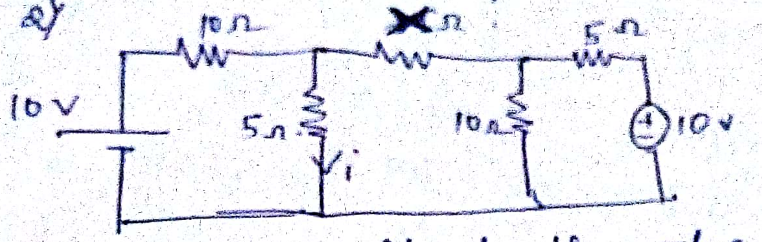
Assignments

1) Derive the vector form of ohm's law.

2)

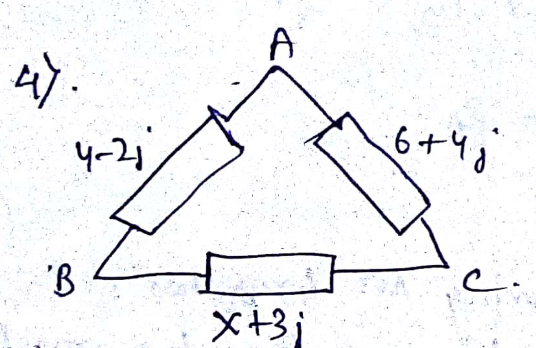


X = 40

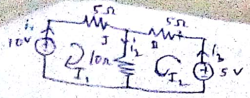
Find the value of i.

3) Derive the inter relationship ~~connection~~ between star & Delta

4).



5) Prove the maximum power transfer for a.c. circuit.



1) Branch currents (i_1, i_2, i_3)
2) Loop currents

$10 = 5i_1 + 10i_2$ — ①
$5 = 5i_3 + 10i_2$ — ②

$i_1 = I_1$
$i_2 = I_1 + I_2$
$i_3 = I_2$

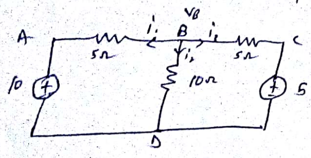
By KVL

$\therefore 3I_1 + 2I_2 = 2$
$2I_1 + 3I_2 = 1$

$\therefore I_1 = 4/5\ A$ & $I_2 = -\frac{1}{5} A$.

$\therefore i_1 = \frac{4}{5} A \quad i_3 = -\frac{1}{5} A \quad i_2 = \frac{3}{5} A$

By KCL, Junction is a point having two branches.
Nodes is a point having more than two branches.



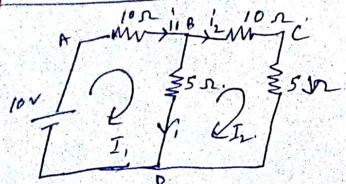
At B,
$i_1 + i_2 + i_3 = 0$

$\Rightarrow \frac{V_B - 10}{5} + \frac{V_B - 0}{10} + \frac{V_B - 5}{5} = 0$

$\Rightarrow \frac{4V_B}{10} + \frac{V_B}{10} = 3$

$\Rightarrow V_B = 6V$.

$i_1 = -\frac{4}{5} \quad i_2 = \frac{3}{5} \quad i_3 = \frac{1}{5}$



$10 = 10i_1 + 5i$

$10i_2 + 5i_2 - 5i = 0$.

$i_1 = i + i_2$.

$\Rightarrow 10 = 10i + 10i_2 + 5i$

$15i_2 - 5i = 0$

$\Rightarrow i = 3i_2$.

$\Rightarrow 15i + 10i_2 = 10$

$\Rightarrow 15i + \frac{10}{3} i = 10$.

$\Rightarrow \frac{55}{3} i = 10 \Rightarrow i = \frac{6}{11} A$.

By KCL,

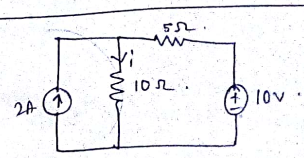
$\frac{V_B - 10}{10} + \frac{3V_B}{15} + \frac{V_B}{75} = 0$.

$\Rightarrow \frac{V_B}{10} + \frac{4V_B}{15} = 1$.

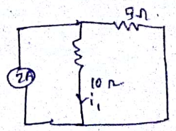
$\Rightarrow \frac{3V_B + 8V_B}{30} = 1 \Rightarrow V_B = \frac{30}{11} V$

$\therefore i = \frac{30/11}{5} = \frac{6}{11} A$

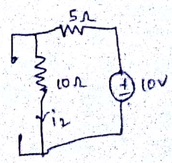
$\frac{V_A}{10} + \frac{V_A}{10} = 3 \Rightarrow V_A = 6V$.



Step 1

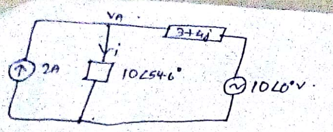


Current $i_1 = \frac{5}{15} \times 2 = \frac{2}{3} A$



Current $i_2 = \frac{10}{15} = \frac{2}{3} A$

$\therefore i_1 + i_2 = \frac{4}{3} A$.

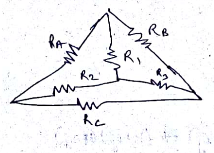


$$2 = \frac{V_A}{10\angle 54.6^\circ} + \frac{V_A - 10}{3+4j}$$

$$2 = \frac{V_A}{5.8+j8.15} + \frac{V_A - 10}{3+4j}$$

$$\cancel{\Rightarrow 2 = (3+4j)V_A + (5.8+j8.15)(V_A - 10)}$$

Y- Delta Transform.



R_A, R_B & R_C known.

$$\therefore R_1 = \frac{R_A R_B}{R_A+R_B+R_C}$$

$$R_2 = \frac{R_A \times R_C}{R_A+R_B+R_C}$$

$$R_3 = \frac{R_B \times R_C}{R_A+R_B+R_C}$$

Star - Delta.

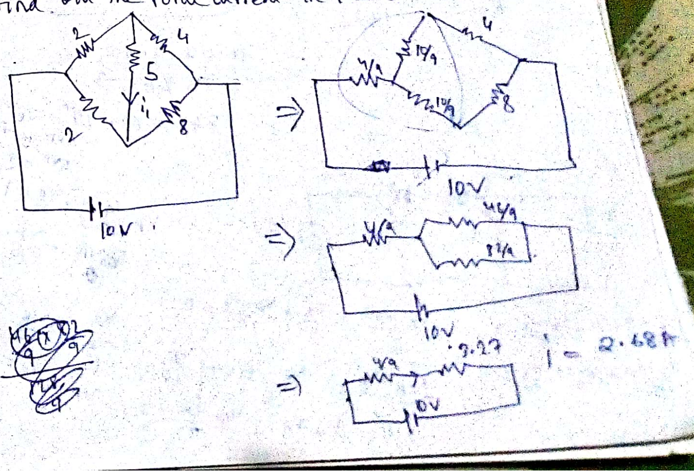
R_1, R_2, R_3 known.

$$R_A = \frac{R_1R_2 + R_2R_3 + R_3R_1}{R_2}$$

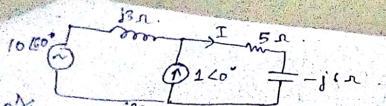
$$R_B = \frac{R_1R_2 + R_2R_3 + R_3R_1}{R_3}$$

$$R_C = \frac{R_1R_2 + R_2R_3 + R_3R_1}{R_1}$$

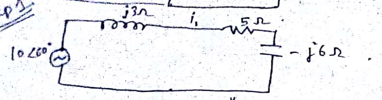
Find out the total current in the circuit.



$i = 2.68A$

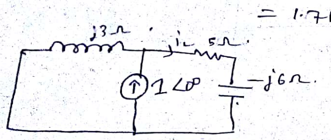


Step 1



$$i_1 = \frac{10\angle 60^\circ}{5 - j3} = \frac{10\angle 60^\circ}{5.83\angle -30.9^\circ}$$
$$= 1.715\angle 90.9^\circ$$

Step 2

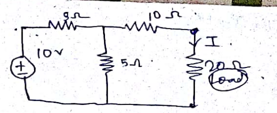


$$i_2 = \frac{j3}{5 - j3} \times 1\angle 0^\circ$$
$$= \frac{3\angle 90^\circ}{5.83\angle 30.9^\circ}$$
$$= 0.515\angle 120.9^\circ$$

$$\therefore i = \underset{i_1}{(-0.026 + j1.715)} + \underset{i_2}{(-0.264 + j0.442)}$$
$$= (-0.290 + j2.157)\ A$$
$$= 2.176\angle 97.6^\circ\ A$$

Thevenin's Theorem:

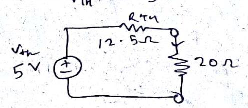
Any linear active network consisting of dependent &/ independent sources and linear bilateral network elements can be replaced by an equivalent circuit consisting of a voltage source in series with a resistance. The voltage source being the open circuited voltage across the open circuited load terminals and the resistance being the internal resistance of the source network looking through the open circuited load terminals with all the active sources either replaced by their internal resistances (if any) or short circuited (In case of voltage source) or open circuited (In case of current source).



Applying Thevenin's theorem,

$R_{TH} = 12.5\,\Omega$

$V_{TH} = 5V$



$\therefore$ Current through 20Ω

$$= \frac{5}{32.5} = \frac{1}{6.5}$$
$$= 0.153\ A$$

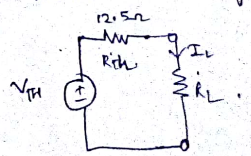
I_N is the current flowing through short circuited load terminals

Maximum Power transfer theorem.

A resistive load connected to a d.c. network receives max. power when the load resistance is equal to the internal resistance of source network as seen from the load terminals i.e. Thevenin's Resistance.

For a.c.

An impedance connected to an a.c. network receives max. power when the load impedance is equal to the ~~internal~~ ~~imp~~ complex conjugate of the internal impedance of source network as seen from the load terminals i.e. Thevenin's impedance



$$P_L = I_L^2 R_L$$
$$= \left(\frac{V_{TH}}{R_{TH}+R_L}\right)^2 R_L$$
$$= (V_{TH})^2 \frac{R_L}{(R_{TH}+R_L)^2}$$

$$\frac{dP_L}{dR_L} = (V_{TH})^2 \left\{ \frac{(R_{TH}+R_L)^2 - 2R_L(R_{TH}+R_L)}{(R_{TH}+R_L)^4} \right\}$$

$$= (V_{TH})^2 \frac{(R_{TH}-R_L)}{(R_{TH}+R_L)^3}.$$

For maximum value of P_L, $\frac{dP_L}{dR_L} = 0$

$\Rightarrow R_{TH} - R_L = 0$

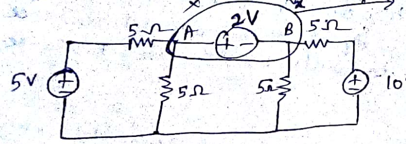
$\Rightarrow R_{TH} = R_L$

Maximum Power $= \frac{(V_{TH})^2 R_L}{4R_L^2} = \frac{(V_{TH})^2}{4R_L} = P_{max}$.

Total Power dissipated or provided by a source

$= 2 \times P_{max} = \frac{V_{TH}^2}{2R_L}$

Super Node Analysis



If a voltage source is connected betn two nodes: then it is said to be a super node

Applying KCL at x,

$$\frac{V_A-5}{5} + \frac{V_A}{5} + \frac{V_B-10}{5} + \frac{V_B}{5} = 0.$$

$V_A - V_B = 2.$

If a resistance connected in parallel with voltage source then also it will be a super node

$$\frac{2V_A}{5} + \frac{2V_B}{5} = 3.$$

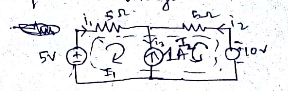
$V_A + V_B = 7.5$

$V_A - V_B = 2$

$2V_A = 9.5 \Rightarrow V_A = 4.75.$

$V_B = 2.75.$

Super Mesh Analysis



Current source being at the junction of two loops.

$5I_2 + 5 = 5I_1 + 10$ — ①.

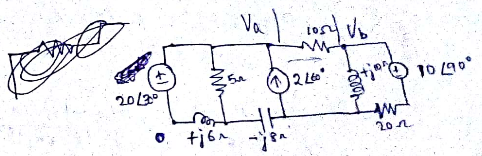
$I_1 + I_2 = -1$ (not KCL).

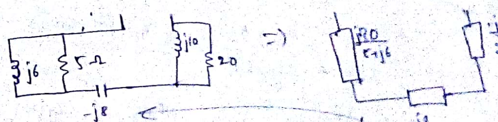
$I_1 - I_2 = -1.$

$2I_1 = -2.$

$I_1 = -1$. $I_2 = 0$

$P = \frac{V^2}{R}$





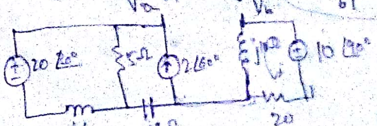
$$Z = \frac{j30(5-j6)}{25+36} - j8 + \frac{j20(2-j)}{5}$$

$$= j\frac{30}{61}(5-j6) - j8 + j4(2-j)$$

$$= j\frac{150}{61} + \frac{180}{61} - j8 + j8 + 4$$

$$Z = j\frac{150}{61} + \frac{424}{61}$$

$Z = 0.261 \angle 18.311$



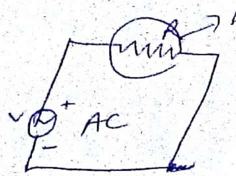
$$i = \frac{j10}{20+j10} = \frac{j}{2+j}$$

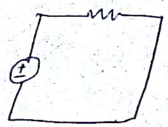
$$= \frac{j(2-j)}{5} = 0.2 + \ldots$$

$(x+1)^n - x^n = {}^nC_1 x^{n-1} + {}^nC_2 x^{n-2} + \dots + {}^nC_{n-1} x + 1$

AC Fundamentals

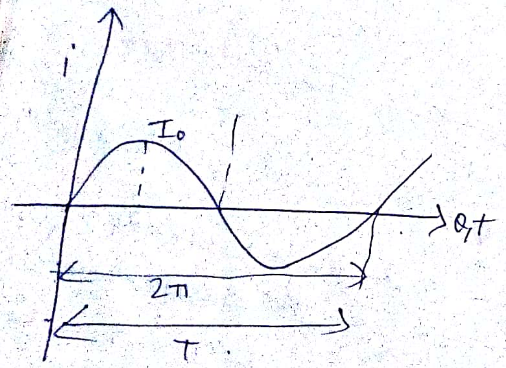
RMS value is the current flowing through a circuit which would produces the same amount of heat generated in a dc resistance, when a.c signal passes through it in a given amt of time





Avg. value of a sinusoidal signal.
$\boxed{\text{transfer same amount of charge}}$ ~~discharged~~.

In a symmetrical signal, average value is taken for a half cycle.
If ~~not~~ asymmetrical, avg. value is taken over full period



Average value:

$$I_{avg} = \cancel{\frac{1}{T/2}\int_0^{T/2} i\,d\theta}$$

$$= \frac{1}{T/2}\int_0^{T/2} i\,dt$$

$$= \frac{1}{T/2}\int_0^{T/2} I_0 \sin\omega t\,dt$$

$$= \frac{I_0}{T/2}\left[\frac{-\cos\omega t}{\omega}\right]_0^{T/2}$$

$$= \frac{I_0}{\frac{2\pi}{T}\times\frac{T}{2}}\left[-\cos\frac{2\pi}{T}\times\frac{T}{2} + \cos 0\right]$$

$$= \frac{2I_0}{\pi}\ A$$

$$I_{r.m.s}^2 = \frac{1}{T}\int_0^T i^2\,dt$$

$$I_{r.m.s}^2 = \frac{1}{T}\int_0^T I_0^2 \sin^2\omega t\,dt$$

$$= \frac{I_0^2}{T}\int_0^T \left(\frac{1-\cos 2\omega t}{2}\right)dt$$

$$= \frac{I_0^2}{T}\left[\frac{t}{2} - \frac{\sin 2\omega t}{\omega 4}\right]_0^T$$

$$= \frac{I_0^2}{T}\left[\frac{T}{2}\right] = \frac{I_0^2}{2}$$

$$\therefore I_{r.m.s} = \sqrt{\frac{I_0^2}{2}} = \frac{I_0}{\sqrt{2}}$$

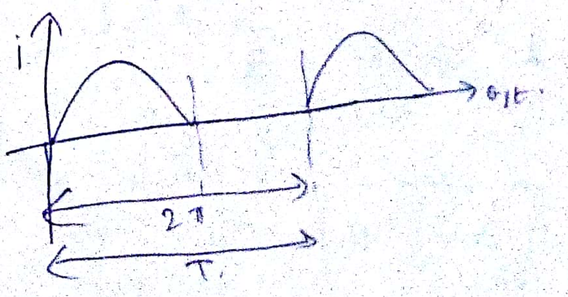
$I_{r.m.s}^2$ for half period $= \frac{1}{\pi}\int_0^\pi i^2\,d\theta$

$$= \frac{I_0^2}{\pi}\int_0^\pi \sin^2\theta\,d\theta = \frac{I_0^2}{\pi}\left[\frac{\theta}{2} - \frac{\sin 2\theta}{4}\right]_0^\pi = \frac{I_0^2}{2}$$

Form factor $= \frac{I_{r.m.s}}{I_{avg}} = \frac{I_0/\sqrt{2}}{\frac{2I_0}{\pi}} = \frac{\pi}{2\sqrt{2}} = 1.11$

Peak factor $= \frac{I_{peak}}{I_{rms}} = \frac{I_0}{I_0/\sqrt{2}} = \sqrt{2} = 1.414$

For half wave rectifier,



$$I_{avg} = \frac{1}{T}\int_0^T i\,dt$$

$$= \frac{1}{T}\int_0^{T/2} i\,dt$$

$$= \frac{I_0}{T}\int_0^{T/2} \sin\omega t\,dt$$

$$= \frac{I_0}{\pi}\ A$$

$$I^2_{r.m.s} = \frac{1}{2\pi}\int_0^{\pi} i^2 d\theta + \frac{1}{2\pi}\int_{\pi}^{2\pi} i^2 d\theta$$

$$= \frac{1}{2\pi}\int_0^{\pi} i^2 d\theta + 0$$

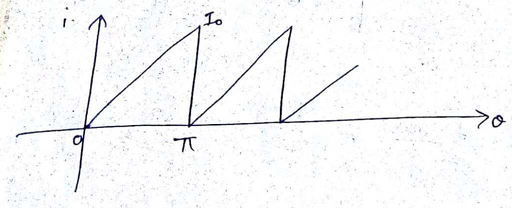
$$= \frac{I_0^2}{2\pi}\int_0^{\pi} \sin^2\theta d\theta = \frac{I_0^2}{2\pi}\left[\frac{\theta}{2} - \frac{\sin 2\theta}{4}\right]_0^{\pi}$$

$$= \frac{I_0^2}{4}$$

$$\therefore I_{r.m.s} = \frac{I_0}{2}$$

Form factor $= \dfrac{I_0/2}{I_0/\pi} = \pi/2 = 1.57$

Peak factor $= \dfrac{I_0}{I_0/2} = 2$.



$y = \dfrac{I_0}{\pi}\theta$.

$$I_{avg} = \frac{I_0 \pi}{2\pi} = \frac{I_0}{2}$$

$$I_{r.m.s.} \frac{1}{2\pi}\int_0^{2\pi} i^2 d\theta = \frac{1}{2\pi}\int_0^{\pi} i^2 d\theta + \int_{\pi}^{2\pi} i^2 d\theta$$

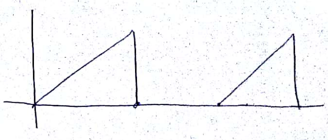
$$= \frac{1}{2\pi}\int_0^{\pi} \frac{I_0^2}{\pi^2}\theta^2 d\theta = \frac{I_0^2}{\pi^3}\int_0^{\pi}\theta^2 d\theta$$

$$= \frac{I_0^2}{\pi^3}\left[\frac{\theta^3}{3}\right]_0^{\pi}$$

$$= \frac{I_0^2}{3}$$

$\therefore$ Form factor $= \dfrac{I_0/\sqrt{3}}{I_0/2} = \dfrac{2}{\sqrt{3}} = 1.154$

Peak $= \dfrac{I_0}{I_0/\sqrt{3}} = \sqrt{3} = 1.732$



$$I_{avg} = \frac{\frac{I_0 \pi}{2}}{2\pi} = \frac{I_0}{4}.$$

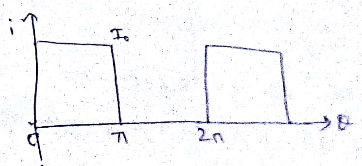
$$I^2_{r.m.s} = \frac{1}{2\pi}\int_0^{\pi} \frac{I_0^2}{\pi^2}\theta^2 d\theta = \frac{I_0^2}{2\pi^3}\left[\frac{\theta^3}{3}\right]_0^{\pi}$$

$$= \frac{I_0^2}{6}$$

$$\therefore I_{r.m.s} = \frac{I_0}{\sqrt{6}}$$

$\therefore$ F.F $= \dfrac{4}{\sqrt{6}} = 1.6329$ P.F $= \sqrt{6} = 2.45$

i)

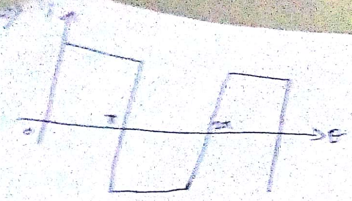


$$I_{avg} = \frac{I_0 \pi}{2\pi} = \frac{I_0}{2}$$

$$I^2_{r.m.s} = \frac{1}{2\pi}\int_0^{\pi} I_0^2 d\theta = \frac{I_0^2}{2}$$

$$\therefore I_{r.m.s} = I_0/\sqrt{2}$$

$\therefore$ F.F $= \sqrt{2} = 1.414$ P.F $= \sqrt{2} = 1.414$



$I_{avg} = \frac{I_0 \pi}{\pi} = I_0$

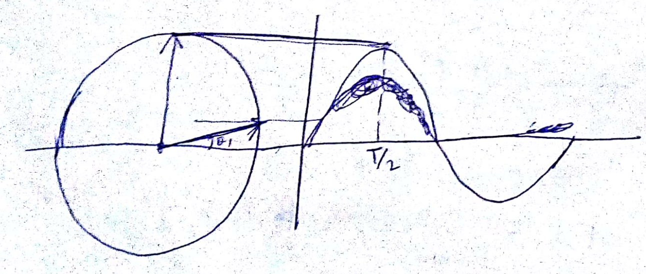
$I_{r.m.s}^2 = \frac{1}{2\pi}\int_0^{2\pi} I_0^2 \, d\theta = \frac{I_0^2}{2\pi}\left[\theta\right]_0^{2\pi} = I_0^2$

$I_{r.m.s} = I_0$

$\therefore$ P.F $= 1$, FF $= 1$.

> F·F ~~is always greater than 1~~
> But for symmetrical square it has a min value of $= 1$.

Only sinusoidal quantities can be represented as a phasor ~~and~~ diagram.
And magnitude of the phasor is the r.m.s value of the quantity.

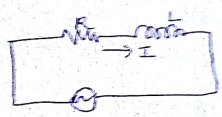


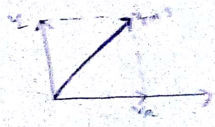
In a resistive circuit, current is in same phase with ...

For induction circuit

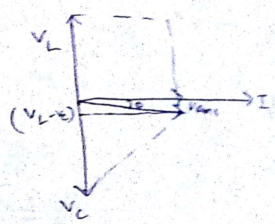
$V = V_0 \sin \omega t$

$I_L = \frac{V}{jX_L} = \frac{V_0 \sin \omega t}{jX_L} = \frac{V_0}{X_L}\sin(\omega t - 90)$





For R L C,



Final angle or phase between V_{rms} & I_{rms} = power factor angle

Apparent power $= V_{r.m.s} I_{r.m.s} =$ VA (Unit)

watt is the unit of active power
↳ power available for ...

Active power $= V_{r.m.s} I_{r.m.s} \cos\theta \rightarrow$ Watt

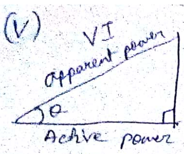
Reactive power : $= V_{r.m.s} I_{r.m.s} \sin\theta$ (Not available for ...) → VAR

volt ampere reach...

$$\boxed{\text{Power factor} = \frac{\text{Active power}}{\text{Apparent power}}} = \frac{R}{Z}$$

(V)

⑦



VI cosθ

R

(V_R)

Reactive Power

VI sinθ

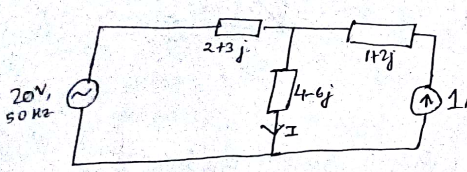
($X_L \sim X_C$)

($V_L \sim V_C$)

( ) — Voltage

○ — Resistance

— Power



$i_1 = \frac{20}{(2+3j+4-6j)} = \frac{20}{6-3j} = \frac{20(6+3j)}{36+9}$

$= \frac{60(2+j)}{45}$

$= \frac{8}{3} + \frac{4j}{3}$

~~$i_2 = 1$~~

~~$\therefore I = \frac{11}{3} + \frac{4}{3}j = 3.9\angle 19.98°\ A$~~

$\frac{(2+3j)(4-6j)}{6-3j} + 1+2j$

$\frac{26}{6-3j} + 1+2j = \frac{26+(1+2j)(6-3j)}{6-3j}$

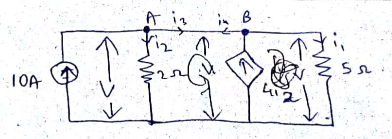
$= \frac{26+12+9j}{6-3j}$

$= \frac{38+9j}{6-3j}$

$\frac{2+3j}{6-3j} = \frac{(2+3j)(6+3j)}{45}$

$= \frac{3+24j}{45}$

$I = \left(\frac{8}{3}+\frac{3}{45}\right) + j\left(\frac{24}{45}+\frac{4}{3}\right) = 2.733 + 1.863 = 3.3\angle 34.28$



$\boxed{10 + 3i_2 = i_1}$

$\frac{V}{5} = i_1$

$\frac{V}{2} = i_2$

$10 + \frac{3V}{2} = \frac{V}{5}$

$\Rightarrow 10 = -\frac{13V}{10} \Rightarrow V = -\frac{100}{13}$

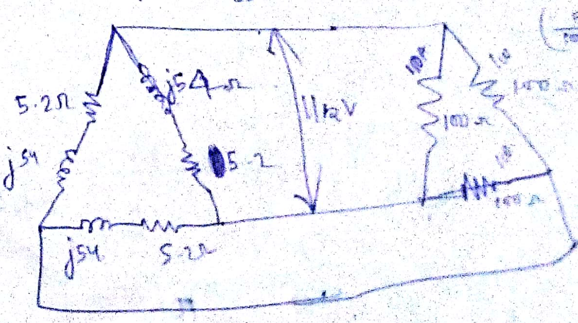
$\therefore i_1 = -\frac{100}{65} = -\frac{20}{13}$

$i_2 = -\frac{100}{26}$

$10 = i_3 + i_2$

$= -(4i_2 - i_1) + i_2$

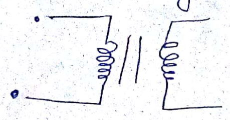
$10 + 3i_2 = i_1$



Transformer:

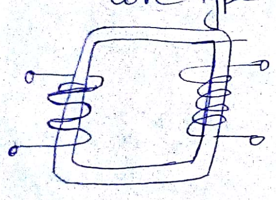
Static electromagnetic device

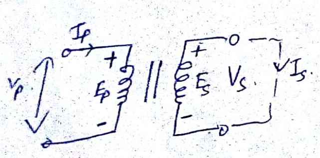
Flux energy is transferred from one part of circuit to another which are electrically isolated and magnetically coupled.



Types of transformer.

core type shell type.





Flux generated by V_p.

$\phi = \phi_m \sin \omega t$.

$e = -N\frac{d\phi}{dt} = -N\phi_m \omega \cos \omega t$.

$= e_0 \cos \omega t$, $e_0 = -N\phi_m \omega$.

$$\boxed{|E_{r.m.s}| = \frac{1}{\sqrt{2}} N\phi_m \omega = \sqrt{2}\pi f N\phi_m}$$

$E_{r.m.s} = 4.44 f N \phi_m$.

$= 4.44 f N B_m A$

$E_p = 4.44 f N_p B_m A$

$E_s = 4.44 f N_s B_m A$.

$$\boxed{\frac{E_p}{E_s} = \frac{N_p}{N_s} = \text{turns ratio}}$$

$\frac{E_p I_p}{E_s I_s} = \text{constant} \Rightarrow \frac{N_p I_p}{N_s I_s} = \text{constant}$

$$\boxed{\frac{I_p}{I_s} = \frac{N_s}{N_p}}$$

Ampere turns of primary = ampere turns of secondary

Power $= \frac{I_p^2 Z_p}{I_s^2 Z_s} = \text{constant}$

$\Rightarrow \frac{N_s^2 Z_p}{N_p^2 Z_s} = \text{const} \Rightarrow \frac{Z_p}{Z_s} = \frac{N_p^2}{N_s^2}$

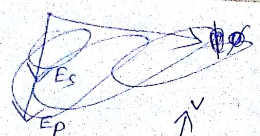
A 1kVA 200V/300V single phase transformer has 200 turns in the secondary. Find out the turns ratio, no. of turns in primary current flowing in primary and the ratio of primary & secondary impedance

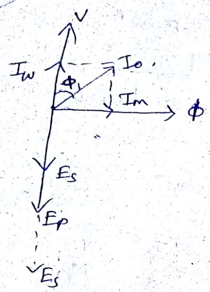
$\frac{200}{300} = \frac{N_p}{200} \Rightarrow N_p = \boxed{\frac{400}{3}}$ $\boxed{\text{turns ratio} = \frac{2}{3}}$

Apparent power $= 1000$ VA

$1000 = 200 \times I_p \Rightarrow \boxed{I_p = 5}$

Ratio of primary to secondary $= \boxed{\frac{4}{9}}$





→ e.m.f induced is caused by flux therefore e.m.f lags behind flux.

→ Voltage caused the flow of current

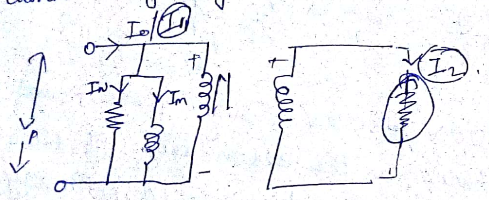
→ current generate flux.

→ No load (in-line current) I_0

$\bar{I_0} = \bar{I_m} + \bar{I_w}$ → covering up No load losses

$\bar{I_0}$ ↓ no load current

$\bar{I_m}$ ↓ magnetising current



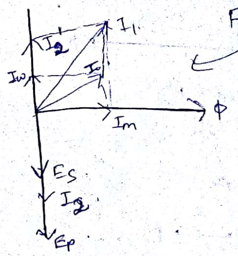
$I_m = I_0 \sin\phi_0$, $I_w = I_0 \cos\phi_0$

Single phase : I_m is 5% of I_0 (Experimental)

When load is connected to secondary, current will flow → flux is created → To negate this flux. more flux is generated in primary which makes the transformer draw more current from primary.

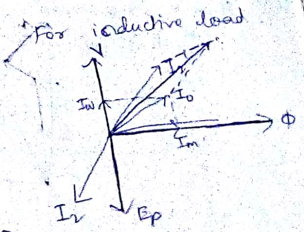
I_0 changes to I_1

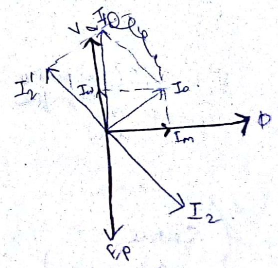
$\bar{I_1} = \bar{I_0} + \bar{I_2'}$



For resistive load

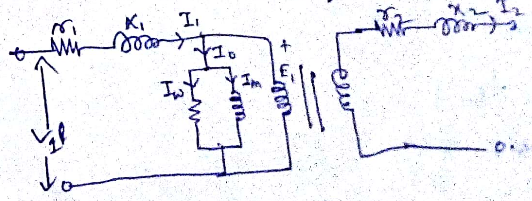
For inductive load





(Ideal Transformer).

For Practical transformer.



$\bar{V_1} = \bar{I_1}r_1 + \bar{I_1}x_1 + \bar{E_1}$

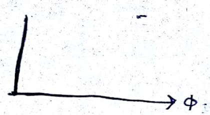
$\bar{V_1} = \bar{I_1} r_1 + \bar{I_1} x_1 + \bar{E_1}$

$\bar{E_2} = \bar{I_2} r_2 + \bar{I_2} x_2 + \bar{V_2}$

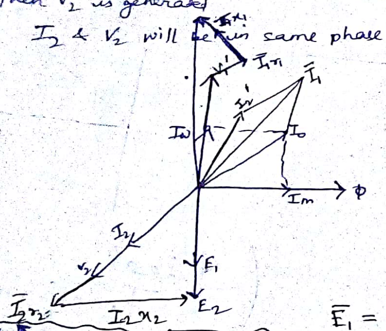
$\boxed{\vec{A} = \vec{B} + \vec{C} + \vec{D}}$ vector addn.

First E_2 is generated

then V_2 is generated

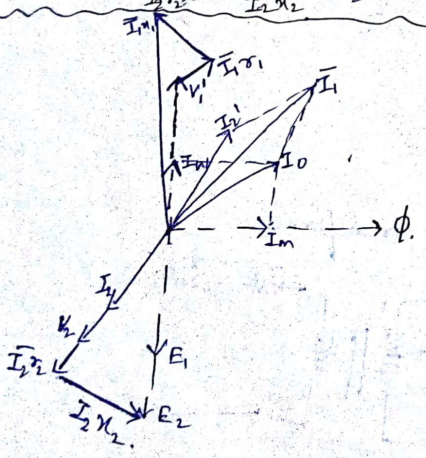


I_2 & V_2 will be in same phase.



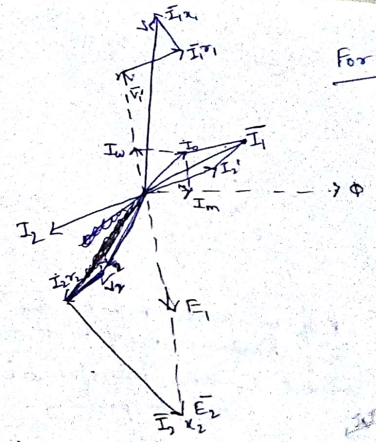
$\bar{E_1} = \bar{V_1}'$ (No practical significance)

(opposite in dir.)

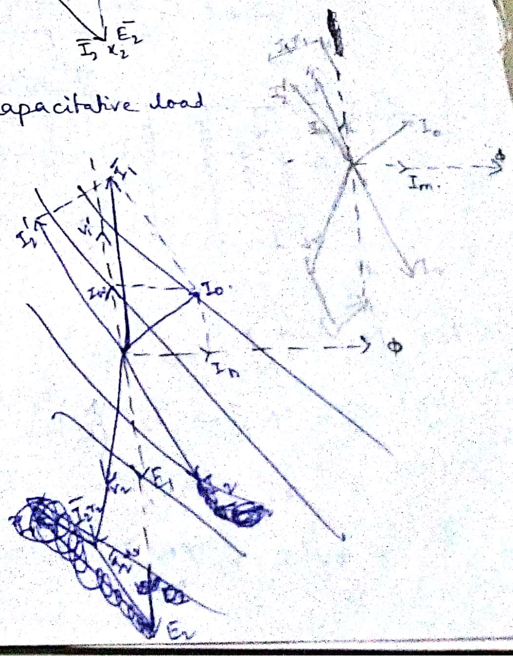


(same as above)

For lagging

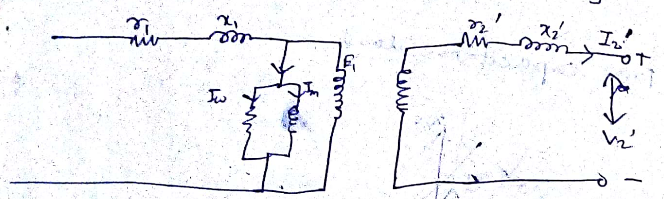


For capacitative load



~~Transfer to~~ If we convert E_1 to E_2, we say transformer is ref. to secondary

If we convert E_2 to E_1, transformer is ref. to primary.



For N_2 turns,

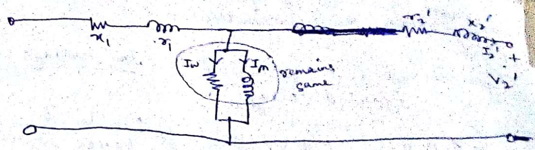
$$N_2 \rightarrow r_2$$

$$N_1' \rightarrow r_2 \times \left(\frac{N_1}{N_2}\right)^2$$

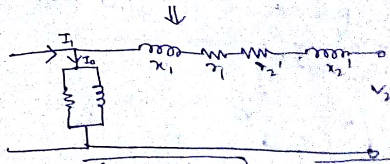
$$r_2' = r_2 \left(\frac{N_1}{N_2}\right)^2$$

$$x_2' = x_2 \left(\frac{N_1}{N_2}\right)^2 \qquad I_2' = \frac{N_2}{N_1} I_2$$

Approx. equivalent circuit.



⇓

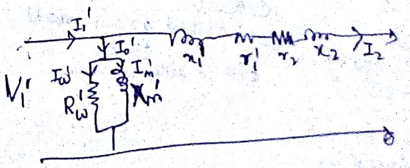


$I_0 << I_1$ Hence the above two circuits are equivalent

$\boxed{r_1 + r_2' = R_{01}}$, $\boxed{x_1 + x_2' = X_{01}}$

$\boxed{\text{refer to secondary}}$

↓



$$\frac{E_1'}{E_1} = \frac{N_2}{N_1}$$

$$E_1' = \left(\frac{N_2}{N_1}\right) E_1$$

$$r_1' = \left(\frac{N_2}{N_1}\right)^2 r_1$$

$$x_1' = \left(\frac{N_2}{N_1}\right)^2 x_1$$

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

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

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

$$\boxed{R_{02} = r_1' + r_2}$$

$$\boxed{X_{02} = x_1' + x_2}$$

$$I_W' = \frac{N_1}{N_2} I_W$$

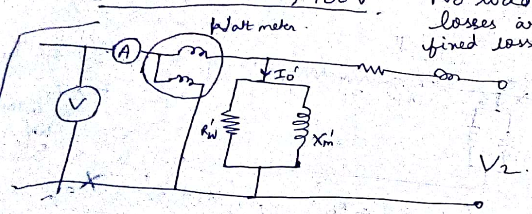
$$I_m' = \frac{N_1}{N_2} I_m$$

Short circuit test & open circuit test is used to obtain the parameters.

Open circuit test is applied to low-voltage side
rated voltage is applied

• 1 KVA 100V/400V.

No load losses are fixed losses.



No load losses hysterisis loss

Hysterisis loss can be reduced by using CRGOS

CRGOS
cold rolled grain oriented steel
with a little bit silicon

Eddy currents loss can be reduced by lamination

Results of OC test

Rated voltage = 100 V, Current = 1A, 50 W

$$\cos\phi_0 = \frac{W_0}{VI_0} = 0.5$$

$$\sin\phi_0 = 0.867$$

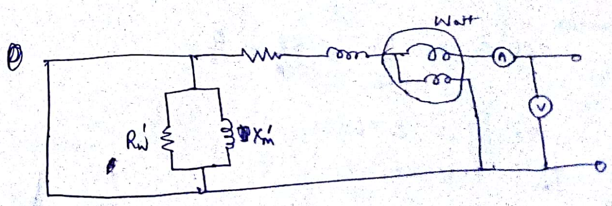
$I_M = 0.867A$

$I_W = 0.5A$

$$X_M = \frac{100}{0.867} = 115.34\Omega$$

$$R_W = \frac{100}{0.5} = 200\Omega$$

Short circuit test is preferably applied on high voltage side.
low voltage side is short circuited.
rated current is applied.



Reading : 40V, 2.5A, 80W
↓
ohmic loss.
(Full load loss)

$$I^2 R_{02} = 80$$

$$\Rightarrow R_{02} = \frac{80}{6.25} \quad I = 2.5$$

$$= 12.8$$

$$Z_{02} = \frac{40}{2.5} = 16\Omega \qquad X_{02} = \sqrt{Z_{02}^2 - R_{02}^2} = 9.6$$

$R_{01} = 12.8 \times \left(\frac{100}{400}\right)^2 \Omega$

$X_{01} = 9.6 \times \left(\frac{100}{400}\right)^2$

---

5 kVA , 500V/200 V

OC Test : 200V , 1.5 A , 80 W

SC Test : 50 V , 10 A , 200 W.

Parameters ref. to primary & secondary.

$\cos\phi_0 = \frac{W_0}{VI_0} = \frac{80}{300} = \frac{4}{15}$

$\sin\phi_0 = 0.963$

$I_m = 1.4445$

$I_W = 0.4$

$R_W = \frac{200}{0.4} = 500\Omega$

$X_M = 138.456$

Ohmic loss = 200

$\Rightarrow 10^2 \times R_{0p} = 200$

$\Rightarrow R_{0p} = 2\Omega$

$Z_{0p} = 5\Omega$ $X_{0p} = \sqrt{25-4} = 4.58\Omega$

~~$R_{01}' = (2.5)^2 \times 2 = 12.5$~~

~~$X_{01}' = (2.5)^2 \times 4.58 = 28.625$~~

Referred to low voltage

$R_{02} = R_{01} \times \left(\frac{1}{2.5}\right)^2 = 0.32$

$X_{02} = X_{01} \times \left(\frac{1}{2.5}\right)^2 = 0.733$

R_W, X_M remains same

Referred to high voltage.

$R_W' = R_W \times \left(\frac{500}{200}\right)^2$

$X_M' = X_M \times \left(\frac{500}{200}\right)^2$

---

10 kVA , 1000 V / 500 V

OC test → 500 V, 2A, 100 W (w.r.t low/second

SC test → 50V, 10A, 300W

$\cos\phi_0 = \frac{W_0}{VI_0} = \frac{100}{1000} = 0.1$

$\sin\phi_0 = 0.995$

$I_m = I_0 \times 0.1 = 0.2$

$I_W = I_0 \times 0.995 = 1.99$

$R_W = 251.3\Omega$

$X_M = 2500\Omega$

$Z_{01} = 5\,\Omega$

$\therefore X_{01} = 4\,\Omega$

Referred to low voltage ~~transformer~~ side,

$R_{02} = R_{01}\left(\frac{1}{4}\right) = \frac{3}{4} = 0.75\,\Omega$

$X_{02} = X_{01}\left(\frac{1}{4}\right) = 1\,\Omega$

R_W & X_M are constant.

Referred to high voltage side,

$R_W' = R_W \times 4 = 1005.2\,\Omega$

$X_M' = X_M \times 4 = 10000\,\Omega$

Voltage Regulation

Fractional change in voltage

Efficiency

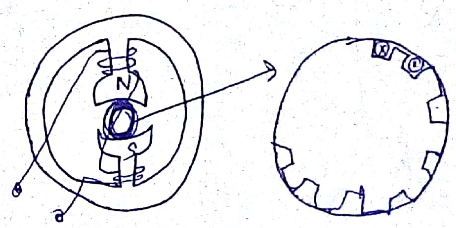
DC Machines

Parts: Stator & Rotor → Mechanical Part

Stator → Field windings

Rotor → Armature winding

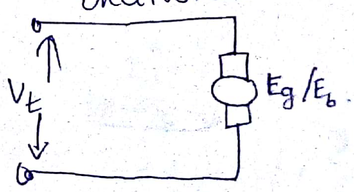
Field windings, Armature winding → Electric Part



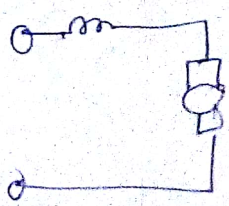
Works on dc supply

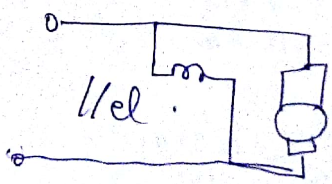
Symbol for dc machines.

Excitations.



Series





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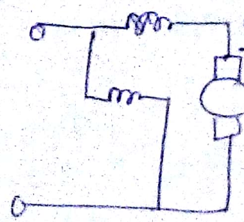


Compound

(Brush & Commutator assembly) in a d.c. machine

P → no. of poles

ϕ → flux due to each pole.

Each conductor cuts $P\phi$ flux in one complete rotation

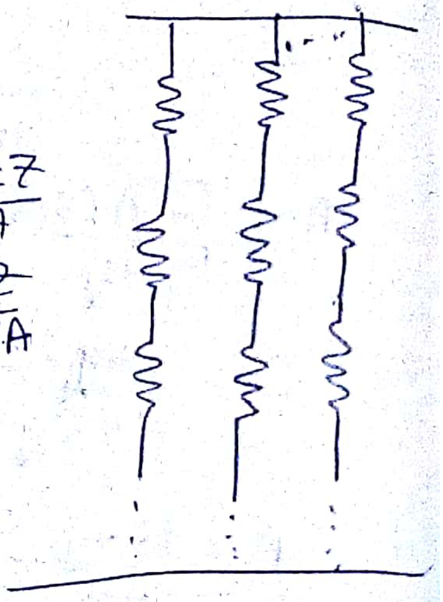
Z Conductors are connected in A parallel paths contain Z/A conductors in series.

N rpm is the speed

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

induced in one conductor

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



e.m.f for one parallel path $= \frac{e \times Z}{A}$

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

⇓

Known as generated e.m.f in case of generator

Back e.m.f in case of motor.

Types of Armature winding connection:

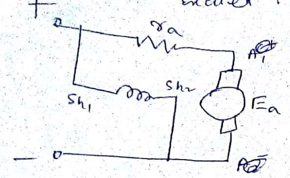
1) Wave connection → $A = 2 \times f$

2) Lap " → $A = P \times f$

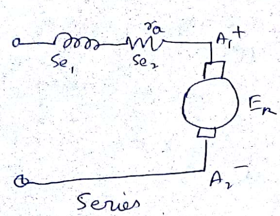
simplex, Duplex, Triplex

$f=1$, $f=2$, $f=3$.

2) Shunt Excited.

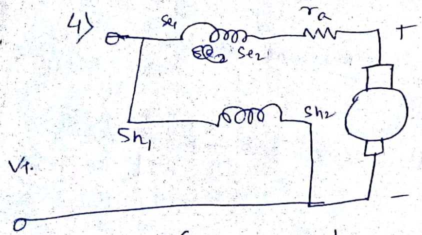


3)



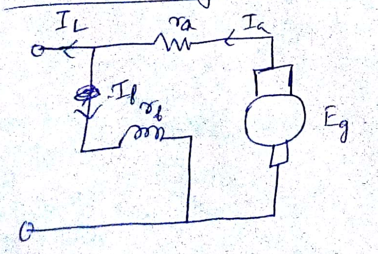
Series

4)



Compound.

As a generator



$I_a = I_L + I_f$.

$I_f = V_T / r_f$

$E_g = V_T + I_a r_a$

As a motor

direction of I_L & I_a reverses

$I_L = I_a + I_f$

$V_t = E_b + I_a r_a$

$$E_g = \frac{P \phi_g N_g Z}{60 A}$$

$$E_b = \frac{P \phi_m N_m Z}{60 A}$$

$$E_g / E_b = \frac{\phi_g N_g}{\phi_m N_m}$$

In a dc shunt M/C, field flux remains constant

A 300 V d.c. shunt M/C, takes a load current of 5A, the field resistance is 200 Ω, armature resi resistance is 1 Ω. Find out the ratio of the speed of the machine as a generator & motor

As a generator

$I_f = \frac{300}{200} = 1.5 A$; $I_L = 5A$

$\therefore I_a = 6.5A$

$E_g = 300 + 6.5 \times 1 = 306.5 V$

As a motor,

$I_L = I_a + I_f$

$\Rightarrow 5 = I_a + 1.5 \Rightarrow I_a = 3.5$

$E_b = 300 - 3.5 \times 1 = 296.5 V$

Since $\phi_m = \phi_g$ for shunt M/C

$$\frac{N_g}{N_m} = \frac{E_g}{E_b} = \frac{306.5}{296.5} = \frac{613}{593} = \boxed{1.033}$$

Armature Reaction

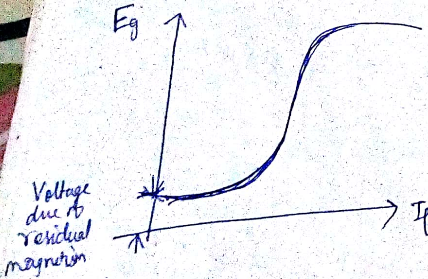
Reaction to armature current
→ generation of armature flux
→ leading to reduction of main field flux
→ Distortion of field flux waveform

Solution to detrimental effects of Armature reacⁿ:

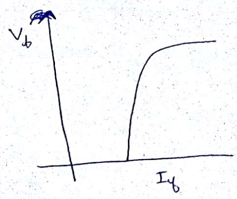
① Compensating Windings
it counteracts the flux generated by armature.

② Interpoles

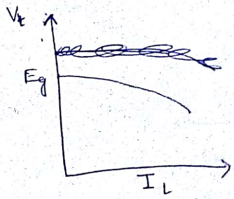
Characteristics of D.C. generators:
→ No load characteristics (E_g vs I_f).
→ Load " (V_t vs I_f)
→ External " (V_t vs I_L)
→ Armature " (I_f vs I_a)



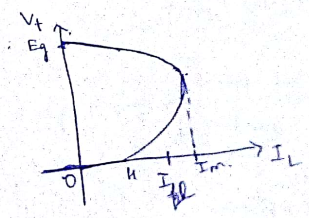
No load characteristics for All the four diff. Excitation modes.



Load characteristics for separately excited & series & shunt



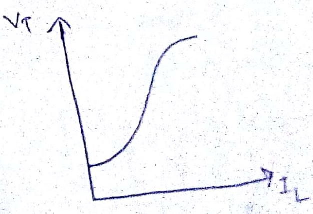
External characteristics for separately excited



For shunt

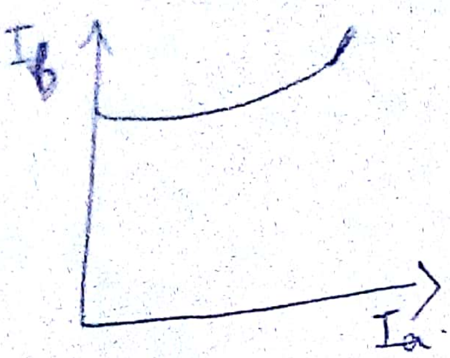
I_m = Max load current
I_{fl} = Full load current
OH = Current due to residual flux

For series



For compound.

Armature characteristics for separately excited D.C generator



<u>Torque equation of D.C - $\boxed{\text{motor}}$</u>

$$V_t = E_b + I_a r_a \quad \times I_a$$

$$I_a V_t = \underline{E_b I_a} + I_a^2 r_a .$$

O/P Mechanical Power.

$$\text{Power} = \text{angular speed} \times \text{Torque}$$

$$E_b I_a = \omega T.$$

$$= 2\pi n T$$

rps.

$$E_b I_a = 2\pi n T.$$

$$\Rightarrow \frac{P\phi N Z}{60 A} \cdot I_a = \frac{2\pi N}{60} \times T.$$

$$T = \frac{P\phi Z I_a}{2\pi A} = \frac{P\phi Z I_a}{2\pi A}$$

$$= \left(\frac{PZ}{2\pi A}\right) \phi I_a = K\phi I_a$$

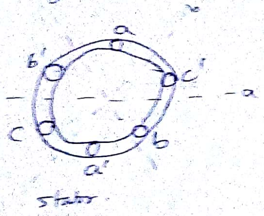
3 – phase induction motor

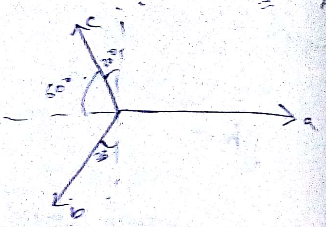
balanced supply

Stator $\longrightarrow$ Field
Rotor $\Rightarrow$ Armature

Rotating mag. field with a synchronous speed

$\Rightarrow N = \dfrac{120F}{P}$





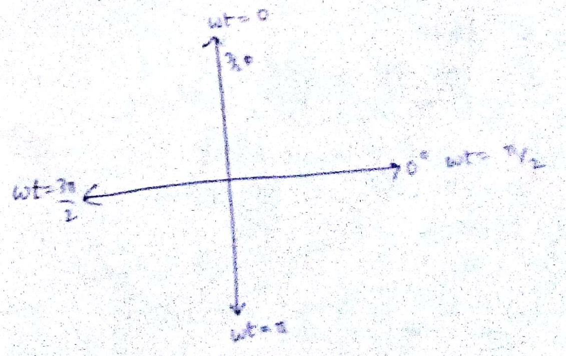
$\phi_a = \phi_m \sin\omega t$
$\phi_b = \phi_m \sin(\omega t - 120°)$
$\phi_c = \phi_m \sin(\omega t - 240°)$

$\phi_H = \phi_a - \phi_b \sin 30° - \phi_c \sin 30°$
$= \phi_m \sin\omega t - \phi_m \sin(\omega t - 120°)\sin 30° - \phi_m \sin(\omega t - 240°)\sin 30°$
$= \cancel{\phi_m [\sin\omega t - (\cos(\omega t - 150°)}$
$= \cancel{\sin\omega t - \frac{\cos(90° - \omega t) - \cos(\omega t - 90°)}{2}}$
$= \cancel{\phi_m \sin\omega t} - \phi_m \sin 30° [2\sin(\omega t - 300°) \sin(\omega$
$= \phi_m \sin\omega t - \phi_m \sin 30° (2\sin(\omega t - \ ) \sin 120°$

$\phi_H = \phi_a - \phi_b \sin 30° - \phi_c \sin 30°$
$= \phi_m \sin\omega t - \phi_m \sin 30° (\sin(\omega t - 120°) + \sin(\omega t - 240°))$
$= \phi_m \sin\omega t - \phi_m \sin 30° (2 \cdot \sin(\omega t - 180°) \cdot \cos 60°)$
$= \phi_m \sin\omega t - \frac{1}{2}\phi_m \cdot 2\left(\frac{-1}{2}\right)\sin(\omega t)$
$= \phi_m \sin\omega t + \frac{1}{2}\phi_m \sin\omega t$
$= \frac{3}{2}\phi_m \sin\omega t$

$\phi_V = \phi_c \sin 60° - \phi_b \sin 60°$
$= \phi_m \sin(\omega t - 240°) \sin 60° - \phi_m \sin(\omega t - 120°) \sin 60°$
$= \phi_m \sin 60° \{\sin(\omega t - 240°) - \sin(\omega t - 120°)\}$
$= \phi_m \sin 60° \cdot 2\cos(\omega t - 180°) \sin(-60°)$
$= \frac{3}{2}\phi_m \cos\omega t$

$\phi = \frac{3}{2}\phi_m \angle \tan^{-1}(\cot\omega t)$
$= \frac{3}{2}\phi_m \angle \tan^{-1}(\tan(\frac{\pi}{2} - \omega t))$



N_r = Rotor speed to oppose the main field flux.

$S = \dfrac{N_s - N_r}{N_s}$ = slip.

f' = freq. of e.m.f induced in rotor.
$= s \cdot f$.

A 4 pole - 3 phase induction machine runs at a speed of 1470 r.p.m. Find out the slip and the frequency of rotor e.m.f.

($f = 50 Hz$) if not mentioned.

$N_s = \dfrac{120 F}{P}$ $\qquad$ $N_s = \dfrac{\cancel{120}^{30} \times 50}{\cancel{4}} = 1500$.

$\therefore N_r = 1470$

$\therefore S = \dfrac{N_s - N_r}{N_s} = \dfrac{\cancel{30}}{\cancel{1500}_{50}} = \dfrac{1}{50}$

$\therefore f' = \dfrac{1}{50} \times 50 = 1 Hz$

$$\therefore T = \frac{K_1 K_2 E_1 s E_2 r_2}{r_2^2 + (sx_2)^2}$$

$$E_1 \propto E_2 \Rightarrow E_1 = K_3 E_2$$

$$\Rightarrow T = \frac{\frac{K_1 K_2}{K_3} (E_1)^2 \cdot s r_2}{(r_2)^2 + (sx_2)^2}$$

$$\Rightarrow T = \frac{K E_1^2 s r_2}{r_2^2 + (sx_2)^2}$$

$$= \frac{3}{\omega_s} \cdot \frac{E_1^2 s r_2}{r_2^2 + (sx_2)^2}$$

On starting $s = 1 \quad \because N_r = 0$

$, sx_2 >> r_2$

$$\therefore T \approx \frac{3}{\omega_s} \frac{E_1^2 \cancel{s} r_2}{\cancel{s^2} x_2^2}$$

$$\approx \frac{3}{\omega_s} \frac{E_1^2 r_2}{s x_2^2} \approx \frac{3}{\omega_s} \left(\frac{E_1}{x_2}\right)^2 \cdot \frac{r_2}{s}$$

$$\approx \frac{3}{\omega_s} (I_2)^2 \frac{r_2}{s}$$

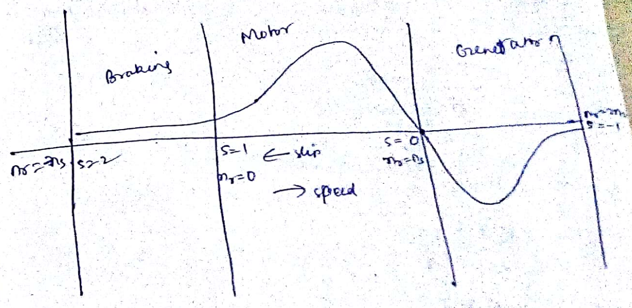
$$T \propto \frac{1}{s}$$

When ~~rotor~~ speed is very high,

$s << 1$

$\therefore T \propto s$

Torque slip characteristics.



For max. torque,

$E_1 = \text{const}$

$$T = \frac{K' s r_2}{r_2^2 + s^2 x_2^2}$$

$$= \frac{K' r_2}{\frac{r_2^2}{s} + s x_2^2}$$

For T to be max^m

$\frac{r_2^2}{s} + s x_2^2 =$ should be min^m

$$\frac{d}{ds}\left(\frac{r_2^2}{s} + s x_2^2\right) = 0$$

$$\Rightarrow -\frac{r_2^2}{s^2} + x_2^2 = 0 \Rightarrow \boxed{r_2 = s x_2}$$

$$\therefore T = \frac{K' s x_2}{2 s x_2^2} = \frac{K'}{2 x_2}$$

$$\therefore T = \frac{3 E_1^2}{2 \omega_s x_2}$$

$$\frac{T}{T_{max}} = \frac{2S \cdot S_{max}}{S^2 + S_{max}^2}$$

S_{max} = frequency slip at which max. torque occurs

$$\frac{T_s}{T} = \frac{S^2 + s_{max}^2}{s(1 + s^2_{max})}$$

T_s = starting Torque

$$T = \frac{K E_1^2 s r_2}{r_2^2 + (s x_2)^2}$$

$$T_{max} = \frac{K E_1^2}{2 x_2}$$

$$\frac{T}{T_{max}} = \frac{\dfrac{\cancel{K E_1^2} s r_2}{r_2^2 + (s x_2)^2}}{\dfrac{\cancel{K E_1^2}}{2 x_2}} = \frac{2 s x_2 r_2}{r_2^2 + (s x_2)^2}$$

$$= \frac{2 s s_{max} x_2^2}{s_{max}^2 x_2^2 + s^2 x_2^2}$$

$$= \frac{2 s s_{max}}{s^2 + s_{max}^2}$$

alternator coils are thick copper coils

Magnet rotates instead of coils because the commutator ring

Principle of OP^n

Cylindrical rotors & Salient/Pole rotors

$\boxed{\text{Assume delta connection if nothing is mentioned}}$

2 pole machine must rotate at twice the speed of 4 pole M/c to generate same freq

$$f = N_s \times \frac{P}{2} \times \frac{1}{60}$$

$\boxed{\text{speed = rpm}}$

Open circuit characteristics

ϕ = Flux / pole

P = No. of poles

N_s = Synchronous

form factor of sine = 1.11 = e_{rms}/e_{avg}

---

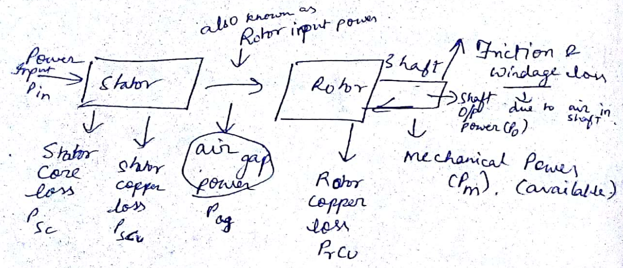
1. delta armature → delta load
2. delta " → star load

Power & Losses

2 types:

1) Fixed loss (No load, iron, hysteresis, eddy.)

2) Variable loss (.



$$P_{rCu} = s.P_{ag}$$

$$P_m = (1-s)P_{ag} = P_{ag} - P_{rCu}$$

Q/ Rotor output power of 3 phase induction motor is 15 kW, Find out the rotor copper loss at 4% slip.

$$15 = 0.96 \times P_{ag}$$

$$P_{rCu} = \frac{15}{0.96} \times 0.04 = 0.625\ kW$$

Q/ A 4 pole 3-phase induction motor is running at 1440 rpm. Rotor input power is 3 kW (or 2 kW)

Find P_{rCu} & P_M

$$N_s = \frac{120 \times 50}{4} = 1500$$

$$N_r = 1440$$

$$\therefore s = \frac{N_s - N_r}{N_s} = \frac{60}{1500} = \frac{4}{100} = 0.04$$

$$P_{rCu} = 0.04 \times 3 \times 1000 = 120\ W$$

$$P_M = 3000 - 120 = 2880\ W = 2.88\ kW$$

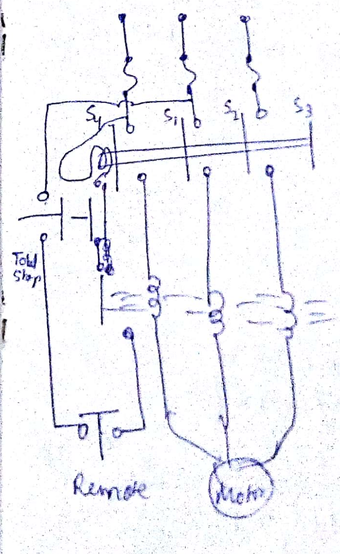
Q//

Direct-on-line

Starter of induction motor

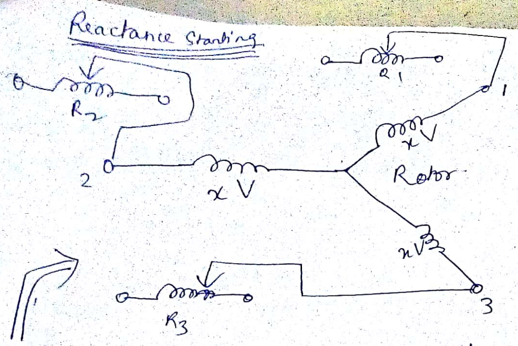
Disadvantage

It has very high starting current



OLC overload control

Reactance Starting



If V is the applied ...

Such an arrangement is provided to vary the reactance dynamically so that initial high current is reduced and later on the reactances R_1, R_2, R_3 can be bypassed

$$\underset{\text{starting current in reactance}}{I_{st}} = \underset{\text{Reduction factor}}{x}\ \underset{\text{starting current in DOL}}{I_{sc}}$$

$$\text{Torque} \propto E_1^2$$

$$\therefore \propto (xV)^2$$

$$T_{st} = I_{2st}^2 \frac{r_2}{1}$$

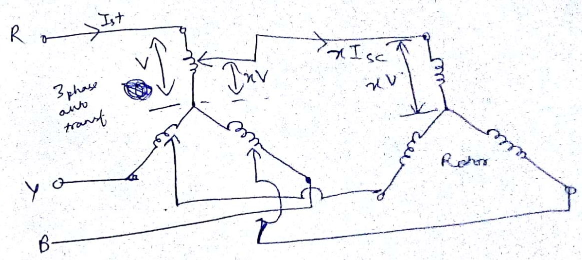
$$T_F = I_{2fl}^2 \cdot \frac{r_2}{s_{fl}}$$

$$T = \frac{K \cdot E_1^2 r_2 s}{r_2^2 + (s x_2)^2} = \frac{K E_1^2 s r_2}{s^2 \left\{ \left(\frac{r_2}{s}\right)^2 + x_2^2 \right\}}$$

$$= \frac{K E_1^2 r_2}{s \left\{ \underbrace{\sqrt{\left(\frac{r_2}{s}\right)^2 + (x_2)^2}}_{Z} \right\}^2} = \frac{K I_2^2 r_2}{s}$$

Auto transformer starting

primary & secondary are electrically connected



Voltage reduces by x

Current " " x^2 (per phase values)

Torque

In an transformer Volt - Ampere is const

$$xV \cdot x I_{sc} = V I_{st}$$

$$I_{st} = x^2 I_{sc}$$

Star Delta starting