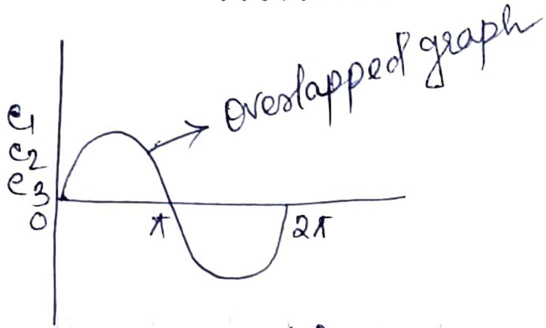
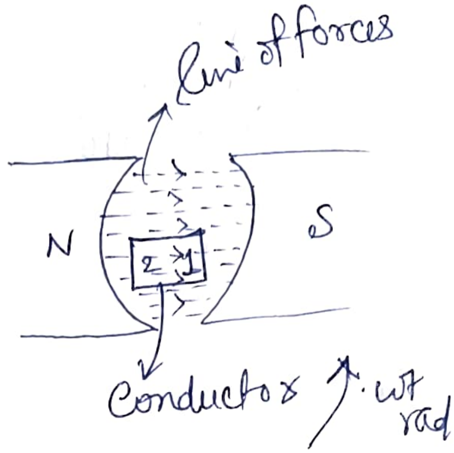
THREE PHASE AC

Introduction to 3ϕ AC:-

Generation of 3ϕ AC:-





$e = -N.\frac{d\phi}{dt}$ $N_1 = N_2 = N_3$

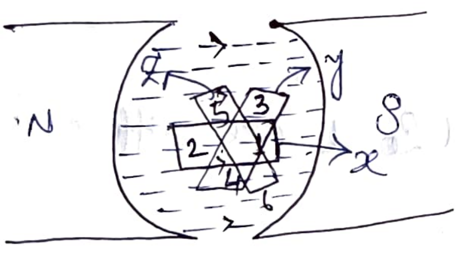
Magnetic field same, $\phi_1 = \phi_2 = \phi_3$

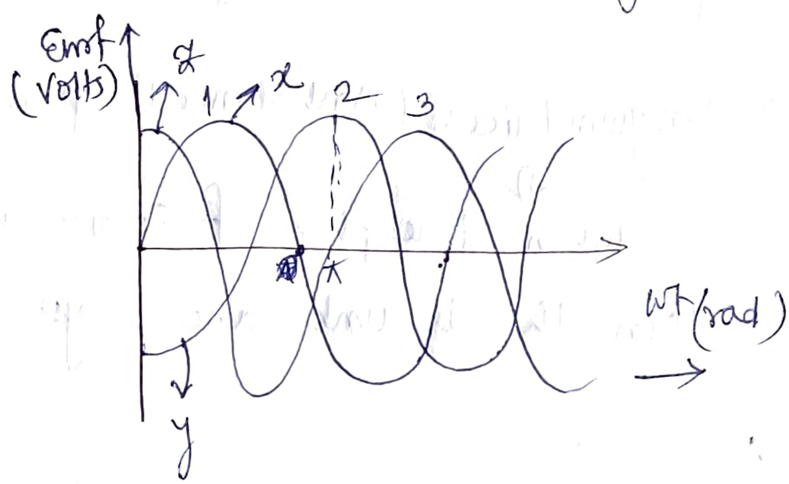
so, $e_1 = e_2 = e_3$.

Phase difference angle $= \frac{360 \text{ Electrical degree}}{N \text{ (no. of Phase)}}$

$\phi = \frac{360^\circ}{3} = 120^\circ$

For two phase, $\phi = \frac{360}{2} = 180^\circ$, so two phase AC not generated



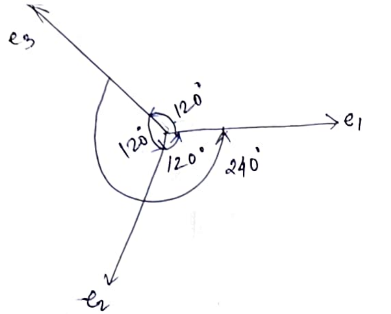


B = Tesla
$H = \frac{NI}{l}$
Constant

$e_1 = E_m \sin \omega t$ —— (1)

$e_2 = E_m \sin (\omega t - 2\pi/3)$ —— (2)

$e_3 = E_m \sin (\omega t - 4\pi/3)$ —— (3)



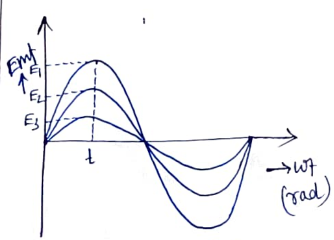
Phase Sequence:- It is a sequence or order in which the alternating quantities attain their positive peak values.

R → Red
Y → Yellow
B → ~~Black~~ Blue

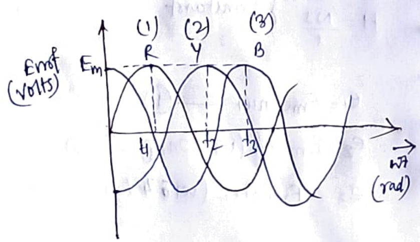
Types of Three phase AC:-

① Symmetrical (Balanced System) → Source: Three phase Magnitude equal; Load: Three phase or Impedence equal.

② Unsymmetrical (Unbalanced System)
When three phase of Source and Load are different then this is unbalanced System.



(No phase diff due to attain peak value in same time)



$E_m = E_{m1} = E_{m2} = E_{m3}$

R Y B → Positive Phase Sequence

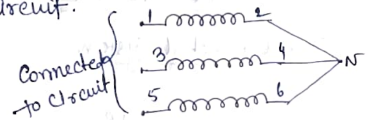
B Y R → Negative Phase Sequence.

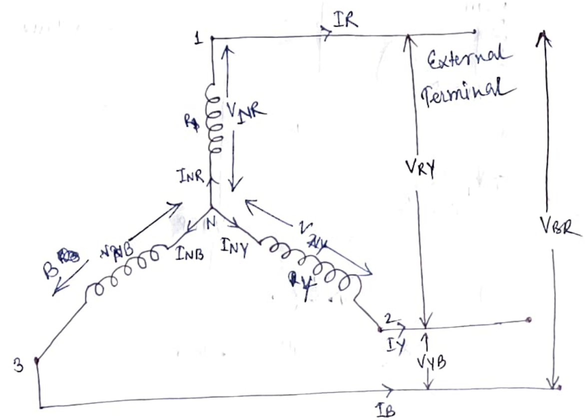
Connection of 3φ AC

- Star Connection
- Delta Connection

Star Connection:- (Balanced Circuit)

It is a type of connection where one terminal from each winding is connected to a common point and the remaining three terminal are connected to the circuit.





3 phase AC Generator ke liye sab Current Outgoing hain.
3 " " Motor " " Current incoming hota hain.

Line Quantities:-

(a) Line Voltages: $V_{RY} = V_{YB} = V_{BR} = V_L$

(b) Line current: $I_R = I_Y = I_B = I_L$

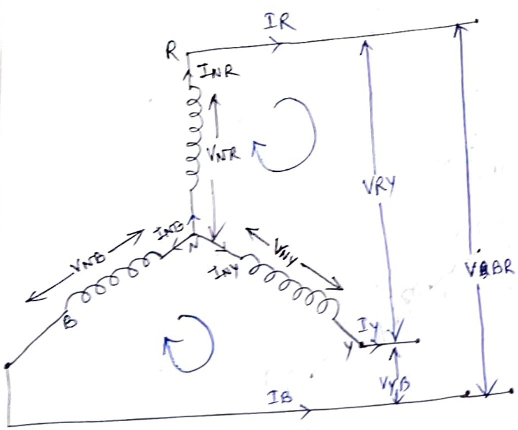
(equal due to Balanced System)

Phase Quantities:-

(a) phase Voltages: $V_{NR} = V_{NY} = V_{NB} = V_{ph}$

(b) Phase Currents: $I_{NR} = I_{NY} = I_{NB} = I_{ph}$

Relation between Line and phase Quantity for a Balanced 3 ϕ Star Connected System:-



--→ phase
--→ Line

For a Balanced 3 ϕ Connection:-

Line Currents:- $I_R = I_Y = I_B = I_L$

Line Voltages:- $V_{RY} = V_{YB} = V_{BR} = V_L$

(a) Relation between Line and Phase Currents:-

$I_{NR} = I_R$

$I_{NY} = I_Y$

$I_{NB} = I_B$

$\rightarrow \boxed{I_{ph} = I_L}$

(b) Relation b/w Line and Phase Voltages:-

Applying KVL in mesh NRYN,

$\vec{V}_{NR} + \vec{V}_{RY} - \vec{V}_{NY} = 0$

$\Rightarrow \vec{V}_{RY} = \vec{V}_{NY} - \vec{V}_{NR}$ —— (i)

Applying KVL in mesh NYBN,

$-\vec{V}_{NB} + \vec{V}_{NY} + \vec{V}_{YB} = 0$

$\Rightarrow \vec{V}_{YB} = \vec{V}_{NB} - \vec{V}_{NY}$ —— (ii)

Applying KVL in mesh NRBN,

$\vec{V}_{NR} - \vec{V}_{BR} - \vec{V}_{NB} = 0$

$\Rightarrow \vec{V}_{BR} = \vec{V}_{NR} - \vec{V}_{NB}$ —— (iii)

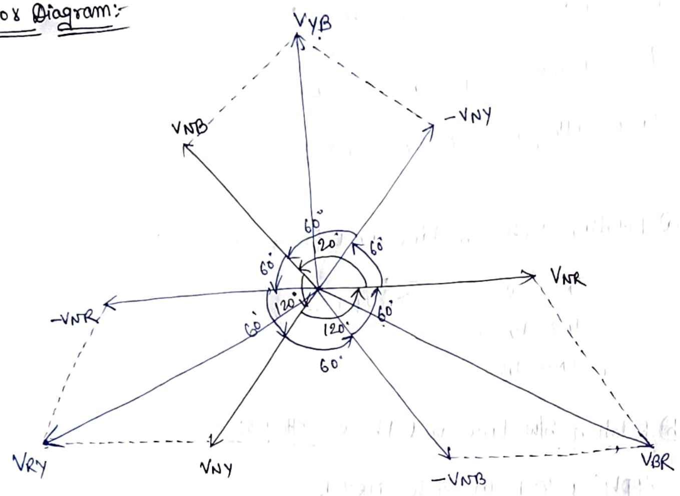
From eqn (1)

$V_{RY} = \sqrt{V_{NY}^2 + V_{NR}^2 + 2 V_{NY} V_{NR} \cos\phi}$

$\Rightarrow V_L = \sqrt{V_{ph}^2 + V_{ph}^2 + 2 V_{ph}^2 \cos 60^\circ}$

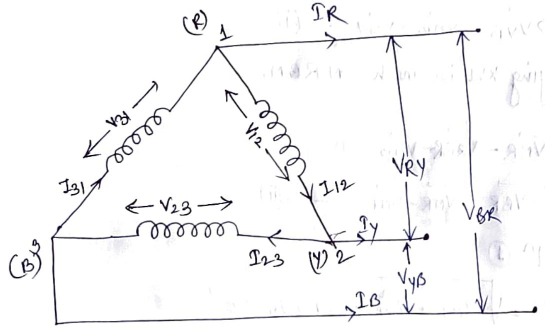
$\Rightarrow V_L = \sqrt{3}\, V_{ph}$ $\therefore \boxed{V_L = \sqrt{3}\, V_{ph}}$

Phasor Diagram:-



Delta Connection:-

→ It is a type of connection of 3 ϕ windings where all the coils are connected in a back to back arrangement.



Line Quantities:-

(a) Line Voltages:- $V_{RY} = V_{YB} = V_{BR} = V_L$

(b) Line Currents:- $I_R = I_Y = I_B = I_L$

Phase Quantities:-

(a) ~~Line~~ Phase Voltages :- $V_{12} = V_{23} = V_{31} = V_{ph}$

(b) Phase Currents:- $I_{12} = I_{23} = I_{31} = I_{ph}$

Relation B/w Line and Phase Voltages:-

$V_{RY} = V_{12}$ — (i)

$V_{YB} = V_{23}$ — (ii)

$V_{BR} = V_{31}$ — (iii)

$\boxed{V_L = V_{ph}}$

Reln b/w Line & phase Currents:-

By Applying KCL at Jn R,

$$\vec{I}_{31} - \vec{I}_{12} - \vec{I}_R = 0$$

$$\Rightarrow \boxed{\vec{I}_R = \vec{I}_{31} - \vec{I}_{12}}$$

Applying KCL at Jn Y,

$$\vec{I}_{12} - \vec{I}_{23} - \vec{I}_Y = 0$$

$$\Rightarrow \boxed{\vec{I}_Y = \vec{I}_{12} - \vec{I}_{23}}$$

Applying KCL at Jn B,

$$-\vec{I}_{31} + \vec{I}_{23} - \vec{I}_B = 0$$

$$\Rightarrow \boxed{\vec{I}_B = \vec{I}_{23} - \vec{I}_{31}}$$

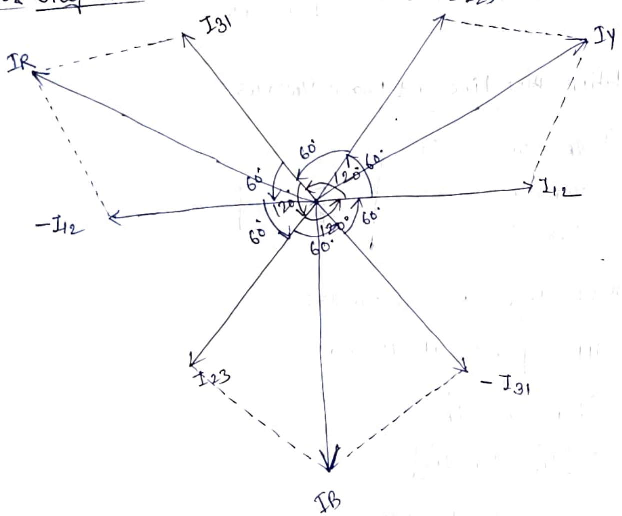
Taking eqⁿ (1),

$$I_R = \sqrt{(I_{31})^2 + (I_{12})^2 + 2 I_{31} I_{12} \cos\phi}$$

$$\Rightarrow I_L = \sqrt{I_{ph}^2 + I_{ph}^2 + 2 I_{ph}^2 \cos 60^\circ}$$

$$\Rightarrow \boxed{I_L = \sqrt{3}\, I_{ph}}$$

Phasor Diagram :-



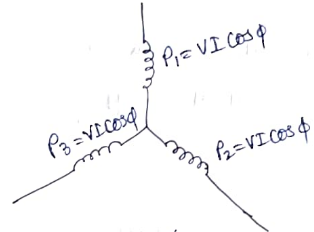
÷ Power in 3ϕ AC Circuit ÷

(a) Active Power (P) = $V_{rms} I_{rms} \cos\phi$

(b) Reactive Power (Q) = $V_{rms} I_{rms} \sin\phi$

(c) Apparant power (S) = $V_{rms} I_{rms}$

Star Connection

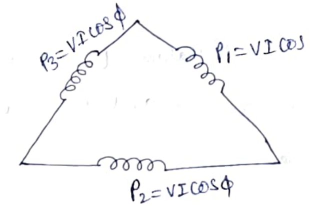


$V_1 = V_2 = V_3 = V_{ph}$

$I_1 = I_2 = I_3 = I_{ph}$

$$\boxed{P_T = 3 V_{ph} I_{ph} \cos\phi}$$

Delta Connection



$V_1 = V_2 = V_3 = V_{ph}$

$I_1 = I_2 = I_3 = I_{ph}$

$$\boxed{P_T = 3 V_{ph} I_{ph} \cos\phi}$$

Power in 3ϕ AC	Interms of Phase Quantity	Interms of line Quantity
(i) A.P =	$3 V_{ph} I_{ph} \cos\phi$ (Watts)	*** A.P = $\sqrt{3} V_L I_L \cos\phi$ (Watts)
(ii) R.P =	$3 V_{ph} I_{ph} \cos\phi$ (VAR)	R.P = $\sqrt{3} V_L I_L \sin\phi$ (VAR)
(iii) Apparant P =	$3 V_{ph} I_{ph} \cos\phi$ (VA)	App P = $\sqrt{3} V_L I_L$ (VA)

Same of Star & Delta Connⁿ.

* Star

$I_L = I_{ph}$

$V_L = \sqrt{3} V_{ph}$

$P_{lin} = 3 \cdot \frac{V_L}{\sqrt{3}} \cdot I_L \cos\phi$

$\Rightarrow \boxed{P_{lin} = \sqrt{3} V_L I_L \cos\phi}$

Delta

$V_L = V_{ph}$

$I_L = \sqrt{3} I_{ph}$

$\boxed{P_{lin} = \sqrt{3} V_L I_L \cos\phi}$

Same for Star & Delta

÷ Numericals on 3 phase AC circuits ÷

Q. If a 3ϕ Balanced star connected system is having a coil of resistance 10Ω and inductance 0.75 mH at a supply of 3A. Calculate —

(a) Total Impedence

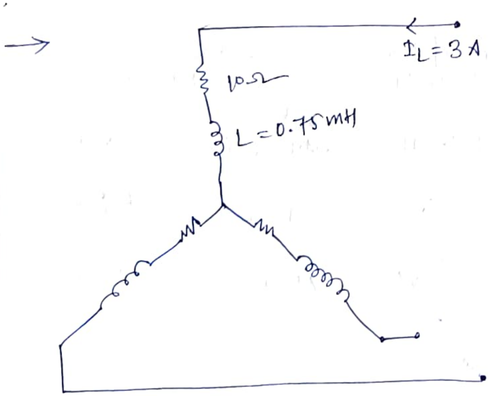
(b) Total Supply Voltage

(c) Net power

(d) Phasor

Z → Always in term of phase
V, I, P → Always Calcule in line form ~~until the question is in phase~~
(যতক্ষণ না বলবে phase বের করতে)

→



$R = 10\Omega$, $L = 0.75 \times 10^{-3}$ H

$X_L = 2\pi f L = 2\pi \times 50 \times 0.75 \times 10^{-3}$

$= 0.235\Omega$

(a) Impedence $(Z_{ph}) = \sqrt{R^2 + X_L^2}$

$= \sqrt{10^2 + 0.235^2}$

$= 10.002\Omega$.

(2) $V_L = I_L \times Z_{ph}$

$\therefore V_{ph} = I_{ph} \times Z_{ph}$

$I_{ph} = I_L = 3A$ for 3ϕ balanced star connected system.

$V_{ph} = 3 \times 10.002 = 30.006$ V

$V_L = \sqrt{3} \cdot V_{ph} = \sqrt{3} \times 30.006$ V

$= 51.971$ V.

(3) Net power $(P) = \sqrt{3} \times V_L I_L \cos\phi$

$= \sqrt{3} \times 51.971 \times 3 \times 0.999$ W

$= 269.779$ W.

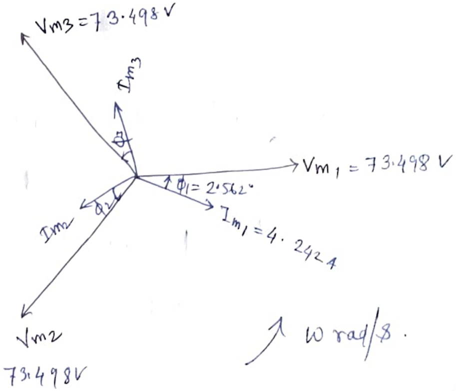
$\cos\phi = \frac{R}{Z_{ph}} = \frac{10}{10.002} = 0.999$

(4) Phasor

$V_m = 51.971 \times \sqrt{2} = 73.498\ V = V_{m_1} = V_{m_2} = V_{m_3}$

$I_m = 3 \times \sqrt{2} = 4.242\ A = I_{m_1} = I_{m_2} = I_{m_3}$

$\phi = \cos^{-1}(0.999) = 2.562° = \phi_1 = \phi_2 = \phi_3$



Q. If a load of $Z = 3-7j\,\Omega$ in series with an inductor of 5Ω is connected in a balanced 3-phase delta connection across 440V, 50 Hz supply. Then calculate —

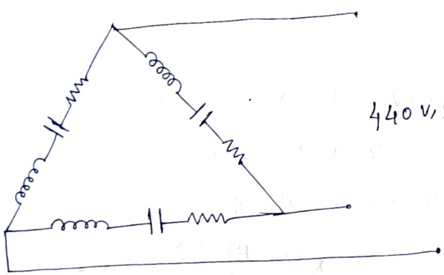
(a) Total Impedence

(b) Net Supply Current.

(c) If same load at same current is connected in 3-phase balanced star formation, find its KVAR Rating.

(d) Phasor

→ $R = 3\Omega$, $X_C = 7\Omega$ $X_L = 5\Omega$, $V_L = 440V$, $f = 50Hz$.



① $Z_T = Z_{ph} = \sqrt{R^2 + (X_C - X_L)^2} = \sqrt{9+4}$ $\{X_C > X_L\}$

$= \sqrt{13} = 3.605\Omega$.

(ii) $I_{ph} = \frac{V_{ph}}{Z_{ph}} = \frac{440}{3.605} A$ [for delta, $V_L = V_{ph}$]

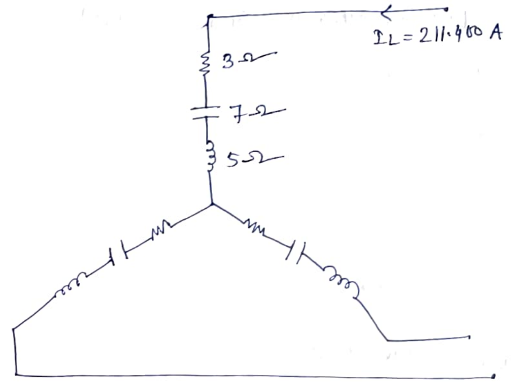
$= 122.052 A$.

$I_L = \sqrt{3}\, I_{ph}$

$= \sqrt{3} \times 122.052$

$= 211.400 A$.

③



$KVAR(Q) = \sqrt{3}\, V_L I_L \sin\phi$

Here use same load so, the Impedence will be same.

$Z_{ph} = 3.605 A$.

$I_L = 211.400 A$.

$I_{ph} = 211.400 A$. $\{I_L = I_{ph}$ for star$\}$

$V_{ph} = I_{ph} \cdot Z_{ph} = 211.400 \times 3.605 V$

$= 762.097 V$

$V_L = \sqrt{3} \times 762.097 V$

$= 1319.990 V$.

$\cos\phi = \frac{R}{Z} = \frac{3}{3.605} = 0.832$

$\Rightarrow \phi = 33.695°$

$\therefore Q = \sqrt{3} \times 1319.990 \times 211.400 \times \sin(33.695°)$

$= 268133.234$ VAR

$= 268.133$ KVAR.

(4) Phasor

$V_m = 440 \times \sqrt{2} = 622.253$ V

$I_m = \sqrt{2} \times 211.400 = 298.964$ A

$\phi = 33.695°$