



$$\frac{V}{f} = constant$$

Ideal Tr

$$\frac{E_1}{E_2} = \frac{V_1}{V_2} = a$$

$$\frac{I_2}{I_1} = a$$

1, 2, 3, 4 for an Ideal Tr

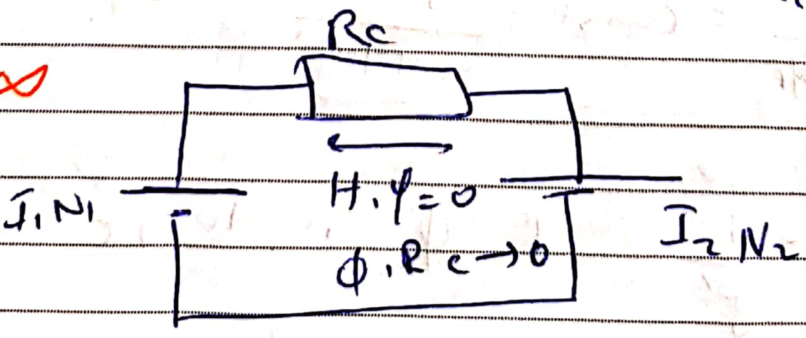
$\boxed{1}$ Coil resistances = 0

$R_1, R_2 \longrightarrow 0$ (No voltage drop, No copper power loss).

$\boxed{2}$ zero-leakage flux $\longrightarrow \phi_\ell \to 0 \to$ tight coupling,

leakage reactances $= 0 \longrightarrow X_{\ell_1}, X_{\ell_2} \to 0$

$\boxed{3}$ $\mu \longrightarrow \infty$



$Rc = \frac{\ell}{\mu A} \longrightarrow 0$

then $H = \frac{B}{\mu} \Longrightarrow 0$

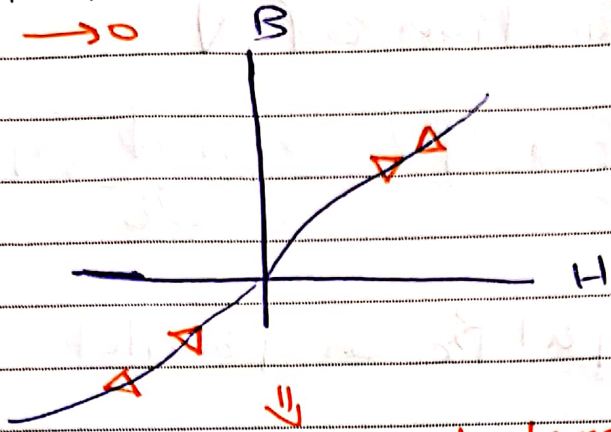
then $I_1 N_1 = I_2 N_2$

No.

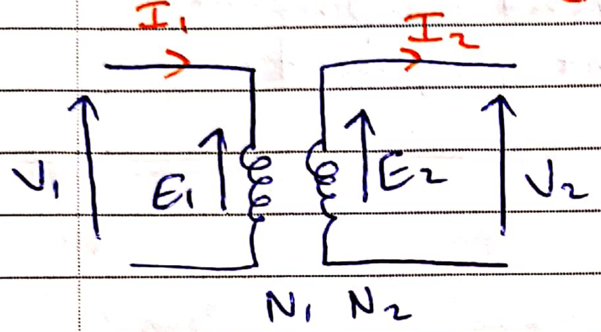
[4] Core loss $\rightarrow 0$

$P_h = 0$

$P_e = 0$

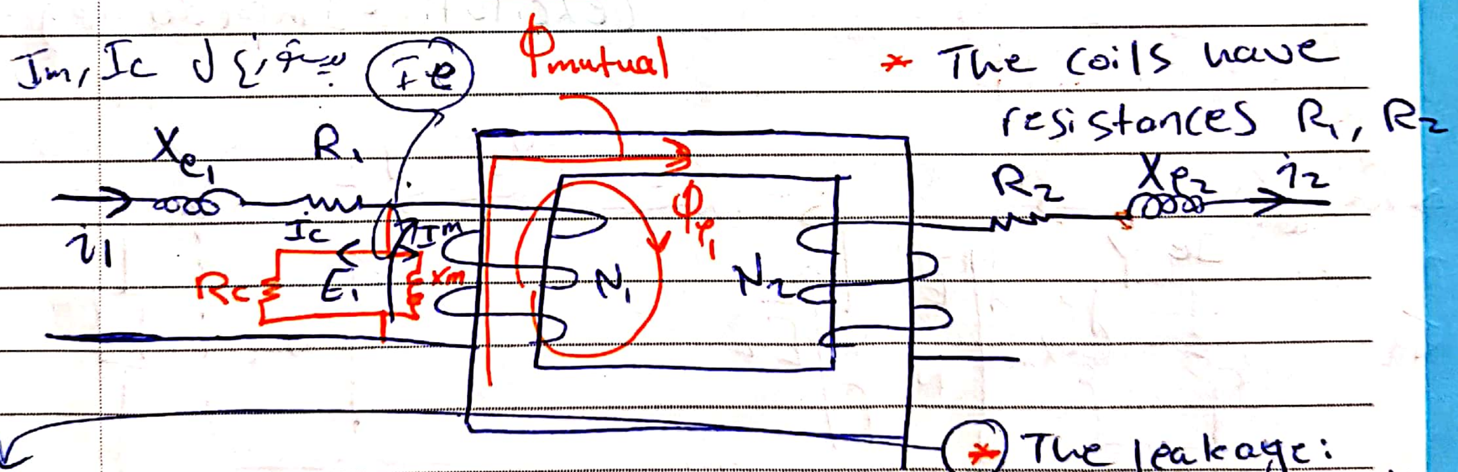


⇓ excellent lamination.



$$\frac{E_1}{E_2} = \frac{V_1}{V_2} = a$$

** practical Transformer



* The coils have resistances R_1, R_2

E1 here less than in Ideal because there is Ic leakage in flux.

(*) The leakage: ϕ_{e_1} leads to $L_{\ell_1} \rightarrow X_{\ell_1}$

* Core loss: Can be represented by a core resistance.

R_c

[*] Xm → Mutual reactance (Parallel with R_c) by which E_1 and E_2 are produced.

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No.

core loss → function of $\underline{\underline{V}}$

$P_h \ldots B^2 \rightarrow \phi \rightarrow \boxed{\frac{N\,d\phi}{dt} = V}$

$P_e \ldots B^2$

then we put R_c on parallel

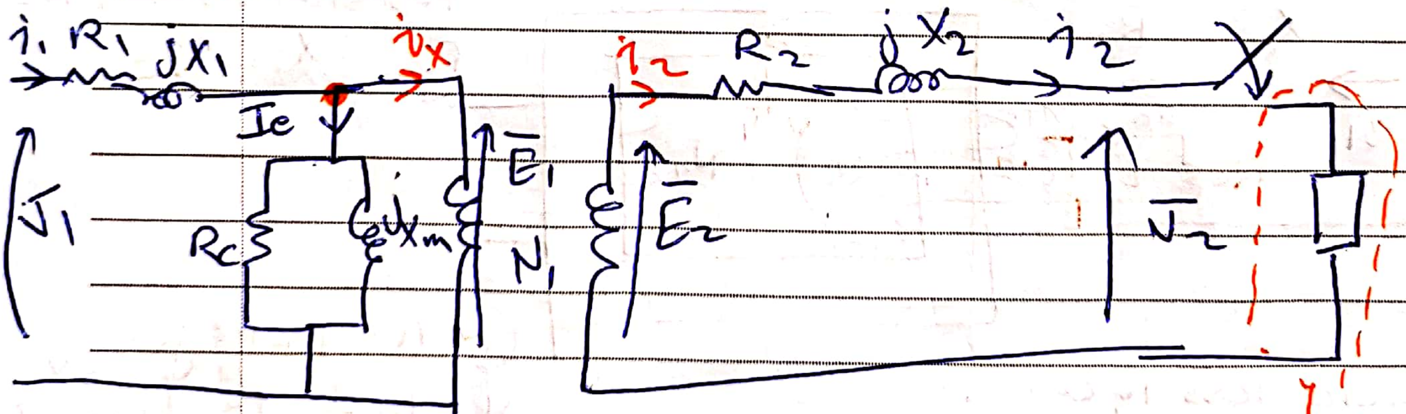
* I_m : Magnetization current component.
  I_c : core-loss current component.

$\boxed{I_\varphi} = I_c + I_m$

↓ excitation current.

$Z_o = (R_c // jX_m)$ → core equivalent Impedance. (excitation Impedance).

eq circuit



$Z_1 = R_1 + jX_1$

transformer at Load.

$\boxed{i_{Load} = i_2}$

No. lecture (9)

$$i_x \stackrel{?}{=} i_2$$

$$i_x N_1 = i_2 N_2$$

$$i_x = \frac{N_2}{N_1} i_2 = \frac{i_2}{a}$$ → (equivalent load current) → current of the supply to compensate for i_2 in the load.

∴ Supply current i_1 has two components $i_1 = i_e + i_x$

$$= \underbrace{i_e}_{\text{compensate for losses and magnetization}} + \underbrace{\frac{i_2}{a}}_{\text{load component}}$$

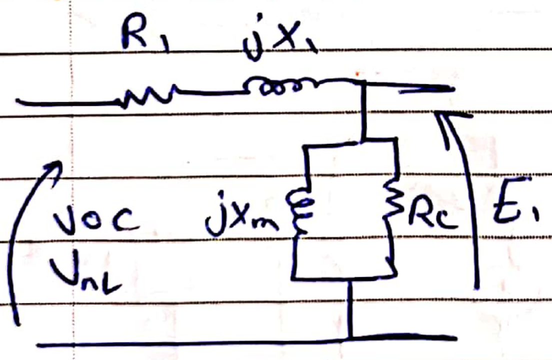
* At No-load or at open circuit

$i_2 = 0$, $i_x = 0$

$$\boxed{i_1 = i_e}$$

i_1 at No-load $= i_e = i_{oc} = i_{(\text{no load})} \equiv i_{NL}$

Eq. Circuit of Tr at No load.

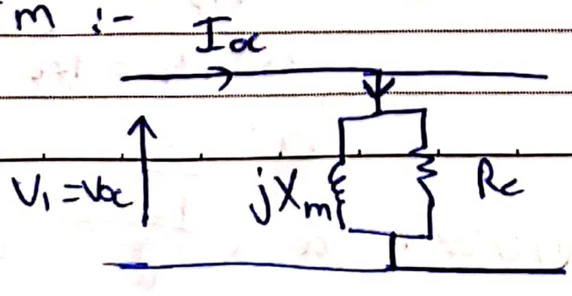


$R_1 \lll R_c$

$X_1 \lll X_m$

$Z_o = (R_c // jX_m) \ggg (Z_1 = jX_1 + R_1)$

** At no-load the eq. circuit is reduced to the form :-

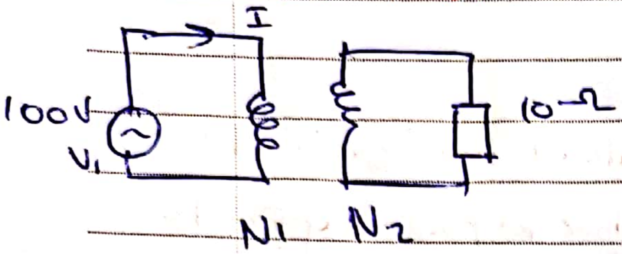


$$\boxed{Z_{oc} = R_c // jX_m}$$

(open ckt impedance or no. load impedance).

No.

* In Ideal transformer in circuits(2)



$I_2 N_2 = I_1 N_1$

$I_1 = \frac{I_2 N_2}{N_2} = \frac{I_2}{a} \longrightarrow I_1 = I_2' \rightarrow$ the (load current refered to the supply or primary)

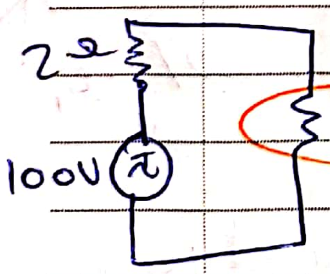
$Z_L = \frac{V_1}{I_1}$ → as seen by the supply.

$$Z_L' = \frac{V_2 * a}{\frac{I_2}{a}} = \frac{V^2}{I_2} * a^2 = Z_L * a^2$$

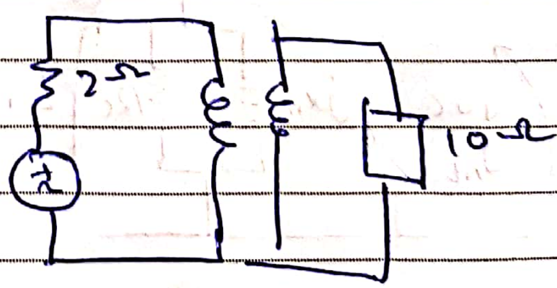
$\boxed{V_2' = aV_2} \longrightarrow$ (load voltage as seen by the primary or the supply).

* supply 100 V, $R_1 = 2\Omega$

$R_{Load} = 10\Omega$



how to make power here maximum.



$R_L' = 2\Omega$

$a^2 R_L = R_L'$

$a^2 = \frac{2}{10}$

(maximum power) الحالة الي بوصل لل *

$a = \sqrt{\frac{2}{10}} = 0.45 = \frac{N_1}{N_2}$

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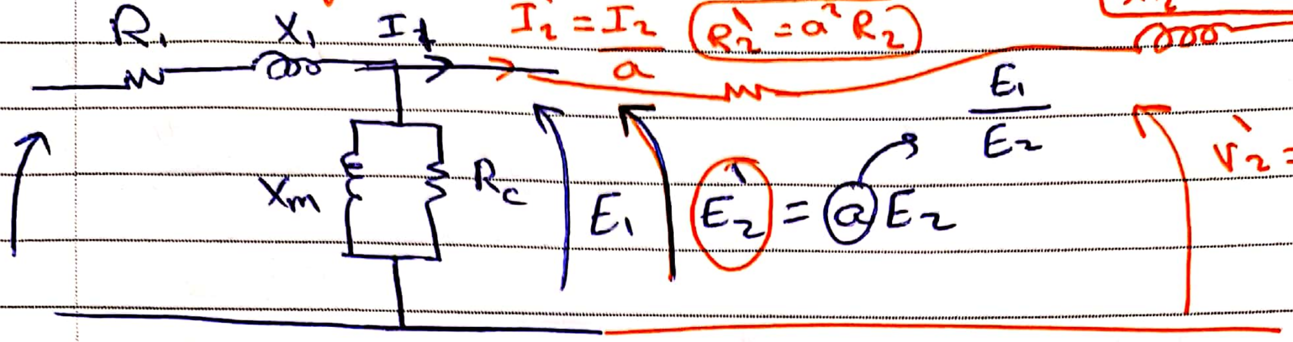
No.

* Refered equiv Circuit to the N_1 side.

$\boxed{X_2' = a^2 X_2}$



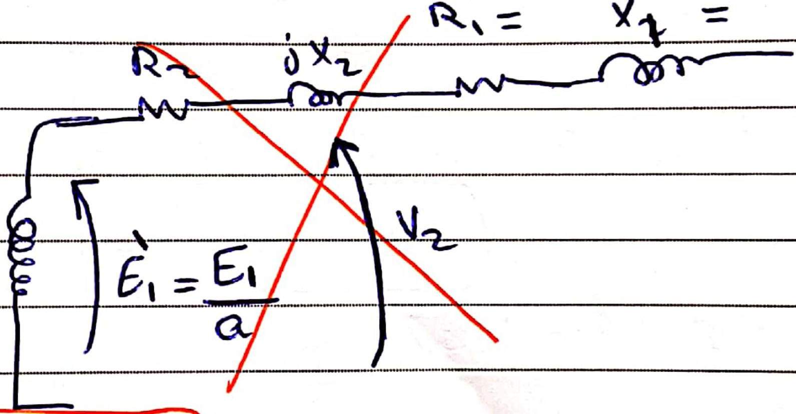
$I_2' = \frac{I_2}{a}$, $\boxed{R_2' = a^2 R_2}$

$\frac{E_1}{E_2}$

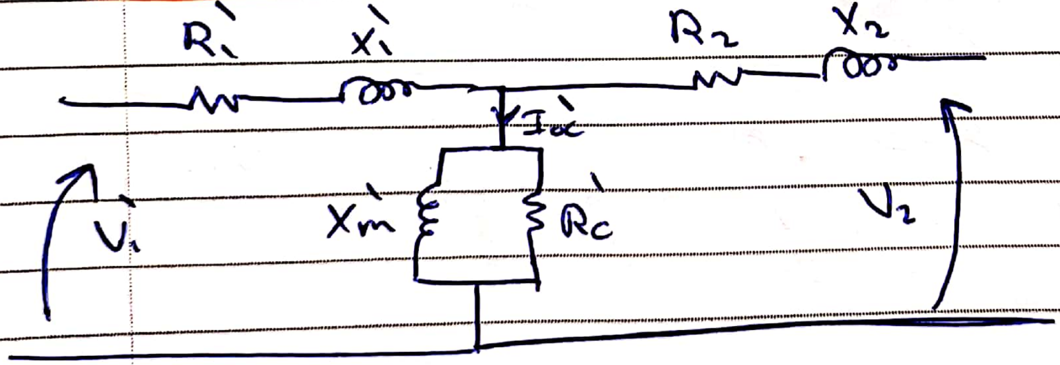
$E_2' = a E_2$

$V_2' = a V_2$

the Exact or T equivalent circuit refered to N_1 side.



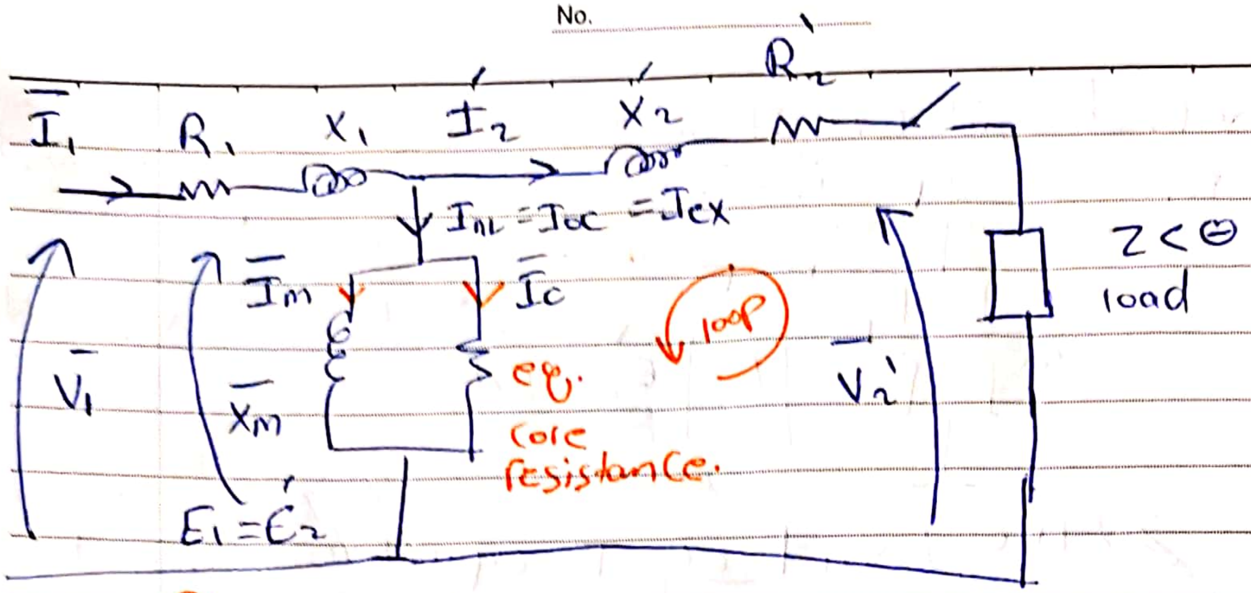
* refering to N_2 side :- (T equi circuit)



$V_1' = \frac{V_1}{a}$, $I_1' = a I_1$, $R_1' = \frac{R_1}{a^2}$, $X_1' = \frac{X_1}{a^2}$

$X_m' = \frac{X_m}{a^2}$

No.



* $\boxed{\frac{N_1}{N_2} = a}$

* phasor 3-Cases:-

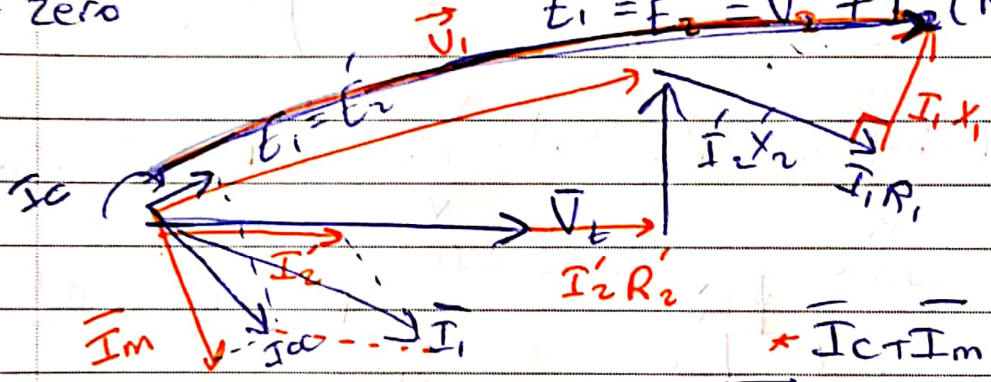
(1) unity PF

ϕ = zero

Applying KVL on the loop:-

$E_1 = E_2' = V_2' + I_2'(R_2' + jX_2')$

90° degree.



* $\bar{I}_c + \bar{I}_m = I_{nL} = I_{oc}$

* $\bar{I}_c = \frac{E_1}{R_c} = \frac{E_2'}{R_c}$

* $I_m = \frac{E_1}{jX_m} = \frac{E_2'}{jX_m} = -j\left(\frac{E_2'}{X_m}\right)$

* $\bar{I}_2' + \bar{I}_{oc} = I_1$

* $V_1 = E_1 + I_1(R_1 + jX_1)$

* Voltage Reg $= \frac{V_1 - V_2'}{V_2'}$ (*100%) or per unit

usually $V_2' = V_{2(r)}$

$\boxed{-6\% \leq \text{V.Reg} \leq +6\%}$

$\boxed{\text{V.Reg} = \frac{\text{volt at no load} - \text{voltage at full load}}{\text{voltage at full load}}}$

(Inductive)

No.

② lagging PF $<\phi \rightarrow \ominus \rightarrow I<-\phi$

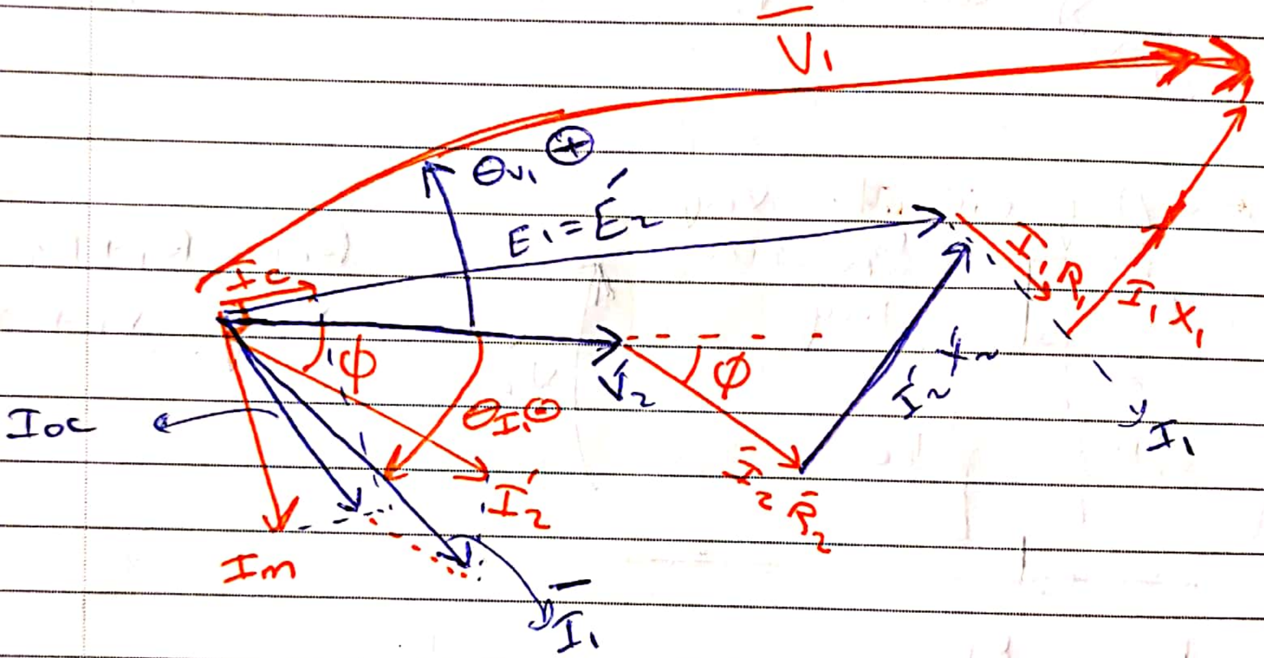
$+ \rightarrow Z<+\phi$

$I = \dfrac{V<0}{Z<\phi}$

$I = \dfrac{V}{Z}<-\phi$

$\boxed{V<\phi} \rightarrow$ angle is positive.

$\bar{S} = \bar{V}\bar{I}^{*} = VI<+\phi$



$PF = \cos(\theta_v - \theta_i)$

ex: $V_1 = 200<+5$
$I_1 = 10<-30$ $\Big\} \rightarrow PF = \cos(5 - -30) = \cos(35°)$

* Efficiency $= \dfrac{P_o}{P_{in}} = \dfrac{\acute{V}_2 * \acute{I}_2 * \cos\phi}{V_1 * I_1 * \cos(\theta_{v_1} - \theta_{i_1})}$ $\rightarrow Z<\phi$ (load)

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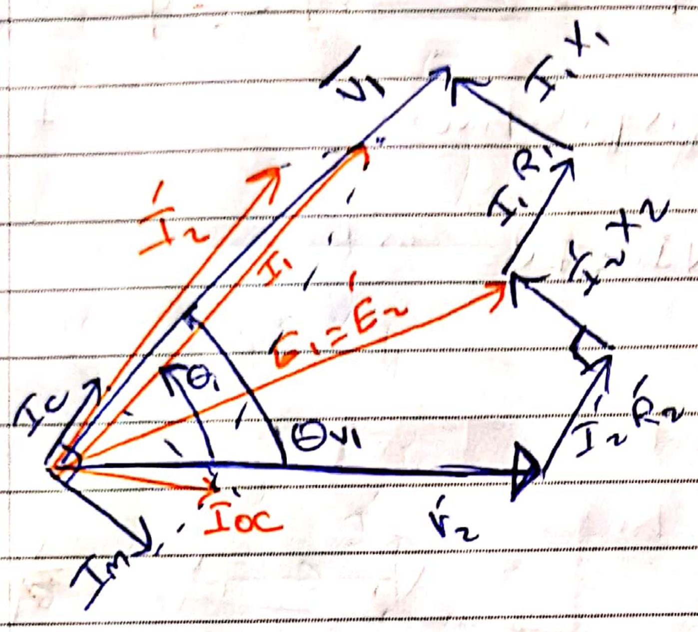
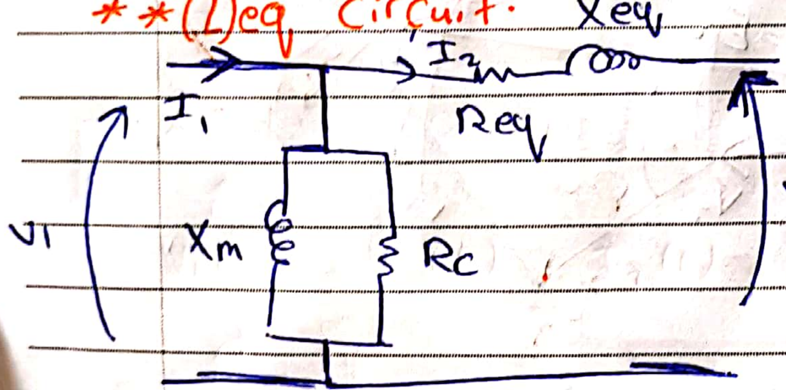
No.

③ leading PF



** (L) eq circuit.



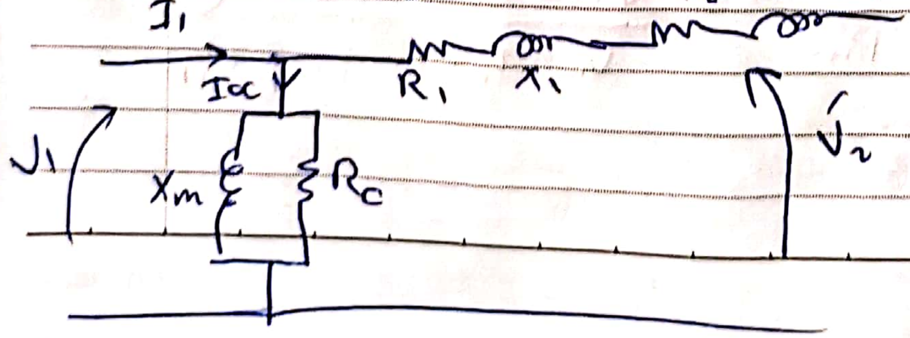
$R_{eq} = R_1 + R_2'$

$X_{eq} = X_1 + X_2'$

$I_{oc} = \frac{E_1}{Z_m}$

but since $E \approx V_1$ $(R_1 + jX_1)$ are very small

$\therefore I_{oc} \approx \frac{V_1}{Z_m}$



Follow →

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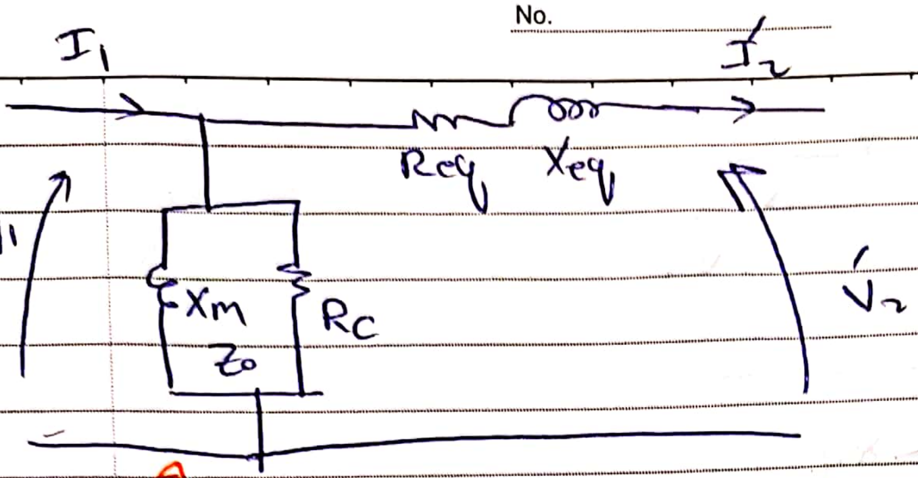
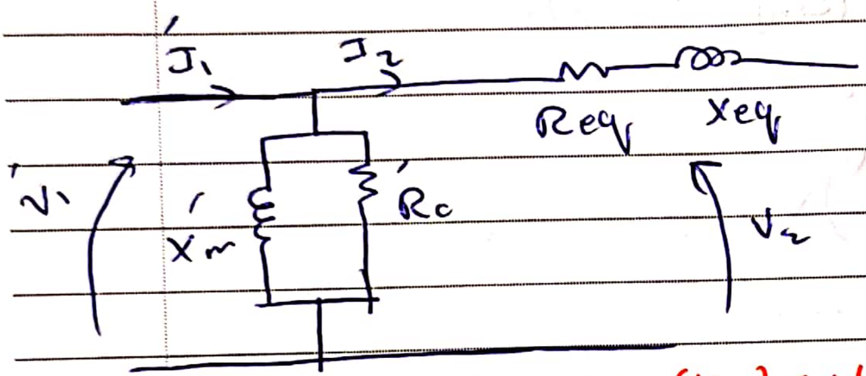
No.



↳ refered to V_1 side (N_1)

$*R_{eq} = R_1 + R_2'$

$X_{eq} = X_1 + X_2'$



↳ refere to (N_2) side.

*Note

$\boxed{1}$ $X = \frac{1}{B}$

$B = \frac{1}{X}$ ↳ susceptance

$\boxed{2}$ $Y = \frac{1}{Z}$

↳ Addmitance

$* R_{eq} = R_1' + R_2$, $R_1' = \frac{R_1}{a^2}$

$X_{eq} = X_1' + X_2$ $\quad X_1' = \frac{X_1}{a^2}$

$V_1' = \frac{V_1}{a}$

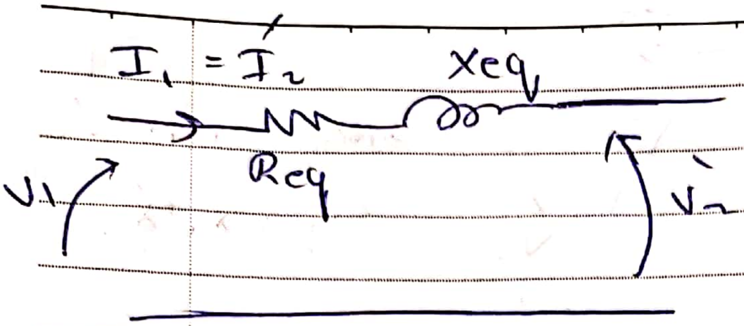
** Approximate linear circuit

$I_{oc} <<< I_{rated}$

$I_1 = \underbrace{\cancel{I_{oc}}}_{\text{approches to zero}} + I_2'$, $I_{oc} \approx (1-5)\%$ of I_{rated}

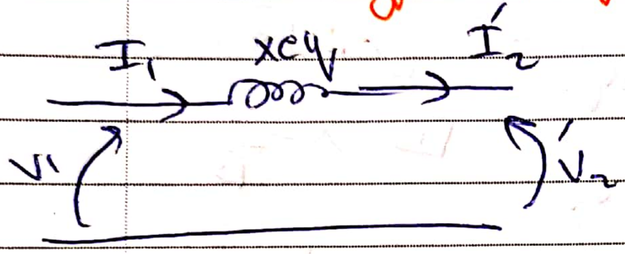
smile for life

No.



Since $R_{eq} < X_{eq}$

$\downarrow$ neglect R_{eq}



* Rated values

$V_1(r)$, $V_2(r)$, $I_2(r)$, $I(r)$

$V_r I_r^* \leftarrow S_r$, f

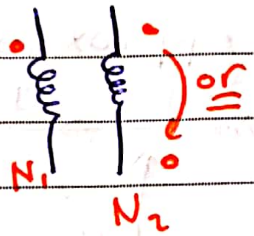
No.

** Transformer testing:-

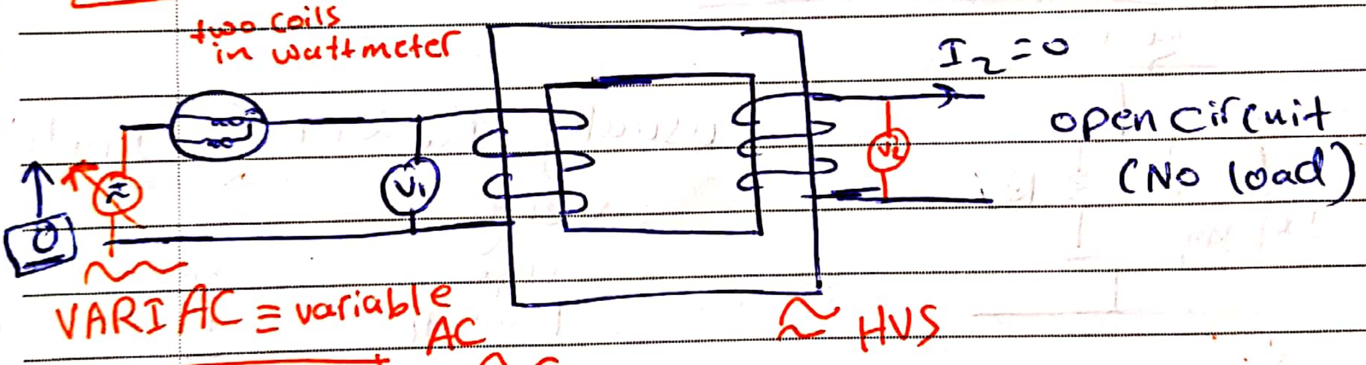
Aim:- to determine the eq circuit parameters.

Tr → $R_1, R_2, X_1, X_2, X_m, R_r$ --- I need to know them.

* Three types of test:-
- open-circuit Test (No - load test)
- short - circuit test
- Polarity test ⟹



$\boxed{\text{No - load test}}$



$\boxed{N_1 : \text{supply}}$

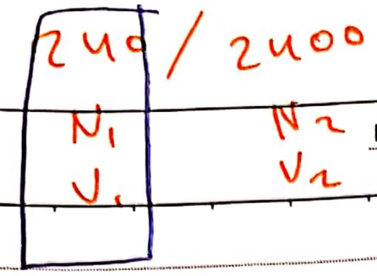
* النسب بالنسبة ل Vrated.

V_{oc} V_1	0	10%	100%	120%
V_2				
I_{oc}				
P_{oc}				

أهم قراءة.

** gradually increase $V_1(oc)$ in steps of in each step Read P_{oc}, I_{oc}, $V_2(oc)$ ---- (approx)

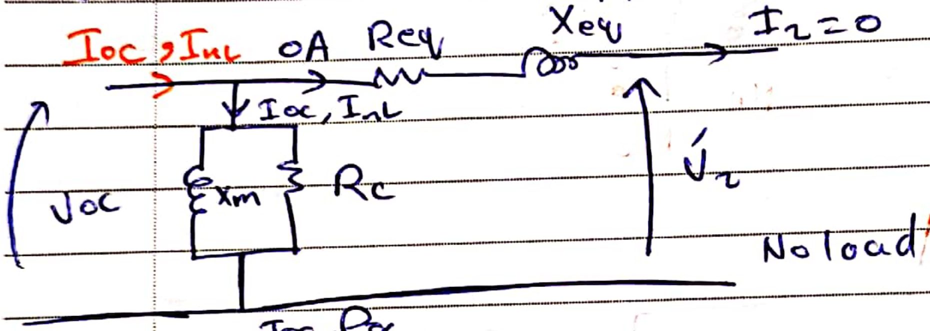
** prefered to be conducted ~~to~~ in the LVS.

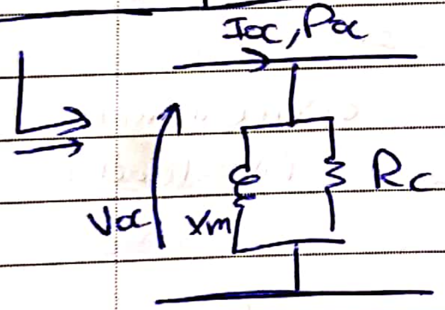


LVS
↓
Prefered to make test on it.

Eq. circuit at No-load.

consider the L- Approximate circuit.





* usually $I_{oc} \approx (1-5\%) I_{rated}$

very large Powe Tr

small power Tr.

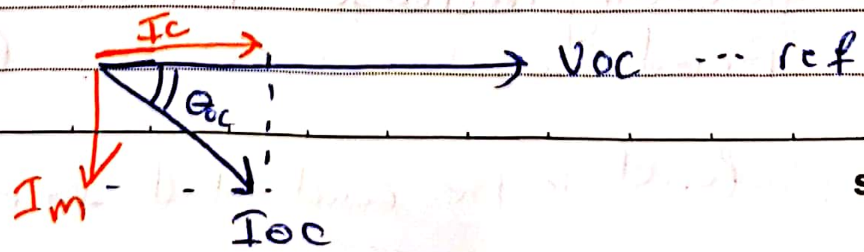
LVS prefered.

$V_{oc} = V_{rated}$ (LVS)

P_{oc} => at rated voltage.

I_{oc} → at V_1 side.

* Phasor diagram.



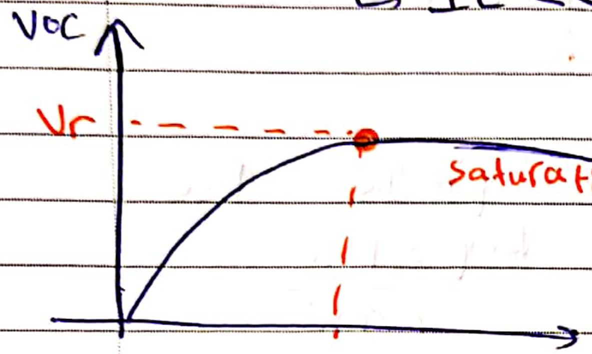
No.

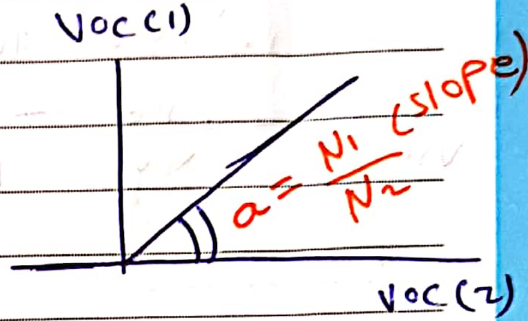
$$R_c = \frac{V_{oc}}{I_c} = \frac{V_{oc}}{I_{oc}\cos\theta_{oc}} \quad , \quad X_m = \frac{V_{oc}}{I_m} = \frac{V_{oc}}{I_{oc}\sin\theta_{oc}}$$

$$\theta_{oc} = \cos^{-1}\left(\frac{P_{oc} \rightarrow \text{real}}{V_{oc} I_{oc} \rightarrow \text{apperant.}}\right)$$

usually $X_m <<< R_c$

↳ $I_c <<< I_m$

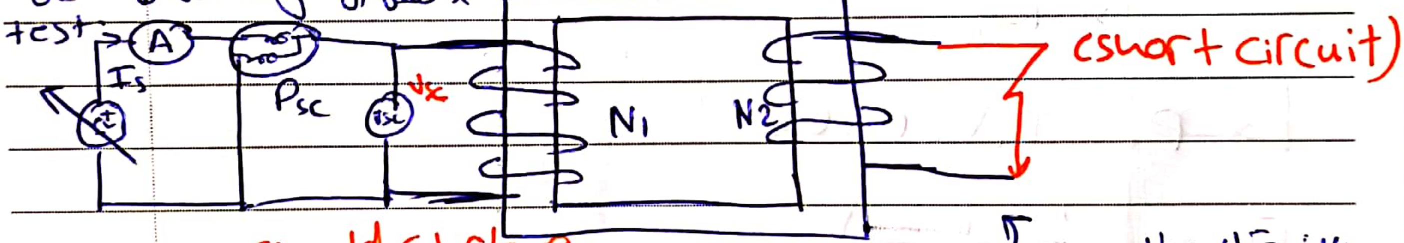




$\left.\begin{matrix} I_{oc} \\ I_m \end{matrix}\right\} \rightarrow$ نفس النتيجة

2 - short circuit test

OC test ال wiring نفس ال * بس عندال supply ②



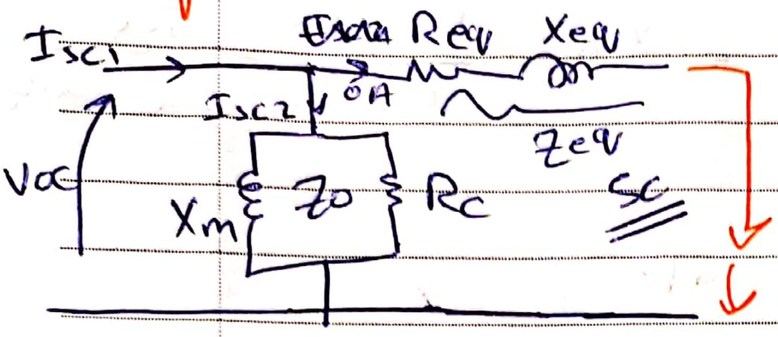
* we should start from zero. ↳ 0 → بالنسبة ل Vsc

Isc	0	10% Ir	20% ...	100% Ir
Vsc				(3-8)% Vr
Psc				

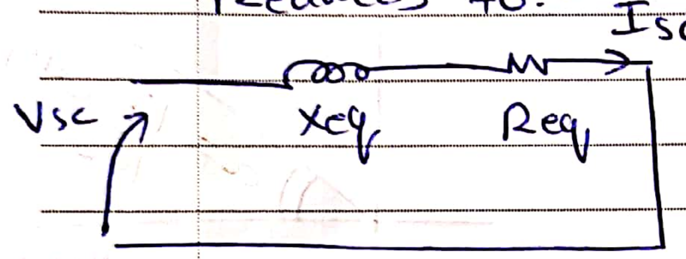
* carefully and gradually increase Isc insteps up to $\boxed{I_{sc} = I_{rated}}$

usually V_{sc} (to give $I_{sc} = I_{rated}$) $= (3-8)\%\ V_{rated}$

Eq. circuit at short circuit conditions.



→ eq. circuit at short ckt conditions:
reduces to:-

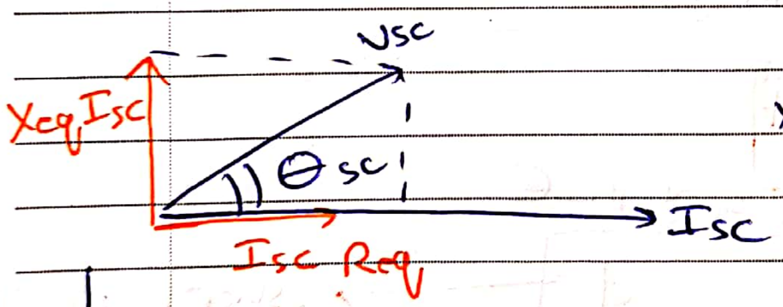


$\therefore R_{eq} * I_{sc}^2 = P_{sc}$

$$R_{eq} = \frac{P_{sc}}{I_{sc}^2}$$

$$Z_{eq} = \sqrt{R_{eq}^2 + X_{eq}^2} = \frac{V_{sc}}{I_{sc}}$$

$$X_{eq} = \sqrt{Z_{eq}^2 - R_{eq}^2}$$



$P_{sc} = I_{sc} V_{sc} \cos\theta_{sc}$

$$\theta_{sc} = \cos^{-1}\left(\frac{P_{sc}}{I_{sc} V_{sc}}\right)$$

$V_{sc} * \cos\theta_{sc} = I_{sc} R_{eq}$

$$R_{eq} = \frac{V_{sc}}{I_{sc}} = \cos\theta_{sc}$$

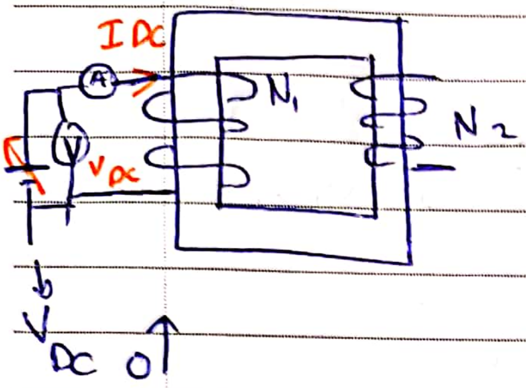
↓

$V_{sc} \sin\theta_{sc} = I_{sc} X_{eq}$

$$X_{eq} = \underbrace{\frac{V_{sc}}{I_{sc}}}_{Z_{sc}} \sin\theta_{sc}$$

No.

DC Test



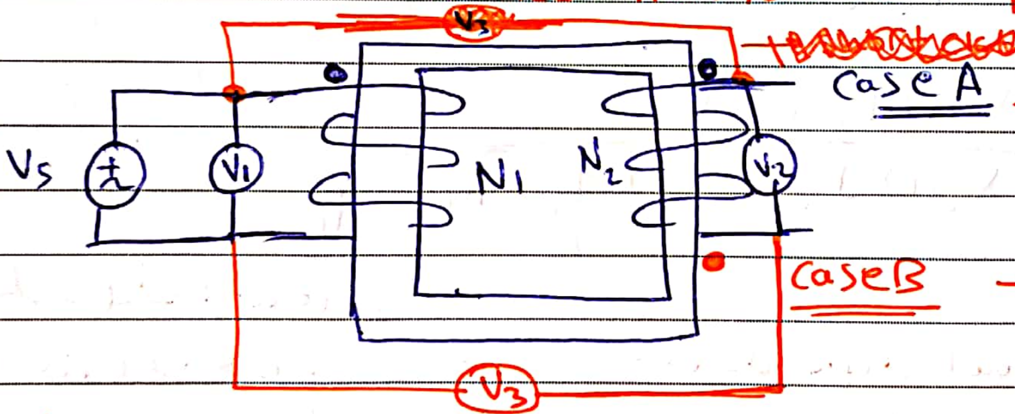
$I_{DC} < I_{rated}$

$R_1 = R'_1 + R'_2 + R'_3$

V_{DC}	I_{DC}	R_1
		R'_1
		R'_2
		R'_3

3- Polarity test :-

(for dot notation) // required to connect transformers in parallel. (ex)



Dot

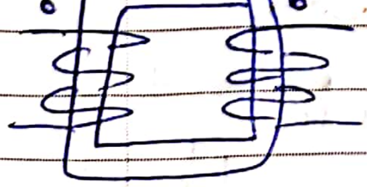
A

$V_3 = V_1 - V_2$ or $V_3 = V_1 + V_2$

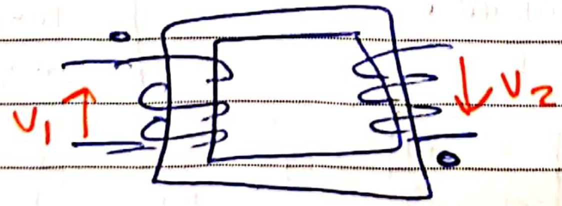
B

↳ case A Dot up

↳ case B Dot



(subtractive polarity)



(additive polarity)

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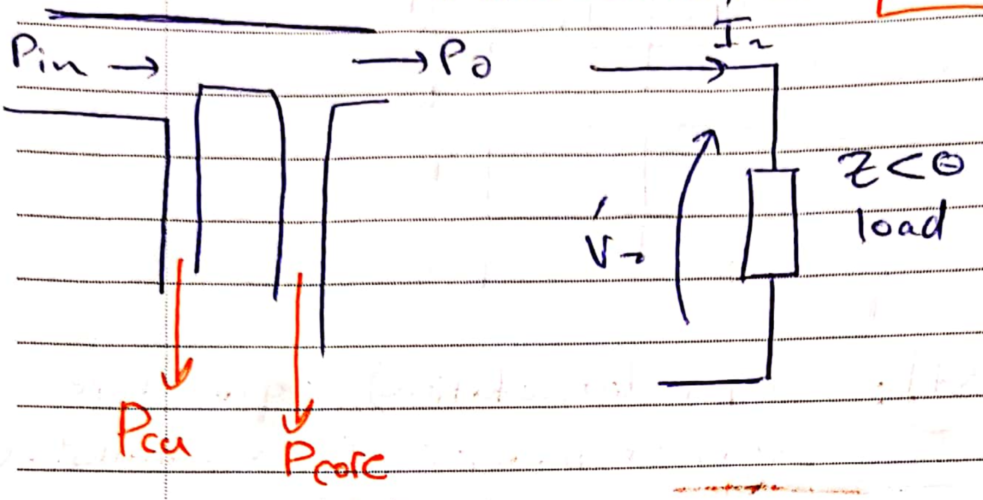
**performance evaluation / Efficiency :-

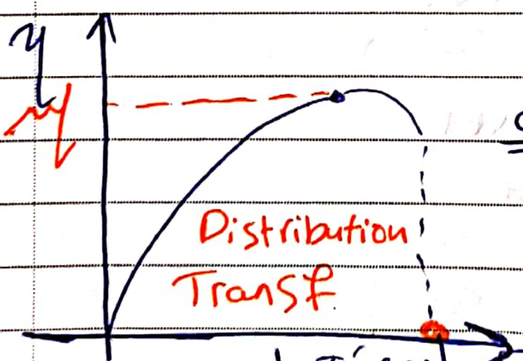
$$\eta = \frac{P_o}{P_{in}} = \frac{V_2' I_2' \cos\theta_2}{\underbrace{V_2' I_2' \cos\theta_2 + P_{core} + P_{cu}}_{= V_1 I_1 \cos\theta_1}} = \frac{S_o \; Pf_o}{S_{in} \; Pf_{in}}$$



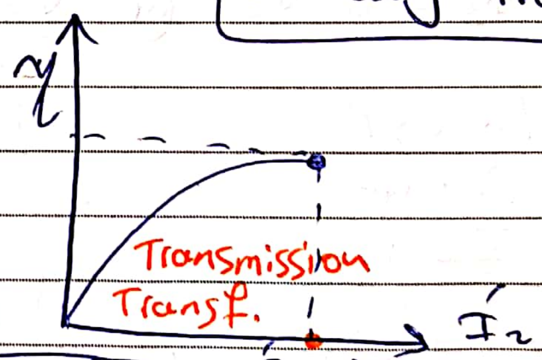
$$\eta = \frac{V_2(r) I_2 \cos\theta_2}{V_2(r) I_2' \cos\theta_2 + I_2'^2 R_{eq} + P_{core}}$$

Pcu : load dependent.
Variable losses

Pcore: load independent.
constant (fixed) losses
$\rightarrow \boxed{P_h + P_{eddy} = P_{noload}}$



or

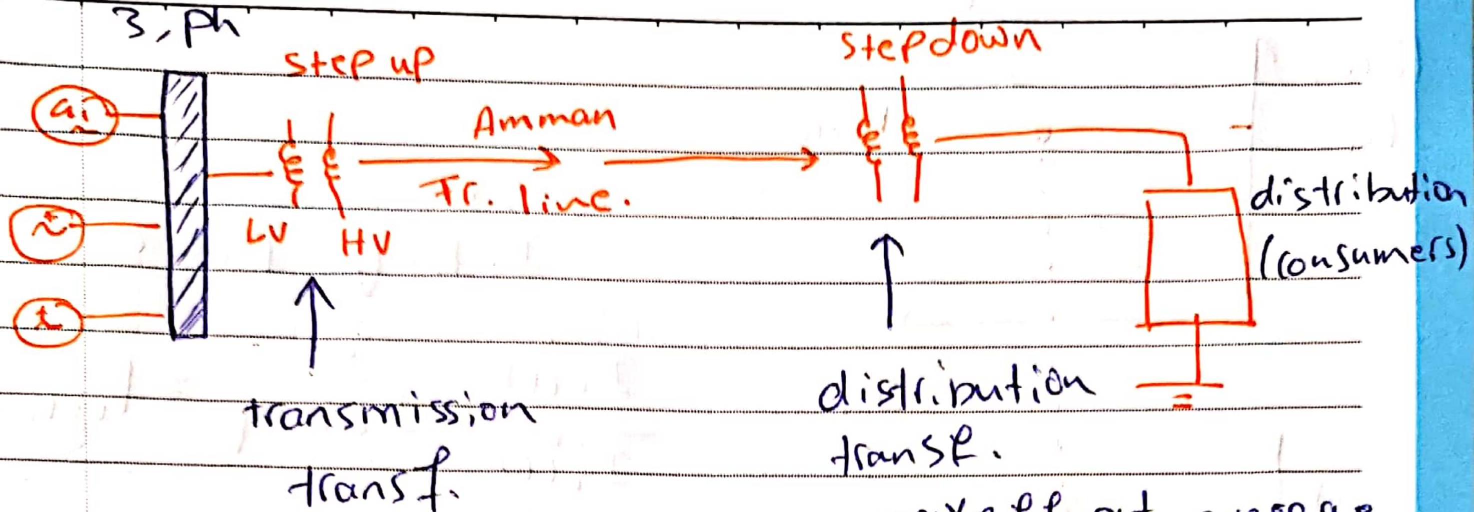


$I_2'(r)$ / $S_o(r)$ / 100% $\quad$ I_2 or $\boxed{S_o = S_L}$ $\quad$ $I_2(r)$ or $S_o = S_L$ max load.

η_{max} at (60-70)% of rated load

لا عابيوفر كذا شكل المنحنى بس. بال Amplitude بيعرف .

No.



max eff ← (full load)

max eff at average power. (60-75)% of rated load.

$$\eta_{max} : \frac{d\eta}{dI_2'} = 0$$

$$0 = \frac{V_2'(r)\cos(\theta_2)\left(V_2'(r)I_2'\cos\theta_2 + I_2'^2 R_{eq}\right) + P_{core} - \left(V_2'(r) I_2' \cos\theta_2\left(V_2'(r)\cos\theta_2 + 2R_{eq}I_2' + P_{core}\right)\right)}{[\;----\;]^2}$$

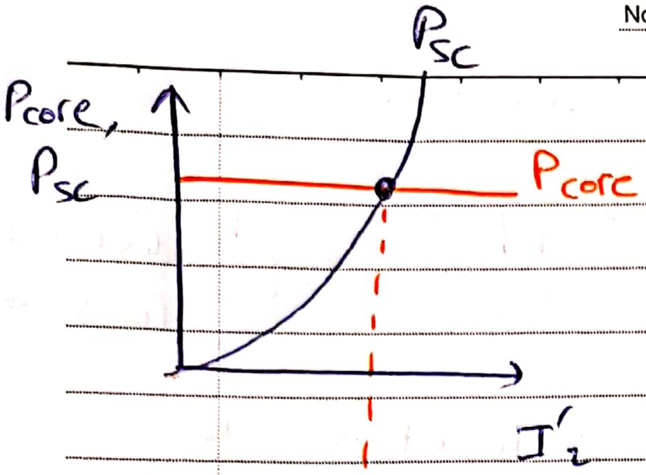
$$\boxed{I_2'^2 R_{eq} = P_{core}}$$

$$P_{cu} = P_{core}$$

* Max η occurs whe the copper (variable) loss equals the constant core loss.

smile for life

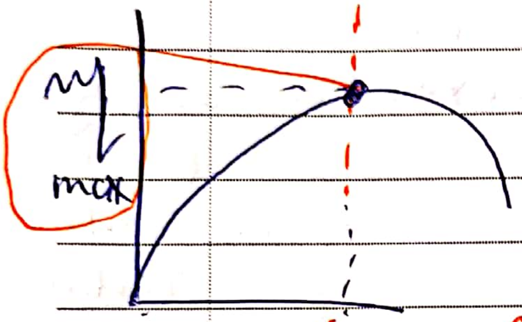
No.



$$I_2'^2 R_{eq} = P_{core}$$

$$\frac{I_2'^2(r)}{I_2'^2(r)} * I_2'^2 R_{eq} = P_{core}$$

$$\left(\frac{I_2'}{I_2'(r)}\right)^2 * I_2'^2(r)\, R_{eq} = P_{core}$$



I_2' at η_{max}

* define load function (k)

$$k = \frac{I_2'}{I_2'(r)} \text{ or } \frac{S_o}{S_r}$$

(at which the eff is max)

$$k_{\eta_{max}} = \left(\frac{I_2'}{I_{2r}'}\right) = \frac{S_o'}{S_r'}$$

$$\Longrightarrow k^2_{\eta_{max}} * P_{cu(r)} = P_{core}$$

$$k_{\eta_{max}} = \sqrt{\frac{P_{core}}{P_{cu(r)}}} = \sqrt{\frac{P_{oc}}{P_{sc}}}$$

$$\Longrightarrow K_{\eta_{max}} * P_{cu(r)} = P_{core}$$

$$K_{\eta_{max}} = \sqrt{\frac{P_{core}}{P_{cur(r)}}} = \sqrt{\frac{P_{oc}}{P_{sc}}}$$

**

$$P_{cu} = K^2 P_{cur}$$

$$P_{core} = P_{oc} \longrightarrow (V_{oc} = V_{rated})$$

$$P_{cur} = P_{sc} \longrightarrow (I_{sc} = I_{rated})$$

smi

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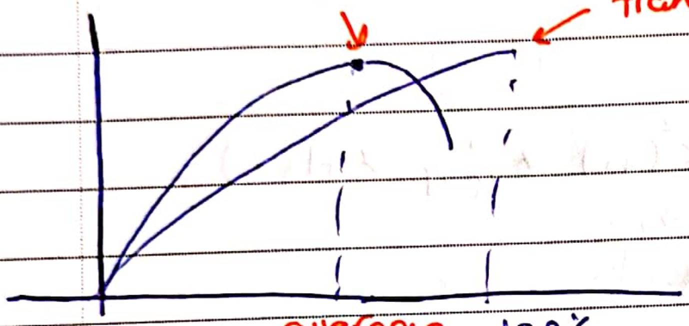
$$\eta = \frac{V_2 I_2 \cos\phi}{V_2 I_2 \cos\phi + 2P_{core} \text{ or } 2P_{cu}}$$

$\left.\begin{matrix} 2P_{core} \\ \text{or} \\ 2P_{cu} \end{matrix}\right\} \rightarrow$ at max eff.

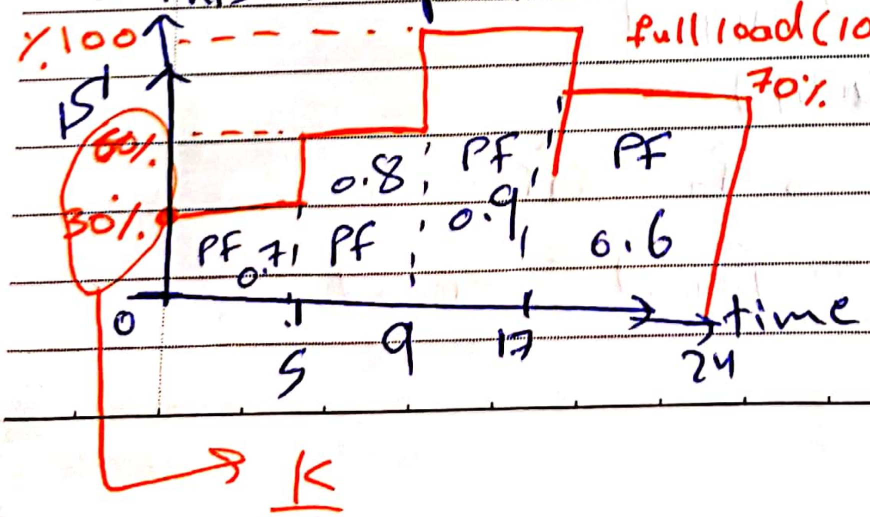
at $\eta_{max} \rightarrow P_{cu} = P_{core} = K^2 P_{cur}$



** Energy (or All-day) Efficiency.

$$\eta_{energy} = \eta_{all\ day} = \frac{W_o}{W_{in}}$$

- This is importont in distribution trans.



No.

$$\boxed{W_o} = \sum_{n=1,2,3,4} \underbrace{K(n) * S_r}_{S_o} * \underbrace{\cos\phi(n)}_{PF} * H(n)$$

$$= 0.3 * S_r * 0.7 * 5 + 0.6 * S_r * 0.8 * 4 + 1 * S_r * 0.9 * 8 + 0.7 S_r * 0.6 * 7 \quad (KW.H)$$

$$\boxed{W_{in}} = W_{out} + W_{Loss}$$

$$W_{Loss} = P_{core} * \underbrace{24}_{=H} + \sum_{n=1,2,3..} K^2(n) * P_{cur} * H(n)$$

$P_{core} = P_{oc}$

* P_{core} is voltage dependent.

$$W_{Loss} = 24 P_{core} + (0.3)^2 P_{cur} * 5 + (0.6)^2 * P_{cur} * 4 + 1 * P_{cur} * 8 + (0.7)^2 * P_{cur} * 7$$

$P_{cur} = P_{sc}$

** voltage regulation: (relative difference in voltage between [no-load] & [full-load] conditions).

$$V.Reg\% = \frac{V_{no\,load} - V_{full\,load}}{V_{full\,load}} * 100\%$$

standard

$\boxed{+7\% \leq V_{reg} \leq -7\%}$ (quality)

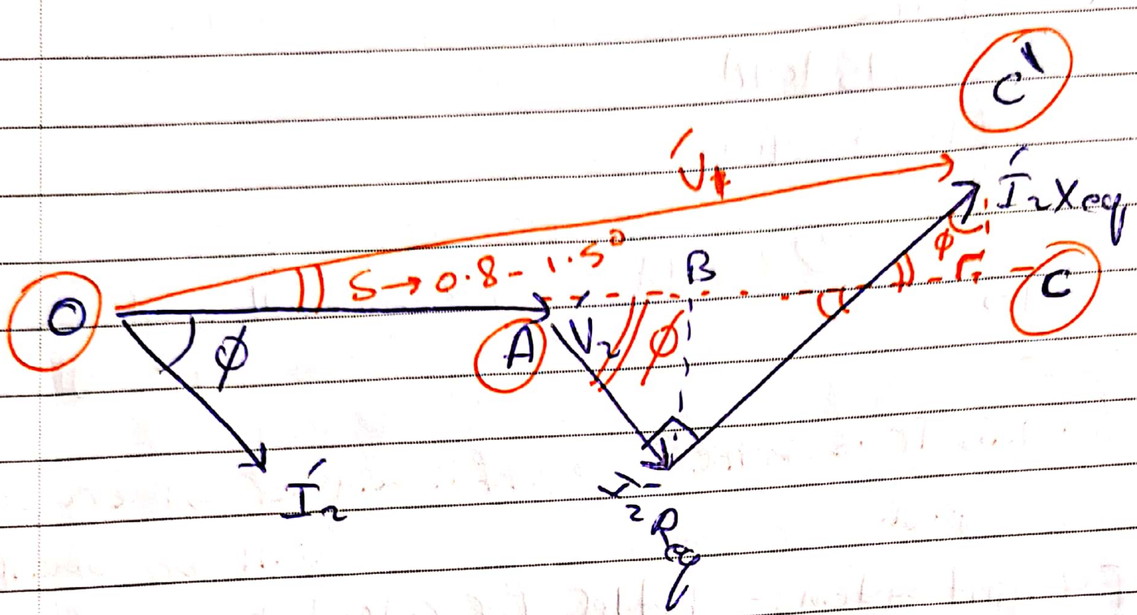
Full-load: $K = 1 \longrightarrow I_2 = I_{2r}$

$$S_{load} = S_{rated}$$

smile

No.

* Case: Inductive load.



* since δ is very small $\to OC' \cong OC$

$$V.Reg \; \frac{V_1 - V_2'}{V_2'} = \frac{OC' - OA'}{OA} \cong \frac{OC - OA}{OA}$$

$$V.Reg = V_2' + AB + BC = V_2' + I_2' R_{eq} \cos\phi + I_2' X_{eq} \sin\phi$$

$$V.Reg = \frac{I_2' R_{eq} \cos\phi + I_2' X_{eq} \cdot \sin\phi}{V_{2r}'}$$

$$= \frac{k I_{2r}' R_{eq} \cos\phi + k I_{2r}' \cdot X_{eq} \sin\phi}{V_{2r}'}$$

$$= k \left[\frac{R_{eq} \cos\phi}{\left(\frac{V_{r2}'}{I_{2r}'}\right)} + \frac{X_{eq} \sin\phi}{\left(\frac{V_{2r}'}{I_{2r}'}\right)} \right].$$

$\hookrightarrow$ we'll be back to it after (base/PU)

* الموضوع مهم للامتحان

No.

**per unit system.

{ Tr_1
500 kVA
losses: 1000 W }

{ Tr_2
375 kVA
losses: 900 W }

$\eta = 0.95$ $\eta = 0.94$

مقياس الأساسي هو ال eff.

↳ this Tr is better → eff is higher → then losses will be smaller.

p.u.

- per unit system:- better for calculation, better to discriminate between Machine in one feild.

* Select two base values out of: V, I, S

usally: $S_r = S_B$ = base power.

$V_r = V_B$ = base voltage.

Calculate $I_B = \frac{S_B}{V_B} = \frac{S_r}{V_r} = I_r$

$Z_B = \frac{V_B}{I_B}$ or $\frac{V_B^2}{S_B}$

$S(pu) = \frac{S}{S_B}$

$V(pu) = \frac{V}{V_B}$

$I(pu) = \frac{I}{I_B}$

*No base values for angles.

$Z(pu) = \frac{Z}{Z_B}$ or $\frac{R}{Z_B}$ or $\frac{X}{Z_B}$

smile

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$$\Rightarrow V.Reg = K\left[\frac{R_{eq}}{Z_B}\cos\phi + \frac{X_{eq}}{Z_B}\sin\phi\right]$$

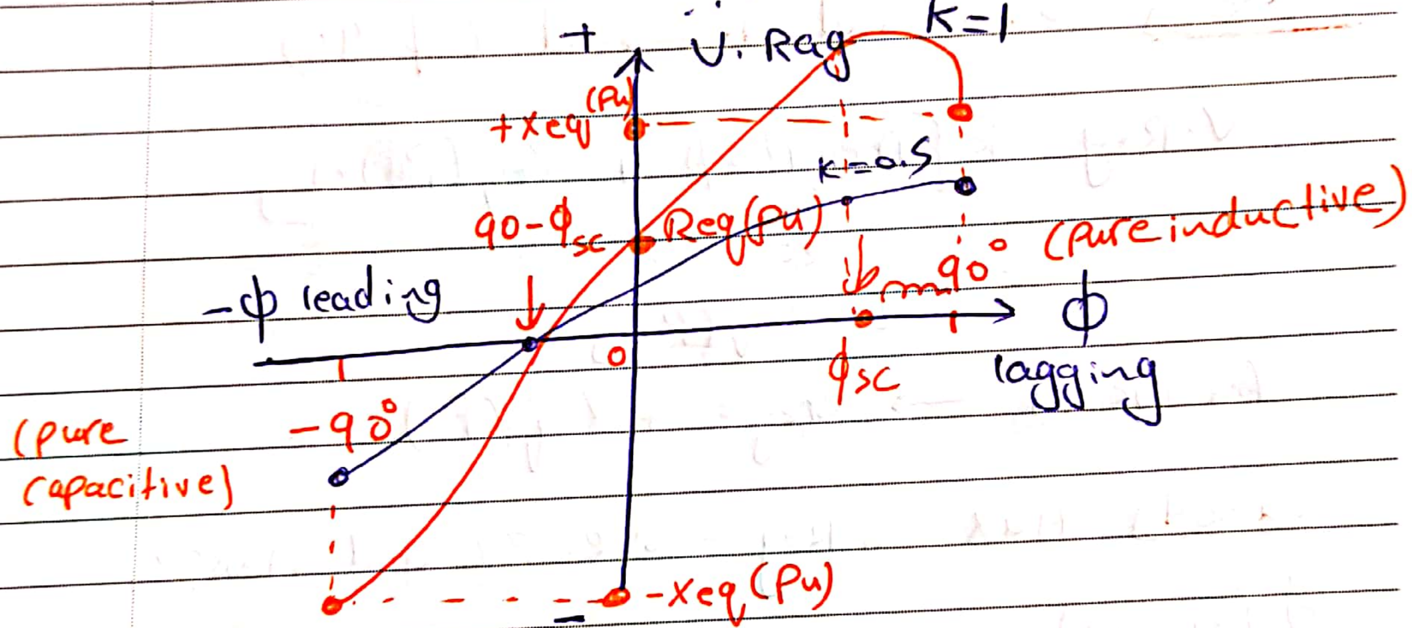
$$V.Reg = K\left[R_{eq}(pu)\cos\phi + X_{eq}(pu)\sin\phi\right]$$

*To generalize : (for lag or lead PF) :-

$$V.Reg = K\left[R_{eq}(pu)\cos\phi \mp X_{eq}(pu)\sin\phi\right]$$

capacitive ($-$), inductive ($+$)

* ϕ بنعوضها موجبة.



Cases,

* zero voltage Reg = ?? at what ϕ ??

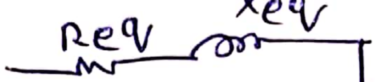
$$0 = R_{eq}(pu) \mp X_{eq}(pu)\sin\phi$$

∴ only with leading PF, V Reg = 0

$$R_{eq}(pu)\cos\phi = X_{eq}(pu)\sin\phi$$

$$\frac{\cos\phi}{\sin\phi} = \frac{X_{eq}(pu)}{R_{eq}(pu)}$$

at $\underline{SCC}$



$$\boxed{\phi_{sc} = \tan^{-1}\left(\frac{X_{eq}}{R_{eq}}\right)}$$

$\Rightarrow \cot\phi = \tan\phi_{sc}$

$\phi = 90 - \phi_{sc}$

Case 2)

at $\phi = \text{zero} \rightarrow$ pure resistive load

$V\,Reg = ?$

$$V.Reg = k\left[R_{eq}(P_u) \mp 0\right] = k\,R_{eq}(P_u)$$

Case 3) $\rightarrow$ pure inductive load ($\phi = 90$)

$$V.Reg = k\left[\underbrace{R_{eq}\cos\phi}_{zero} \mp X_{eq}(P_u) * 1\right]$$

$$= k\left[\mp X_{eq}(P_u)\right]$$

for $k = 1 \longrightarrow V_{reg} = \mp X_{eq}(P_u)$

Case 4) Max. $V.Reg$ = when?? and How??

$$\frac{d(V.Reg)}{d\phi} = 0$$ (self evaluation)

$$\frac{d\left(k\left[R_{eq}(P_u)\cos\phi \mp X_{eq}(P_u)\sin\phi\right]\right)}{d\phi} = k\left[-R_{eq}(P_u)\sin\phi \mp X_{eq}(P_u)\cos\phi\right]$$

$0 = k\,[$

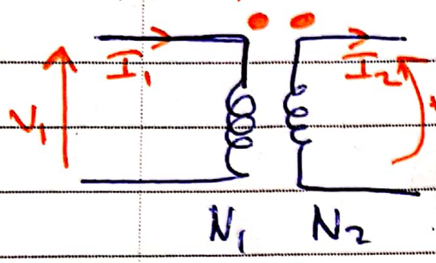
$R_{eq}(P_u)\sin\phi = X_{eq}(P_u)\cos\phi$

$$\tan\phi = \frac{X_{eq}(P_u)}{R_{eq}(P_u)} = \phi_{sc} \longrightarrow = \tan\phi_{sc}$$

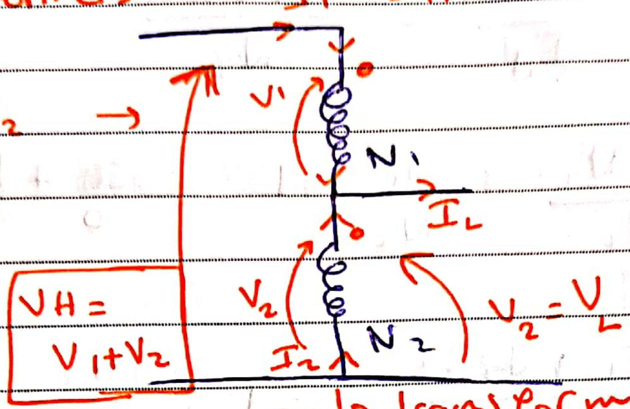
result) Max V.Reg $\longrightarrow$ $\boxed{\tan\phi = \tan\phi_{sc}}$

$\phi = \phi_{sc} \rightarrow V_{reg}(max) = R_{eq}(pu)\cos\phi_{sc} + x_{eq}(pu)\sin\phi_{sc}$

** Auto-Transformers:-



ordinary Tr



auto transformer case (A)

$$\left.\begin{aligned} * V_H &= V_1 + V_2 \\ I_H &= I_1 \\ V_L &= V_2 \\ I_L &= I_1 + I_2 \end{aligned}\right\}$$

Case (A) ordinary and auto Tr are physically Identical (No extra copper or core material).

$S_o = V_1 I_1 = V_2 I_2$

$S_a = V_H I_H = V_L I_L$

$\Rightarrow S_a = V_H I_H = (V_1 + V_2) * I_1 = \boxed{V_1 I_1 + V_2 I_1}$

or

$S_a = V_L H_L = V_2(I_1 + I_2)$

$S_a = \boxed{V_2 I_2 + V_2 I_1}$

$\longrightarrow$ $V_2 I_1 \rightarrow$ extra power gain $\downarrow$ power by conduction

No.

* $V_2 I_2$ or $V_1 I_1$ → power by induction

$$a_o = \frac{V_1}{V_2} = \frac{I_2}{I_1} = \frac{N_1}{N_2}$$

$$a_a = \frac{V_H}{V_L} = \frac{I_L}{I_H} = \frac{N_1 + N_2}{N_2}$$

$$a_a = \frac{N_1 + N_2}{N_2} = \frac{N_1}{N_2} + 1 = a_o + 1$$

$$\frac{S_a}{S_o} = \frac{V_1 I_1 + V_2 I_1}{V_1 I_1} = 1 + \frac{V_2}{V_1} + \frac{1}{a_o}$$

* More power gain can be obtained $\boxed{\text{if } a_o < 1}$

* $\boxed{\text{lower } a_o}$ ⟶ More power gain

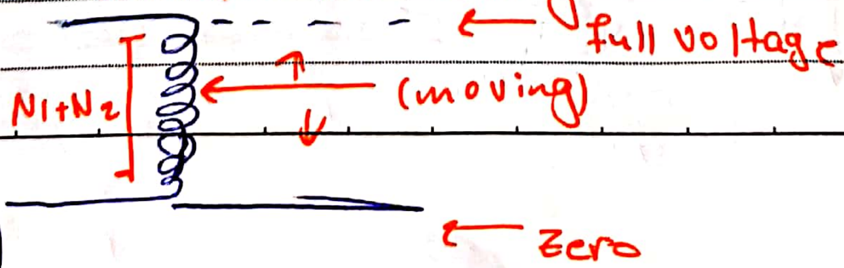
** Due to saftey precautions, auto-transformers use is limited

- dangerous SC conditions, where N_1 should recieve $(V_1 + V_2) = V_H$.

يصير V_1+V_2 كاملة تمر عال N_1

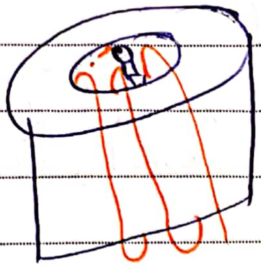
- operators saftey.

* usually used in the lab to gain extra power variable AC voltage.



(VARIAC)

(VARIAC)

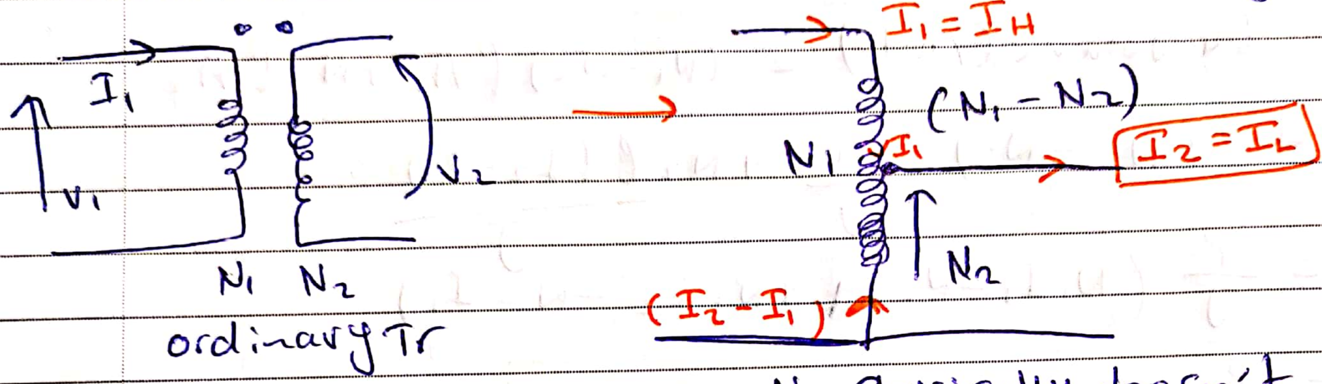


(Same electric features).

Same ~~Po~~ voltage rating , voltage rating

* Case (B) ⟶ Same Power ratings ($S_a = S_o$) , (Same electric features)

Select the coil whose number of turns is higher



N_2 Physically doesn't exist.

Case (B)

* In Case (B),

copper required lower in auto-Tr than that of equivelent ordinary Tr.

① coild N_2 is completley saved.

② cross-section of N_2 part of coil N_1 has lower cross section

since $I(N_2) = I_2 - I_1$

No.

* Copper Saving Δ Cu volume ??

$$Cu\ Vol(o) = N_1 * \ell * A_1 + N_2 \ell * A_2$$

length of each turn — coil cross section Area.

$$A = \frac{I}{J} \quad , J \equiv \text{Current density}$$

$J_1 = J_2 = J$ (نفس الحالة)

$$Cu\ Vol(o) = N_1 \ell \frac{I_1}{J} + N_2 \ell \frac{I_2}{J}$$

$$\boxed{Cu\ Volume\ (o) = \frac{\ell}{J}(N_1 I_1 + N_2 I_2)} \quad --- ①$$

** Cu Volume (Auto) $= (N_1 - N_2)\ell A_1 + N_2 \ell A_2$

$$= (N_1 - N_2)\ell \frac{I_1}{J} + N_2 \ell \frac{(I_2 - I_1)}{J}$$

$$= \frac{\ell}{J}(N_1 I_1 - N_2 I_1 + N_2 I_2 - N_2 I_1)$$

$$\boxed{= \frac{\ell}{J}(N_1 I_1 + N_2 I_2 - 2 N_2 I_1)} \quad --- ②$$

* compare ① with ②

$N_1 I_1 = N_2 I_2$

$$Cu\ Volume\ Saving = \frac{2\ell}{J} N_2 I_1$$

$$\%\ saving = \frac{\frac{2\ell}{J} * N_2 I_1}{\frac{\ell}{J}(N_1 I_1 + N_2 I_2)} = \frac{\cancel{2} N_2 \cancel{I_1}}{\cancel{2} N_1 \cancel{I_1}}$$

$$\Rightarrow \boxed{\%\ Cu\ Saving = \frac{1}{a} * 100\%}$$

* $N_1 > N_2$

* More saving is possible when a. is small $\boxed{\text{but} > 1}$

EX: No load test conducted on 20 KVA, 7200/400 V, 50 Hz Tr

$\underline{\underline{V_{oc}}} = 400V$, $\underline{\underline{I_{oc}}} = 2.5A$, $\underline{\underline{P_{oc}}} = 250W$

V_{nL} $\quad I_{nL}$ $\quad P_{nL}$

Neglect Zeq and calculate:-

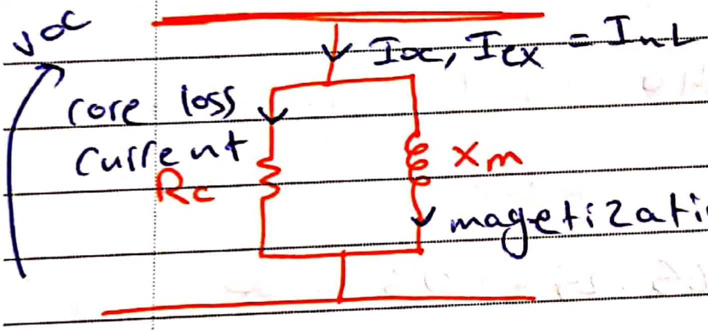
a) core loss current.

b) magnetizing current

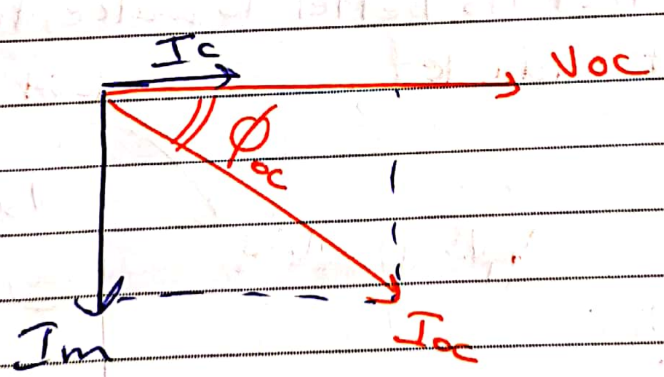
c) elements of the excitation branch refered to HVS and LVS.

d) No load power factor.

Sol.



Zeq. circuit at no load.



d) $PF_{in(nL)} = \cos(\phi_{oc})$

$P_{oc} = V_{oc} I_{oc} * \cos\phi_{oc} \longrightarrow \dfrac{P_{oc}}{V_{oc} I_{oc}} = 0.25$ lag

then $\phi_{oc} = \cos^{-1}(0.25) = 75.5^\circ$

No.

a) $I_c = I_{oc} \cos\phi_{oc} = 0.25 * 2.5 = 0.625 A$

b) $I_m = I_{oc} \sin\phi_{oc} = 2.4206 A$

or

$I_m = \sqrt{I_{oc}^2 - I_c^2}$

c) $R_c = \frac{V_{oc}}{I_c} = 640 \Omega$

$X_m = \frac{V_{oc}}{I_m} = 165.25 \Omega$

$R_c >> X_m$ ✓

refered + LV side.

* رفت لأنه ال test

انفصل على 40% Voc

بحتى عند ال low.

$R_{c_{HVS}} = a^2 R_{c_{LVS}} = (18)^2 * 640$

$X_{m_{HVS}} = a^2 X_{m_{LVS}} = (18)^2 * 165.25 = 53 k\Omega$

* In oc test its better to make the test in the LVS

EX: Sc test conducted on a 20 kVA, 7200/400V, 50 Hz Tr.

$V_{sc} = 360 V$

$I_{sc} = 2.777 A$

$P_{sc} = 400 W$

بختار ال HVS

* the test is connect to the HVS → بعرف شو الشار

$\boxed{I_{sc} = I_r}$

$V_{sc} \approx (3-8)\% V_r$

a) $HVS \quad \frac{7200 * 5}{100} = 360 V$

b) $LVS \quad \frac{400 * 5}{100} = 20$

$I_{sc} = I_{rated}$

$HVS \rightarrow \frac{20 * 10^3}{7200} = 2.7$

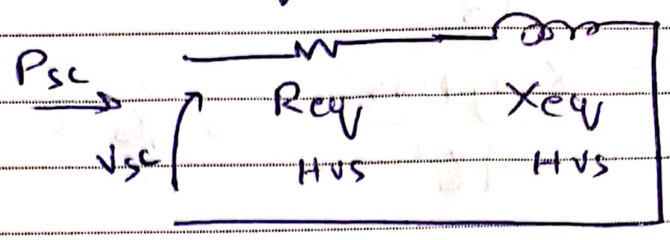
$I_r \rightarrow LVS = \frac{20 * 10^3}{400} = 30 A$

No. ....

$R_{eq} = ?$

$X_{eq} = ?$

Sc equivelent circuit

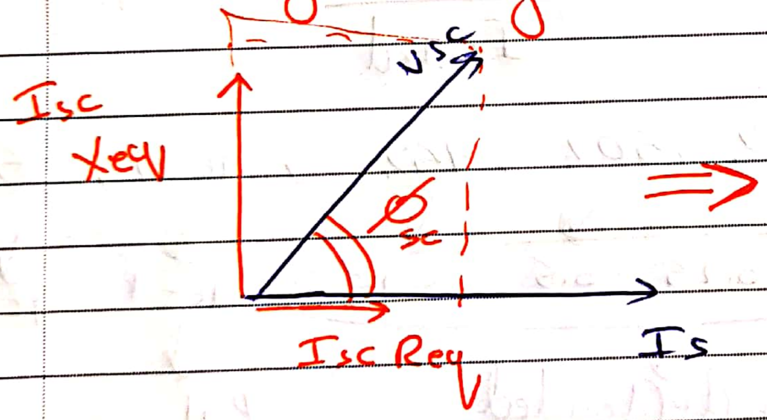


$P_{sc} = I_{sc}^2 R_{eq} \Rightarrow \frac{400}{(2.777)^2} = 51.84\ \Omega$

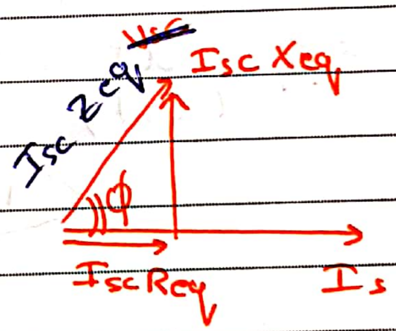
$X_{eq} = ?$ $\quad X_{eq} = \sqrt{Z_{eq}^2 - R_{eq}^2} = 118.7\ \Omega$

$Z_{eq} = \frac{V_{sc}}{I_{sc}} = \frac{360}{2.777} = 129.6\ \Omega$

or by drawing phasor diagram.



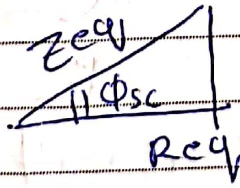
$\Rightarrow$



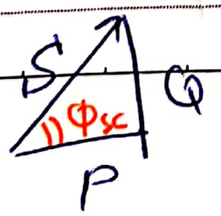
بال series مضروبة بال $\boxed{*}$ ÷ common factor هو ~~factor~~ ال common factor

بال parallel بتكون ال common factor هو // I_{sc}

$\underline{V}$ هو ال $\longrightarrow$



هيك بحصل على impedance triangle.



← common factor *بأضرب بال

smi)e for life

No.

$$R_{eq\,LVS} = \frac{R_{eq\,HVS}}{18^2} = 0.16\ \Omega$$

$$X_{eq\,LVS} = \frac{X_{eq\,HVS}}{18^2} = 0.36\ \Omega$$

T-eq

In well-designed:

R_1, R_2' , X_1, X_2' } $R_1 = R_2' = \frac{1}{2} R_{eq}$, $X_1 = X_2' = \frac{1}{2} X_{eq}$

$$R_{eq} = R_1 + R_2'$$

EX: transformer 300 kVA, has full voltage (rated voltage) core loss 1.5 kW (Pcore) and a full load (Irated) copper loss 4.5 kW

$\boxed{PF = 1}$

① η = ?? at 25%, 50%, 75%, 100%, 125% (loads)

25% → $k = 0.25$, 50% → 0.5, 75% → 0.75 → underloaded

100% → $k = 1$ → full loaded

125% → $k = 1.25$ → over loaded

$$\eta = \frac{P_o}{P_o + P_{loss}} = \frac{P_o}{P_{core} + P_o + \underbrace{k^2 P_{cur}}_{P_{cu}}}$$

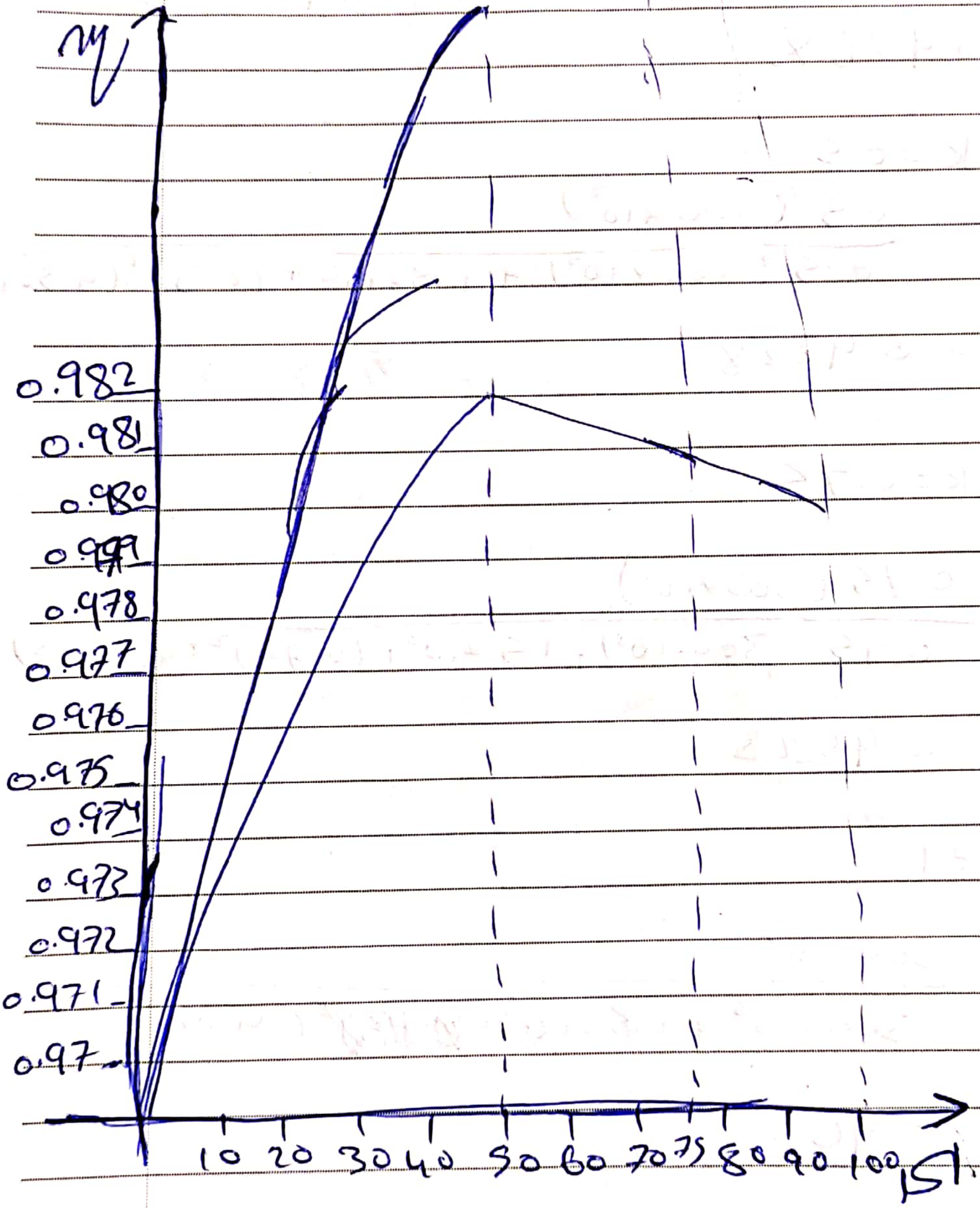
$$P_{out} = V_r I \cos\phi = V_r (k I_r) \cos\phi = k S_r \cos\phi$$

$$\eta = \frac{k S_r \cos\phi}{k S_r \cos\phi + P_{core} + k^2 P_{cur}}$$

No.

at $k = 1.2$

$\eta = 0.9777$



$\eta_{max} = 0.982$

at 50%

Homework:-

500 KVA, 2400/480 V, 50 Hz power Tr has: $R_c = 2000\ \Omega$, $X_m = 500\ \Omega$ (R to HVS)

$R_1 = 0.06\ \Omega$, $R_2 = 0.003\ \Omega$
$X_1 = 0.3\ \Omega$, $X_2 = 0.012$

* المقاومة يلي قيمتها ؟؟ أكبر بتكون عال HVS

load: connected to LVS, draws rated current at 0.8 PF lagging, while voltage is at rated value.

① Sketch the eq circuit r. to. HVS and LVS.
② Calculate the voltage Reg, Input power factor and η of the transformer.

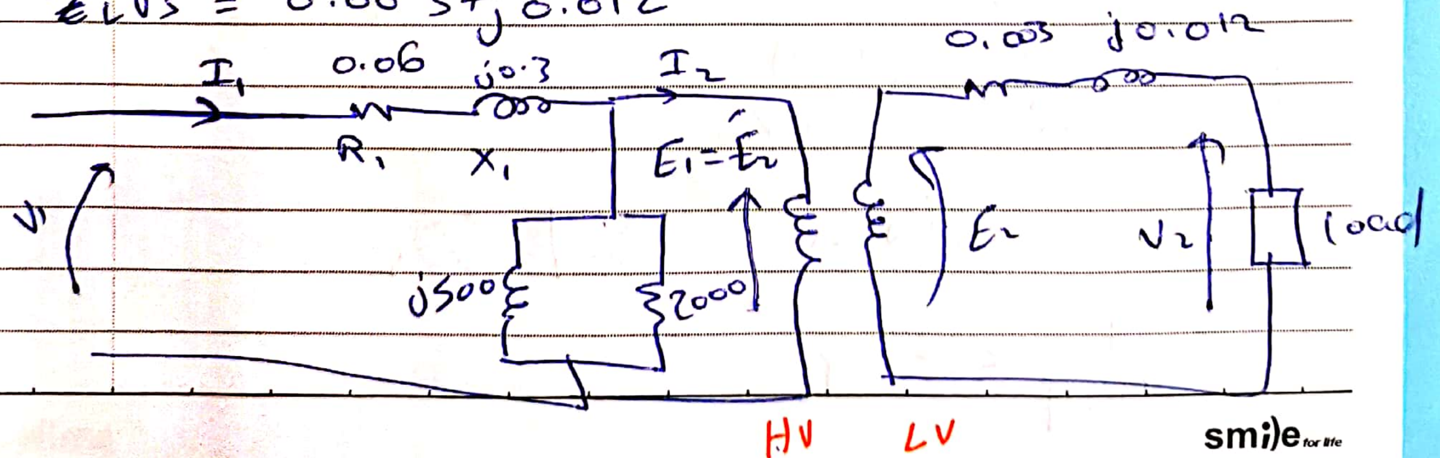
Use the T-eq circuit R. to HVS

Repeat by using L-eq circuit r. to H.VS. (compare results).

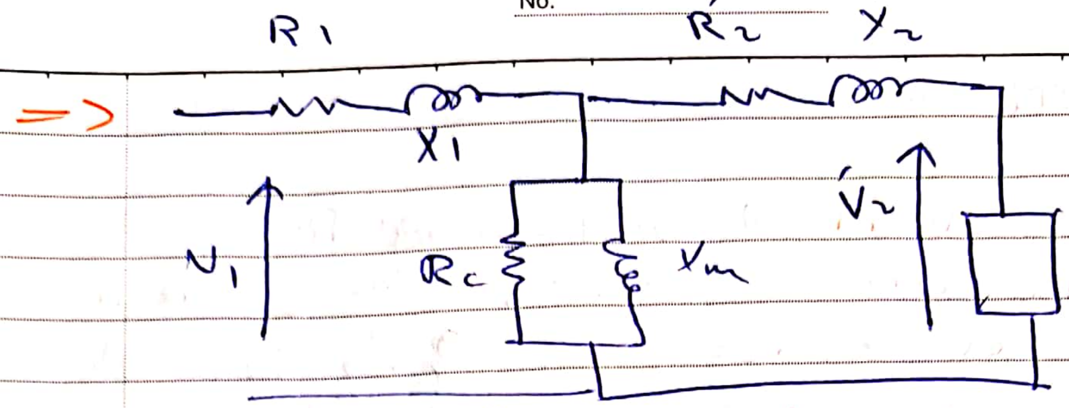
* Since $R_1 > R_2 \rightarrow R_1$ (2400V) HVS
R_2 (480) LVS

$Z_{HVS} = 0.06 + 0.3j$

$Z_{LVS} = 0.003 + j0.012$



No.



$$R_2' = R_2 \underbrace{\left(\frac{2400}{480}\right)^2}_{a^2}$$

$$I_2'(r) = \frac{S_r}{V_2(r)'} = \frac{500 * 10^3}{2400} = 208.3 \text{ A}$$

or $$I_2(r) = \frac{S_r}{V_{2r}}$$

$$\bar{E}_1 = E_2' = V_2' + \bar{I}_2' (R_2' + jX_2')$$

$$= 2400 \angle 0 + 208.3 \angle -\cos^{-1}(0.8) * (R_2' + jX_2')$$

lagging

$$Z_{oc} = \frac{R_c * X_m \angle 90}{R_c + jX_m} = \frac{R_c}{\sqrt{R_c^2 + X_m^2}} \cdot \angle 90 - \tan^{-1}\left(\frac{X_m}{R_c}\right)$$

$$Y_{oc} = \frac{1}{R_c} + \frac{1}{jX_m}$$

$$= G_c - jB_m = |Y_{oc}| \angle \theta_Y$$

$$Z_{oc} = \frac{1}{|Y_{oc}|} \angle -\theta_Y$$

No.

$$\overline{I_1} = \overline{I_{oc}} + \overline{I_2'}$$

$$\overline{V_1} = E_1 = (\overline{E_2'}) + \overline{I_1} * (R_1 + jX_1)$$

$$V_{reg} = \frac{V_1 - V_2'}{V_2'}$$

$$PF_{in} = \cos(\theta_{V_1} - \theta_{I_1})$$

$$\eta = \cancel{PF_{in}(\theta_{V_1} - \theta_{I_1})} = \frac{V_2' I_2' \, pf_o}{V_1 I_1 \, pf_{in}}$$

* 3KVA , 220/110 , 60 Hz Tr.

لفتح OCT : 200V , 1.4A , 50W (conducted on the HVS)

قصر SCT : 4.5V , 13.6 A , 30W

$\eta = ??$ at 2KVA , 0.85 lag PF

في ال Current بحدد هو

كان ال LVS or HVS

$$P_{core}(r) = P_{NL}(r) = \frac{V_r^2(oc)}{R_c}$$

طالب

بحسبها

في ال

OCT

* but 200V at OCT $\neq$ 220 (rated)

$$P_{nL}' = 50\,W = \frac{V_{oc}^2}{R_c}$$

$$P_{core}(r) = P_{nL}' * \left(\frac{V_r(oc)}{V_{oc}}\right)^2 = 50\left(\frac{220}{200}\right)^2$$

$$= \boxed{60.5 \text{ watt}}$$

$$I_r(H) = \frac{3000}{220} = 13.64$$ the SCT on HVS

$$I_r(L) = \frac{3000}{110} = 27.28$$

smile for life

No.

$$P_{sc} = I_{sc}^2 R_{eq}$$

$$P_{cu}(r) = I_r^2 R_{eq}$$

$$\frac{P_{cu}(r)}{P_{sc}} = \left(\frac{I_r}{I_{sc}}\right)^2 \longrightarrow P_{cu}(r) = P_{sc}$$

since $I_{sc} = I_r$

$$\boxed{\eta = \frac{k S_r \cos\phi}{k S_r \cos\phi + k^2 P_{cu}(r) + P_{core}(r)}}$$

بعد التعديل   بعد التعديل

$$K = \frac{S_L}{S_r} = \frac{2}{3}$$

is it (Dist or trans transformer) ??

$$K_{\eta_{max}} = \sqrt{\frac{P_{core}(r)}{P_{cu}(r)}}$$

$K \geq 1 \rightarrow$ transmition

$K < 1 \longrightarrow$ distributive -

smi:)e for life

No.

3-ph Transformers

Tr upto 10 GVA

* Two forms :-

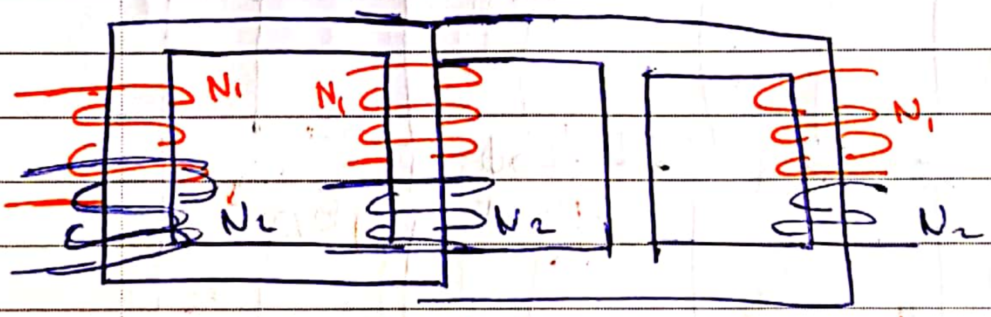
a) Bank of three Single-ph Transformers.

b) single unit 3-ph transformer: The most common

a) • easy transportation
• less stand by requirements (in terms of cost)
• easily allows open delta connection.

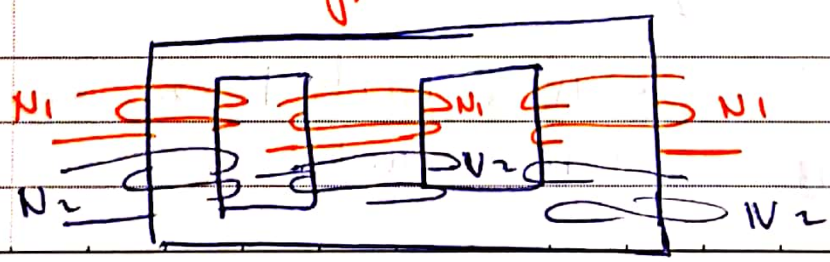
b) • less connection, cheaper for same power ratings. • less weigh, size for same power ratings.

Connections: * core type.
* shell type.



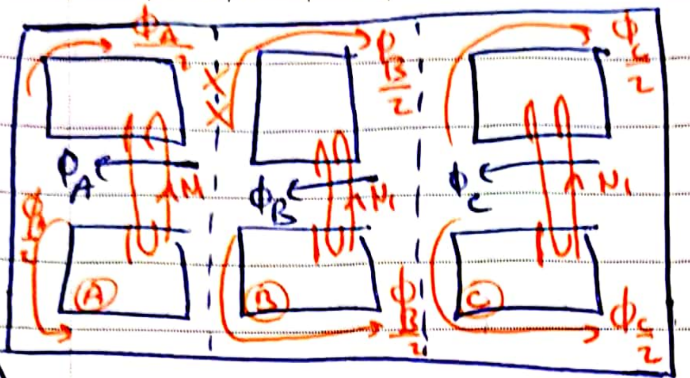
X not Actual

Actual core type.



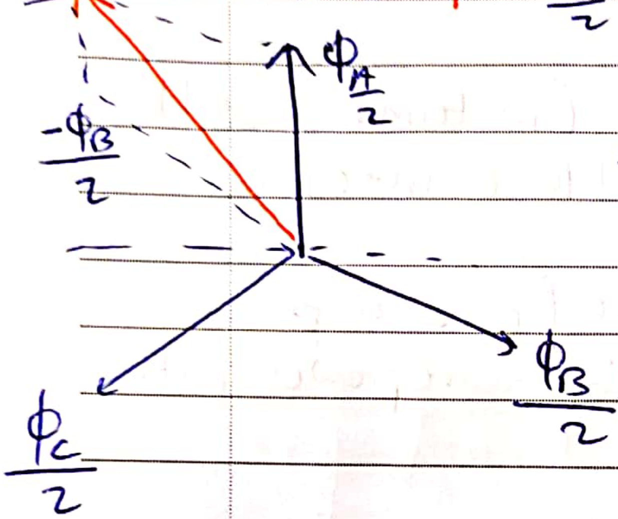
Actual core type.

* Shell type.



$= \frac{\sqrt{3}}{2}\frac{\phi_A}{2}$

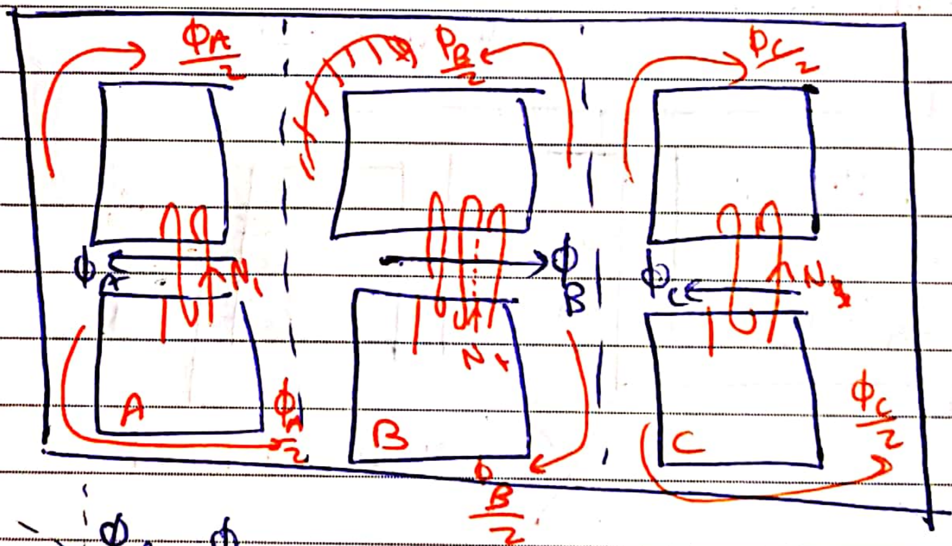
at (XX) $\phi = \frac{\phi_A}{2} - \frac{\phi_B}{2} = \frac{\sqrt{3}}{2}\frac{\phi_A}{2} = 0.866$

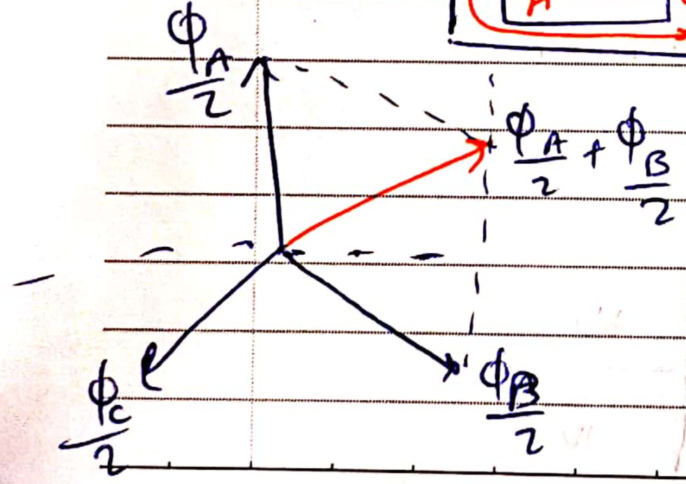


__limp__ needs more cross sectional Area.

$\boxed{*}$ To avoid this:- the center phase is wound in opposite direction

$\Rightarrow$





* This leads to 15% less core weight.

No.

Shell type:- More expensive than core type. it gives more mechanical strength under sc conditions and it allows for open-Δ connection.

Connections:- Y-y

D-y

Y-d

D-y

Y_z -d

* In distribution transformers → the secondery must be y

* high current → D connection.

*** Groups of 3-ph power transformer:-**

Group ① → the phase between any secondary line to voltage and the corresponding primary due to voltage is 0° (In phase).

Group ② → '''' is 180° (out of phase)

Group ③ → '''' is -30° (secondy line voltage lags primary line voltage by 30°)

Group ④ '''' 30° ('''' leads by 30°)

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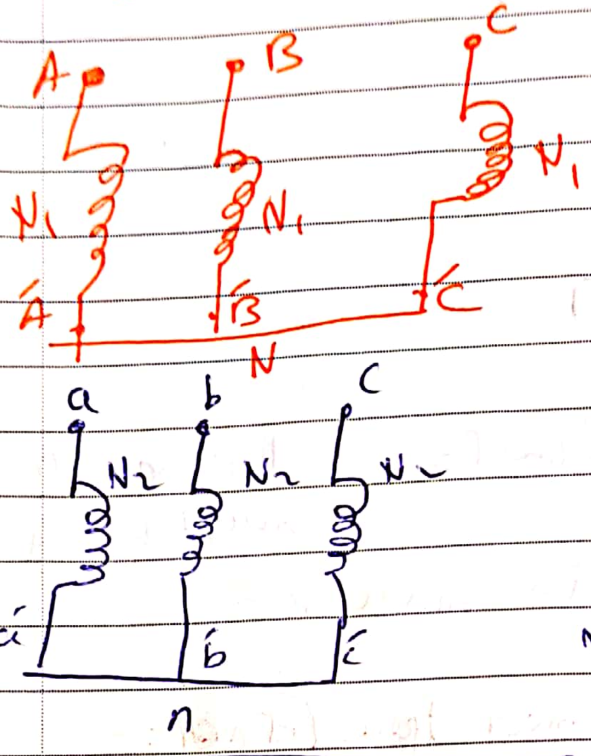
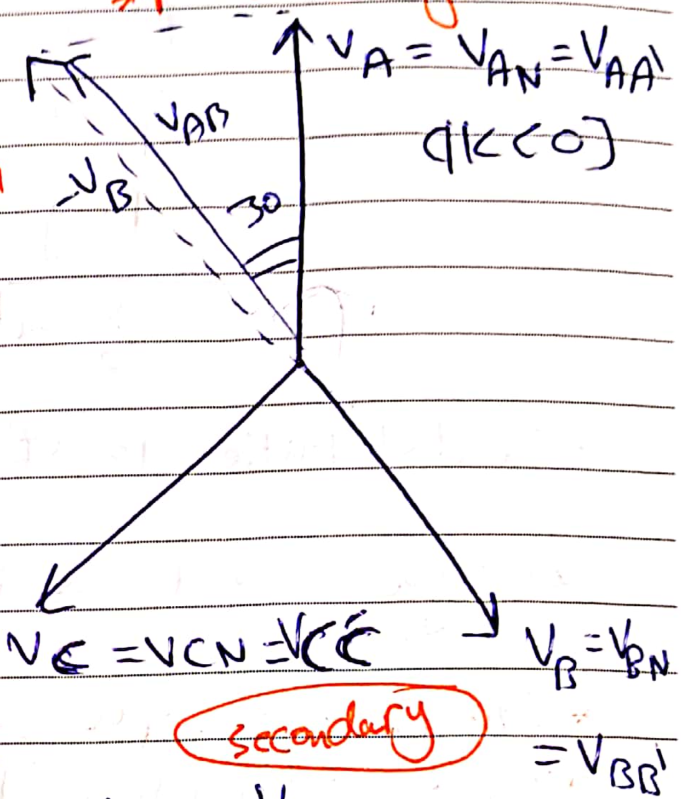
Aim of groups:- to say if certain 3ph Tr is safely connected in parallel with another 3-ph Tr.

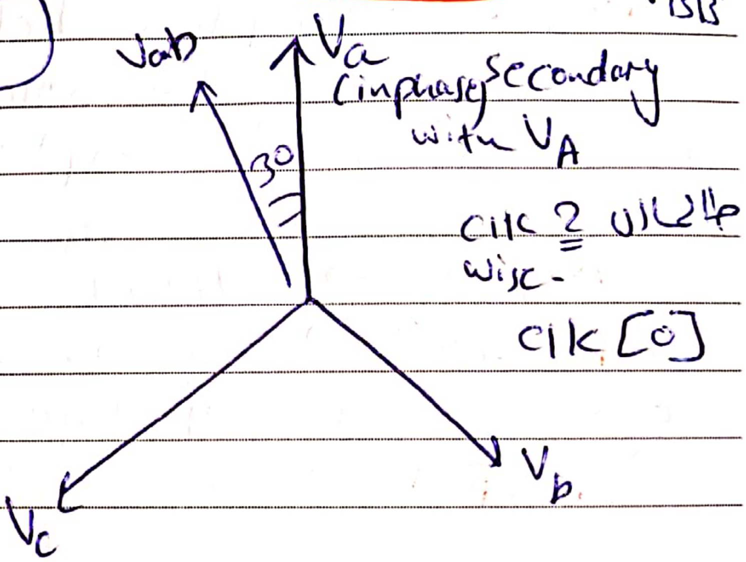
① Y-y transformer



* phasor diagram



secondary



* **6 line voltages**

$$V_{AB} = V_A - V_B$$

V_A inphase V_a

V_B " V_b

V_C " V_c

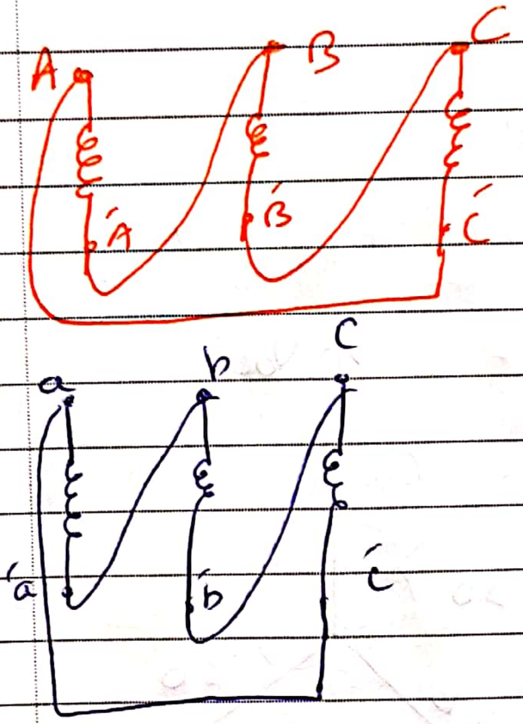
V_{ab} In-phase with V_{AB} (Phase shift صفر)

Tr Y-y can be group No. 1

No.

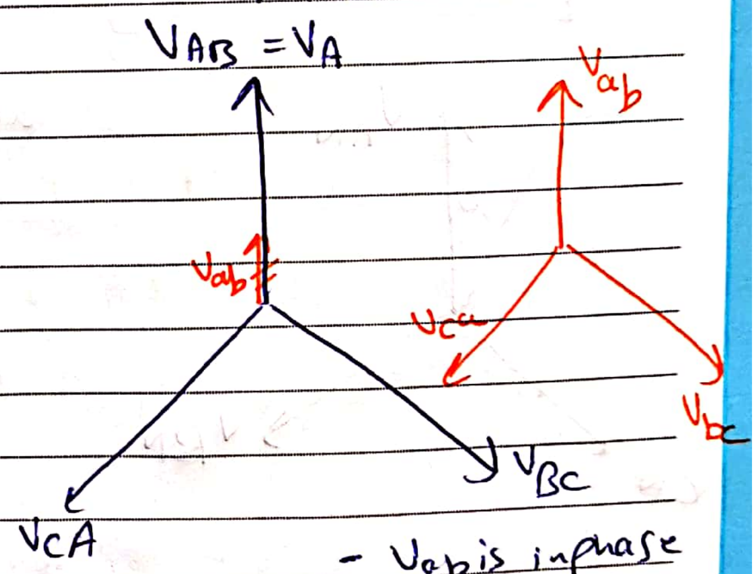
Y-y connection can also be Y-y belongs to G2 (V_{ab} lag V_{AB} by 180)

D-d Transfomer:-



- من بداية ملف الى نهاية ملف الثاني.

ref clock(0)

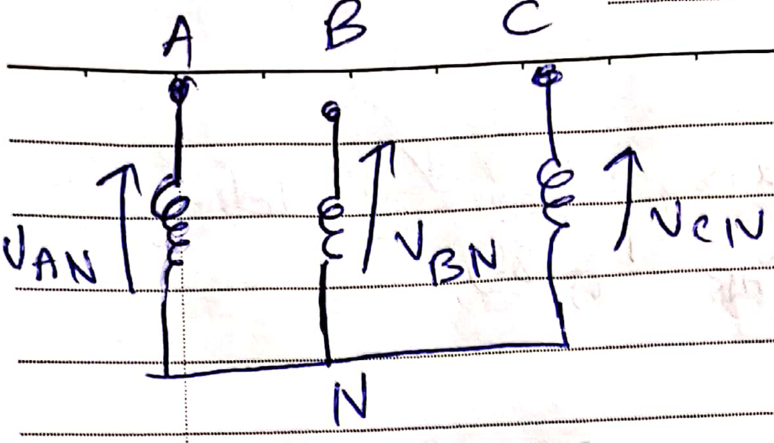


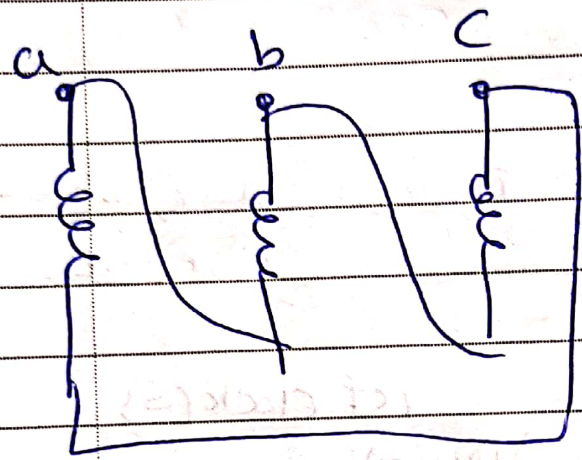
- V_{ab} is inphase with AB

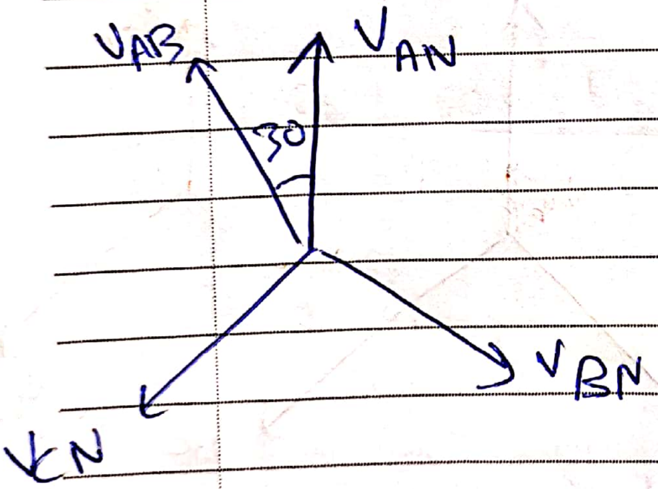
group No(1) D-d

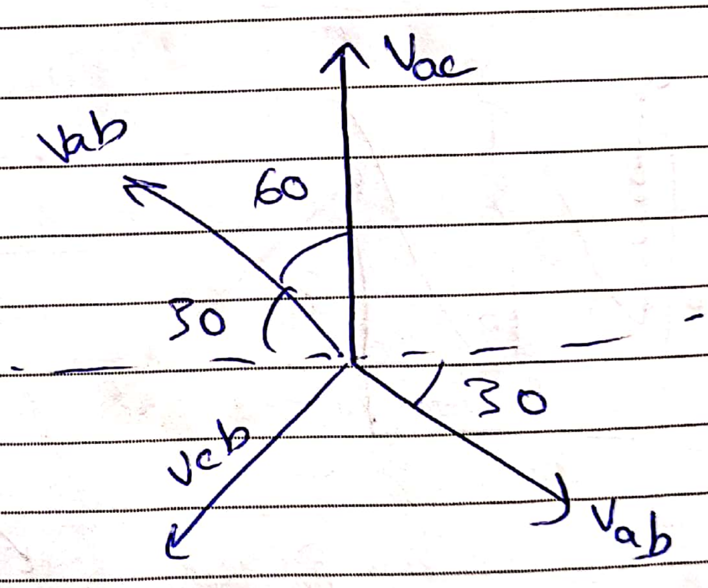
Y-y and D-d can be connected on parallel.

group(1) group









V_{ab} leads V_{AB} by (30°) group Y

100 kVA , 480/120 volt , 60 Hz Tr pf = 1

η = 95.75% at rated conditions

its leakage impedance = (2.5 + j5.0) pu

OCT data : 100 V , 1400 W , 50 Hz

find

(1) P_{eddy} , P_h at 60 Hz , 120

(2) Can the transformer dilever rated power at rated voltage and 50 Hz.

Safe side operation : $\frac{V}{f}$ = constant

$$\frac{V_r}{f_r} = \frac{120}{60} \text{ must equal } = \frac{V_?}{50} = \frac{100}{50}$$

2 = 2

$\boxed{V = 100}$ equal the ϕ constant, B constant → no problem

$V_{oc} \neq V_r$

~~$V_{rated} = V_{oc}$~~

~~$P_{oc} = P_{core} = P_e + P_h$ when $V_{oc} = V_{rated}$~~

~~$P_{oc}(r) = 1400 \times \left(\frac{120}{100}\right)^2 = 2016$~~

$P_{oc} = P_{NL} = 1400$ watt at 50 Hz, 100 V

$$\eta = \frac{k\, S_r\, P.F.}{k\, S_r\, P.f. + k^2 P_{cu}(r) + P_{core}}$$

$$95.75\% = \frac{1 \times 100k}{100k + k^2 P_{cu}(r) + P_{core}}$$

* $\boxed{P_{cu}(r)_{(pu)} = R_{eq}}\ (pu)$

*مهم جدا

$$Z_{eq}(pu) = \underbrace{(2.5 + j5)}_{R_{eq} + j X_{eq}}$$

$$P_{cu}(r)_{pu} = 0.025 * \underbrace{100\,k}_{S_r}$$

$$P_{cu}(r) = 2500$$

$$0.9575 = \frac{100 * 10^3}{100 * 10^3 + 2500 + P_{core}(r)}$$

$$P_{core} = 1938 \text{ watt}$$

Rated conditions.

$$P_{core(r)} = P_h + P_e$$

$$= k_h * f * \underline{B}^2 + k_e f^2 * \underline{B}^2$$

ثابتة $\underline{B}$

$$P_{cor} = k_h' \, \underline{60} + k_e' \, \underline{(3600)}$$ rated frequency.

$$1938 = 60 k_h' + 3600 k_e'$$

test conditions

~~2400~~

$$1400 = k_h' \, 50 + 2500 k_e'$$

$$k_e' = 0.43 \, , \quad k_h' = 6.5$$

$$P_e = k_e' (50)^2$$

No.

$S_r = V_{r2} \, I_{r2}$

new

dilivered power $= \frac{S}{S} \times 100\%$

(rated) مقنن

$\tilde{B} = \frac{S}{S} B$

No.

HW:-

$P_{cu}(r)\,pu) \overset{??}{=} Req\,(pu)$

$P_{cu}(r) = I_2' \, Req$

$P_{cu}\,pu = I_2'(r)pu\; Req\,(pu)$

$$= \left(\frac{I_2'(r)}{I_2'(r)}\right)^2 Req\,(p)$$

$$= 1 * Req\;\underline{\underline{pu}} = Req\,(pu)$$

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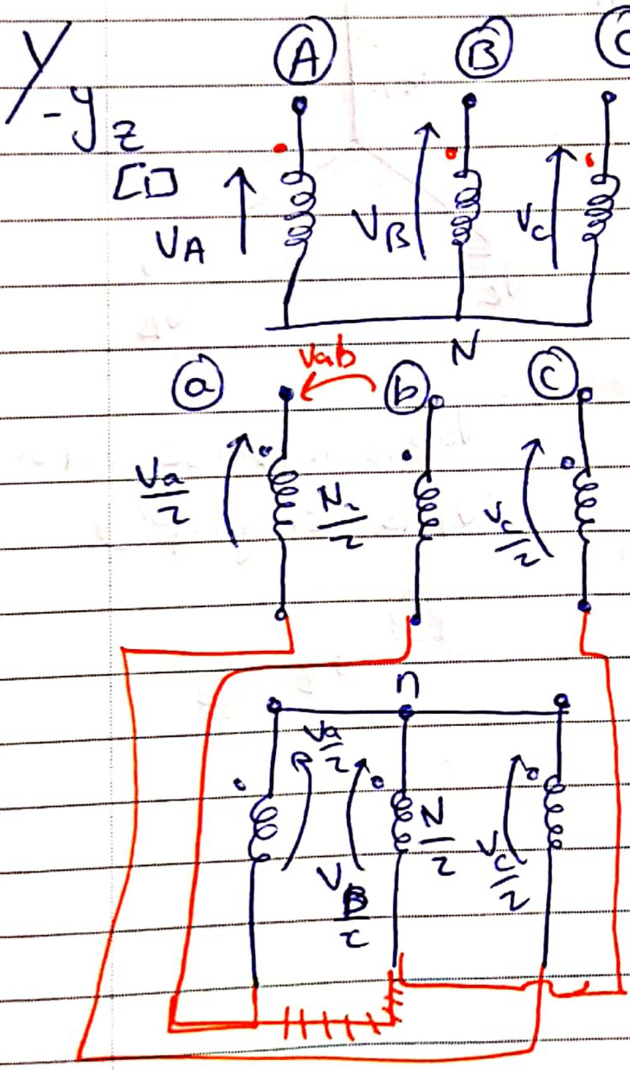
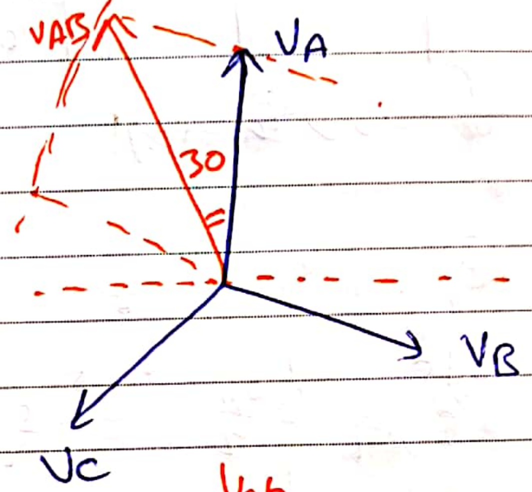
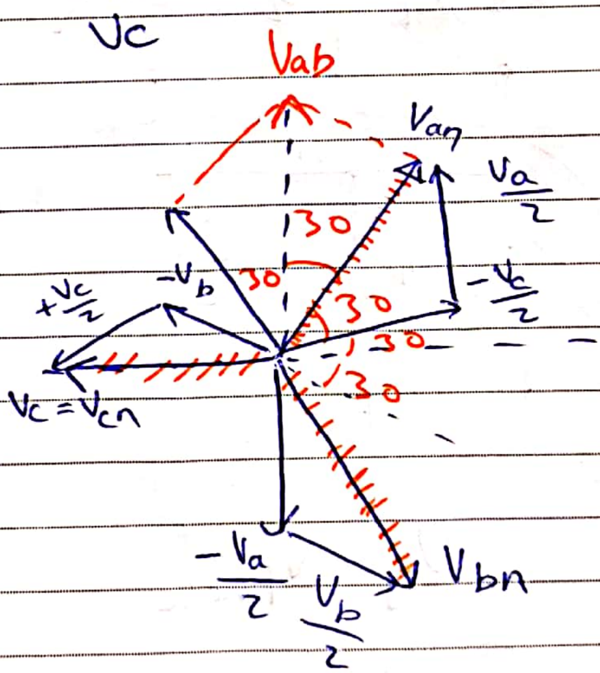
No.

* To reduce Harmonics in transformers and to allow 3-ph parallel operation of Tr with different groups, Zig-Zag connection is the solution.

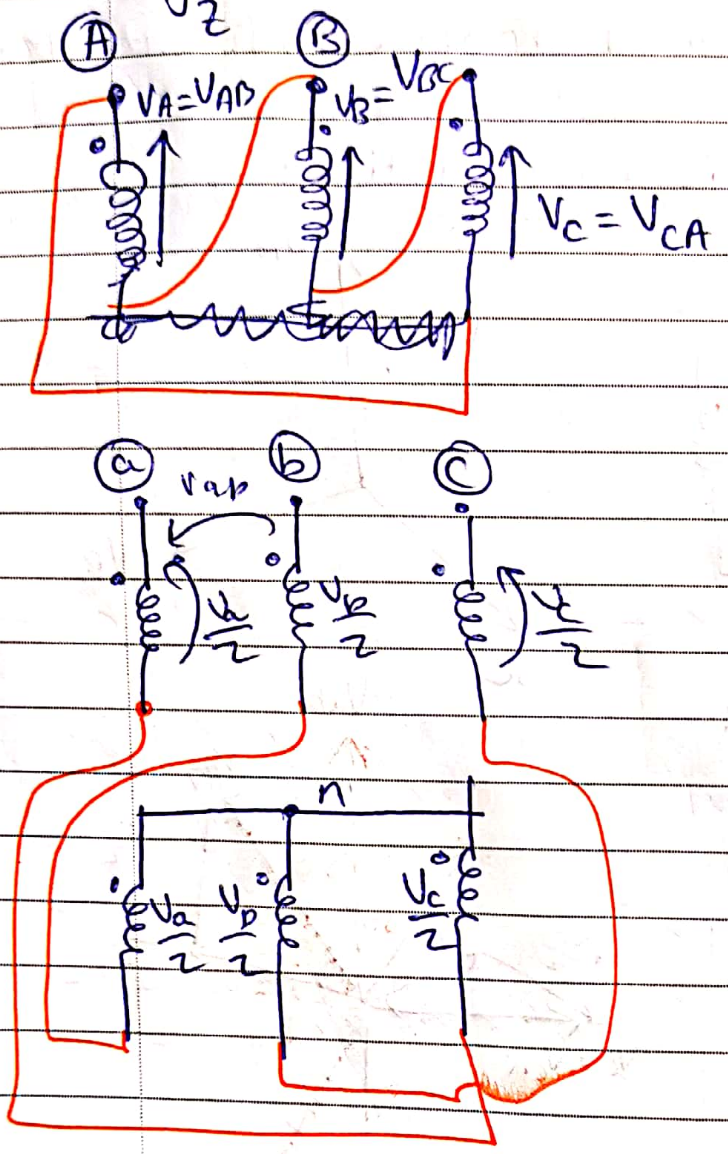


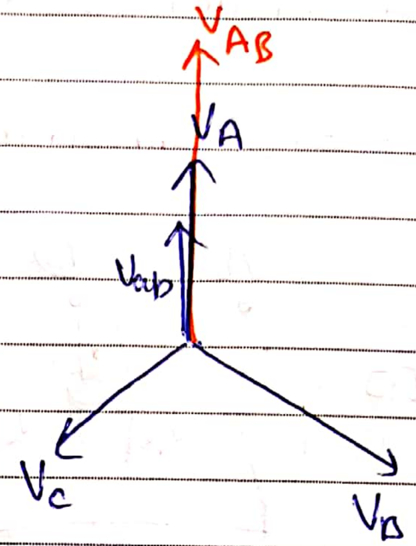




No.

$D\text{-}y_z$





V_{ab} is inphase with V_{AB} $\therefore$ group (1)

$D\text{-}y_{z[0]}$

$V_y = V_{Phase}$

$Y\text{-}y$:-

$$aT = \frac{V_{phY}}{V_{phY}} = \frac{N_1}{N_2}$$

No.

Y-y_z :-

$$V_{an} = \sqrt{3}\,\frac{V_{ph}}{2} = \frac{\sqrt{3}}{2} V_{ph}$$

$$V_{ab\,y_z} = \sqrt{3}\left(\frac{\sqrt{3}}{2} V_{ph}\right) = \frac{3}{2} V_{ph}$$

$$V_{an\,y} = \frac{\cancel{2} V_{ph}}{\cancel{2}} = V_{ph}$$

$$V_{ab\,y} = \sqrt{3}\, V_{ph}$$

$$\frac{V_{ab\,y}}{V_{ab\,z}} = \frac{\sqrt{3}\, V_{ph}}{\frac{3}{2} V_{ph}} = \frac{2}{\sqrt{3}} \Longrightarrow \boxed{\frac{V_{ab\,y}}{V_{ab\,z}} = 1.15}$$

⟹ This implies that Y_z looses 15% of the voltage compare to Y connection.

⟶ to obtain $\boxed{\text{same}}$ voltage as for Y connected Tr, Y_z should have 15% <u>extra</u> turns in the windings

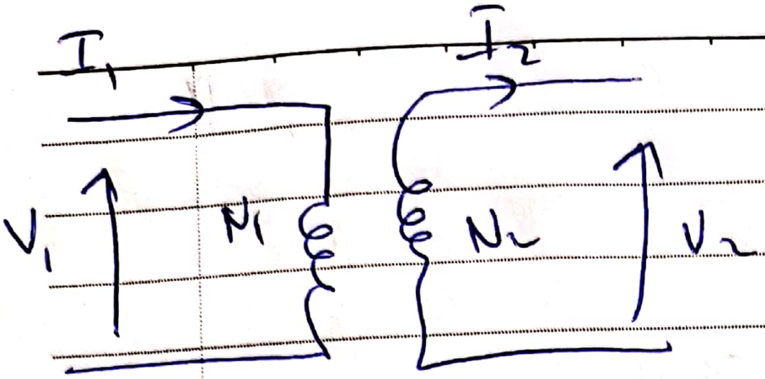
⟹ Y_z have more weight, more expensive.

a_T :- transformation ratio:

a : turns ratio

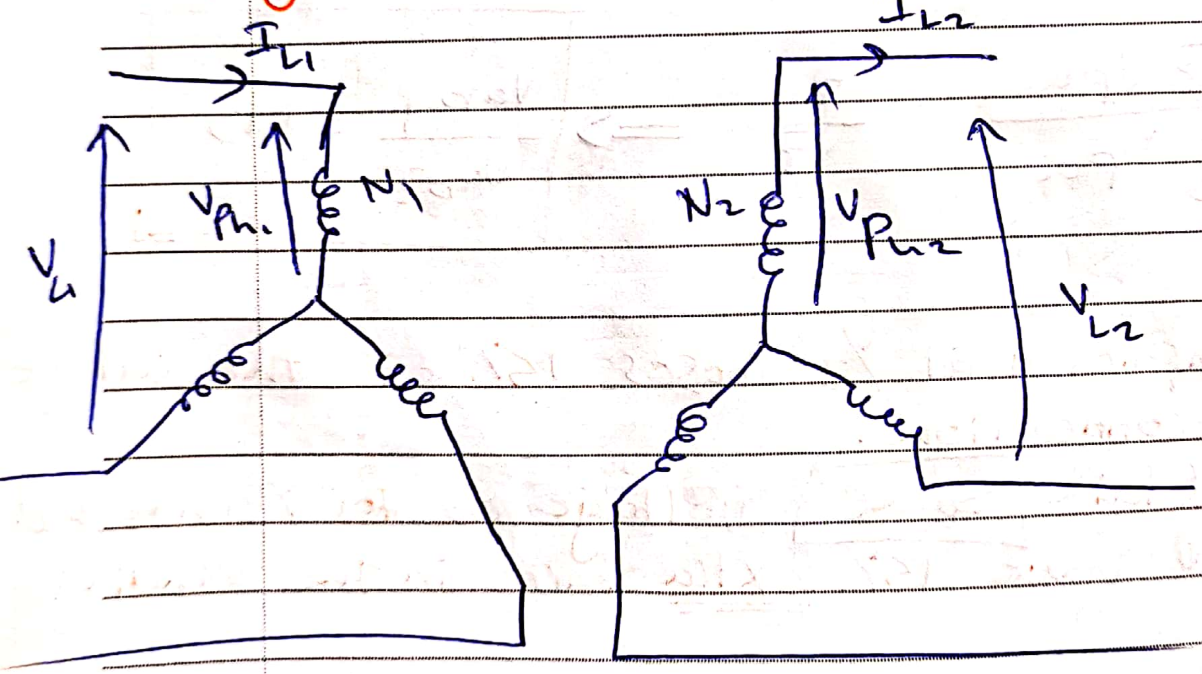
$$\boxed{a = \frac{N_1}{N_2} = \frac{V_{ph_1}}{V_{ph_2}} = \frac{I_2 ph_2}{I_1 ph_1}} \rightarrow \text{single Phase.}$$

No.



a_T : ??

ⓐ Y-y



$$a_T = \frac{V_{L1}}{V_{L2}} = \frac{V_{ph1}\sqrt{3}}{V_{ph2}\sqrt{3}} = \frac{V_{ph1}}{V_{ph2}} = \frac{N_1}{N_2} = a$$

$\boxed{\text{** So in Y-y connection } a_T = a}$

$$\frac{I_{ph1}}{I_{ph2}} = \frac{I_{L1}}{I_{L2}} = \frac{N_2}{N_1} = \frac{1}{a}$$

smile for life

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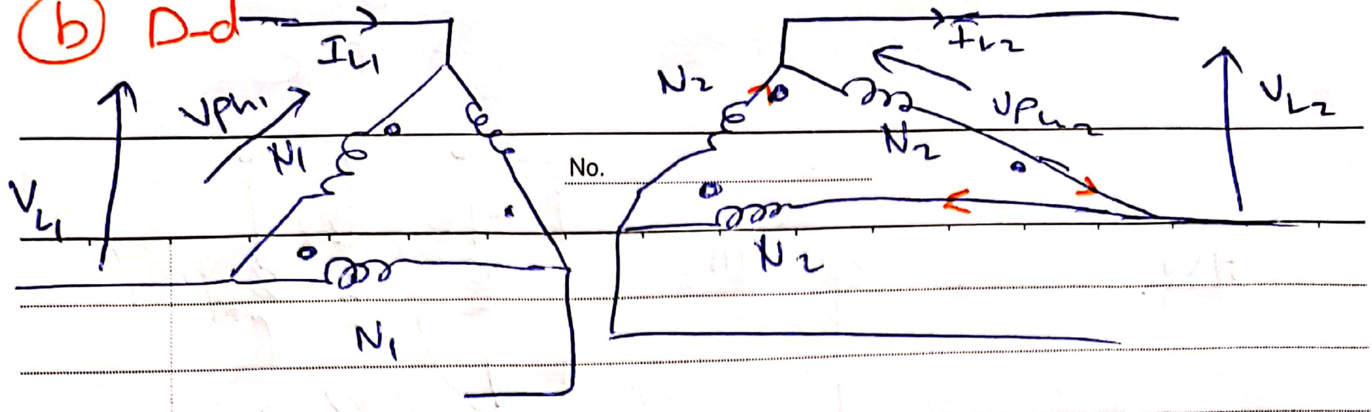
(b) D-d



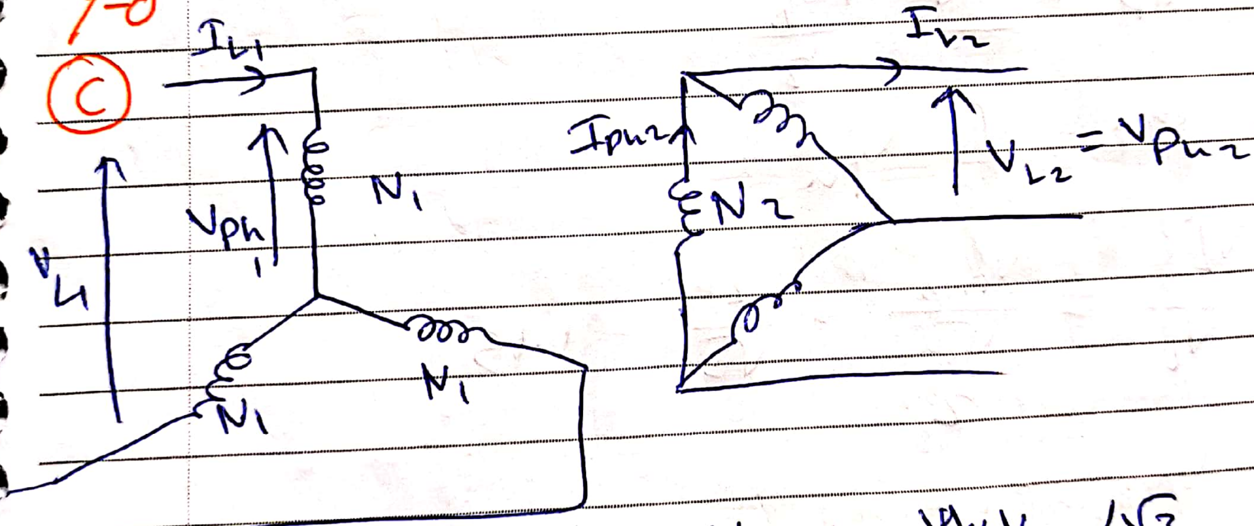
$$a = \frac{N_1}{N_2} = \frac{V_{ph1}}{V_{ph2}} = \frac{V_{L1}}{V_{L2}} = a_T$$

$\boxed{* \ a_T = a}$ in D-d

$$a = \frac{I_{ph2}}{I_{ph1}} = \frac{I_{L2}/\sqrt{3}}{I_{L1}/\sqrt{3}} = \frac{I_{L2}}{I_{L1}} = a_T$$

Y-d

(c)



$$a = \frac{N_1}{N_2} = \frac{V_{ph1}}{V_{ph2}} = \frac{V_{L1}/\sqrt{3}}{V_{L2}}$$

$$a = \frac{1}{\sqrt{3}} \frac{V_{L1}}{V_{L2}} \Rightarrow \underline{\underline{so}}$$ ** $a = \frac{1}{\sqrt{3}} a_T$

$a_T > a$

at Y-d

** at D-y

$$\boxed{a_T = \frac{a}{\sqrt{3}}}$$

smile for life

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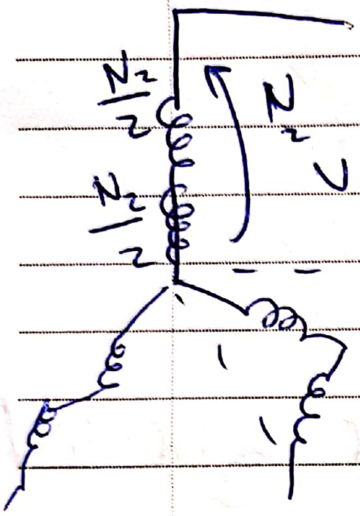
No.

H.W

D-Y_z



$$V_{ph_z} = \frac{\sqrt{3}}{2} V_{ph}$$

$$a = \frac{2}{\sqrt{3}} \frac{V_{ph\Delta}}{V_{phY}}$$

$$a_Z = \frac{2}{\sqrt{3}} \frac{N_1}{N_2}$$

$$= \frac{2}{\sqrt{3}} \cdot a$$

$$= 1.15a$$

$$a_T = \frac{V_{L\Delta}}{V_{LZ}} = \frac{V_{ph\Delta}}{\sqrt{3} \cdot \frac{\sqrt{3}}{2} V_{ph\lambda}} = \frac{2}{3} \frac{V_{ph\Delta}}{V_{ph\lambda}}$$

$$a_{T_Z} = \frac{2}{3} a$$

Parallel operation of transformers:-

why??

① More reliable system.

② To face growth of the network.

How?

conditions to be satisfied:-

① Same voltage Ratings and Tr. ratio.
line

②

↳ the (two or more) should belong to the same group.

smile for life

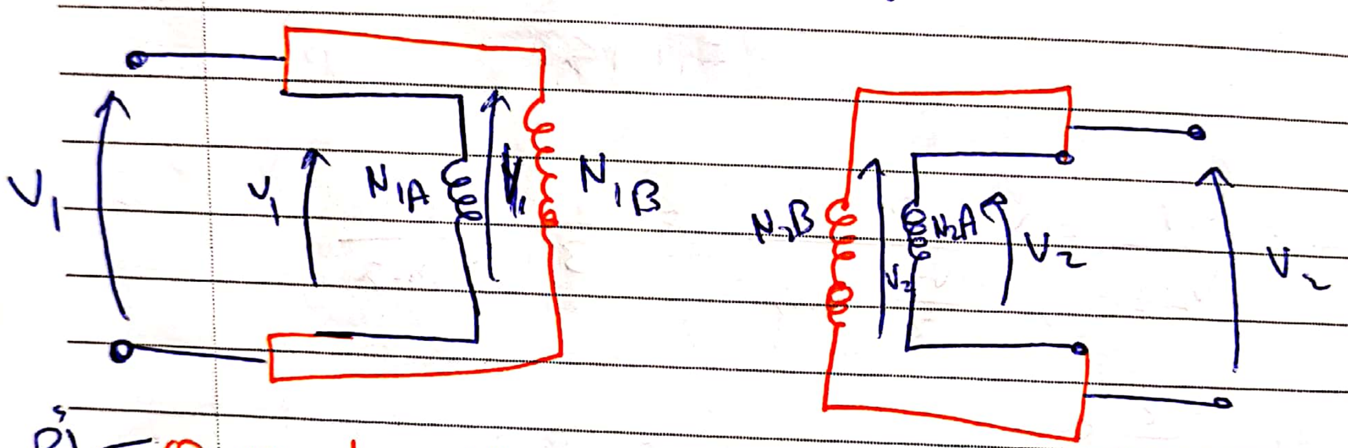
No.

③ for good power sharing :-

$Z_{eq}(pu)_A = Z_{eq}(pu)_B$

④ $\left.\frac{X_{eq}}{R_{eq}}\right|_A = \left.\frac{X_{eq}}{R_{eq}}\right|_B$

$\Longrightarrow$ this leads to equal power factor. (PF)



أهم شرطين [① equal voltage ratings.
② Pr-per polarity (same group in 3ph Tr)
$\Sigma V = 0$ (closed path).

$V_2 = \frac{V_1}{a_B}$ (Transformer B)

$V_2 = \frac{V_1}{a_A}$ (Transformer A)

if $a_A = a_B$

$\frac{V_1}{a_A} = \frac{V_1}{a_B}$

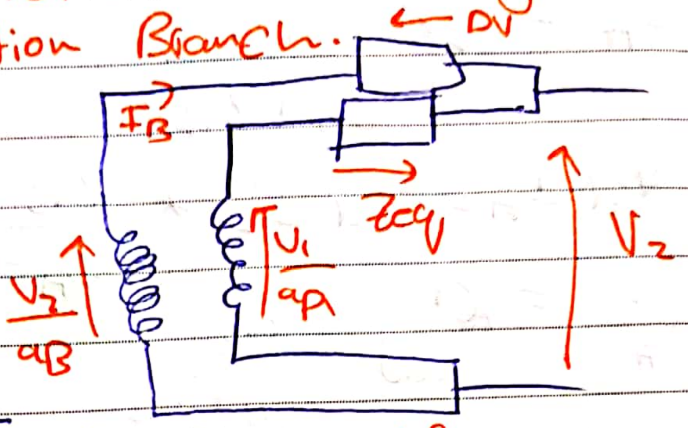
$$I_{cc} = \frac{\frac{\bar{V_1}}{a_A} - \frac{\bar{V_1}}{a_B}}{Z_{eq_1} + Z_{eq_2}} = 0$$

$\boxed{\text{if } a_A \neq a_B}$ $\longrightarrow$ $\frac{\bar{V_1}}{a_A} \neq \frac{\bar{V_1}}{a_B}$

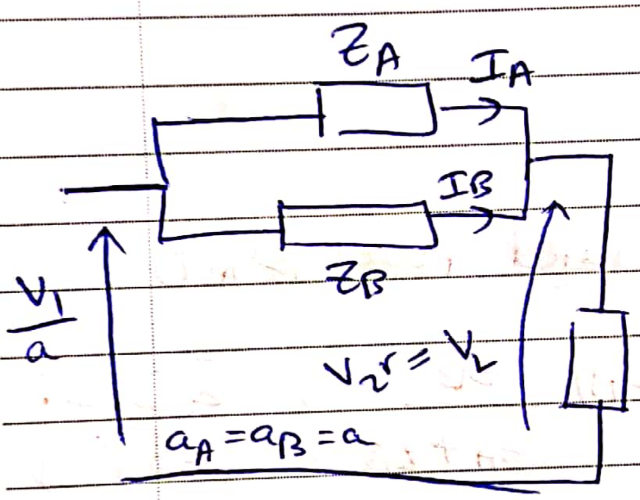
$I_{cc} \neq 0 \rightarrow$ problem

→ Equivalent Circuit refered to secondery (load).

** Neglect excitation Branch.



$\bar{I}_L = \bar{I}_A + \bar{I}_B$ if $a_A \neq a_B$



← $I_{cc} = 0$ (proper connection)

$$I_A Z_A = I_B Z_B$$

$$\frac{I_A}{I_B} = \frac{Z_B}{Z_A} \qquad \frac{V_{2r} I_A}{V_{2r} I_B} = \frac{Z_B}{Z_A}$$

3rd:- $\left.\frac{X_{eq}}{R_{eq}}\right|_A = \left.\frac{X_{eq}}{R_{eq}}\right|_B$ for same PF

$$\frac{S_A}{S_B} = \frac{Z_B}{Z_A} \Longrightarrow \boxed{\frac{S_A(r)}{S_B(r)} = \frac{Z_B}{Z_B}}$$

Proper Power sharing

↳ 4th condition for power connection.

No.

Power sharing:-

$$I_A = I_L * \frac{Z_B}{Z_A + Z_B}$$

$$V_{2r} I_A = V_{2r} I_L * \frac{Z_B}{Z_A + Z_B}$$

similarity

$$\boxed{S_A = S_{load} * \frac{Z_B}{Z_A + Z_B}}$$

$$\boxed{S_B = S_{load} * \frac{Z_A}{Z_A + Z_B}}$$

→ if Tr_A is to provide its rated power $S_{A(r)}$

similarity

$$S_A(r) = S_{load}(\text{max due to } A) \frac{Z_B}{Z_A + Z_B}$$

$$S_B(r) = S_{load}(\text{max due to } B) \frac{Z_A}{Z_A + Z_B}$$

أكبر قيمة
لل power
يلي ممكن تطلع
من Tr A
هي ال rated

→ for Tr_A not to be over loaded:-

$$S_{load\,max\,A} = S_A(r) * \frac{Z_A + Z_B}{Z_B}$$

→ for Tr_B not to be over loaded:-

$$S_{load\,B\,max} = S_B(r) * \frac{Z_A + Z_B}{Z_A}$$

(A) No.

$$\boxed{\text{If } S_{load\ max\ A} = S_{load\ max\ B}}$$

Proper sharing occurs

ex: $S_L = 100M \rightarrow S_{A(r)} = 60M$
$S_{B(r)} = 40M$

يعني
$S_{A(r)} + S_{B(r)} = S_{load}$

ex: $S_L = 80m \xrightarrow{} \left.\begin{array}{l} S_{A(r)} = 60 \\ S_{B(r)} = 40 \end{array}\right\} \rightarrow S_A = 80 * \frac{60}{100} = 40m$

$S_B = 80 * \frac{40}{100} = 32m$

ex: $S_{load} = 110 \rightarrow S_{A(r)} = 60$
$S_{B(r)} = 40$

ما بتحقق الشرط

(B) $S_L(max A) \neq S_L(max B)$

$S_L(max) =$ either $S_L(max A)$ or $S_L(max B)$
which of them is lower.

* In this case one Tr will run at rated power
second will be under rated.

$$\frac{S_{A(r)}}{S_{B(r)}} \neq \frac{Z_{eq}(B)}{Z_{eq}(A)}$$

last comment :-

$$\frac{I_A Z_A}{V_{2r}} = \frac{I_B Z_B}{V_{2r}}$$

$$\frac{Z_A}{\left(\frac{V_{1r}}{I_A}\right)} = \frac{Z_B}{\left(\frac{V_{1r}}{I_B}\right)}$$

No.

* if two Tr share rated power :-

$$\frac{Z_A}{\left(\frac{V_{2r}}{I_{A(r)}}\right)} = \frac{Z_B}{\left(\frac{V_{2r}}{I_{B(r)}}\right)}$$

$$\frac{Z_A}{Z_{Base(A)}} = \frac{Z_B}{Z_{Base(B)}}$$

$$\boxed{Z_{A}(Pu) = Z_{B}(Pu)}$$

No.

* if two Tr share rated power :-

$$\frac{Z_A}{\left(\frac{V_{2r}}{I_{A(r)}}\right)} = \frac{Z_B}{\left(\frac{V_{2r}}{I_{B(r)}}\right)}$$

$$\frac{Z_A}{Z_{Base(A)}} = \frac{Z_B}{Z_{Base(B)}}$$

$$\boxed{Z_A\,(Pu) = Z_B\,(Pu)}$$

Ex:

S_A 25 KVA, S_B = 75 KVA } Transformer connected on parallel.

$Z_B = 0.0125 < 53.13$

$Z_A = 0.375 < 53.13$

load :- 100 kVA.

a) $S_A = S_L * \frac{Z_B}{Z_A + Z_B} = 100 * \frac{0.0125}{Z_A + Z_B} = \frac{100 \times \cancel{0.0125}\ 0.012}{0.0.5}$

$= 25\,kVA$.

$S_B = 100 * \frac{0.0375}{0.05} = 75$ KVA ← excellent sharing.

$$\frac{S_{A(r)}}{S_{B(r)}} = \frac{Z_{B(r)}}{Z_{A(r)}} = \frac{1}{3}$$

smile for life

No.

If $Z_A = 0.075 \angle 53.13\ \Omega$
$Z_B = 0.05 \angle 53.13\ \Omega$

$$\frac{S_{A(r)}}{S_{B(r)}} = \frac{1}{3}$$

no good sharing.

$$\frac{Z_{B(r)}}{Z_{A(r)}} = \frac{2}{3}$$

$$S_{L\,max_A} = S_{A}(r) * \frac{Z_A + Z_B}{Z_B} = \frac{\cancel{100}^{\,25k}(0.125)}{0.05} = 62.5\ \text{kVA}$$

$$S_{L\,max_B} = S_B(r) * \frac{Z_A + Z_B}{Z_A} = \frac{\cancel{100}^{\,75k*}(0.125)}{6.075} = \frac{500}{3}\ \text{kVA}$$

$$= \cancel{167.67}$$
$$125\ \text{KVA}$$

$$S_A = 100 * \frac{Z_A}{Z_A + Z_B} = 40\ \text{kVA (over loaded)}$$

S_L

$$S_B\ 100 * \frac{Z_B}{Z_A + Z_B} = 60\ \text{kVA (under loaded)}$$

$\rightarrow S_{L\,max} = 62.5$ Can be served

*Ex:-
3-phase, 230V, 27 KVA, 0.9 pF lag load is supplied by 3 single phase Tr (10 kVA, 1330/230V 50 Hz) connected in Y-d

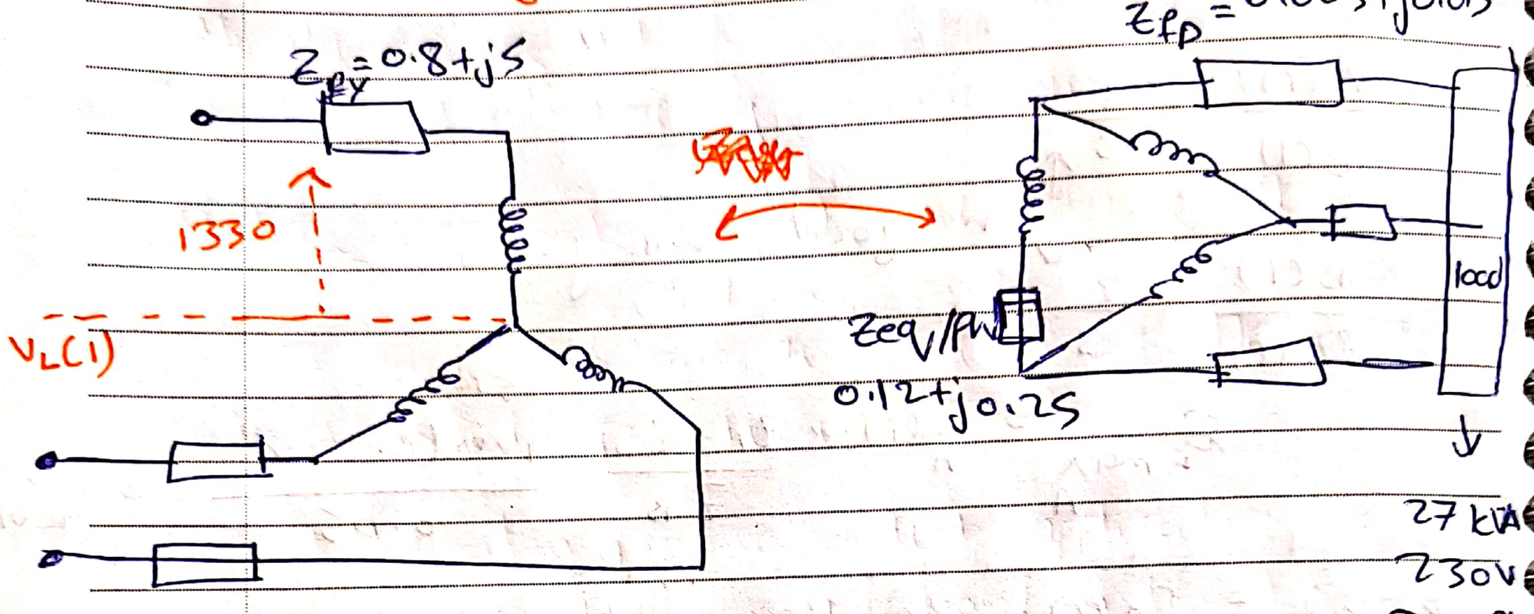
Tr secondary is connected to the load through a feeder $(0.003 + j0.015)\ \Omega/\text{ph}$

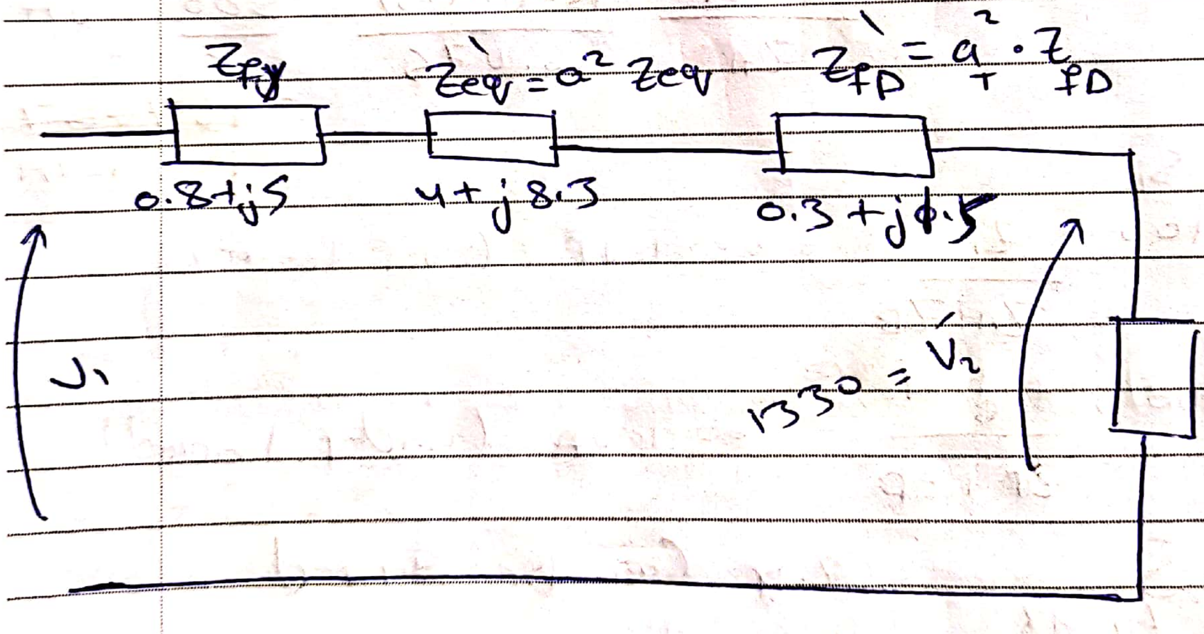
smile for life

Tr. primary is connected to 3-ph supply through a feeder $(0.8 + j5)\ \Omega/ph$

Eq. Impedence :- $(0.12 + j0.25)\ \Omega/ph$ R. to LVS

Z_o is neglected.





$a = \dfrac{1330}{230} = 5.78$

$Z_{eq}' = (5.78)^2 (0.12 + j0.25)$

$= 4 + j8.3$

$Z_{fD}' = (a_T)^2 Z_{fD} = 100 Z_{fD}$

$a_T = \dfrac{1330\sqrt{\ }}{} = 10$

No.

$\hat{V_2} = V_2 * a = 230 * 5.78 = 1330 \angle 0$

Per phase.

$S = 27*10^3 = \sqrt{3} V_L I_L \cos\phi$

$I_{L\Delta} = \dfrac{27*10^3}{\sqrt{3}*230*0.9} = 75.$

$\hat{I_2} = \dfrac{75.3}{a_T} = 7.5$

$\Rightarrow R_{eq} = 0.8 + 4 + 0.3 = 5.1\,\Omega$

$X_{eq} = 5 + 8.3 + 1.5 = 14.8\,\Omega$

$\Big\} Z_{eq} = 15.65 \angle 70.9\,\Omega$

$\cos^{-1}(0.9)$

$\bar{V_1} = 1330 \angle 0 + 7.53 \angle -25.84\,(15.65 \angle 71)$

$= 1413 \angle 3.3^\circ$ V/ph.

$1415\sqrt{3} = V/L_1$

$V.Reg = \dfrac{1415 - 1330}{1330}$

$\eta = \dfrac{P_o}{P_{in}} = \dfrac{27*10^3}{7.53 * 1415 \cos(29)}$

$PF_{in} = \cos(29)$

***DC Machines :-

Mainly used as Motors.
Recently : load sharing no more than 10%.

Motor expensive (2-3) cost of eq. AC
control → so easy.
* power electronics ease the control of AC motor (which is cheaper than eq. DC)

=> still used in precise control Applications, & in certain mech load (ex: traction system).

DC Machines classification.

- **self excited machines**
  - the machine excites itself.
  - ~~one extra Power source is required to create excitation field.~~
  - Series machines
  - Compound machine
    - Commulative machine
    - Diff mach
    - long shunt.
    - short shunt
  - Shunt machine
- **Permenet magnet machine.**
  - Small - power machine.
- **seperetly - excited machine**
  - one extra Power source is required to create excitation feild (extra cost)
  - more controilability since feild and Power circuit are physicaly independent.

No.

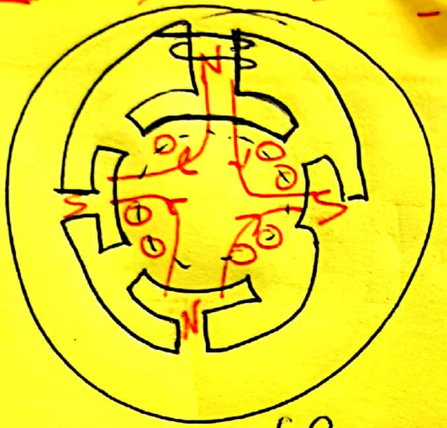
(feild excitation)

Construction :- Stationary elements - (Stator)
Rotating elements. (Armature)

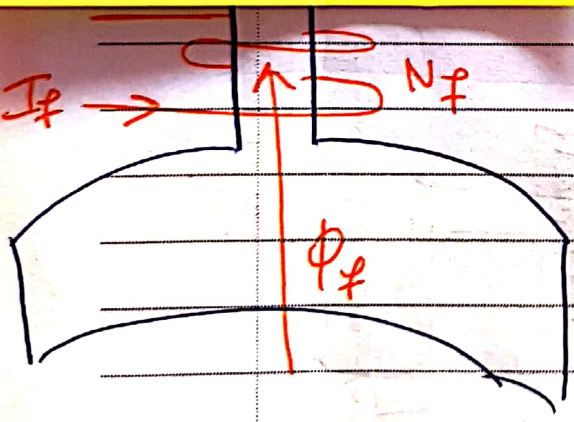
Part where mech power is converted into electrical (generator)

or electric to mech power (motor)

- في عندي تماثل بين ال Poles

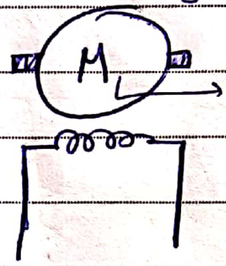


Stator
Yolce
(Ferro mgntic core)



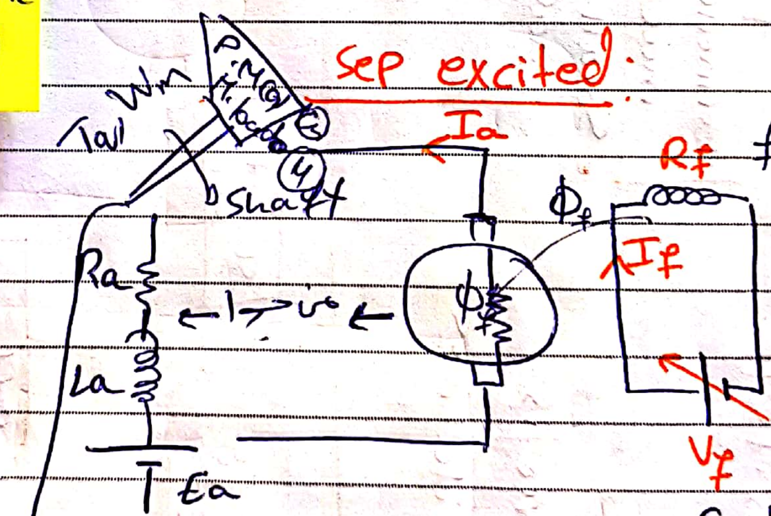
Dc Machine Symble

G → generator



→ motor.

Sep excited:



feild circuit.

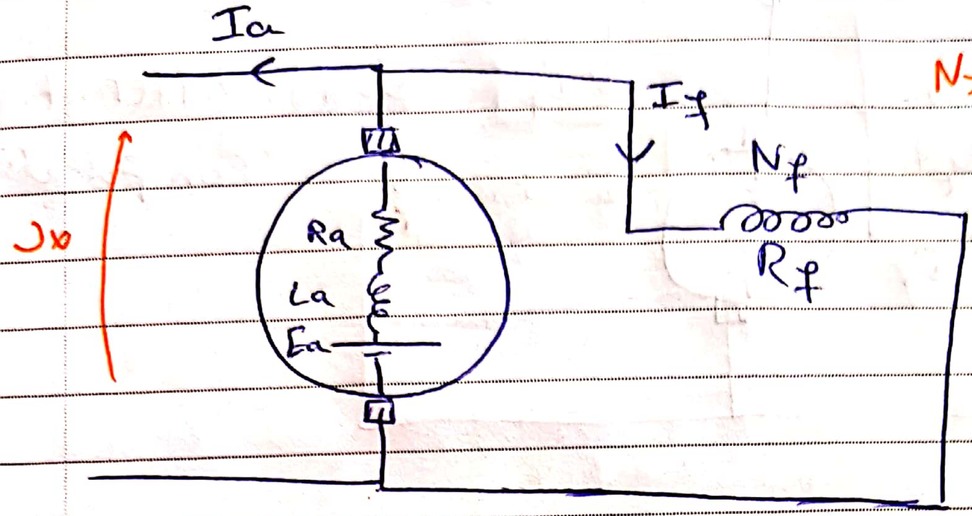
Controlled rectifire circuit.

→ P.M: Generator.
→ M. load: Motor,

$\boxed{R_f \text{ very large.}}$

No.

~~self excited~~, shunt (self)



N_f: large.

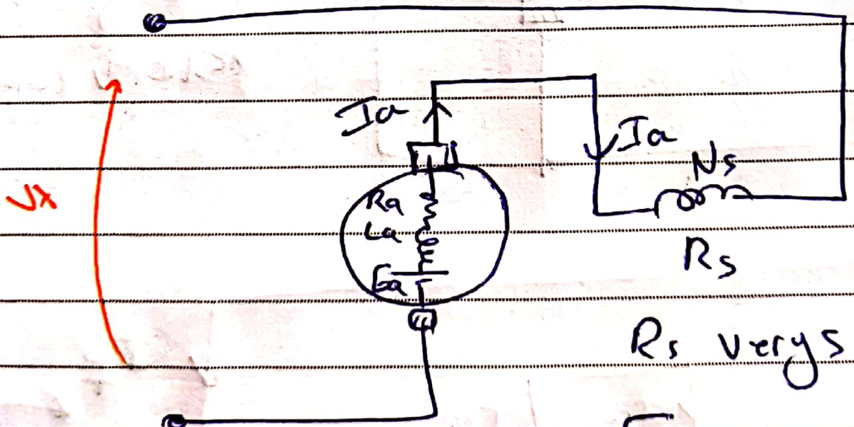
A_f: thin

$I_f <<<< I_a$

thin R_f = huge.

$f_f = MMF = I_f{\downarrow} \, N_f{\uparrow}$

series, (self)

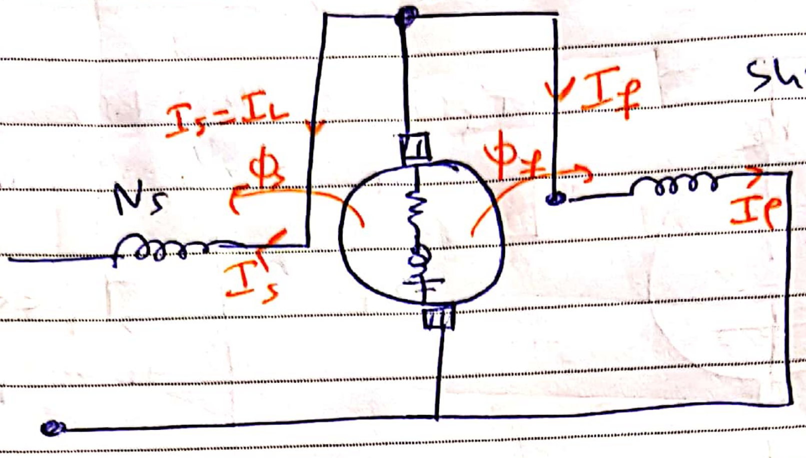


R_s very small ($\approx R_a$)

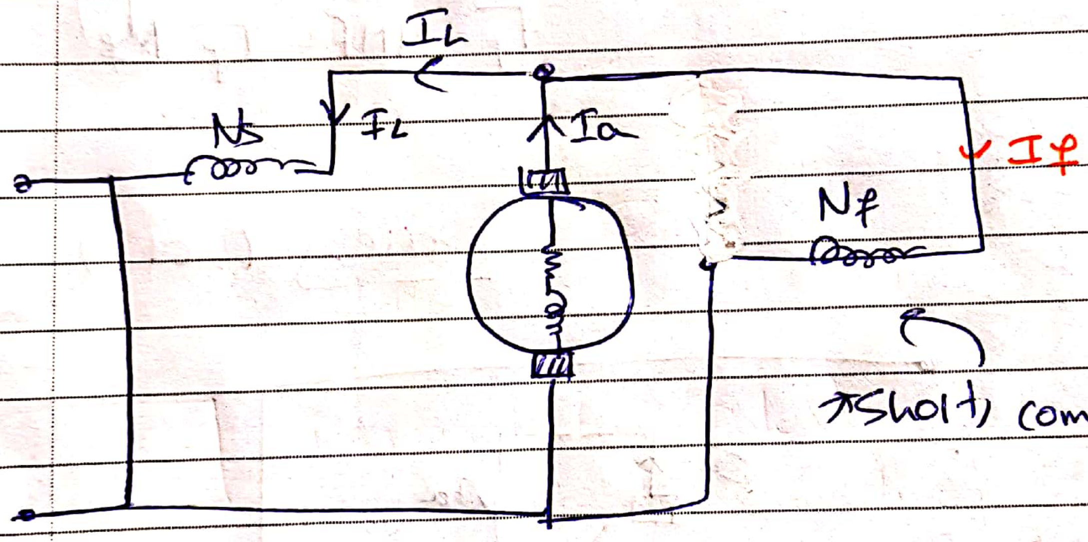
$f_f = I_a * N_s$

N_f = few turns.

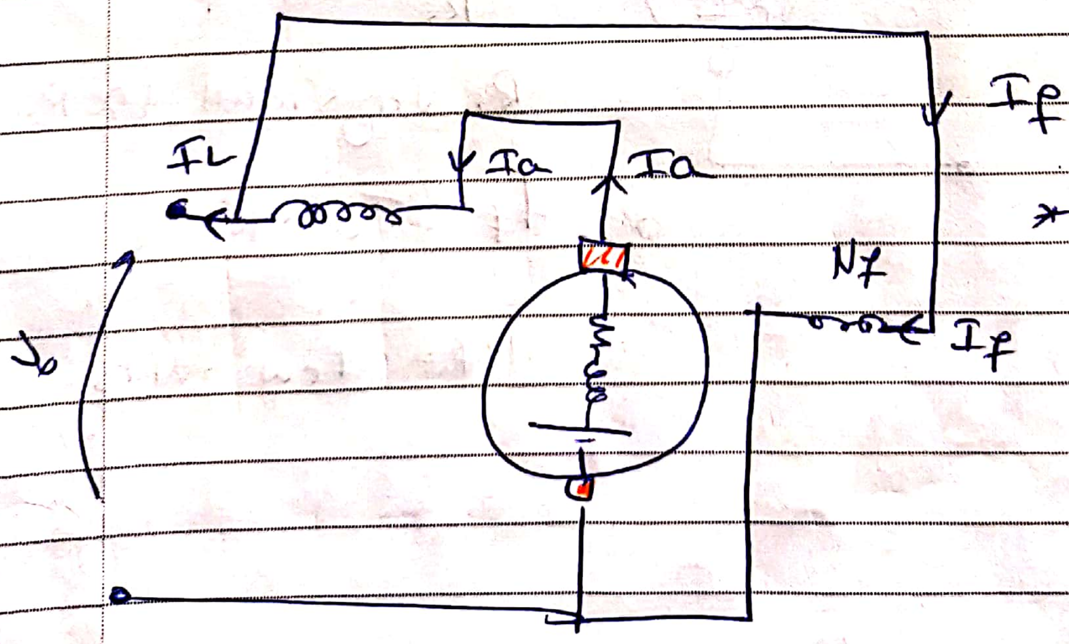
compound (self).



short, differential compound.



*short, commulative

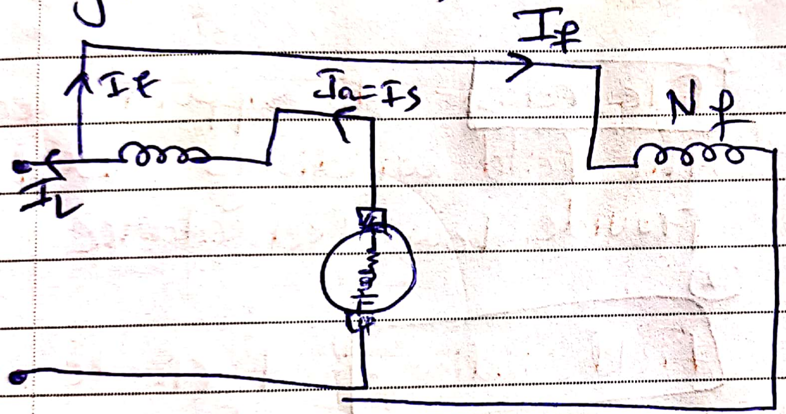


*long, commulative

No.

Shunt

long, Differential, Compound.



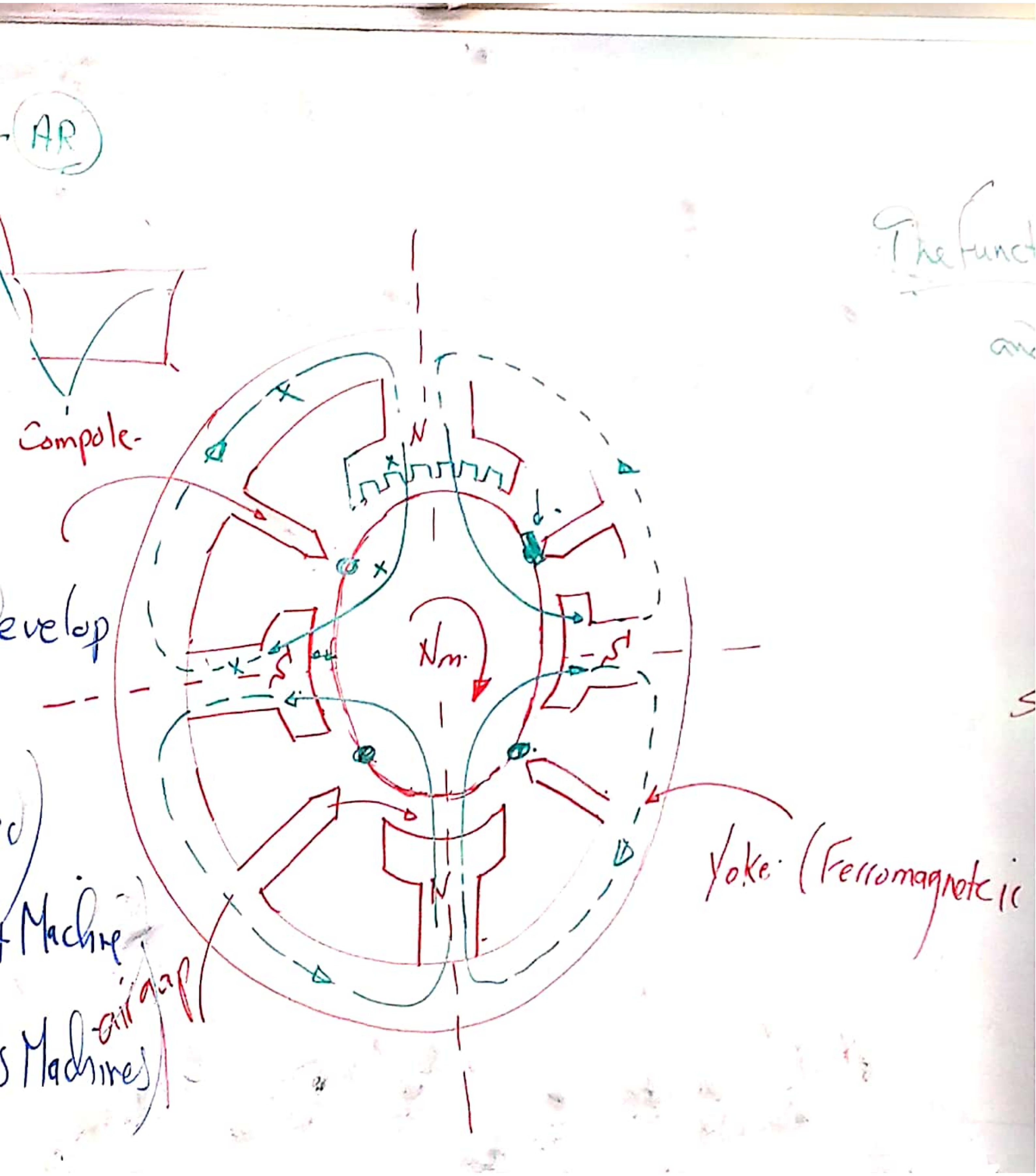
* Construction of DC machine:

- Stationary elements

• Stator Yolke:-

a) To mech. support the feild (excitation) poles.

b) to provide a low reluctance closed path for the flux.



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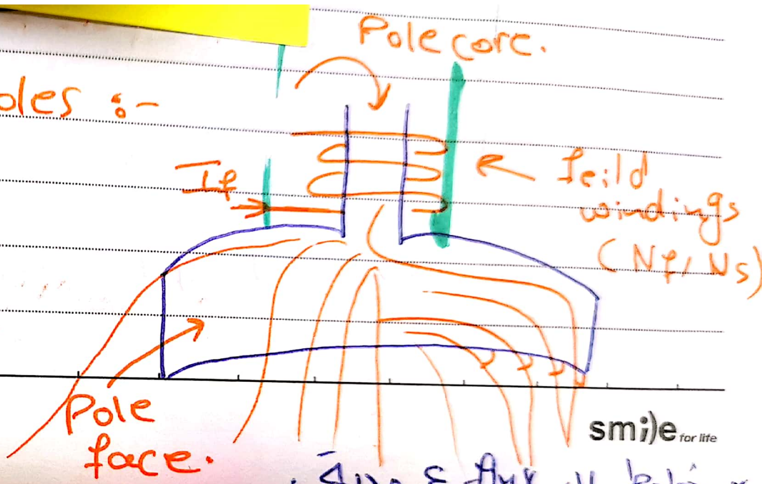
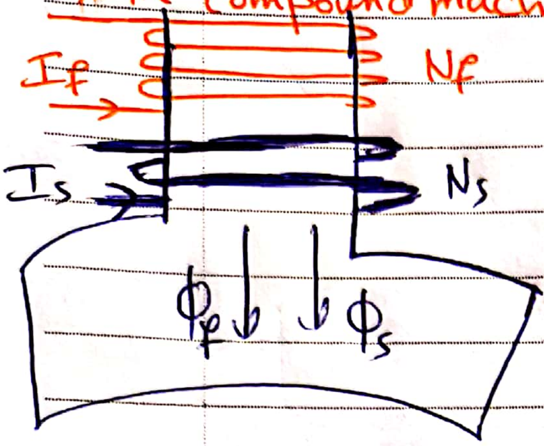
- excitation (field) poles :-
  - polecore
  - Pole face
  - feild windings.



* خطوط ال flux عمودية .

No.

* in compound machine



(*) Pole cores :- to support mech the feild windings and to provide low - Reluctance

(*) Field windings : to create main flux that is required to develop EMF in the Armature . (-) could be separated from the rotor (sep. excited).

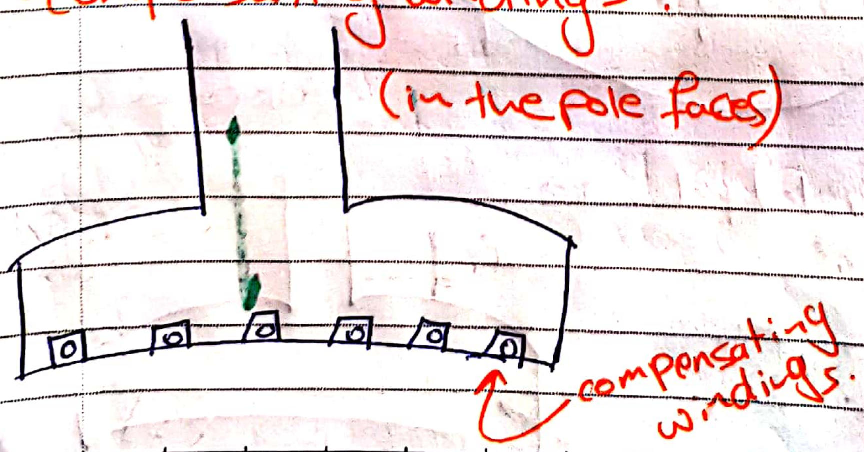
(-) could be connected in parallel to the rotor (shunt machine).

(-) colud be connected in series to the rotor (series machines).

- Compoles :- (commutating poles) to avoid Problems of the commutation Process.

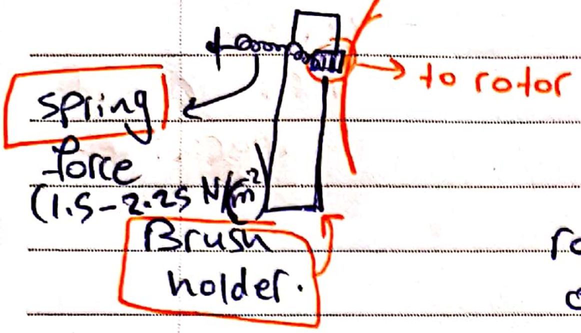
- ~~comps~~

- compensating windings. (in the pole faces)



• Brush Gear

→
- sping
- brush holder
- brush. → graphite.



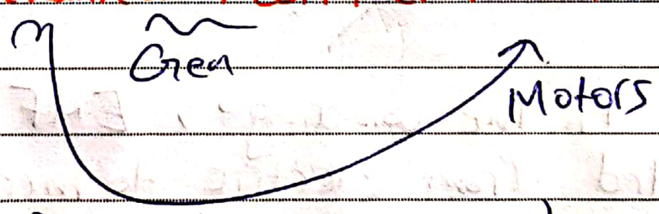
the function → interfacing between rotational and stationary elements of the machine.

**Rotating elements:-

a) • Armature:-

- Armature core
- Shaft [for interconnection between the motor and PM (G) or mech load (M)].
- Armature windings.

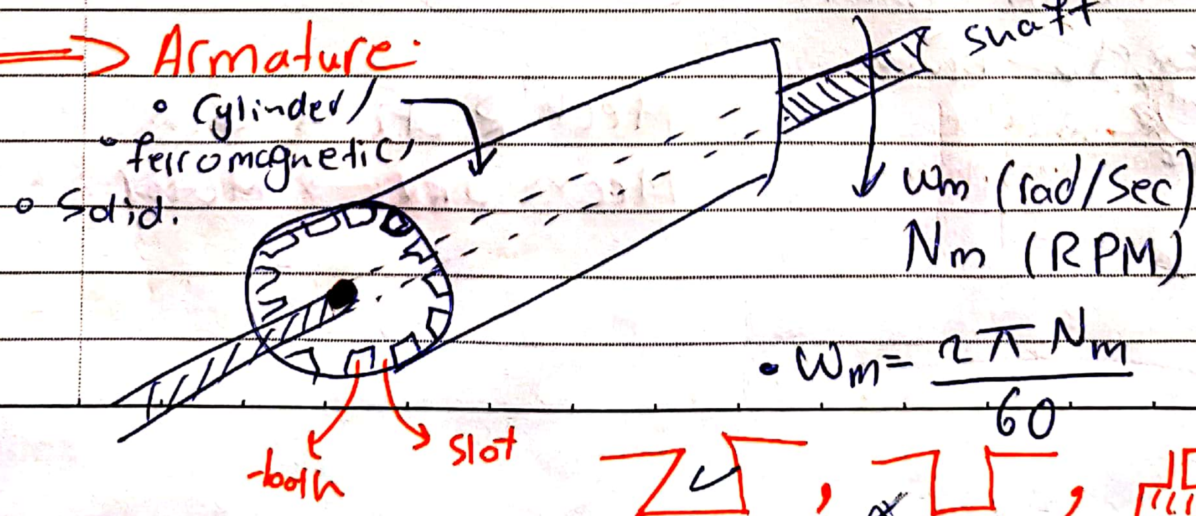
b) • Commutator :- Mechanical Rectifier / Inverter



c) • Bearings :- (to facilitate rotations)

⟹ Armature:

- Cylinder/
- ferromagnetic/
- Solid.

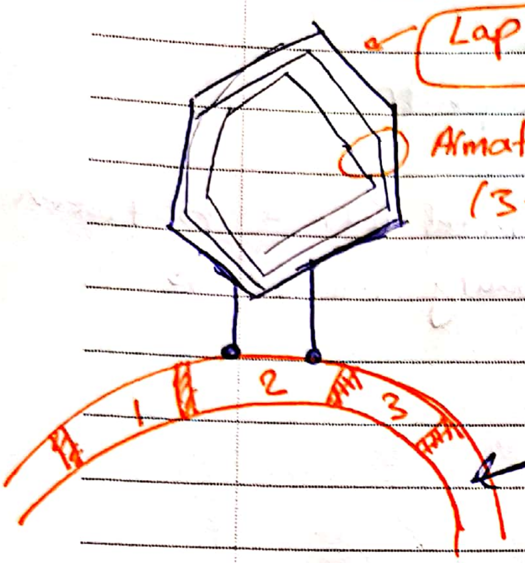


• $W_m = \frac{2\pi N_m}{60}$

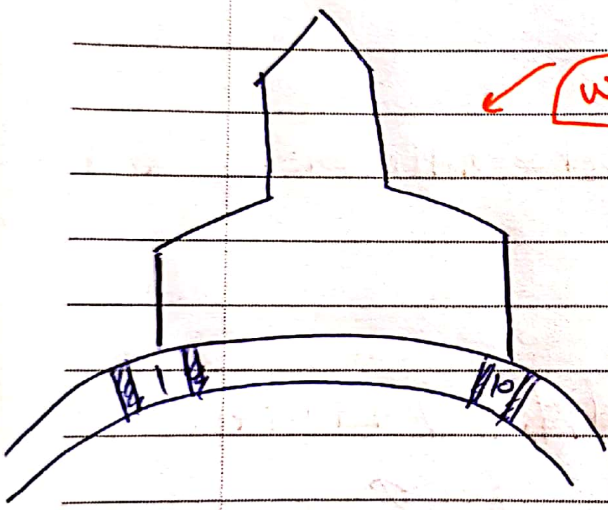
for high current machine. ← type ①: - Lap wi-dings
-لف تطابقي-

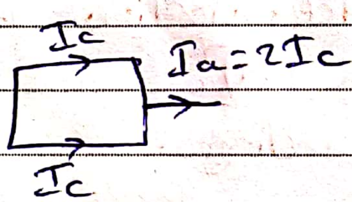
No.

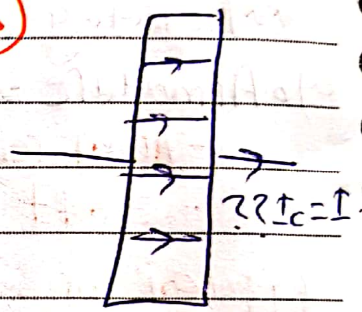
Inside slots → Armature windings
→ type ②: wave windings
- تعرجي -
→ type 3
for low current machine.



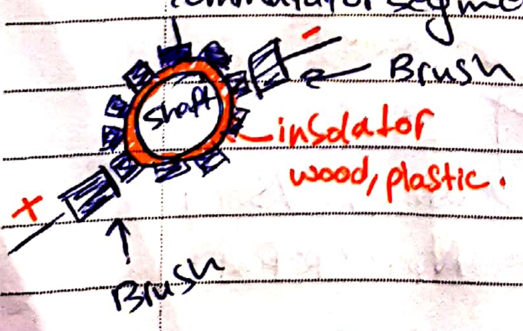
(High voltage machines)





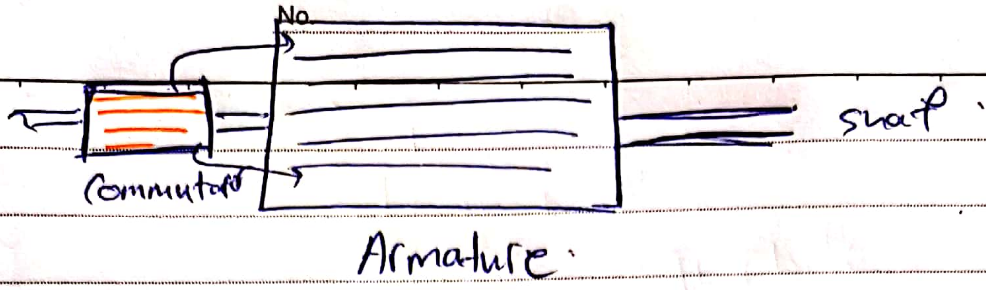


** In the windings, EMF induced and power converted from electric to mechanical (Motor) or from mech to elelctrical (generator).



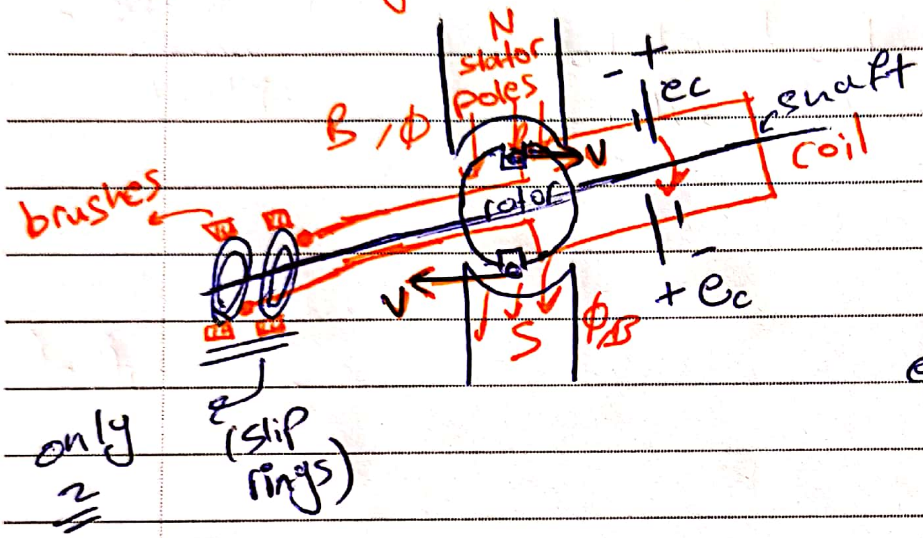
Mech Recti → Gen
Mech Inv → Motor.

Scanned by CamScanner



* Principle of operation:-

Elementery machine. (Generator)



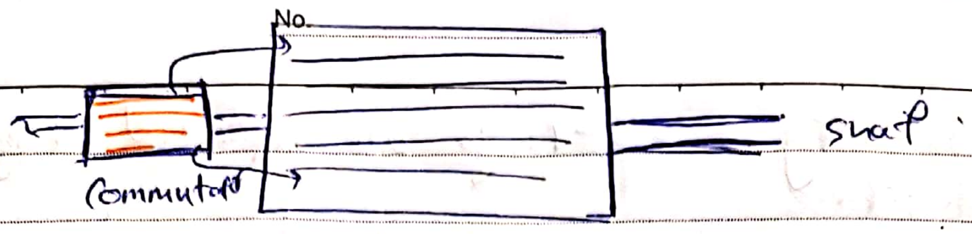
R.H.R *

* ال flux

نازل عمودي ع راحة اليد

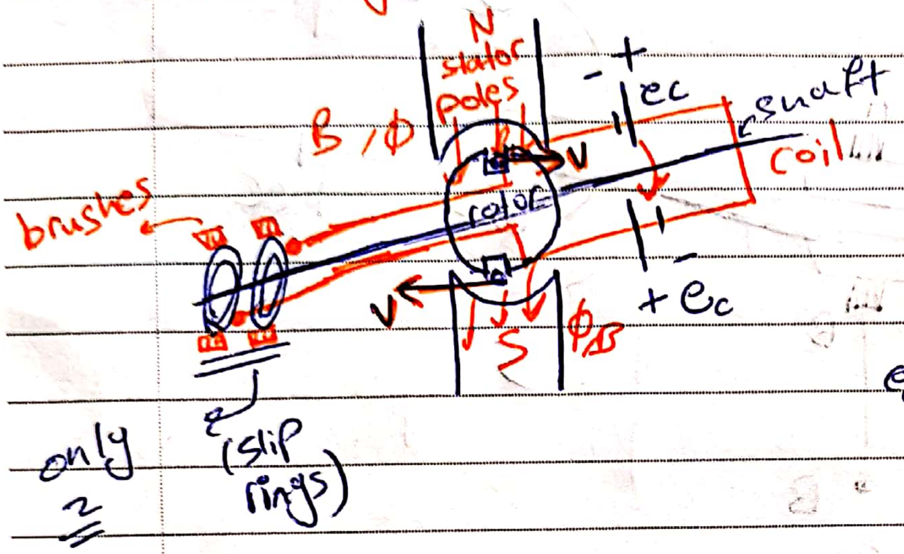
الإبهام مع الvelocity

معها بجيب اتجاه e_c



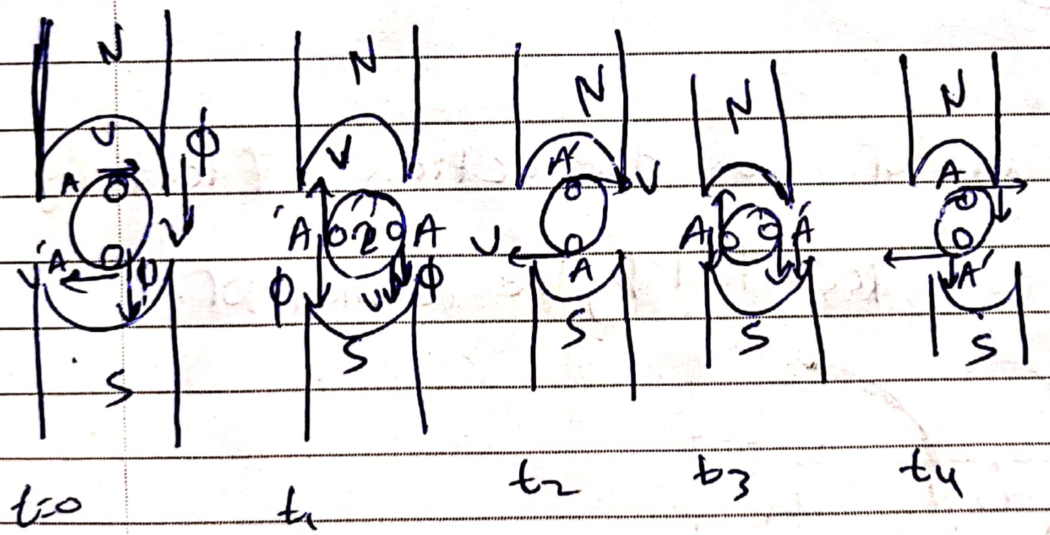
Armature

*** Principle of operation:-**
Elementery machine. (Generator)

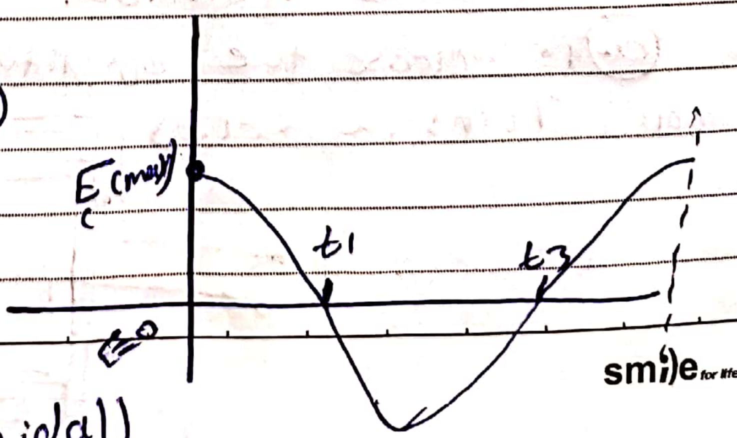


R.H.R *

* الـ flux
نازل عمودي ع راحة اليد
الإبهام مع الـ velocity
صوابعي اتجاه e_c



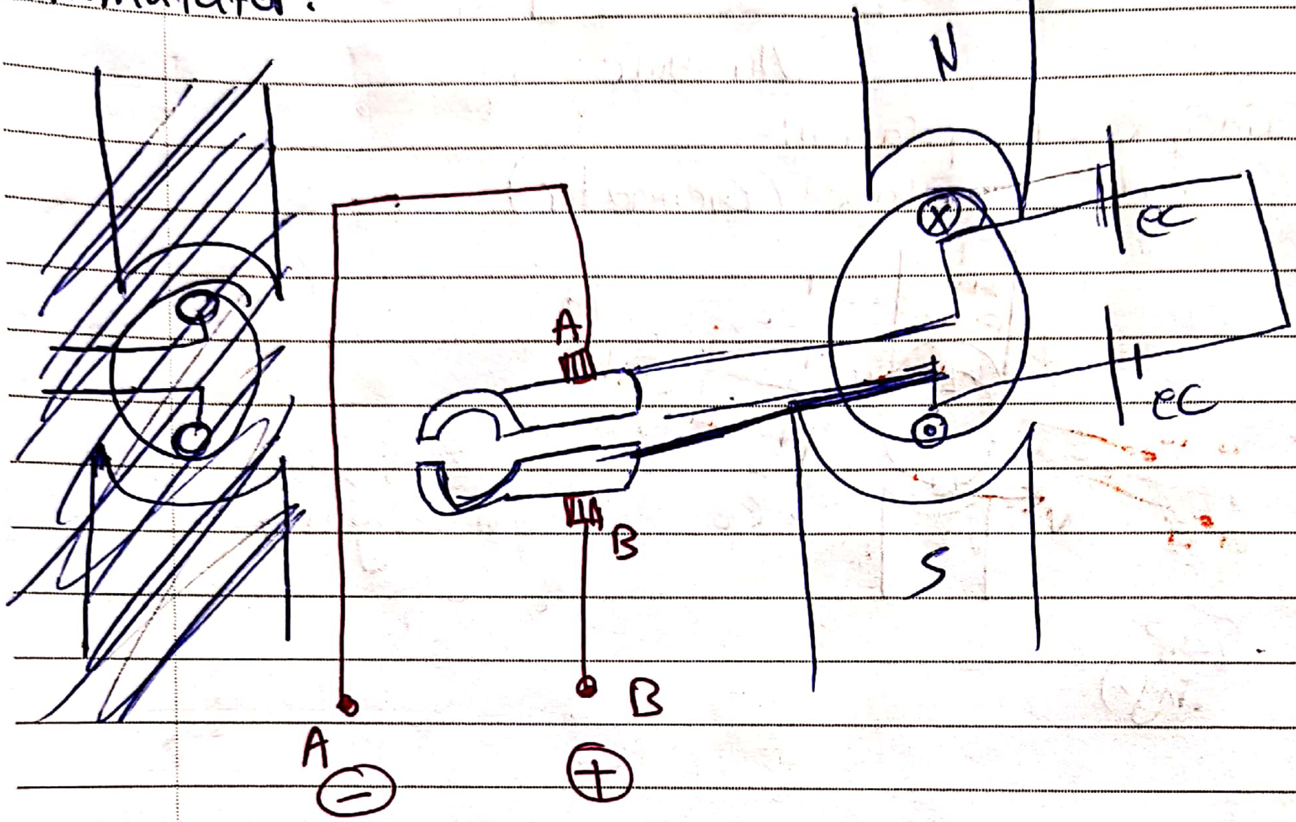
$e_c = \ell B V \sin\theta$
↑ (B, V)



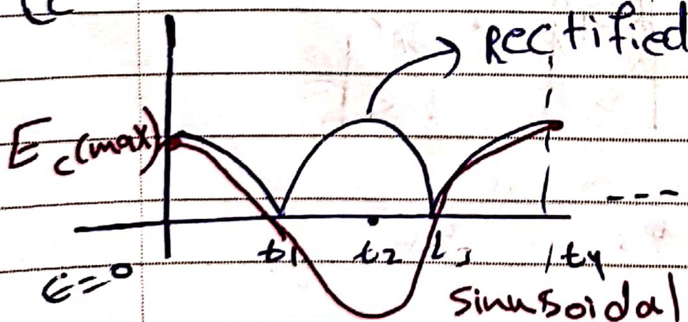
(sinusoidal)

No.

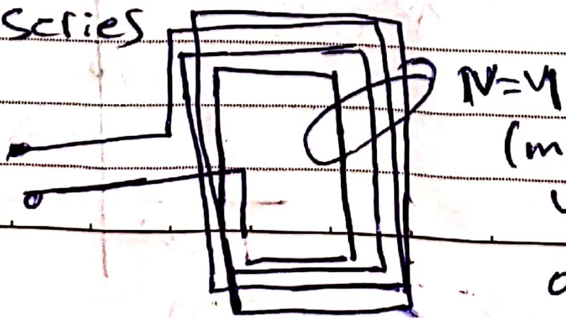
to Rectify : sliprings are replaced by a two-Segment commutator.



* The commutator has the action of rectifying e_c

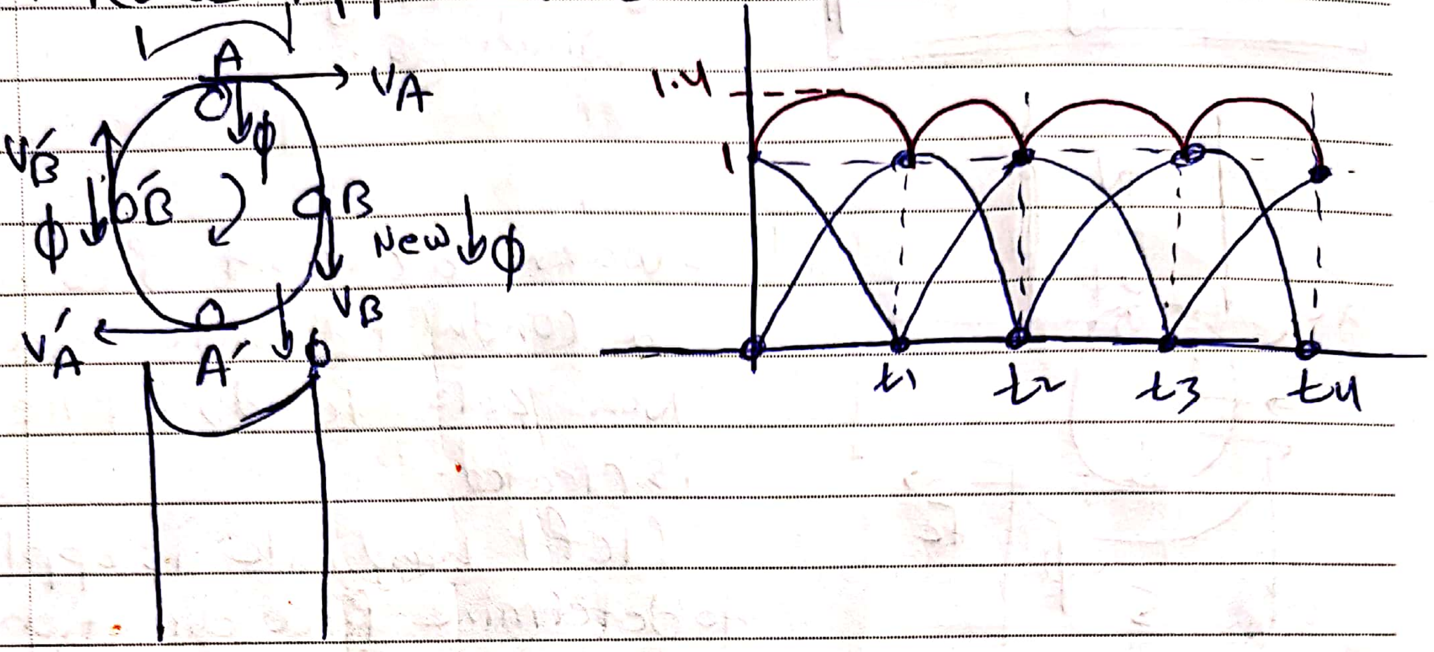


a- To increase the amplitude of EMF : Add more Turns in series

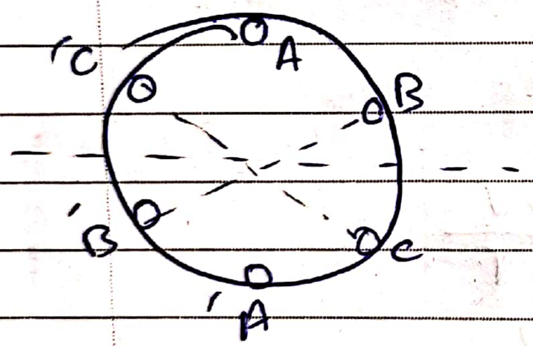


(means e_c Now 4 time that of N=1)

(b) to reduce ripple of ec ⇒



3-Coils

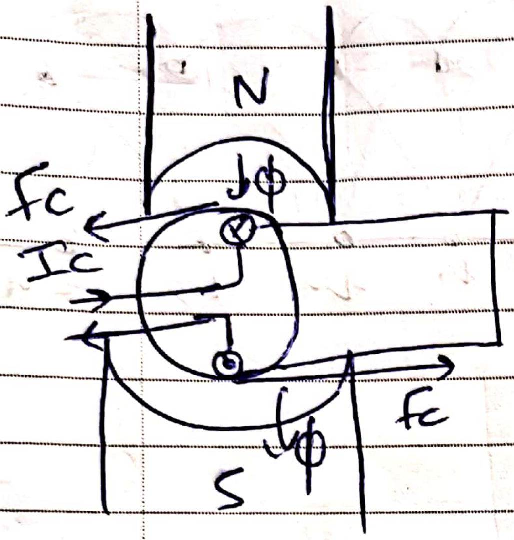


• To reduce the ripple add one more coil (B-B') in series with (A-A') an phase shifted by 90°

If more coils are added (ex: 3 coils with 60° phase an so on---) then less ripple is exuted with reasonable core, almost pure DC is obtained.

No.

* **Motoring action** : you supply current to the windings.



- when a current flow in a conductor within a Non_zero feild, a force is created. (left hand rule is applied to determine force direction, and hence the direction of rotation).

$$\boxed{F = lB\cancel{\phi}I}$$ → force

$T_q = F \cdot r$, $w_m = \frac{V}{r}$

$P_{ower} = T_q * w_m$ (mecanical) $= FV$

$T_q = \frac{P}{w_m}$

*Windings :- two types → (A) lap-winding, (B) wave winding

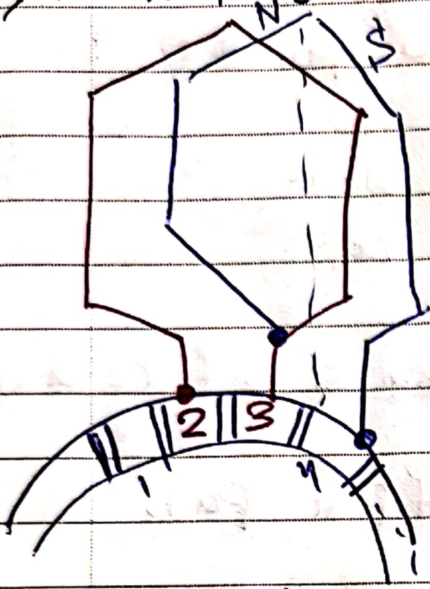
Armatuer

*In all cases :-

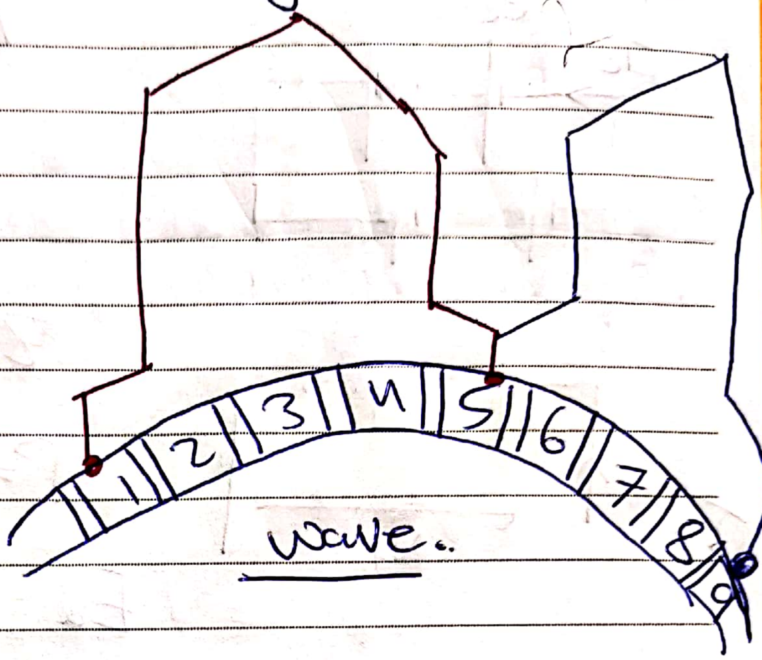
each coil starts at one commutator segment to slot under certain pole polarity, then pack

smile for life

to another slot under opposite pole polarity , then to another Commutator segment.



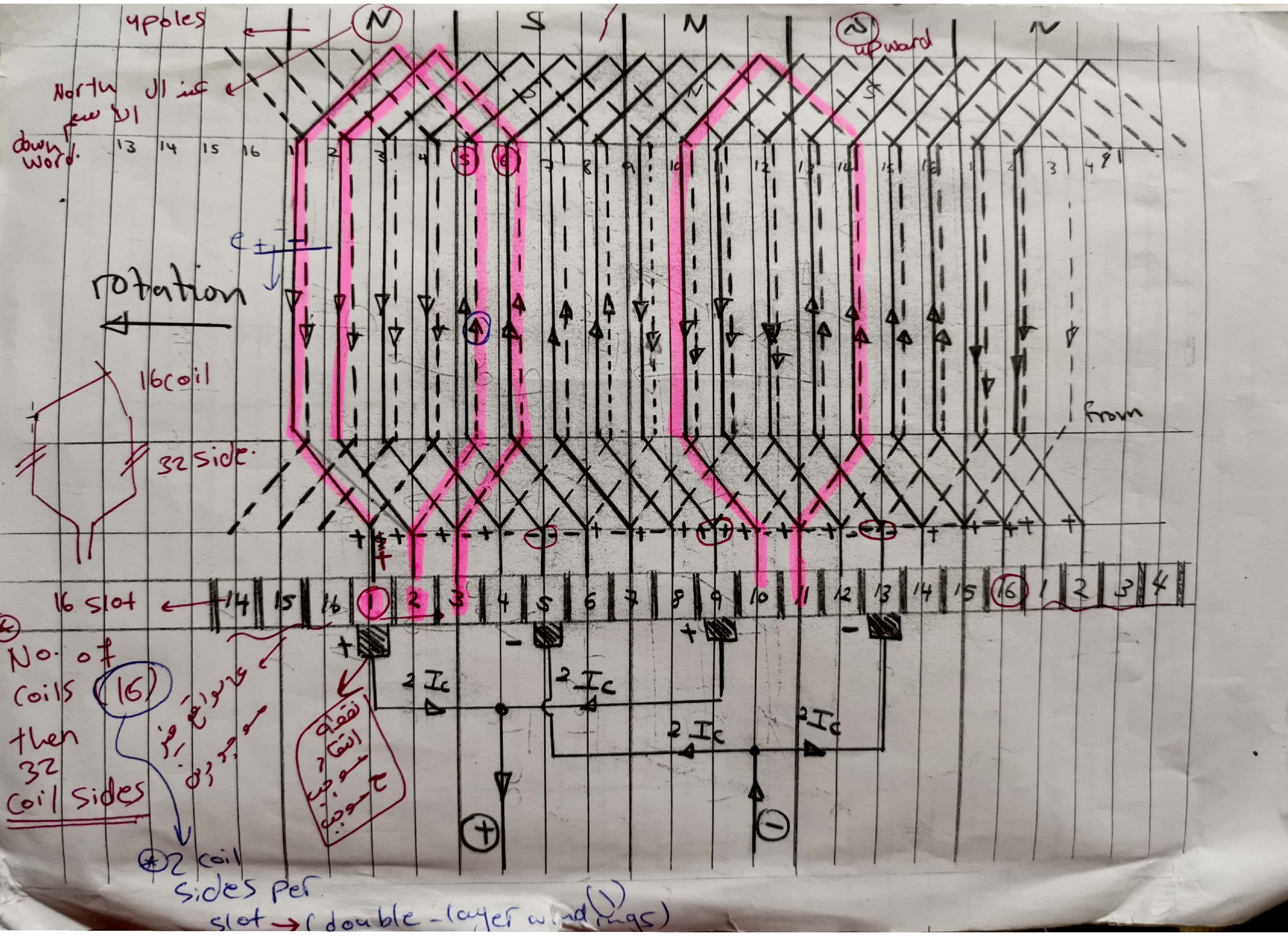
Lap winding



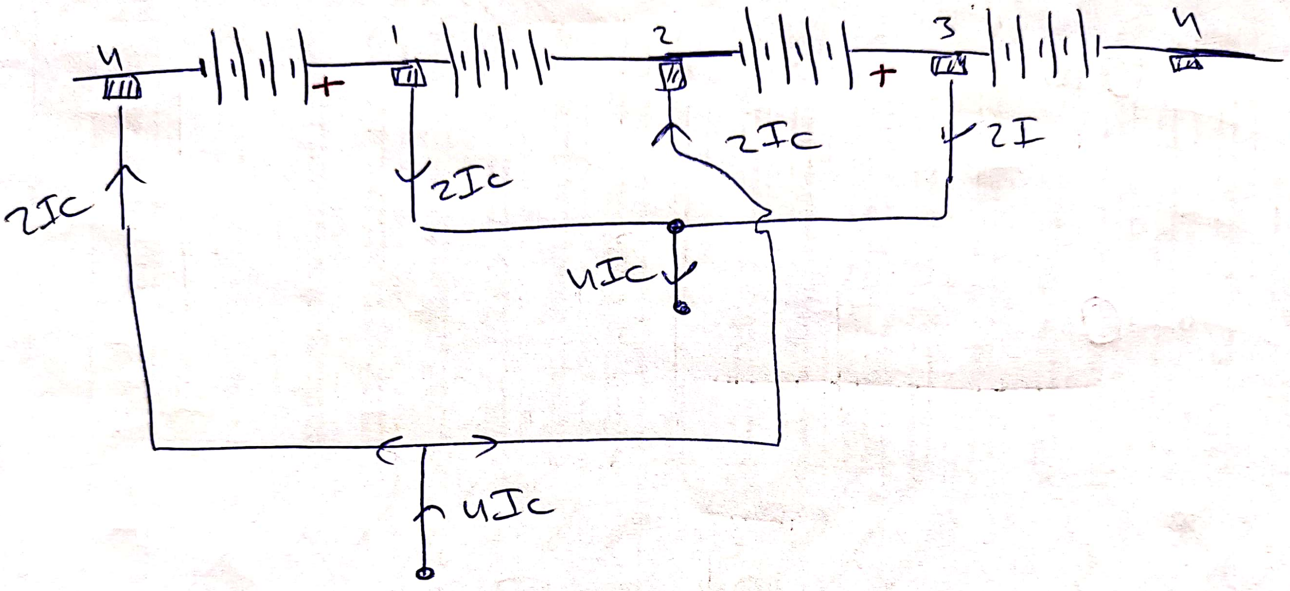
wave.

Lap winding : No parallel paths (High current machine).

wave windings : only 2 current paths by more coils in series (high Voltage machine)



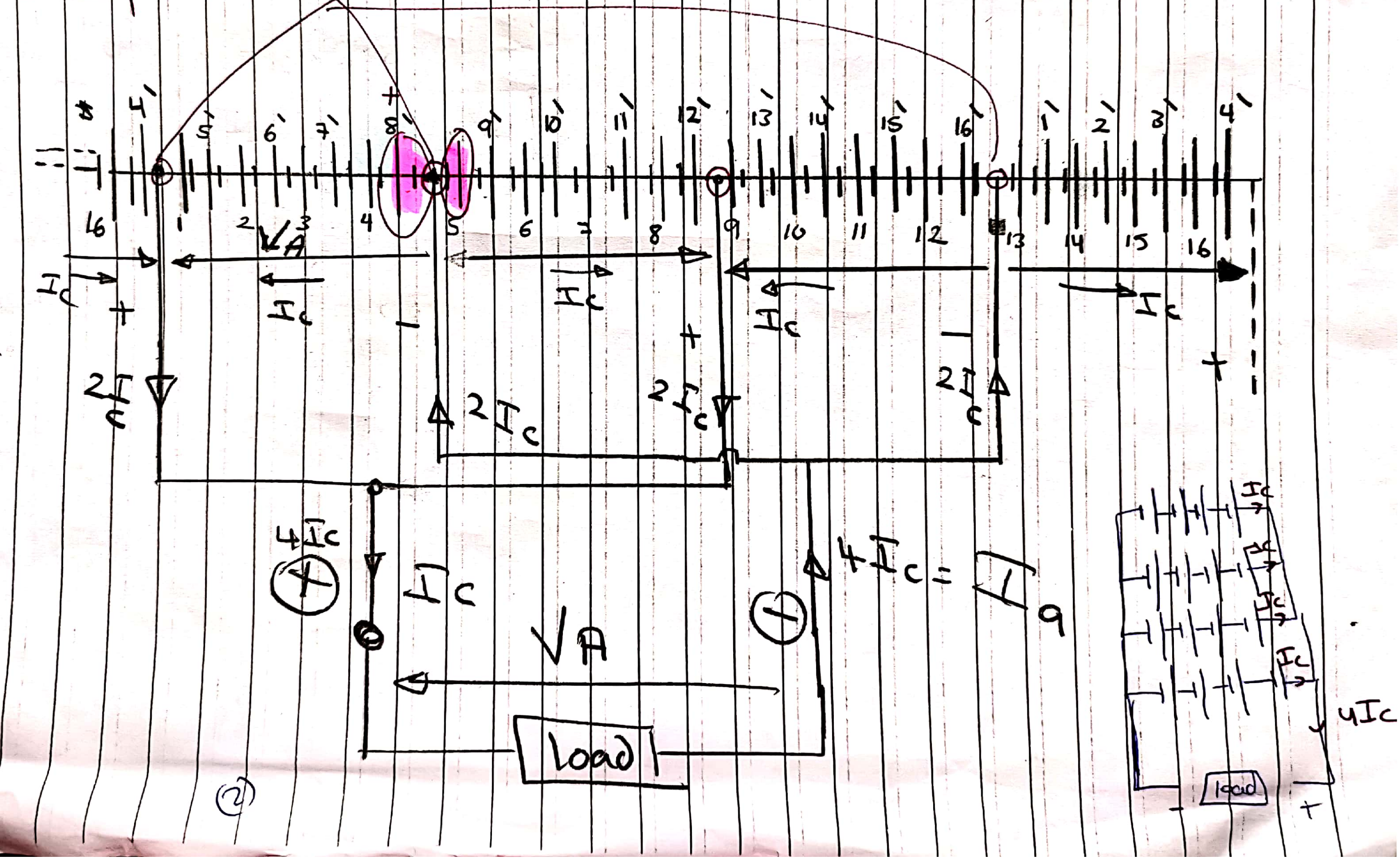
4poles
N
S
N
S
N
upward
North عند ال
الا سهم
downword.
rotation
16coil
32side.
16 slot
No. of
coils (16)
then
32
coil sides
*2 coil
sides per
slot → (double-layer windings)
2 I_c
2 I_c
2 I_c
2 I_c
from


4
1
2
3
4
+
+
2Ic
2Ic
2Ic
2I
4Ic
4Ic

No. of parallel paths $= 2P = 4$

نقاط التقاء الموجب مع الموجب والسالب مع السالب

وبحطها عندهم Brushes



-3-

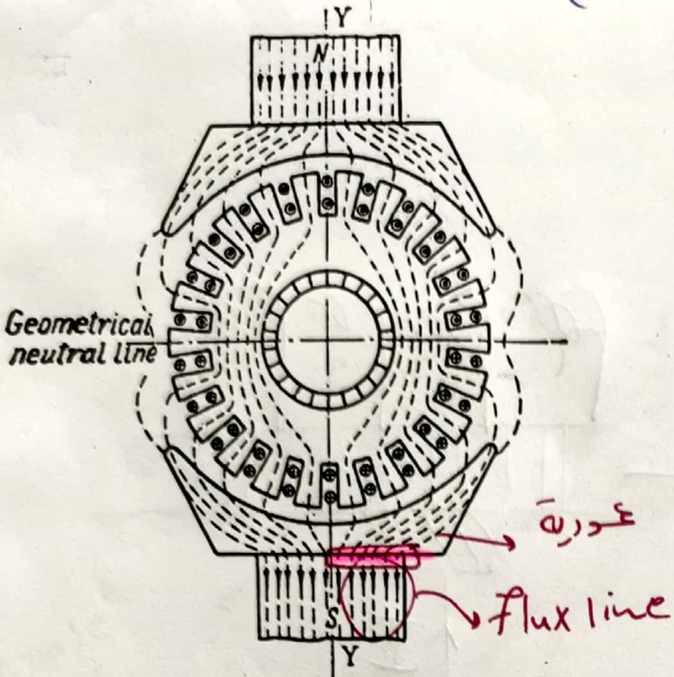


Fig. Main field

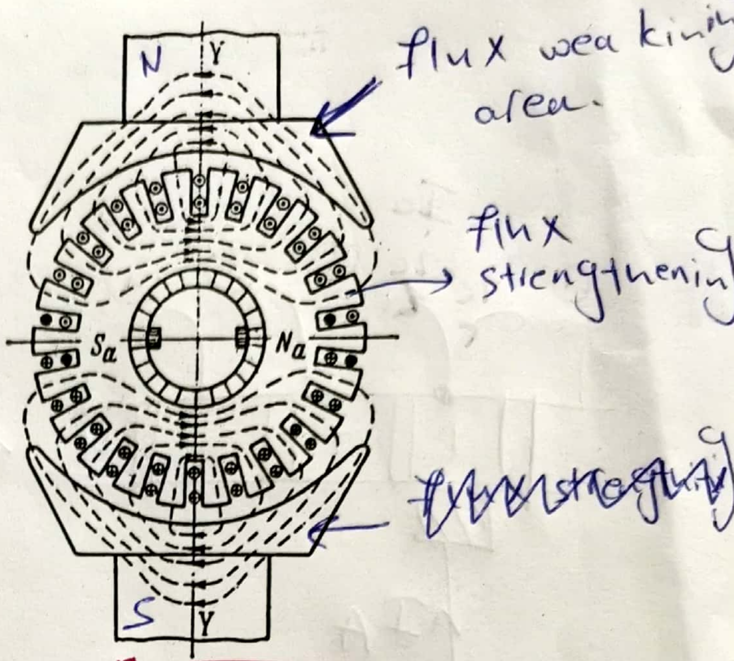


Fig. * Armature field (reaction) :-

:- due to the current in the armature, the armature flux cause distortion to the main flux leading to shift in the MNA from GNA, This is called **Armature reaction**

* weakining & concentration of flux in the Armature feild let the magnetic neutral axis by $\underline{\underline{\alpha}}$.

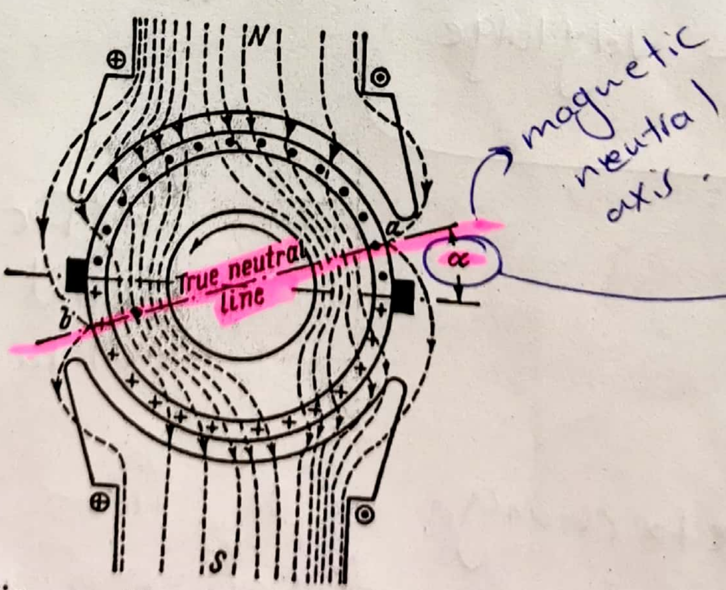
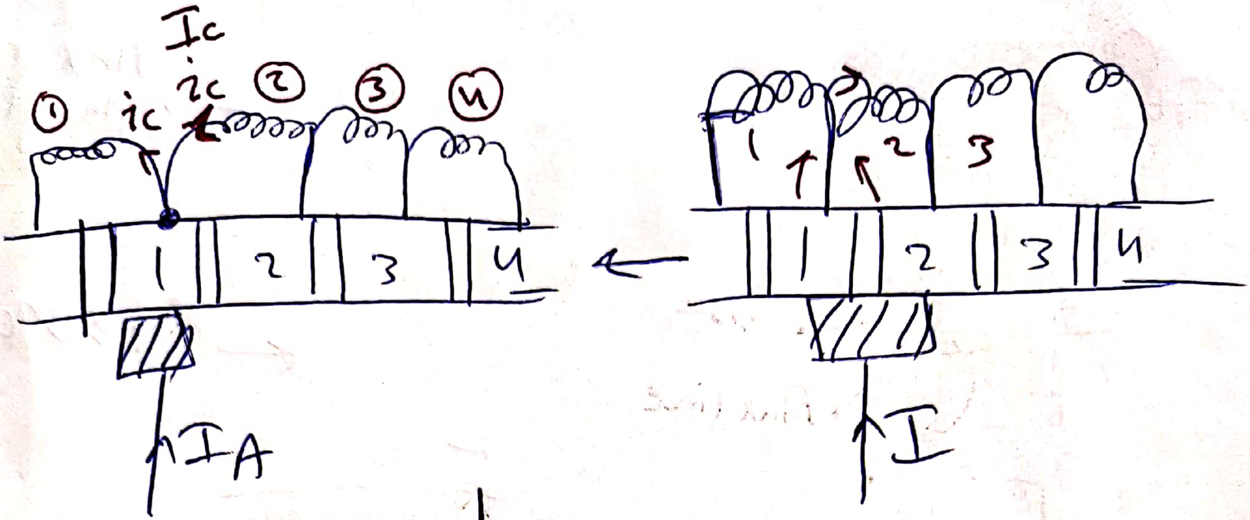
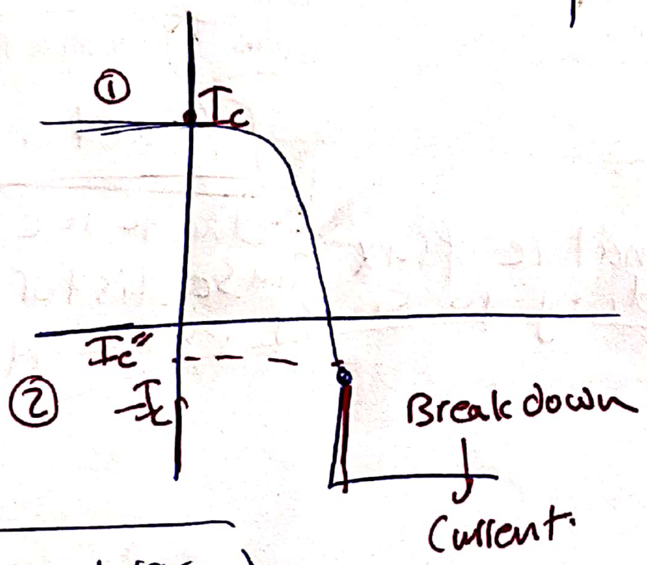


Fig. Distribution of resultant magnetic field of machine when brushes are on geometrical neutral line





$\boxed{\frac{di}{dt} \text{ very large}}$

of DC Motor above
rated speed
limitation np (2-3)

* due to change in ic from I_c'' in I_c
very large e is induced, ionize the
surrounding area, causing harmful spark
[Commution Process].

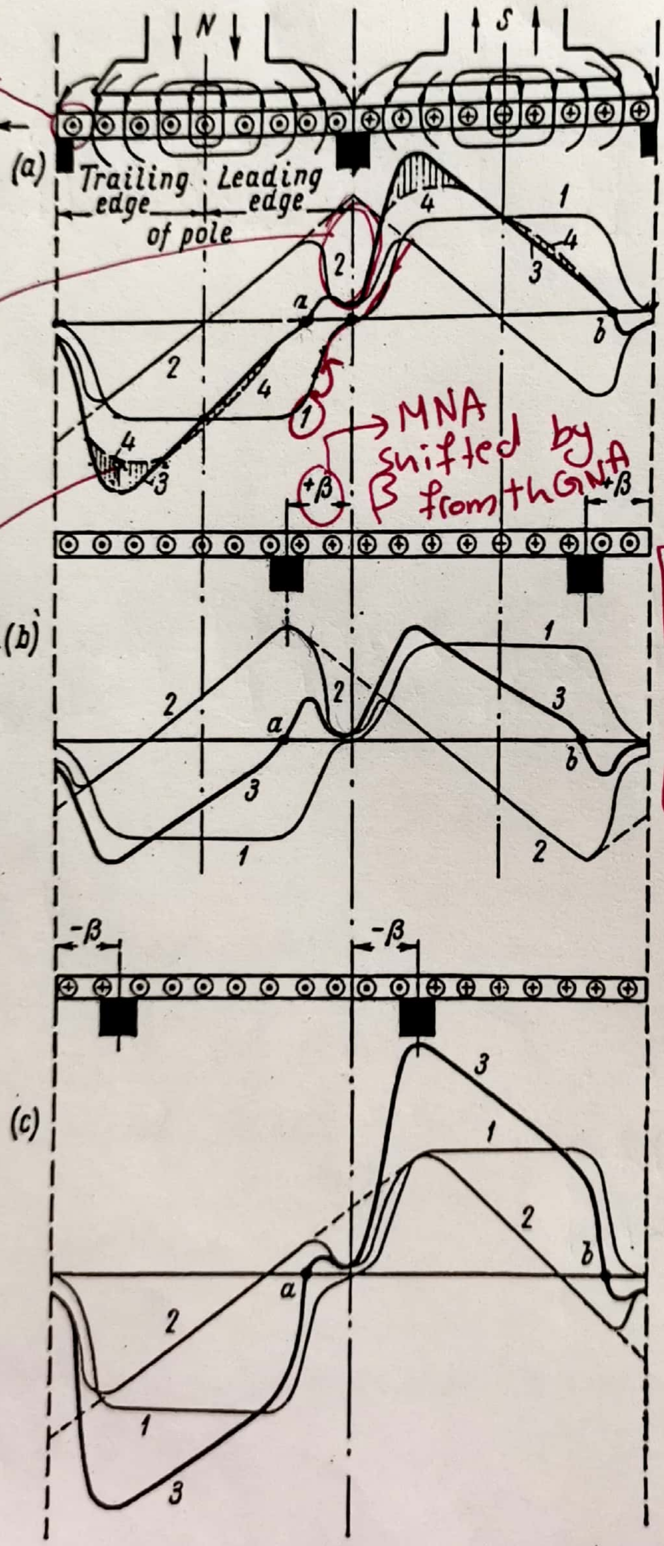
* sparks increase as
speed increas, this is
a limit to speed control

(x) To explain the Armature reaction

by th R.H.R

because of air gap.

due to saturation.



1: flux distribution

2: due to Armature Current.

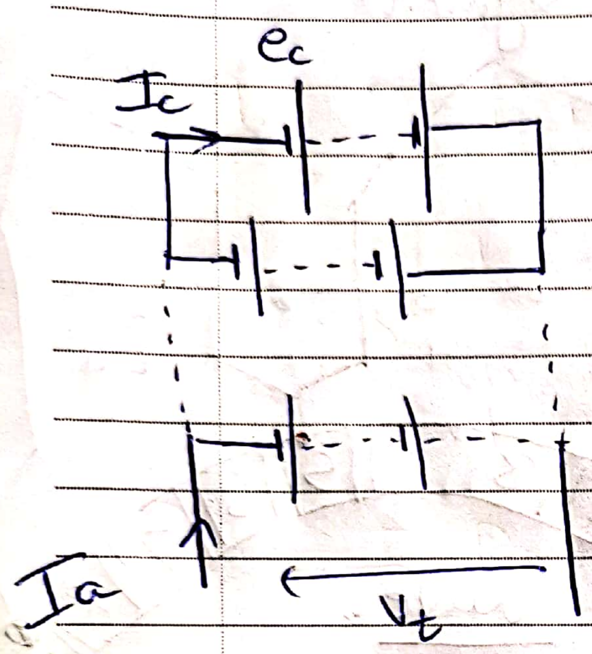
3: due to Armature reactions & main poles

→ overall average flux under one pole is reduced, leading to reduced Ea.

Fig. Curves of generator fields for different positions of brushes

No.

EMF, Torque equations:-



A: No. of parallel paths.

A = 2 wave

A = 2P Lap.

Z total number of conductors

P = No of pole pairs

$$E_a = \left(\frac{Z}{A} \cdot \frac{P}{\pi}\right) \cdot \phi_f * W_m$$

$$= K_a \cdot \phi_f \cdot W_m$$

K_a : Design constant.

ϕ_f : flux per pole.

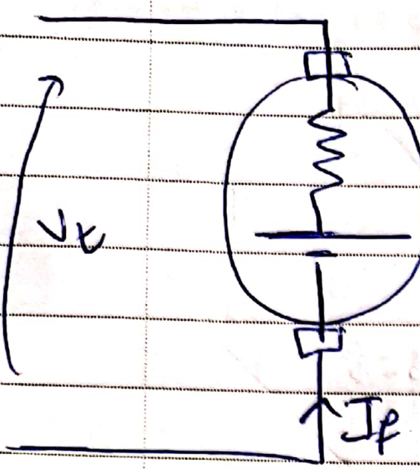
W_m = Rotor speed (rad/sec)

$$W_m = \frac{2\pi N_m}{60}$$

where N_m : speed in revulution per minuite. (R.P.M)

$$E_a = K_a \cdot K_f \cdot I_f \cdot \frac{2\pi N_m}{60}$$

$$E_a = K I_f \cdot N_m$$



EMF developed.

$$E_a = \left(\frac{Z}{A} \cdot \frac{P}{\pi}\right) \cdot \phi_f \cdot \omega_m$$

$$= K_a \, \phi_f \, \omega_m$$

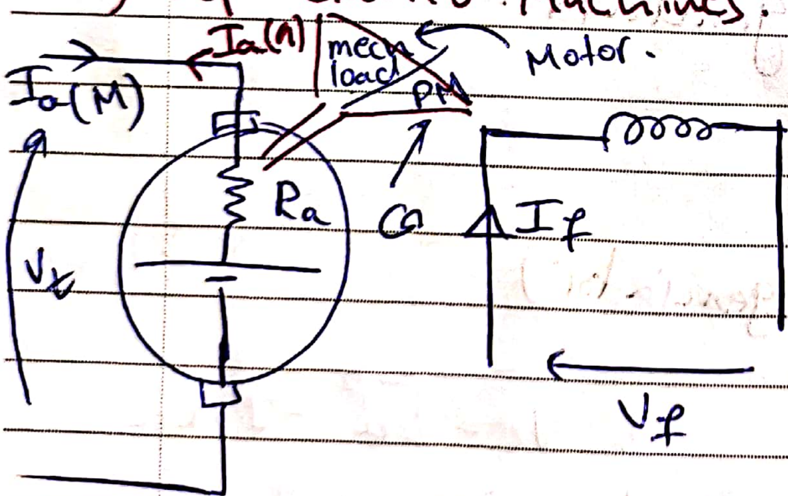
T_a : developed armature torque.

$$T_a = T_d = K_a * \phi_f * I_a$$

$$T_a = T_d = \frac{P_a = P_d}{W_m}$$

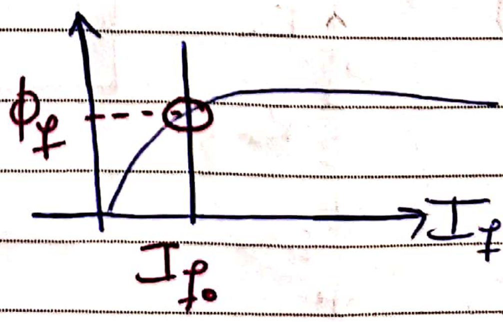
Circuit model

a) sep-excited Machines.



$$I_f = \frac{V_f}{R_f}$$

$$\phi_f = k_f I_f$$



Gen

$$V_t = E_a \ominus \oplus \ I_a R_a$$

Motor

$P_d = P_a = E_a I_a$

$P_{sh} = P_o = P_a - P_{rot}$

P_{rot} = rotational mechanical losses

$= \underset{\text{friction}}{P_{mech}} + P_{windings}$

$P_{cu} = I_a^2 R_a$

copper loss

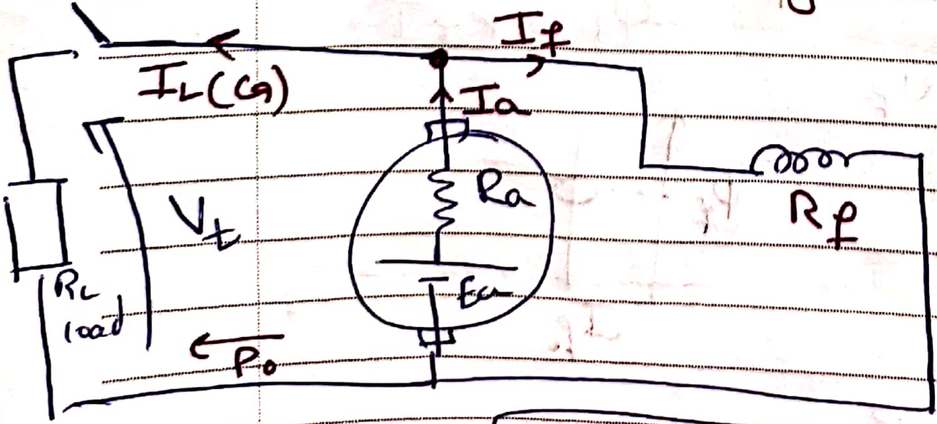
$\boxed{P_{in} = V_t I_a}$ (Motor)

$P_a = P_{in} - P_{cu}$ (Motor case).

$\boxed{P_o = I_a V_t}$ (generator)

$\boxed{P_a = P_o}$ generator.

B * Shunt machine. (generator)



$V_t = E_a - I_a R_a$

$P_o = V_t I_{L(G)}$

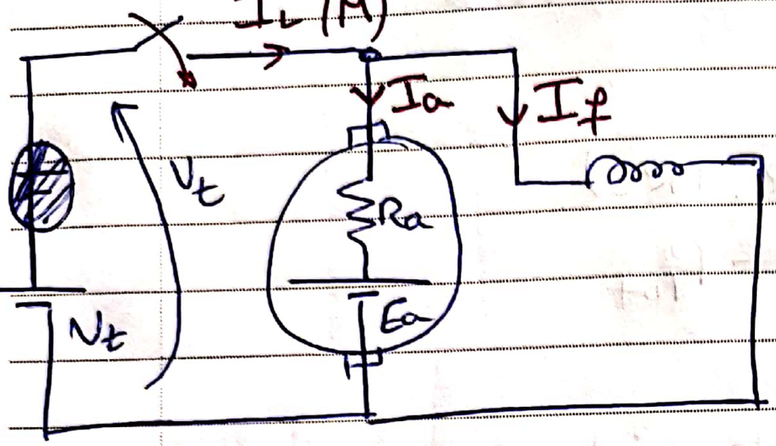
$P_d = E_a I_a$

$P_d = P_o + I_{a(G)}^2 R_a$

$\boxed{I_a = I_L + I_f}$

No.

shunt motor



$V_t = E_a + I_a R_a$

$P_a = E_a I_a$

$P_{in} = V_t + I_L$

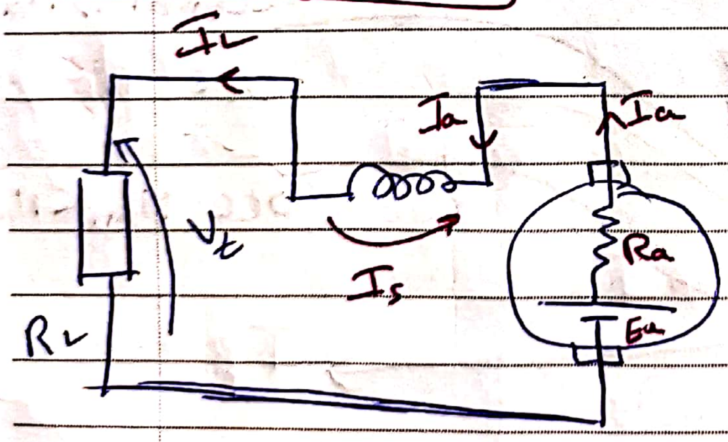
$P_a = P_{in} - I_a^2 R_a$

$P_o = P_a - P_{rot}$

$P_a = P_{in} - I_a^2 R_a$

$\frac{V_f}{R_f} = I_f$

series generator



$V_t = E_a - I_a R_a - I_s R_s$

$= E_a - I_a (R_a + R_s)$

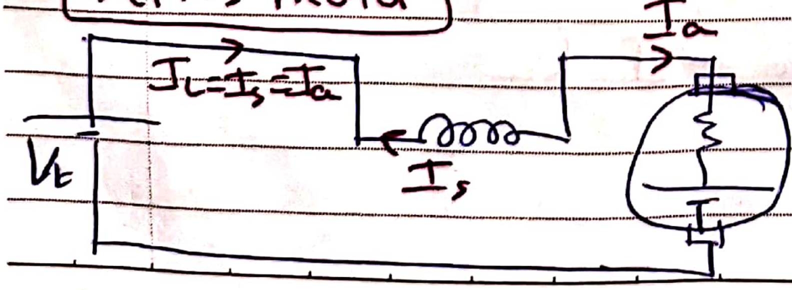
$\boxed{I_a = I_s} = I_L$

$P_d = E_a I_a$

$P_o = I_L V_t$

$P_o = P_d - I_a^2 (R_s + R_a)$

series motor



$I_s = I_a = I_L$, $V_t = E_a + I_a (R_a + R_s)$

No.

$P_{in} = V_t I_L$

$P_a = P_d = E_a I_a$

$P_a = P_d = P_{in} - I_a^2 (R_s + R_a)$

$P_o = P_{sh} = P_a - P_{rot}$

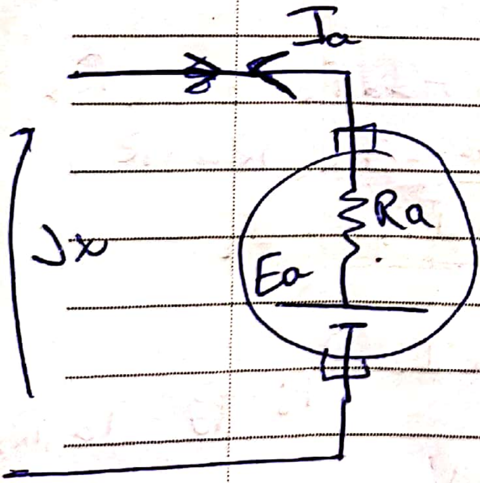
** Generators characteristics:-

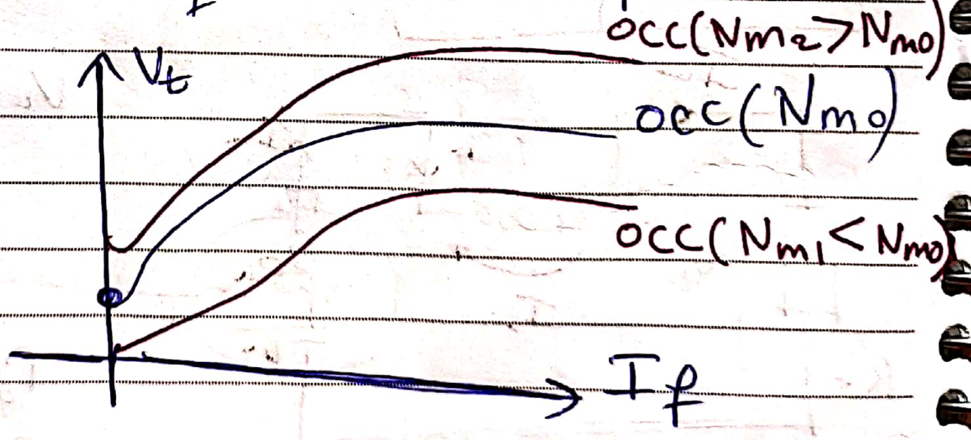
① OCC (open-circuit ch) $\Rightarrow V_t = f(I_f)$

② load charectoristics $\longrightarrow V_t = f(I_a)$

$\boxed{\text{Sep excited}}$

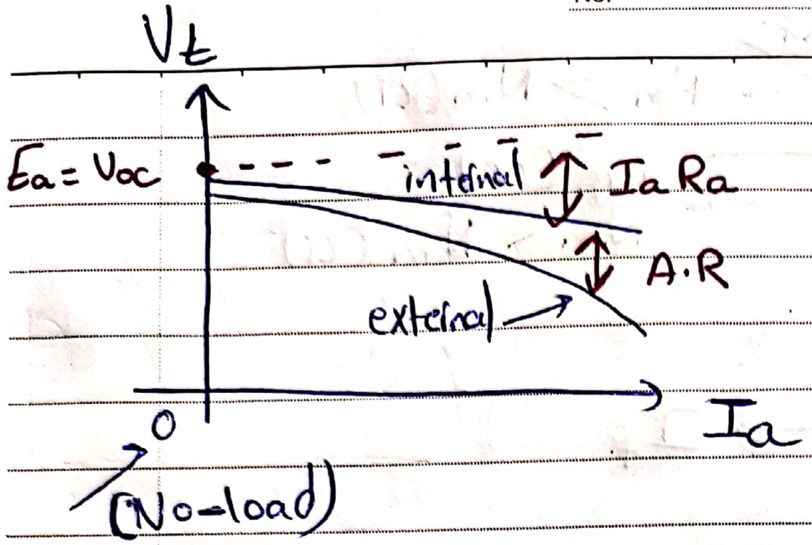
① $V_{oc} = E_a = K_a \phi_f \omega_m \longrightarrow K \cdot I_f N_m$





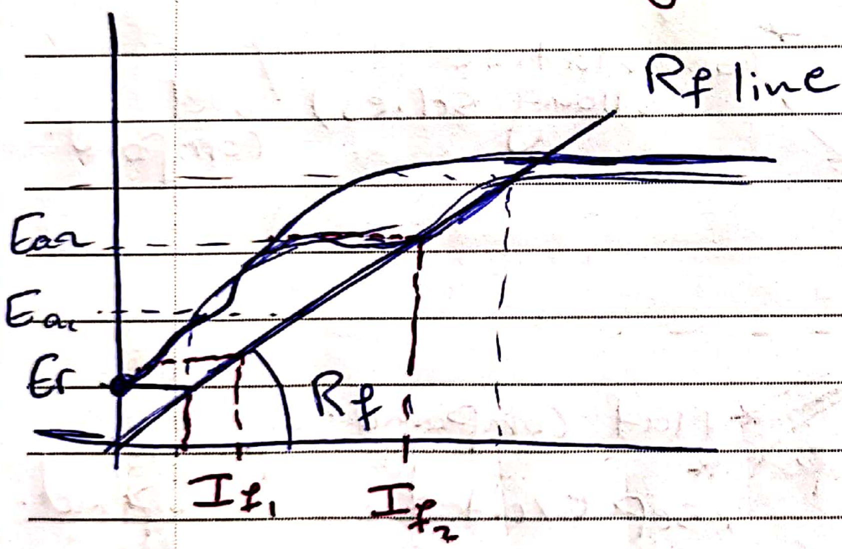
② $V_t = E_a - I_a R_a$

No.



Shunt generator :-

Residual flux is very importants since if $\phi_r = 0, E_r = 0$ & no building of E_a

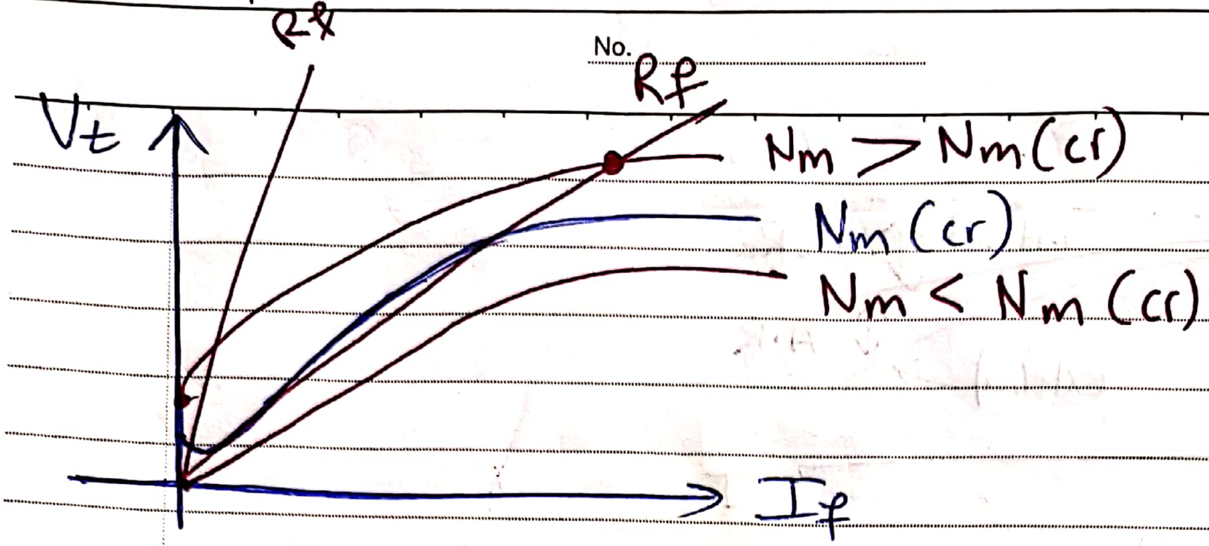


* failuer to build EMF is due to the following reasons :-

① No residual flux.
in this case, reexcite separatly the feild coils by external DC source.
but I_f E_a fails to build ??

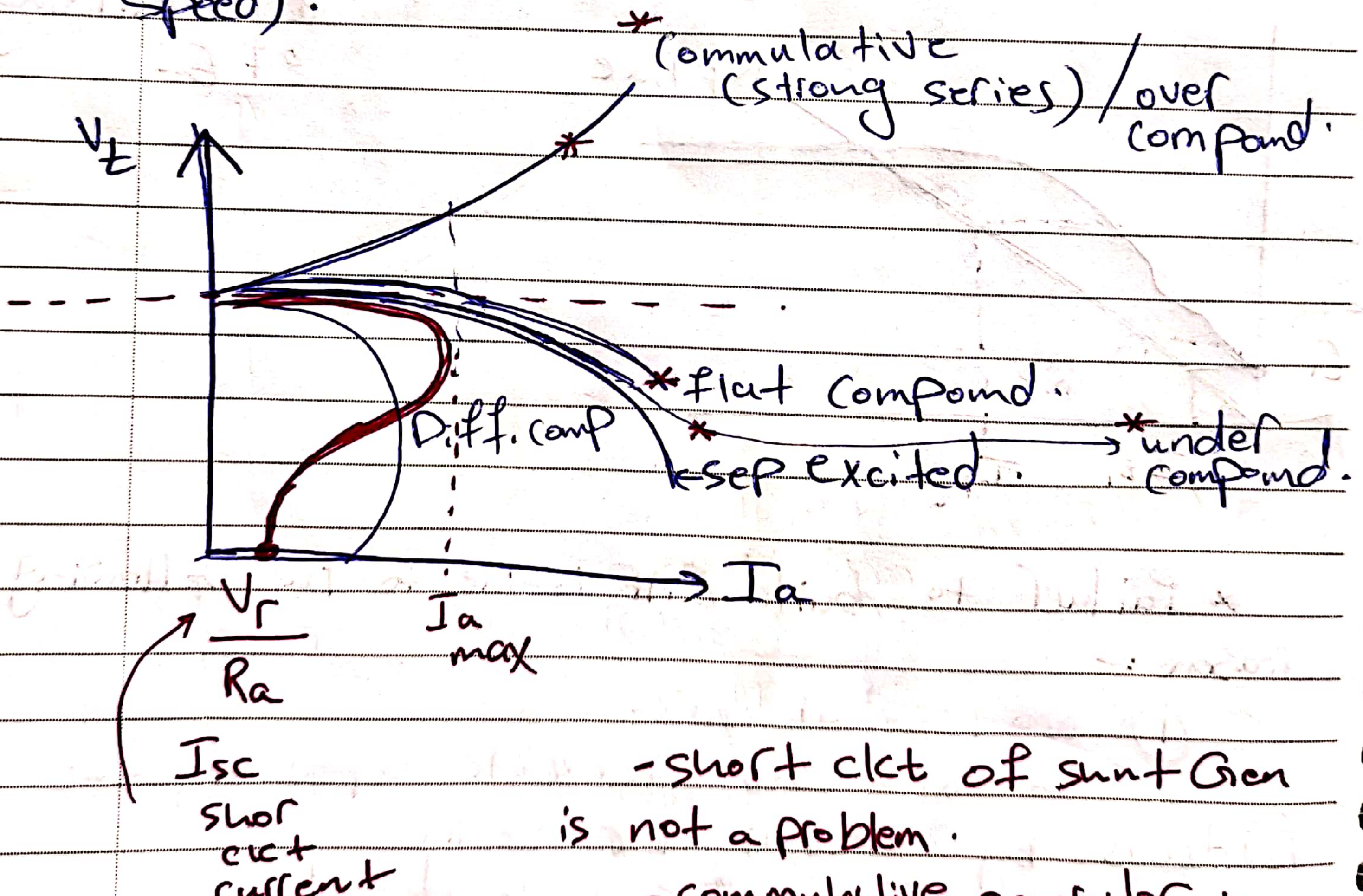
② $N_m < N_{m(cr)}$. for certain R_f

No.



I_f not $\geq$???

③ If $R_f > R_f$ critical (for certain speed).



- short clct of sunt Gen is not a problem.
- commulative generator to compensate for voltage regulation, (flat compound commulative results in zero V. Reg at full load).

smile for life

No.

Motors :-

$$N_m = f(T_q)$$
$$\omega_m$$

$$N_m = f\left(\frac{I_L}{I_a}\right)$$

Sep excited Motor

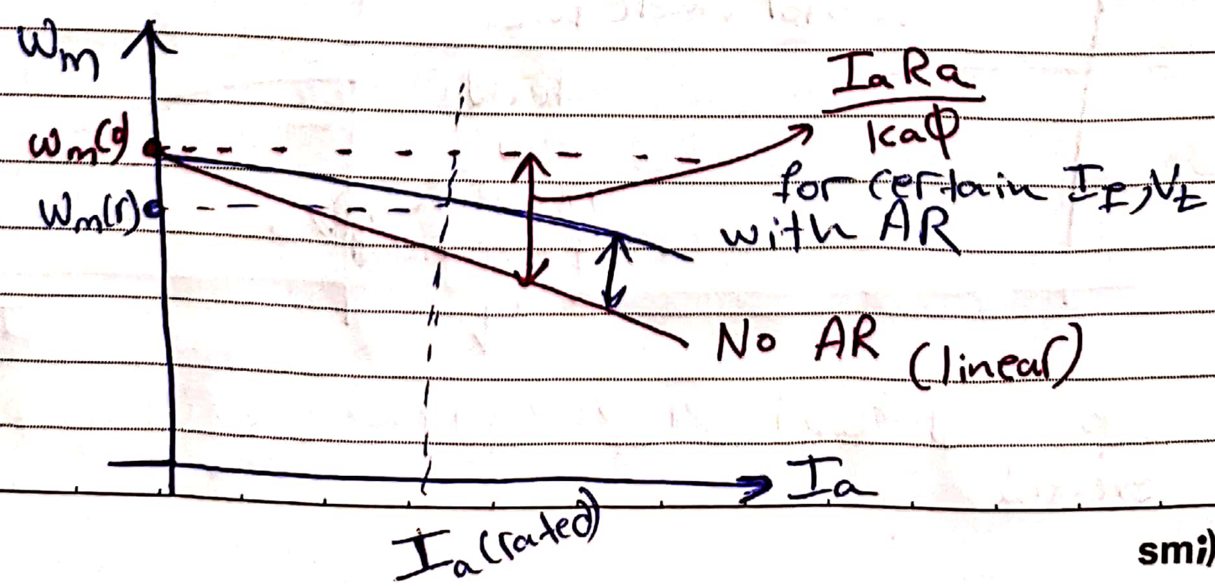
$$E_a = V_t - I_a R_a$$

$$K_a \phi W_m = V_t - I_a R_a$$

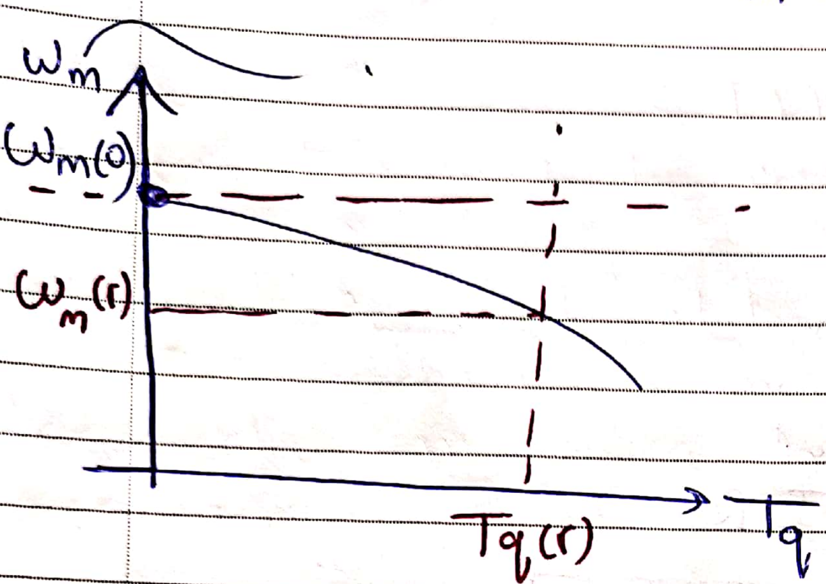
$$\boxed{W_m = \frac{V_t}{K_a \phi} - \frac{R_a}{K_a \phi} \cdot I_a}$$

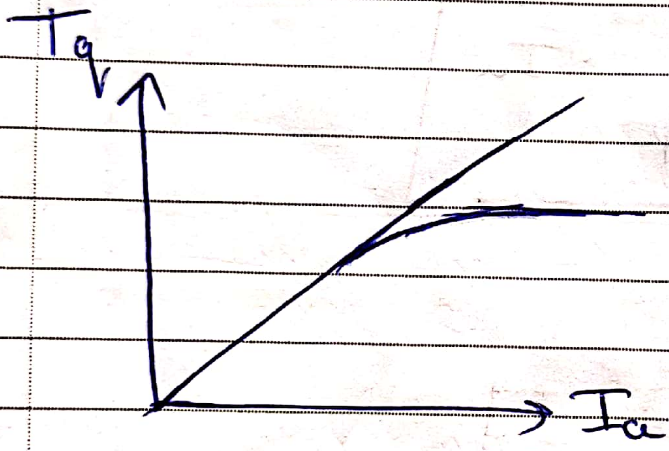
$$I_a = \frac{T_q}{K_a \phi}$$

$$\boxed{W_m = \frac{V_t}{K_a \phi} - \frac{R_a \cdot T_q}{(K_a \phi)^2}}$$



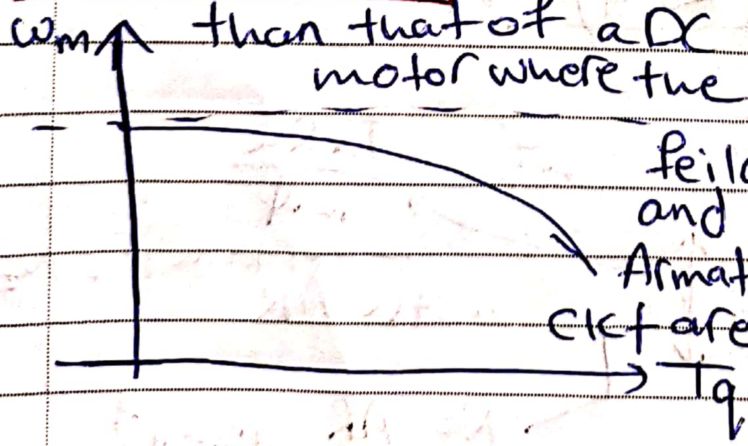
$$\text{Speed Reg} = \frac{W_m(nL) - w_m(r)}{W_m(r)}$$

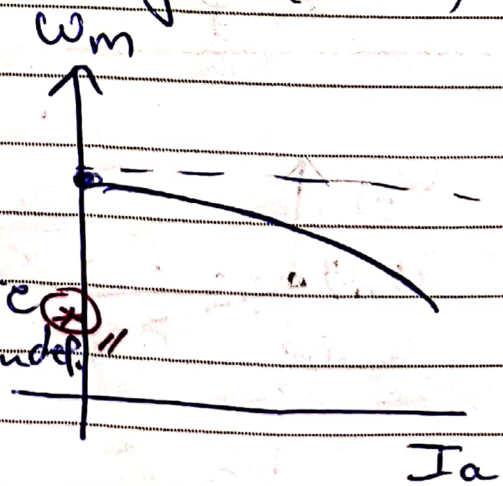




slope $= k\phi$

Shunt motor :- "Controllability in (Shunt) less than that of a DC motor where the feild and Armature ckt are Indep."

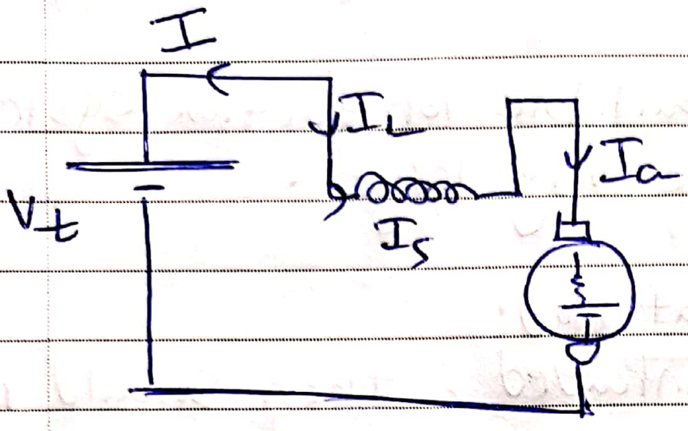


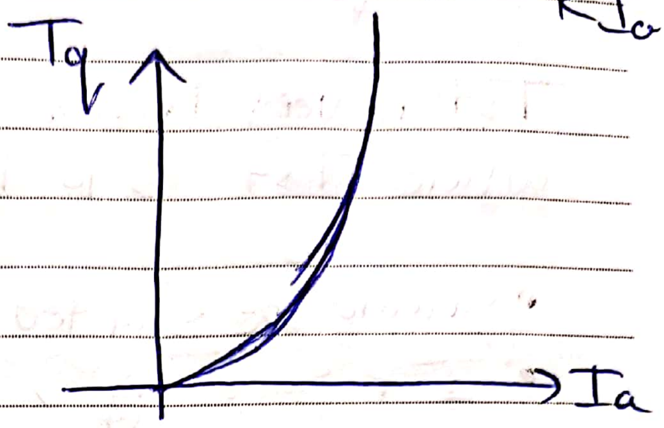


- نفس العلاقات الرياضية لل sep. excited

Series motor :- $T_q = K_a \phi I_a = K_a (K I_a) I_a$

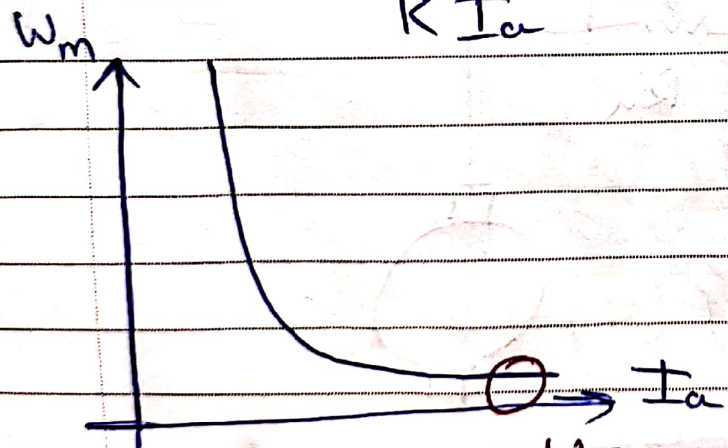
$= K I_a^2$





$E_a = V_t - I_a(R_s + R_a) \rightarrow K I_a \omega_m = V_t - I_a(R_a + R_s)$

$$\omega_m = \frac{V_t}{K I_a} - \frac{(R_a + R_s)}{K}$$



No load

light load

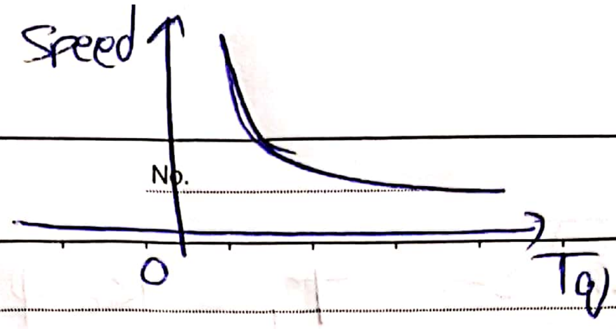
ω_m Very low

I_a high.

$$\omega_m = \frac{V_t}{K I_a} - \frac{(R_a + R_s)}{K}$$

$T_q = K I_a^2 \longrightarrow I_a = \sqrt{\frac{T_q}{K}}$

$$\omega_m = \frac{V_t}{K\sqrt{\frac{T_a}{K}}} - \frac{(R_a + R_s)}{K}$$



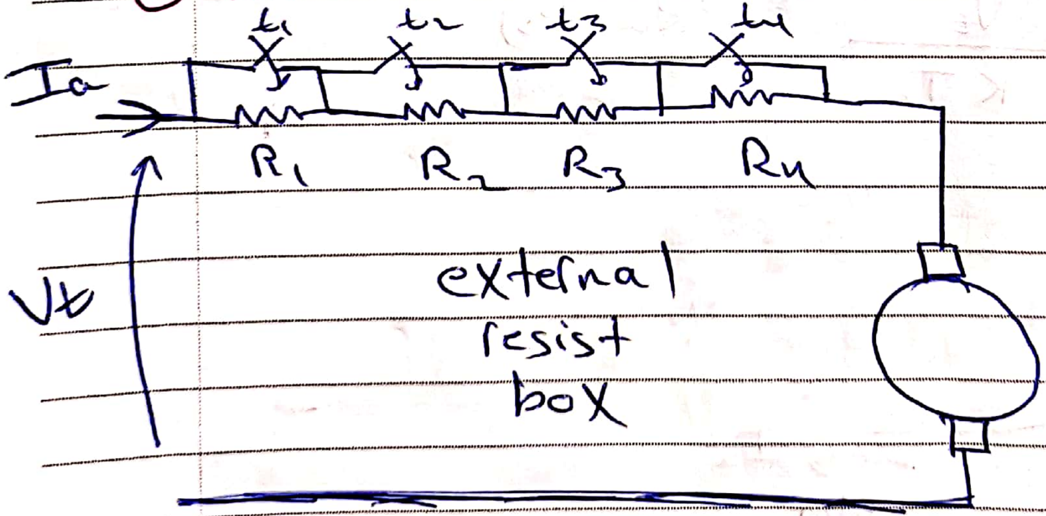
starting tourqe

$\boxed{T_{st}}$ is very large. Suitable for traction system where T_{st} is to be very large.

- Should be started at load.
- If suddenly, unloaded, then should be disconnected from source to avoid dangerous accelaration.

** speed control method:-

(1) Armature Resistance Control.



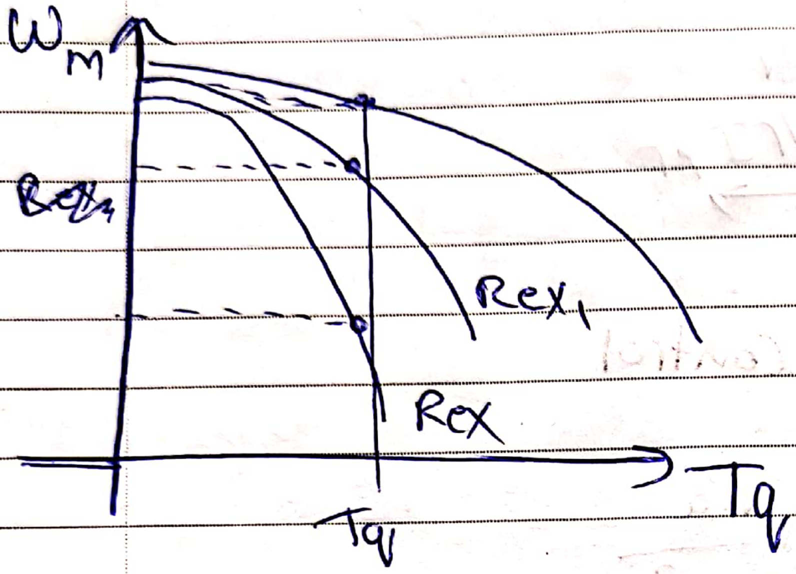
$$I_a = \frac{V_t - E_a}{R_a}$$

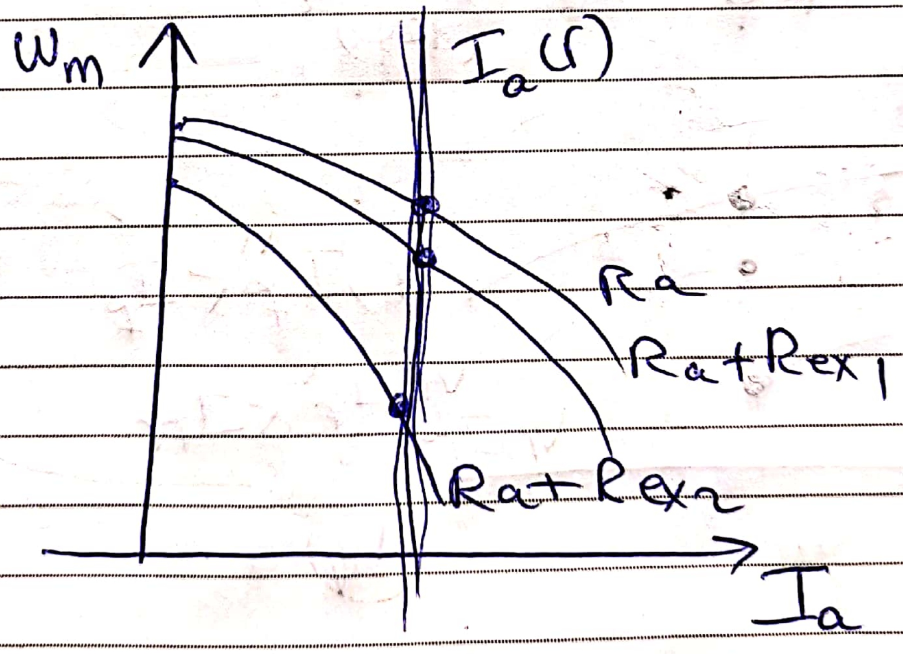
- at starting $\omega_m = 0$

$\downarrow$ $E_a \to 0$

$$I_a(st) = \frac{V_t}{R_a} \quad \text{(very large)}$$

$$I'_{st} = \frac{V_t}{R_a + (R_1 + R_2 + R_3 + R_n)}$$

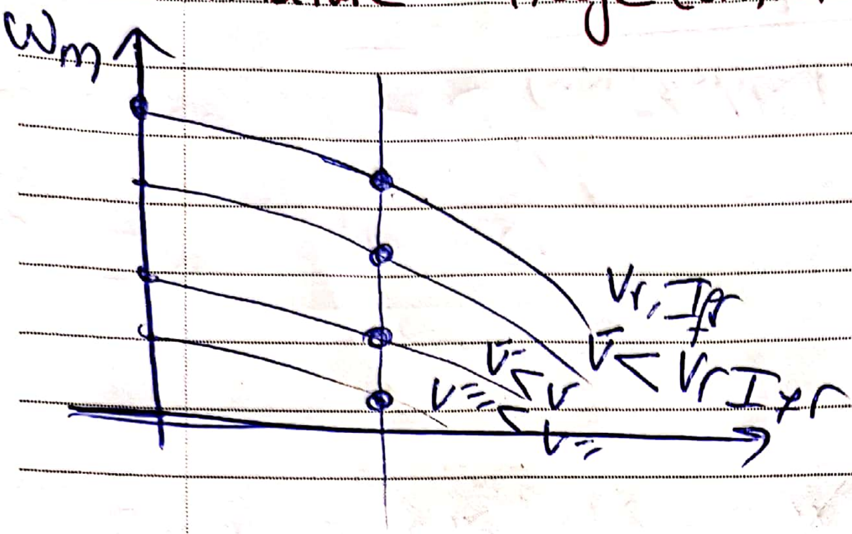




$Rex_2 > Rex_1$

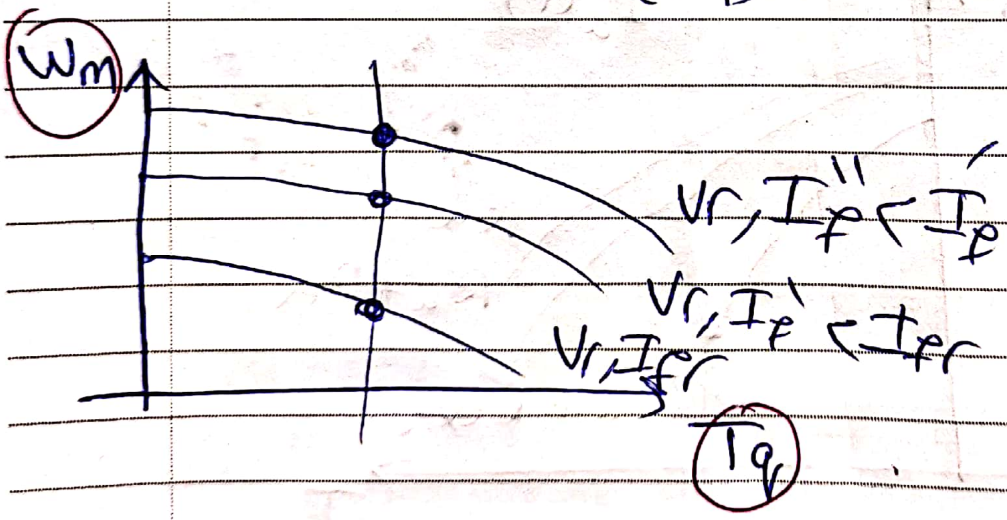
*Inefficient due to copper losses.

② Armature voltage control



③ feild weakining control

$$\omega_m = \frac{V_t}{k\phi} - \frac{T_q R_a}{(k\phi)^2}$$



$\omega_{m(r)} \leq \omega_m \leq (2-3)\,\omega_{m(r)}$

limit?? due to what?

① due to commulation

② " " mech design

No.

** given a DC machine with the following parameters
- sep. excited
- $V_r = 250$ V, $N_m(r) = 500$ RPM
- $\phi = 30 \, mW_b$/pole.
- No. of Armature slots = 120 slot
- No. of conductors per slot = 8 c/slot.
- R_c (conductor resistance) = 0,015 Ω/cond
- Winding : Lap , double layer , $2p = 6$

Required.

a) Machine Motor or generator?

b) I_a at rated speed and voltage

c) developed at (b) above.

sol.

Motor: $V_t > E_a$

Generator : $V_t < E_a$

$$E_a = k_a \phi * W_m$$

$$k_a = \frac{Z}{A} \cdot \frac{P}{\pi}$$

$Z = 120 * 8 = 960$ Condt

$P = 3$, $A = 6$ $\left[\frac{P}{A} = \frac{3}{6} = \frac{1}{2} \text{ Always}\right]$

$$k_a \rightarrow \frac{480}{\pi}$$

$$W_m(r) = \frac{2\pi N_m(r)}{60} = 52.36 \text{ rad/sec}$$

$\phi = 30 * 10^{-3}$ Wb

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$E_a(r) = \frac{480}{\pi} * 52.36 * 30*10^{-3} = 240\,V$

Since $V_t > E_a \rightarrow$ Motor

b) $I_a = \frac{V_t - E_a}{R_a}$

$R_a = ??$

$R_{path} = 0.015 * 16 = 2.4\,\Omega$

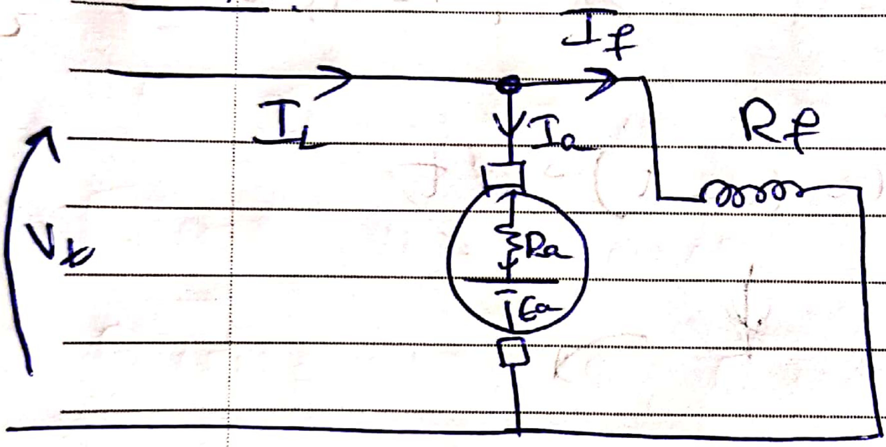
c) $P_a = \frac{E_a I_a}{W_m} = 116.$

$\frac{960}{6} = 16$ cond/Path

- given : DC shunt motor (10 hp, 230 V, $R_a = 0.3\,\Omega$, $R_f = 160\,\Omega$).

* The motor draws a line current of 3.938A on No-load, and a speed of 1200 RPM
- at full load : the armature current is 40
* Find Arm current at No load.
* developed power at No load.
* η_{FL}
* Full load speed of the motor.

Sol



$$I_{(nL)} = I_f + I_{a(nL)}$$

$$I_f = \frac{V_t}{R_f} = \frac{230}{160} = 1.4375\ A$$

$$I_a(nL) = I_L(nL) - I_f = 3.938 - 1.4375 = 2.5A$$

$$P_d = P_a = E_a(nL) * I_{a(nL)} = 229.25 * 2.5$$
$$= 573.125\ W$$

$$E_a(nL) = V_t - I_a(nL) * R_a = 230 - 2.5 * 0.3$$
$$= 229.25$$

No.

$P_a = P_d = P_{rot} + P_o$ → (o) at no-load.

$P_{rot} = 573.125$ W

) $\eta = \dfrac{P_o\,(FL)}{P_{in}\,(FL)}$

$I_a(FL) = 40A$

$I_L(FL) = I_a(FL) + I_f$
$= 40 + 1.4375 = 41.4375$

$P_{in}(FL) = V_t * I_L(FL) = 230\,(41.4375)$
$= 9530.625$ watt

$P_{out}(FL) = P_a(FL) - P_{rot} = E_a(FL)\,I_a(FL) - P_{rot}$
$= 218$ volt

$P_a(FL) = E_a(FL) * I_a(FL) = 218 * 40 = 8720$ watt

$P_o(FL) = 8750 - 573.125 = 8146.875$ Volt.

$\eta = \dfrac{P_o(FL)}{P_{in}(FL)} = 85.88\%$

3) $E_a(FL) = K\Phi_f\, N_m(FL)$ –

$E_a(nL) = K\Phi_f\, N_m(nL)$

$\dfrac{N_m(FL)}{N_m(nL)} = \dfrac{E_a(FL)}{E_a(nL)} \longrightarrow N_m(FL) = 1141.11$ RPM

لازم تكون أقل من 1200

* Speed Reg $= \dfrac{N_m(nL) - N_m(FL)}{N_m(nL)} = \dfrac{1200 - 1141}{1200}$

230 V, 25 hp, DC shunt motor.
draws An armature of 90 A at full-load.

$R_a = 0.2\ \Omega$, $R_f = 216$

$P_{rot} = ??$ at full-load an $\eta_{EL} = ??$

$I_L = I_{a(FL)} + I_f = 90 + 1.0648 = 91.0648\ A$

$I_f = \frac{230}{216} = 1.0648\ A$

$P_{in} = 230 * 91.0684 = 20944.9\ W$

$P_d = ? = P_a \rightarrow P_{nL} = P_a - P_o$

$P_a = E_{a(FL)} * I_{a(FL)}$

$E_{a(FL)} = V_t - I_{a(FL)} * R_a = 230 - 90 * 0.2 = 212\ V$

$P_{a(FL)} = 212 * 90 = E_{a(FL)} * I_{a(FL)} = 19080\ W$

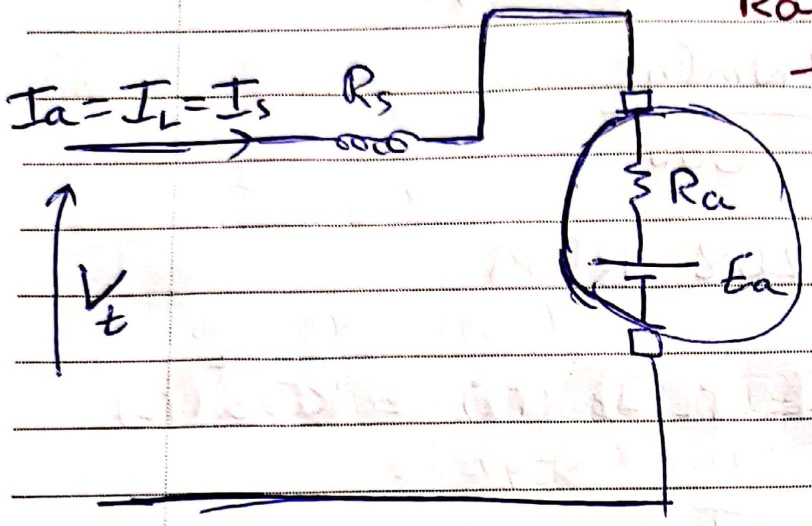
$P_o = 25 * 746 = 18650\ W$

$P_{rot} = P_{a(FL)} - P_{o(FL)} = 19080 - 18650 = 430$ watt

$$\eta = \frac{25 * 746 = 18650}{20944.9} = 89\%$$

No.

Series - Motors :– 600 volt, 150 Hp, DC Series motor
at full load $N_m(r) = 600$ RPM
$R_a = 0.12\,\Omega$, $R_s = 0.04\,\Omega$
the motor draws 200A at full load.



a) $E_a(nL) = ??$

b) $P_a(FL)$, $T_d(FL)$

c) change in the load:

$I_L = 150A \rightarrow$

$N_m(n)$, $T_d(n) = ??$

a) $E_{a(FL)} = 600 - 200(R_s + R_a) = 568\ V.$

b) $P_{a(FL)} = E_{a(FL)} * I_a = 568 * 200 = 113.6\ kW$

$$T_{a\,(FL)} = \frac{P_{a\,(FL)}}{W_m} = \frac{113600}{\frac{2\pi * 600}{60}} = 1808\ Nm$$

c) $E_a^{(n)} = 600 - 150\,(R_a + R_s) = 576\ V$

$$\frac{E_a(n)}{E_a(FL)} = \frac{K_a \cdot \phi_{(n)} W_m(n)}{K_a \cdot \phi_{(r)} * W_m(r)} = \frac{K_a \cdot K_s I_a * \frac{2\pi N_m(n)}{60}}{K_a \cdot K_s I_a(r) * \frac{2\pi N_m(r)}{60}}$$

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$$\frac{E_a(n)}{E_a(r)} = \left(\frac{I_a(n)}{I_a(r)}\right) * \frac{N_m(n)}{N_m(r)}$$

$$\frac{576}{568} = \left(\frac{150}{200}\right) * \frac{N_m(n)}{600}$$

$$\longrightarrow N_m(n) = 811.268 \text{ RPM}$$

$$T_{a(FL)} = K_a \cdot K_s I_{a(FL)} I_{a(FL)} = K I_a^2(FL)$$

$$T_a(new) = K_a \cdot K_s I_a(n) * I_a(n)$$
$$= K I_a^2(n)$$

$$\frac{T_a(new)}{T_a(FL)} = \left(\frac{I_a(new)}{I_a(FL)}\right)^2$$

$$T_a(new) = 1808 \left(\frac{150}{200}\right)^2 = 1017 \text{ N.m}$$

* Same motor above is to be started such that the $I_{st} = 150\%\ I_{rated}$.

a) $R_{st} = ??$ and $T_{st} = ??$

b) If R_{st} still connected and $I_L = 200A$,

$E_a = ??$ $N_m = ??$

No.

$$I_a = \frac{V_t - E_{(a)}}{R_a + R_s}$$

$$I_{st} = \frac{V_t - 0}{R_a + R_s} = \frac{600}{0.16} = 3750\,A$$

$$\left(\frac{I_{st}}{I_a}\right)_{\text{direct start}} = \frac{3750}{200} = 18.75$$

** to start safely reduced I_{st}

a) reduced ~~R_a~~ V_t → using controlling rectifiers

$I_{st}' = 150\% = 1.5 \times 200 = 300\,A$

$V_{st} = 300 \times 0.16 = 48$

b) $R_{st} = ??$

$$I_{st}' = \frac{V_t(r)}{(R_a + R_{st} + R_{st})} \rightarrow 300 = \frac{600}{0.16 + R_{st}} \longrightarrow 1.84$$

تقاطع

$$\frac{T_{st}'}{T_r} = \left(\frac{1.5}{1}\right)^2 = 2.25 \checkmark \text{ good.}$$

No.

* Same motor parameters

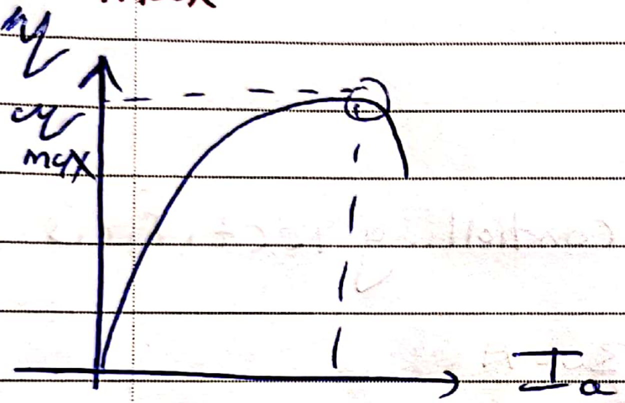
$P_o = 150\ hp,\ I_L = I_a = 200\ A$

find : $P_{rot} = ?$

find the Armature Current at Max Efficiency

I_a

, $\eta_{max} = ??$



$P_{a(r)} = E_{a(r)} * I_{a(r)} = 568 * 200 =$

$= 568\ V$

$P_o = 150 * 746 = \_\_\_$

$P_{rot} = P_{a(r)} - P_{o(r)} = 1700\ W$

$I_a(\eta_{max}) = ??$

$\eta = \dfrac{P_o}{P_{in}}$

$P_{out} = V_t I_a - I_a^2 (R_s + R_a) - P_{rot}$

$P_{in} = V_t I_a$

$$\eta = \frac{V_t I_a - I_a^2 (R_s + R_a) - P_{rot}}{V_t I_a}$$

الاسهل

$$\left.\frac{d\eta}{dI_a}\right| = 0 = \frac{[V_t - 2I_a(R_s + R_a)] V_t I_a - V_t \boxed{V_t I_a -}}{(V_t I_a)^2}$$

$$\boxed{I_a(\eta_{max}) = \sqrt{\left(\frac{P_{rot}}{R_a + R_s}\right)}}$$ مهم

$$I_a(\eta_{max}) = \sqrt{\frac{1700}{0.16}} = 103.07 \text{ A}$$

$$E_a = 600 - 103.07(0.16) = 583.5 \text{ V}$$

$$\cancel{P_o = P_a}$$

$$P_a = E_a I_a = 583.5 * 103.07 = \text{[illegible]}$$

$$P_o = P_a - P_{rot} = 58446.584 \text{ watt}$$

$$\eta_{max} = \frac{5844.584}{103.07 * 600} = 94.5\%$$

done