



The Shirpur Education Society's

R. C. Patel College of Engineering and Polytechnic, Shirpur
Department of Electrical Engineering

Notes

Unit - III

Three Phase Circuits

NAME OF COURSE: - ELECTRICAL CIRCUITS AND NETWORK

CODE OF COURSE: - 313332

SEMESTER: - SYEE-3K

SUBJECT TEACHER: - Mr. Jayesh M. Suryawanshi

Unit 3: Three phase circuit.

(12-Marks)

Subject: ECN (313332)

Prepared by: Mr. J. M. Suryawanshi

Generation of three phase alternating emf

The generation of three phase alternating emf is based on the principle of electromagnetic induction.

Principle:

"When conductor cuts magnetic flux, an EMF is induced in it" According to Faraday's law of electromagnetic induction.

In three phase alternator

Three separate armature windings are placed on the stator.

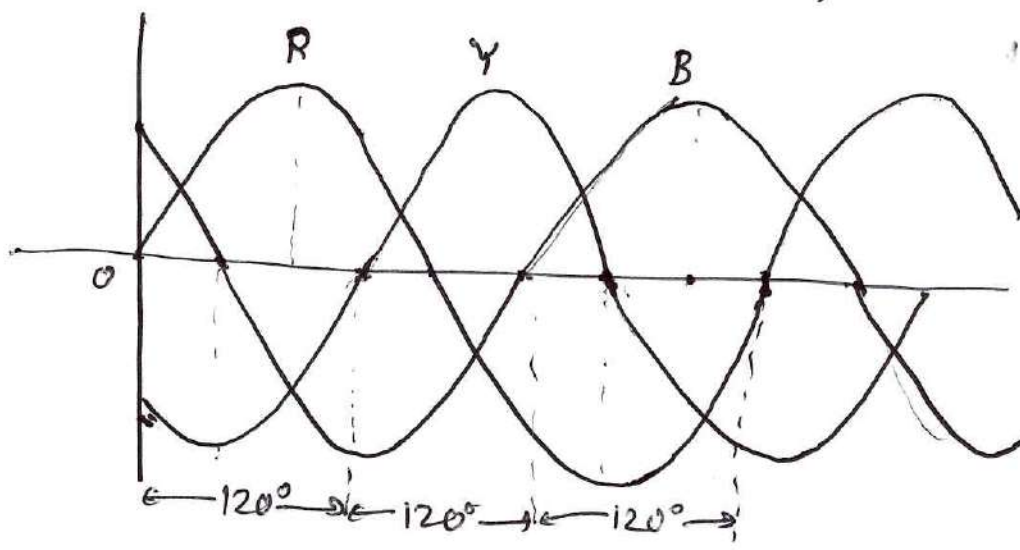
These windings are spaced 120° electrical apart.

A rotating magnetic field cuts these windings.

As the rotor rotates, sinusoidal EMFs are induced in each winding.

Because the windings are displaced by 120° , the induced EMFs are also displaced in phase by 120° .

Waveform of three phase voltages.



Representation of three phase EMF

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

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

$$V_B = V_m \sin(\omega t - 240^\circ) = V_m \sin(\omega t + 120^\circ)$$

Where

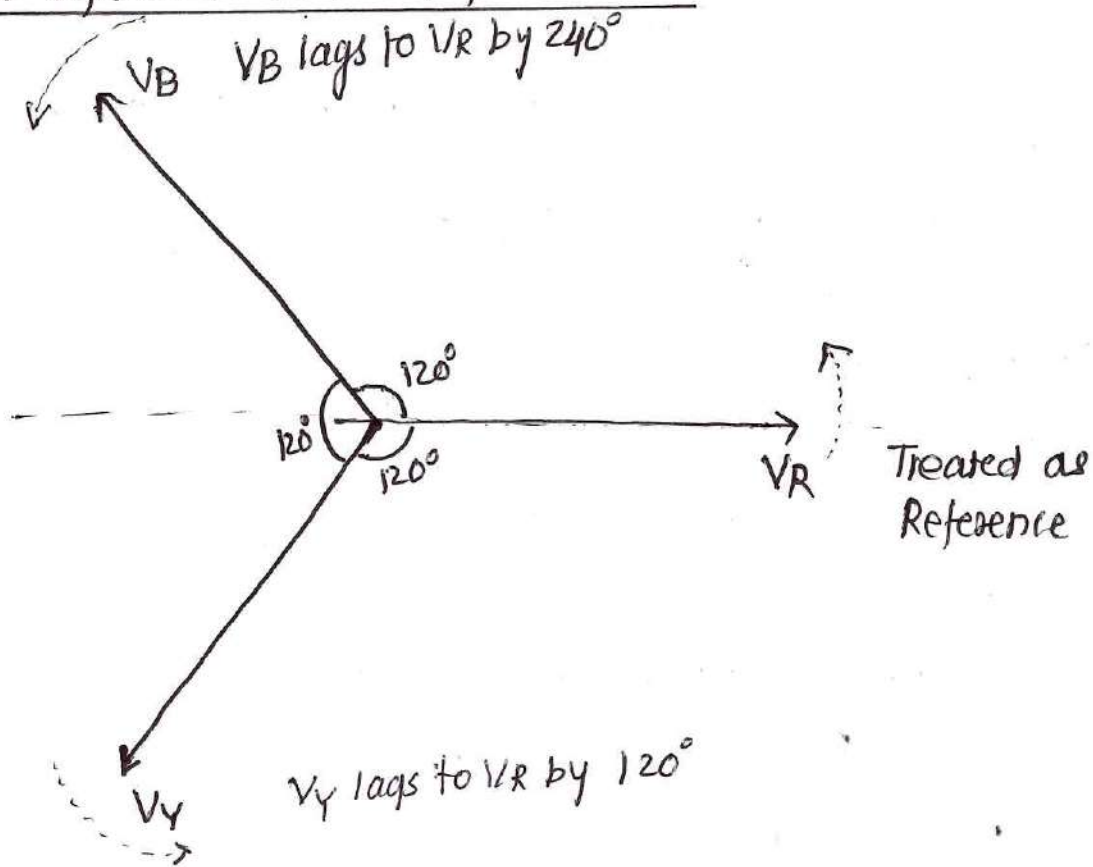
V_R, V_Y, V_B = Voltages of three phases R, Y, B.

V_m = Maximum voltages.

ω = angular velocity

t = time

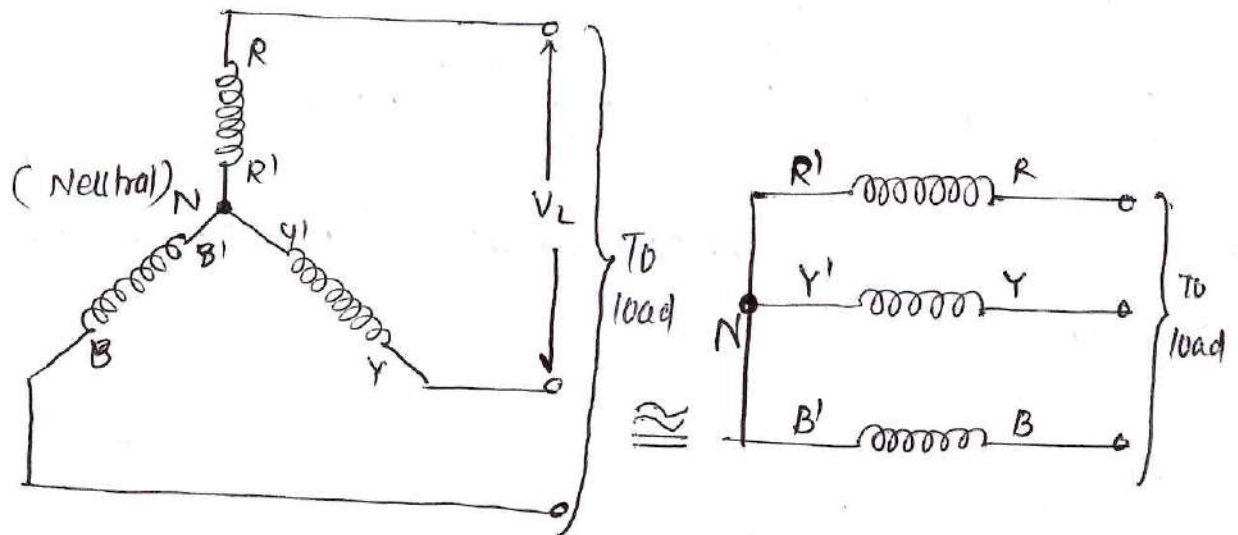
Phasor representation of phasor



Types of three phase connection

- 1) star connection
- 2) Delta connection

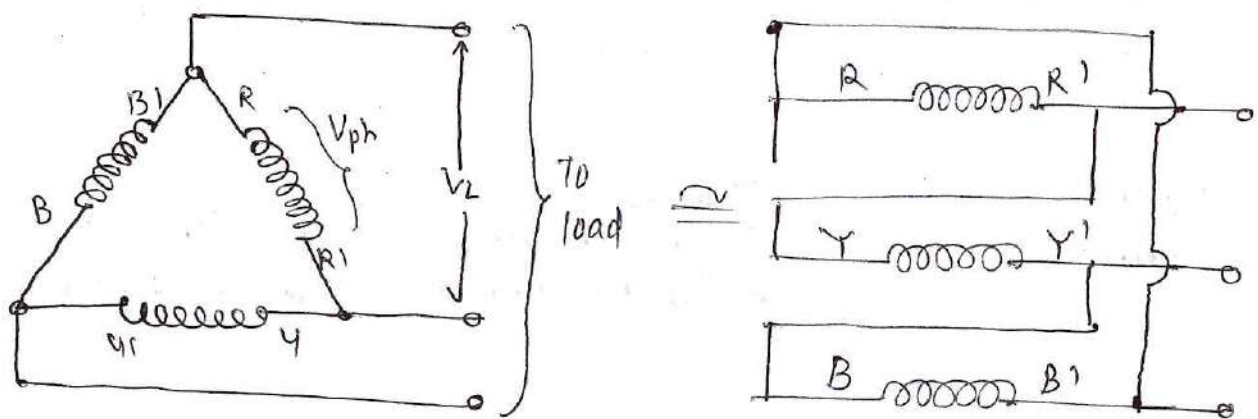
1) star connection (Wye connection)



The star connection of alternator shown in above figure.

Star connection obtained by connecting one end of three phase winding together.

2) Delta connection (Mesh connection)



The Delta connection of alternator shown in above figure.

Delta connection obtained by connecting one end of winding to starting end of other winding

Phase Sequence

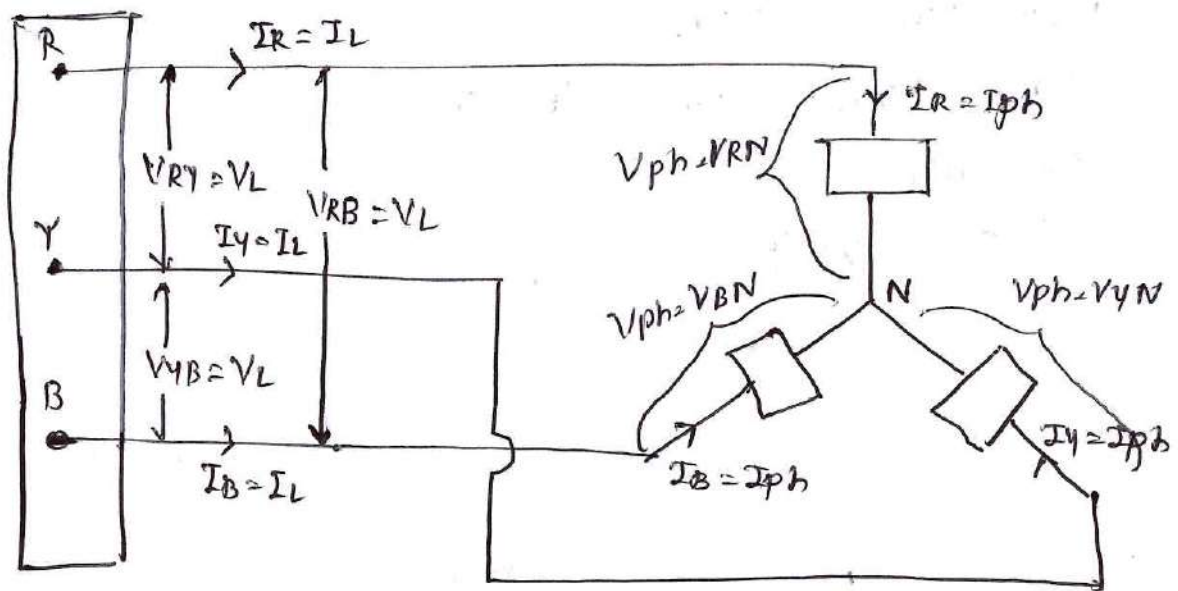
The phase sequence is defined as the sequence in which the three phases reach their maximum positive values.

Phase sequence is R-Y-B

Comparison of Single phase & Three phase circuit

Sl. No	Points	Single phase circuit	Three phase circuit
①	No. of phases	One or two	Three or four
②	Phase difference	NO	120° phase displacement bet ⁿ phases.
③	Power delivery	Pulsating	Constant
④	Efficiency	Less	More
⑤	Transmission Cost	Higher for large power	Lower for large power transmission
⑥	Copper Requirement	Less More conductor material needed	less conductor material needed
⑦	Maintenance cost	Lower for small system	Economical for large system

Relation between voltages & current (phase & line values)
for Balance star load.



Three phase
Supply connection

Balance load.

Line voltage: The potential difference between any two line is known as line voltage (V_L)

$$V_L = V_{RY} = V_{YB} = V_{BR}$$

Line current: The current flowing through line is known as line current. (I_L)

$$I_L = I_R = I_Y = I_B$$

Phase voltage: The potential difference measure across phase is known as phase voltage (V_{ph})

$$V_{ph} = V_{RN} = V_{YN} = V_{BN}$$

Phase current: The current flowing through any branch of the star connected load is known as phase current (I_{ph})

$$I_{ph} = I_R = I_Y = I_B$$

For Balance star connected load

$$I_L = I_{ph}$$

Derive relation between V_L & V_{ph} from above

$$V_{RY} = V_{RN} + V_{NY}$$

But $V_{NY} = -V_{YN}$

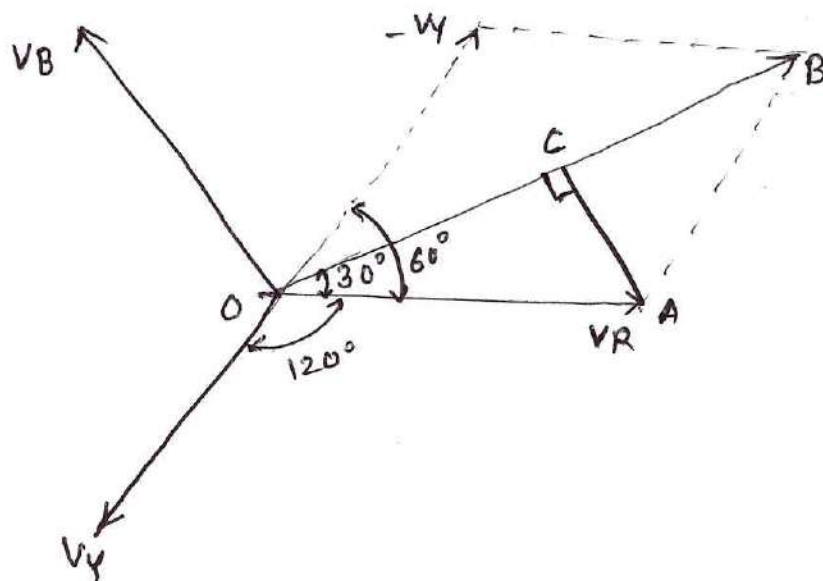
$$V_{RY} = V_{RN} - V_{YN} = V_R - V_Y \quad \text{--- (1)}$$

Similarly

$$V_{YB} = V_Y - V_B \quad \text{--- (2)}$$

$$V_{BR} = V_B - V_R \quad \text{--- (3)}$$

The phasor diagram of V_{RY} is shown below



The perpendicular is drawn from point A on vector V_R to vector OB

Hence OC bisects angle between V_R & $-V_Y$

$$\angle GOA = 30^\circ$$

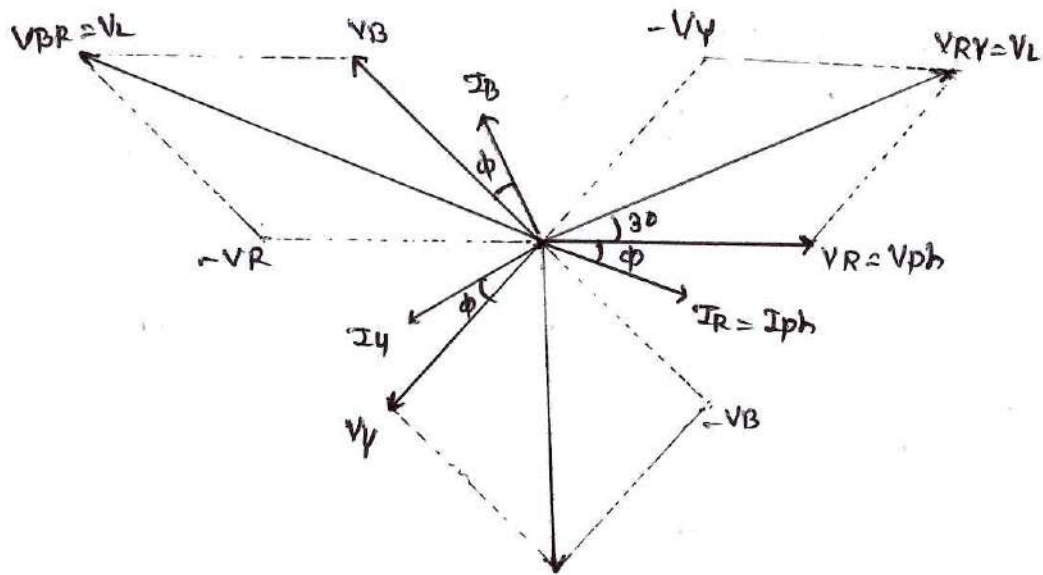
From $\triangle OBA$

$$\cos 30^\circ = \frac{OC}{OA} = \frac{V_{RY}/2}{V_R} = \frac{V_L/2}{V_{ph}}$$

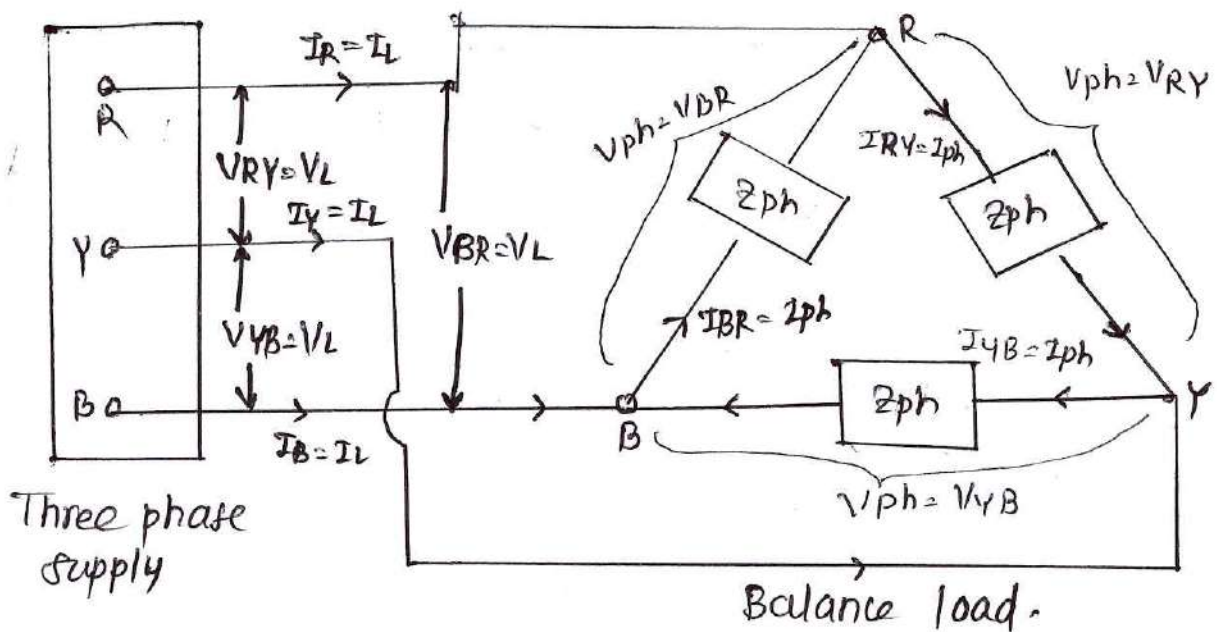
$$\frac{\sqrt{3}}{2} = \frac{V_L/2}{V_{ph}}$$

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

$$\boxed{V_L = \sqrt{3} V_{ph}} \text{ volt}$$



Relation between voltage & current for Balance Delta load



line voltage = $V_L = V_{RY} = V_{YB} = V_{BR}$

line current = $I_L = I_R = I_Y = I_B$

Phase voltage = $V_{ph} = V_{RY} = V_{YB} = V_{BR}$

Phase current = $I_{ph} = I_{RY} = I_{YB} = I_{BR}$

For Delta connected load

$$V_{ph} = V_L$$

Derive relation between line current & phase current
(I_{ph} & I_L)

Apply KCL at node R

\sum current entering at node R = \sum Current leaving from node R

$$\vec{I}_R + \vec{I}_{BR} = \vec{I}_{RY}$$

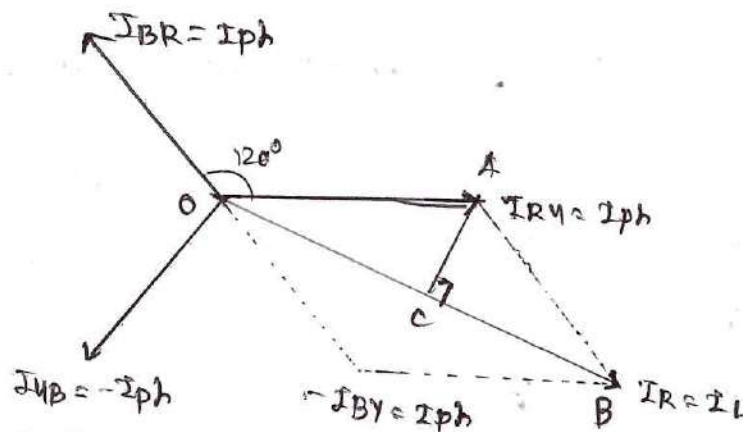
$$\vec{I}_R = \vec{I}_{RY} - \vec{I}_{BR} \quad \text{--- (1)}$$

Similarly

$$\vec{I}_Y = \vec{I}_{YB} - \vec{I}_{RY} \quad \text{--- (2)}$$

$$\vec{I}_B = \vec{I}_{BR} - \vec{I}_{YB} \quad \text{--- (3)}$$

Phasor diagram for I_{RY}



$$\angle BOA = 30^\circ$$

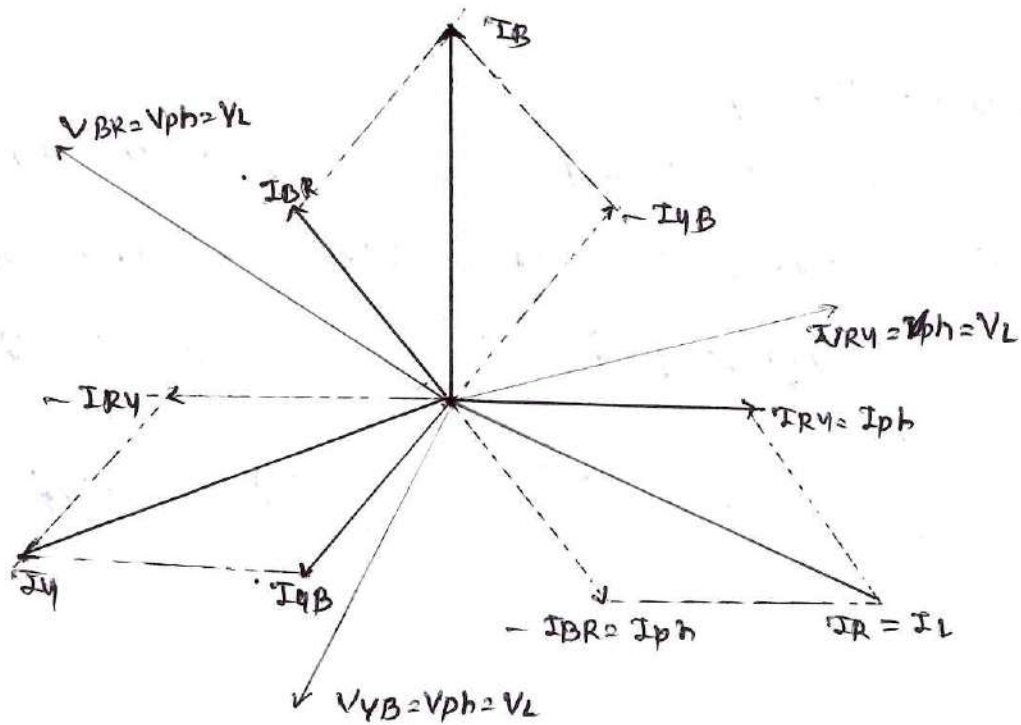
$$OC = CB = I_L/2$$

From triangle OAB

$$\cos 30^\circ = \frac{OC}{OA} = \frac{I_L/2}{I_{RY}}$$

$$\frac{\sqrt{3}}{2} = \frac{I_L/2}{I_{ph}}$$

$$\boxed{I_L = \sqrt{3} I_{ph}} \quad \text{Amp}$$



Active power (P)

Active power consumed by 3 ϕ system is defined as the product of $\sqrt{3}$ times of Line voltage, Line current cosine angle between voltage & current.

It is denoted by P & SI unit is Watt or kW

$$P = \sqrt{3} V_L I_L \cos \phi \quad \text{Watt or kW}$$

Reactive power (Q)

Reactive power in 3 ϕ system is defined as the product of $\sqrt{3}$ times of Line voltage, Line current & sine angle between voltage & current.

It is denoted by Q & SI unit is VAR or KVAR

$$Q = \sqrt{3} V_L I_L \sin \phi \quad \text{VAR or KVAR}$$

Apparent Power

The apparent power is defined as the product of $\sqrt{3}$ times of line voltage & Line current

It is denoted by S & SI unit is VA or KVA

$$S = \sqrt{3} V_L I_L \quad \text{VA or KVA}$$

Balance load

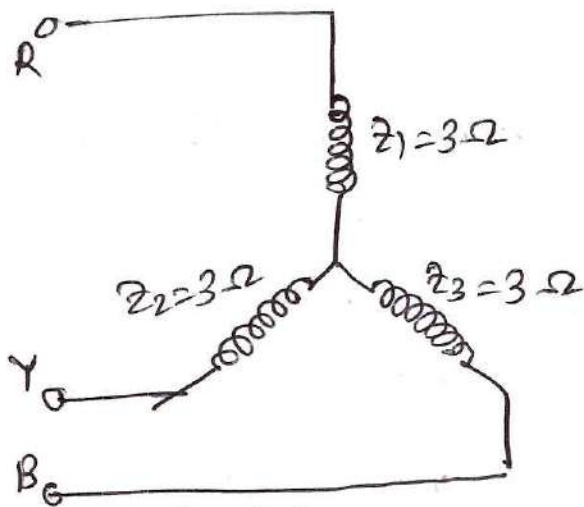


Fig (a)

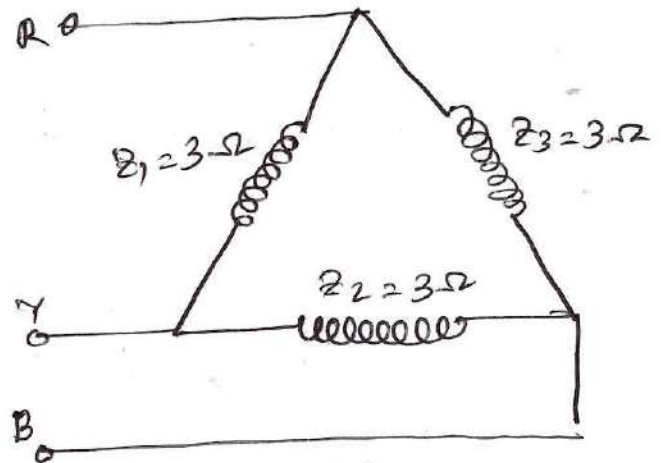


Fig (b)

$$|Z_1| = |Z_2| = |Z_3|$$

A balance load is that in which magnitude of all impedances of load are equal & phase angle are also equal.

$$|Z_1| = \sqrt{3^2} = \sqrt{9} = 3$$

$$|Z_2| = \sqrt{3^2} = \sqrt{9} = 3$$

$$|Z_3| = \sqrt{3^2} = \sqrt{9} = 3$$

$$|Z_1| = |Z_2| = |Z_3|$$

Hence the load are Balanced.

Unbalance load.

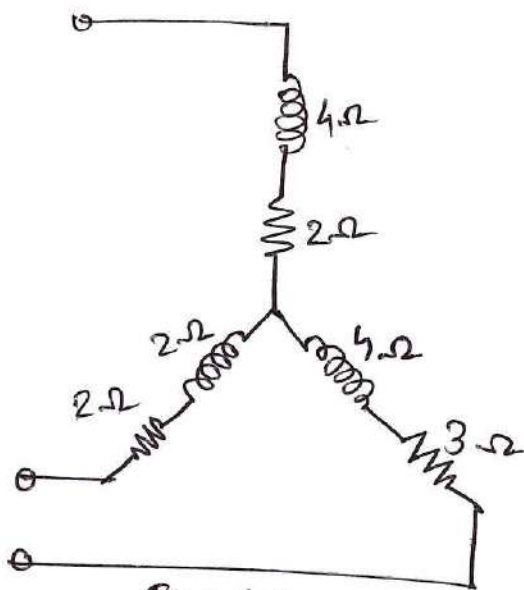


Fig: (a)

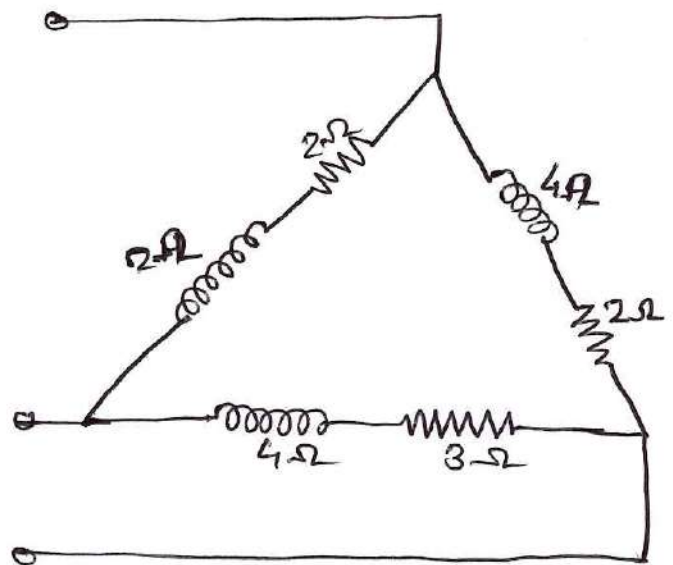


Fig: (b)

$$|z_1| \neq |z_2| \neq |z_3|$$

A unbalance load is that in which magnitude of all impedances of load are unequal & phase angles are different from each other

$$|z_1| = \sqrt{4^2 + 2^2} = \sqrt{16 + 4} = \sqrt{20}$$

$$|z_2| = \sqrt{4^2 + 3^2} = \sqrt{16 + 9} = \sqrt{25}$$

$$|z_3| = \sqrt{2^2 + 2^2} = \sqrt{4 + 4} = \sqrt{8}$$

$$|z_1| \neq |z_2| \neq |z_3|$$

Hence the load are unbalanced.

Q. A balance star connected load is supplied from $\Delta\phi$ 400 volts, 50 System. The current in each phase is 30 Amp & lag 30° behind phase voltage.

Find (1) Phase voltage (2) resistance & reactance per phase (3) load inductance per phase (4) Total power consumed.

Given things.

$V_L = 400$ volt, $I_{ph} = 30$ A, $\phi = 30^\circ$
for Balance Star connected load.

$$V_L = \sqrt{3} V_{ph}, \quad I_L = I_{ph}$$

(1) V_{ph}

$$V_{ph} = \frac{V_L}{\sqrt{3}} = \frac{400}{\sqrt{3}} = 230.94 \text{ VOLT}$$

$$(2) Z_{ph} = \frac{V_{ph}}{I_{ph}} = \frac{230.94 \angle 0^\circ}{30 \angle -30^\circ} = \frac{230.94}{30} \angle (0^\circ - (-30^\circ))$$

$$Z_{ph} = 7.698 \angle 30^\circ$$

$$Z_{ph} = 6.666 + j3.849$$

$$R_{ph} = 6.67 \ \Omega \quad X_{ph} = 3.849 \ \Omega$$

(3) load inductance per phase (L_{ph})

$$X_{Lph} = 2\pi f L_{ph}$$

$$L_{ph} = \frac{X_{Lph}}{2\pi f} = \frac{3.849}{2\pi \times 50} = 0.012 \text{ H}$$

(4) Total power consumed (P_T)

$$P_T = \sqrt{3} V_L I_L \cos \phi$$

$$= \sqrt{3} \times 400 \times 30 \times \cos(30^\circ)$$

$$P_T = 18000 \text{ watt or } 18 \text{ kW}$$

Q. A Delta connected balanced load is connected to 3 ϕ 420 volt supply. The load p.f is 0.6 lag. The line current is 40.64 Amp find

- ① R, X & impedance per phase
- ② Total power
- ③ Total reactive power

Given:

$$V_L = 420, \quad f = 50 \text{ Hz}, \quad \cos \phi = 0.6 \quad \phi = \cos^{-1}(0.6)$$

$$I_L = 40.64 \text{ A}$$

$$\phi = 53.13^\circ$$

for balanced Δ connected load

$$I_L = \sqrt{3} I_{ph}, \quad V_L = V_{ph}$$

① I_{ph}

$$I_{ph} = \frac{I_L}{\sqrt{3}} = \frac{40.64}{\sqrt{3}} = 23.463 \text{ Amp}$$

② $Z_{ph} = \frac{V_{ph}}{I_{ph}} = \frac{420 \angle 0^\circ}{23.463 \angle -53.13^\circ} = \frac{420}{23.463} \angle (0 - (-53.13))$

$$= 17.9 \angle 53.13^\circ$$

③ $Z_{ph} = 17.9 \angle 53.13^\circ = 10.740 + j 14.319 \ \Omega$

$$R_{ph} + j X_{ph}$$

$$R_{ph} = 10.740 \quad \cdot \quad X_{ph} = 14.319$$

④ $P_T = \sqrt{3} V_L I_L \cos \phi = \sqrt{3} \times 420 \times 40.64 \times 0.6$

$$P_T = 17738.417 \text{ watt}$$

UNIT 3 : Three phase circuit

Subject: ECN (313332)

1. State any four advantages and 3-phase circuit over 1-phase circuit.
2marks (w-2024)
2. Draw phasor diagram for three-phase voltages. Express these voltages in polar form. 2marks(w-2025)
3. State relationship between line and phase values of voltage and current in balanced star connected system. 2 marks (s-2025)
4. State relationship between line and phase values of voltage and current in balanced star connected system. 2 marks (S-2025)
5. With the help of vector diagram derive the relationship between line values and phase values for balanced delta connected system. 4marks (w-2024) (s-2025)
6. A 3 – ϕ , 400V, 50 Hz, A.C. supply is feeding a 3 – ϕ delta connected load with each phase having a resistance of 25Ω , an inductance of 0.15H and a capacitor of 120mf in series. Determine :- i) Z_{Ph} ii) I_{Ph} iii) I_L iv) P.f.
4marks(w-2024)
7. The load in each branch of a star-connected 3- ϕ circuit consists of an inductance of 0.0318 H in series with a resistance of $10\ \Omega$. The line voltage is 400 V at 50 Hz. Calculate: i) The line current ii) The total power in the circuit iii) The VAR in the circuit. 4marks(w-2024)
8. Compare star connected network with Delta connected network.
4marks(s-2025) (s-2026)
9. Draw waveform of three phase voltages. Draw phasor diagram for these voltages. Write equations for instantaneous values of these voltages. Express these voltages in polar form. 4marks(s-2025)
10. Three equal impedances having $R = 20\Omega$ in series with $C = 50\ \text{mF}$ are connected in delta across 415 V, 3 phase, 50 Hz AC supply. Determine :-
i) Impedance per phase ii) Phase and line currents iii) Total power consumed by load. 4marks(W-2025)
11. A star connected 3 phase load is supplied with three phase 415 volt, 50 Hz, supply. If the line current is 20A and total 3phase power taken from supply is 100 KW, find – i) load Power factor ii) per phase Resistance & reactance iii) three phase reactive power. 4marks(s-2026)

12. A star connected load is supplied from 3phase, 415V, 50 Hz, supply. If the line current is 15A and total 3phase power taken from supply is 30 KW, find – i) Power factor ii) Resistance in each phase iii) Capacitance in each phase. 6marks(s-2025)
13. A balanced star connected load of $(8 + j6)\Omega$ per phase is connected to a balanced 3phase 400V supply. Find the line current, power factor, power and total volt amperes. 6 marks (s-2025)
14. In a 3 phase star connected system, derive the relationship $V_L = \sqrt{3} V_{ph}$. 6 marks (w-2025) (s-2026)
15. A balanced delta connected load, consists of per phase impedance of $(5 + j7) \Omega$. It is supplied with 415 V, 50 Hz, 3 phase AC supply. Calculate :–
i) Line current ii) Phase current iii) Phase voltage iv) Total power absorbed v) Power factor of the combination. Also draw vector diagram. 6 marks (w-2025)