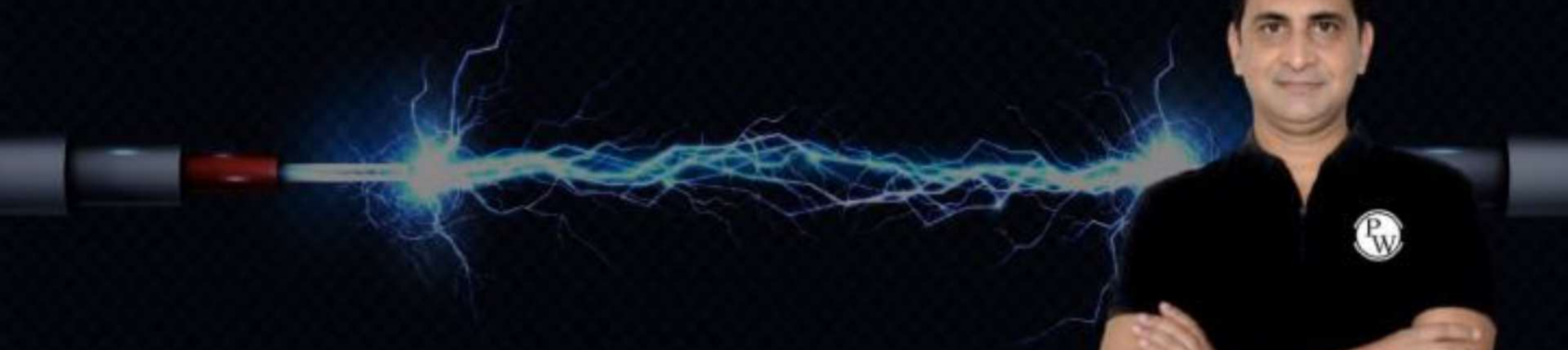




Electrical Engineering

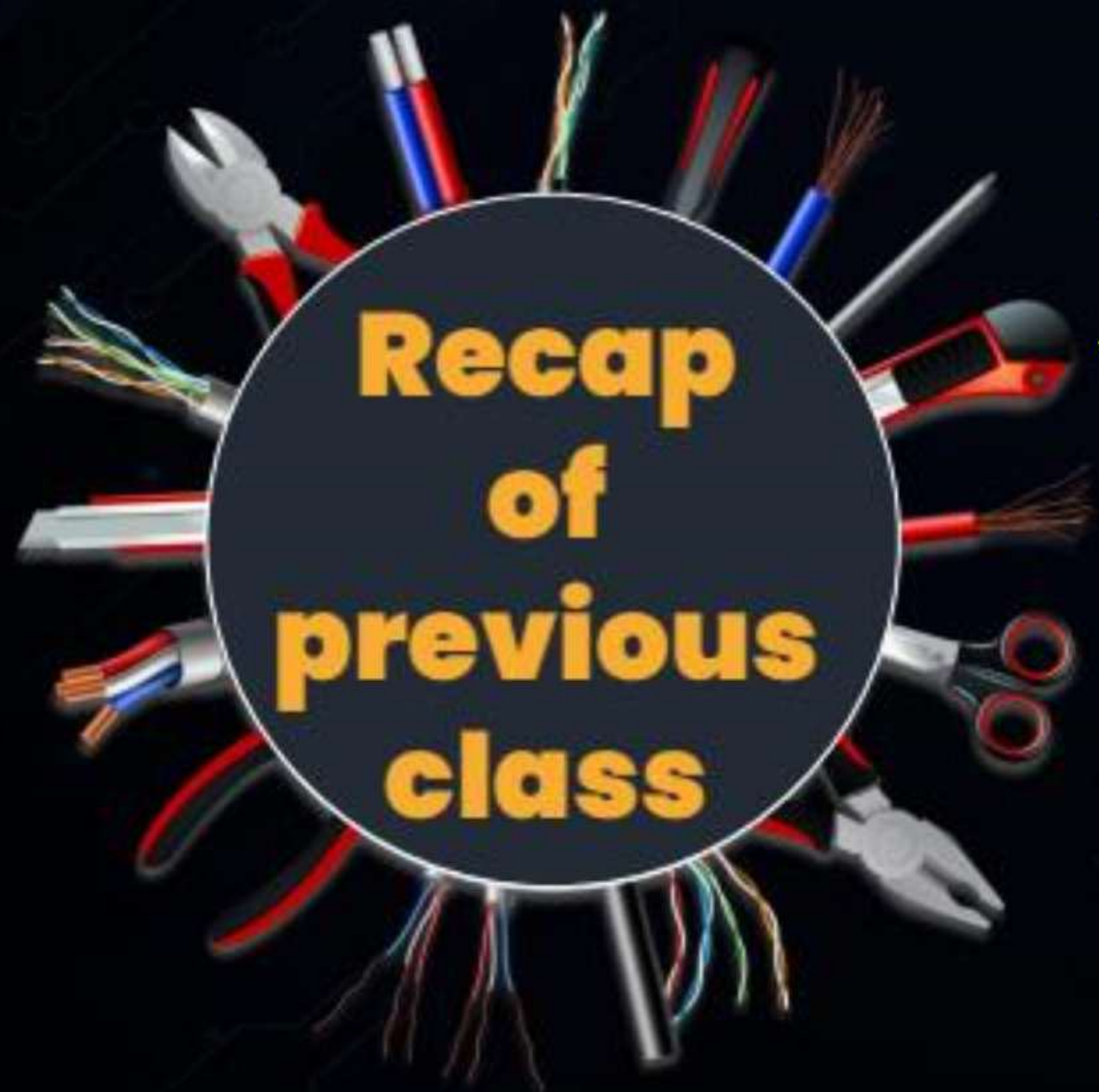
POWER SYSTEM



Topic : 3 phase Circuits

Lecture : 1

By- Ajay Gupta Sir



Recap of previous class

- ✓ 1. Why 3 phase power is used
- ✓ 2. 3 phase system
- ✓ 3. 3 phase balance star connected
- ✓ 4. 3 Phase balance delta connected



Topics to be Covered

1. Unbalance delta load

2. Unbalance star load



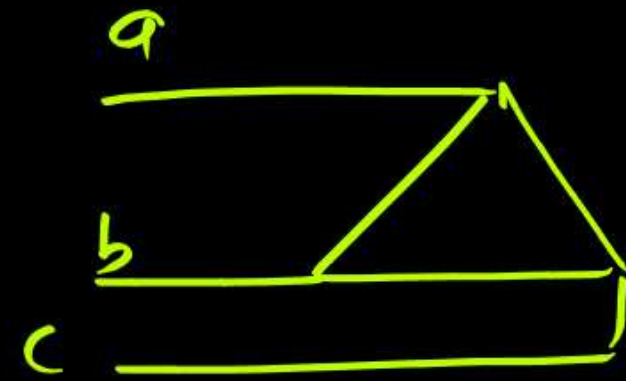
✓ @AJAYGUPTASIRPW

Positive seqⁿ (ABC)

$$\underline{V_{ab}} = V_L \angle 0 \Rightarrow \underline{V_a} = \frac{V_L}{\sqrt{3}} \angle 0 - 30$$

$$\underline{V_{bc}} = V_L \angle 0 \Rightarrow \underline{V_b} = \frac{V_L}{\sqrt{3}} \angle 0 - 30$$

$$\underline{V_{ca}} = V_L \angle 0 \Rightarrow \underline{V_c} = \frac{V_L}{\sqrt{3}} \angle 0 - 30$$



$$I_p = I_L$$

Negative seqⁿ (A<B)

$$V_{ab} = V_L \angle 0 \Rightarrow V_a = \frac{V_L}{\sqrt{3}} \angle 0 + 30$$

$$V_{bc} = V_L \angle 0 \Rightarrow V_b = \frac{V_L}{\sqrt{3}} \angle 0 + 30$$

$$V_{ca} = V_L \angle 0 \Rightarrow V_c = \frac{V_L}{\sqrt{3}} \angle 0 + 30$$

In Delta (Positive seqⁿ) (ABC)

$$V_{ph} = V_L$$

$$I_a = I_L \angle 0 \Rightarrow I_{ab} = \frac{I_L}{\sqrt{3}} \angle (0 + 30)$$

$$I_b = I_L \angle 0 \Rightarrow I_{bc} = \frac{I_L}{\sqrt{3}} \angle 0 + 30$$

$$I_c = I_L \angle 0 \Rightarrow I_{ca} = \frac{I_L}{\sqrt{3}} \angle 0 + 30$$

$$-1 = 1 \angle 180$$

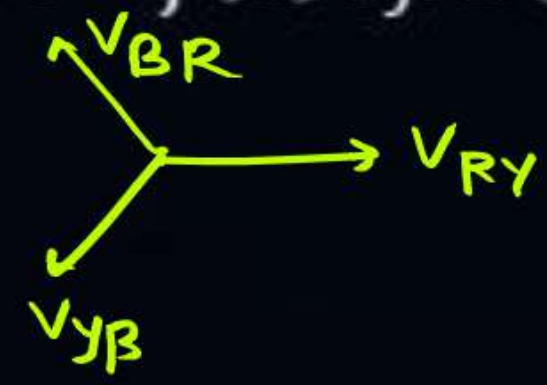
$$\therefore V_{ab} = V_L \angle 0$$

$$\Rightarrow V_{ba} = V_L \angle 0 + 180$$

$$= V_L \angle 0 - 180$$

Q. A 3 Phase system supplies 110 V to a delta connected load whose phase impedance $(3.54 + j 3.54)$. Determine $I_R = ?$

- ✓ $V_{RY} = 110 \angle 0$
- ✓ $V_{YB} = 110 \angle -120$
- ✓ $V_{BR} = 110 \angle 120$



$$\underline{\underline{120 - 360 = -240}}$$

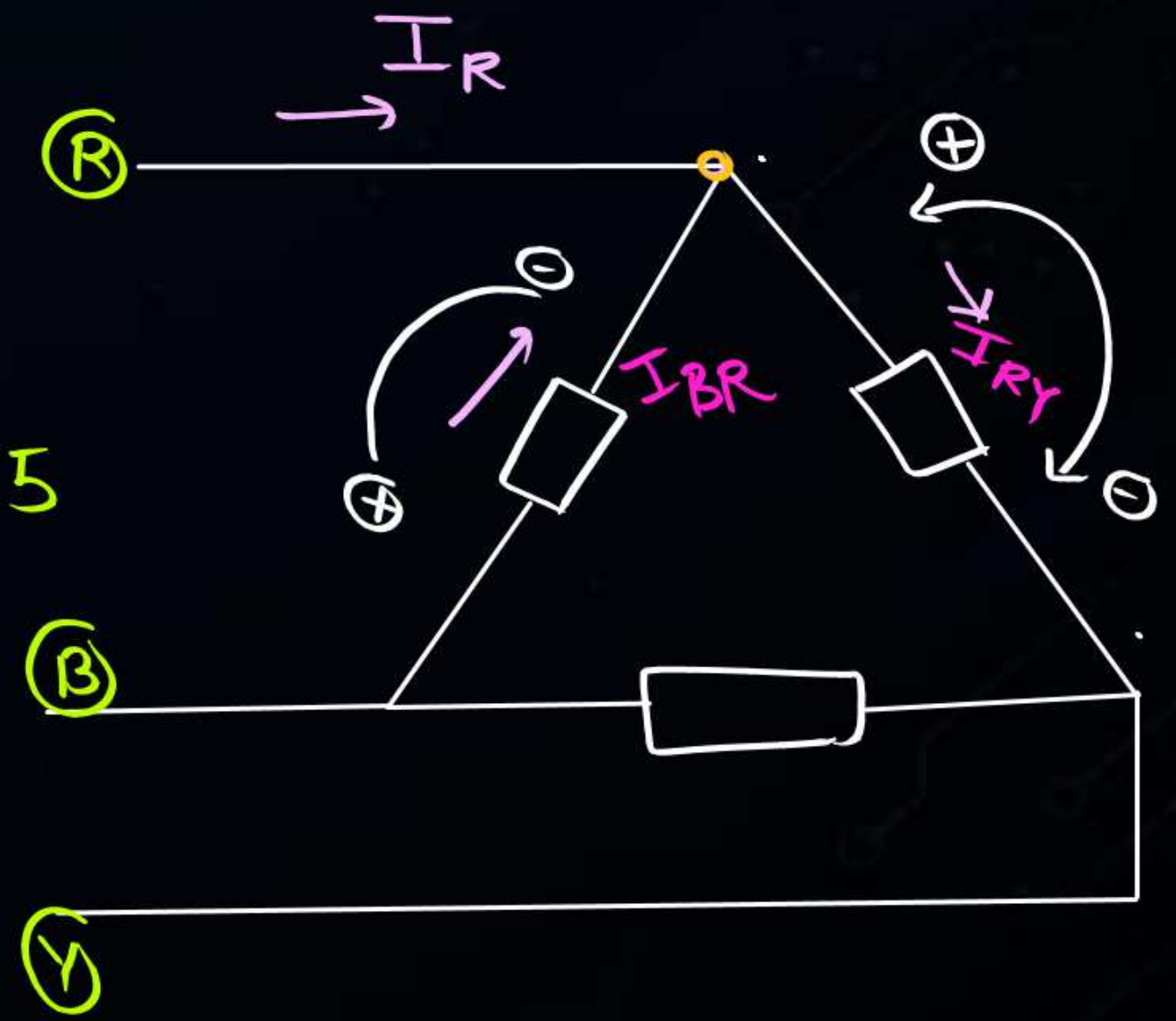
- A** $38.5 \angle 75$
- B** $38.5 \angle -75$
- C** $22 \angle -165$
- D** $22 \angle 75$

$$Z = 3.54 + j 3.54$$

$$|Z| = \sqrt{3.54^2 + 3.54^2} = 5$$

$$\theta = \tan^{-1} \frac{3.54}{3.54} = 45$$

$$Z = 5 \angle 45^\circ$$



Method 1



$$I_{RY} = \frac{V_{RY}}{Z} = \frac{110 \angle 0}{5 \angle 45} = 22 \angle -45$$

$$I_{BR} = \frac{V_{BR}}{Z} = \frac{110 \angle 120}{5 \angle 45} = 22 \angle 75.$$

KCL $I_R + I_{BR} = I_{RY}$

$$\begin{aligned} I_R &= I_{RY} - I_{BR} = (22 \angle -45) - (22 \angle 75) \\ &= 38.1 \angle -75 \end{aligned}$$

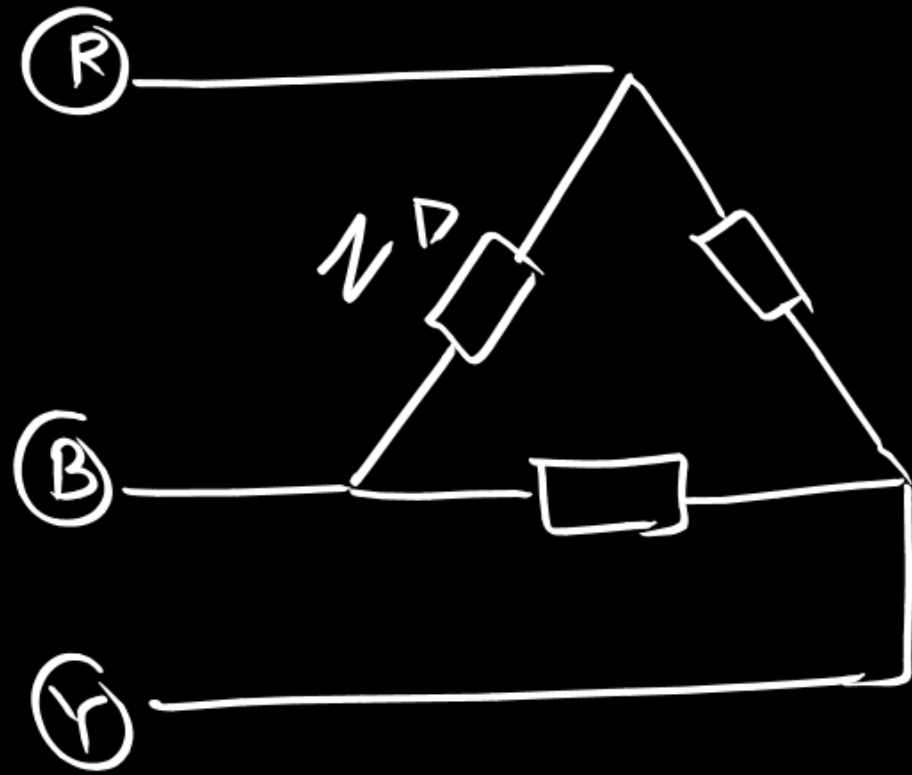
Method. 2

$$I_R = ? \quad I_{RY} = 22 \angle -45$$

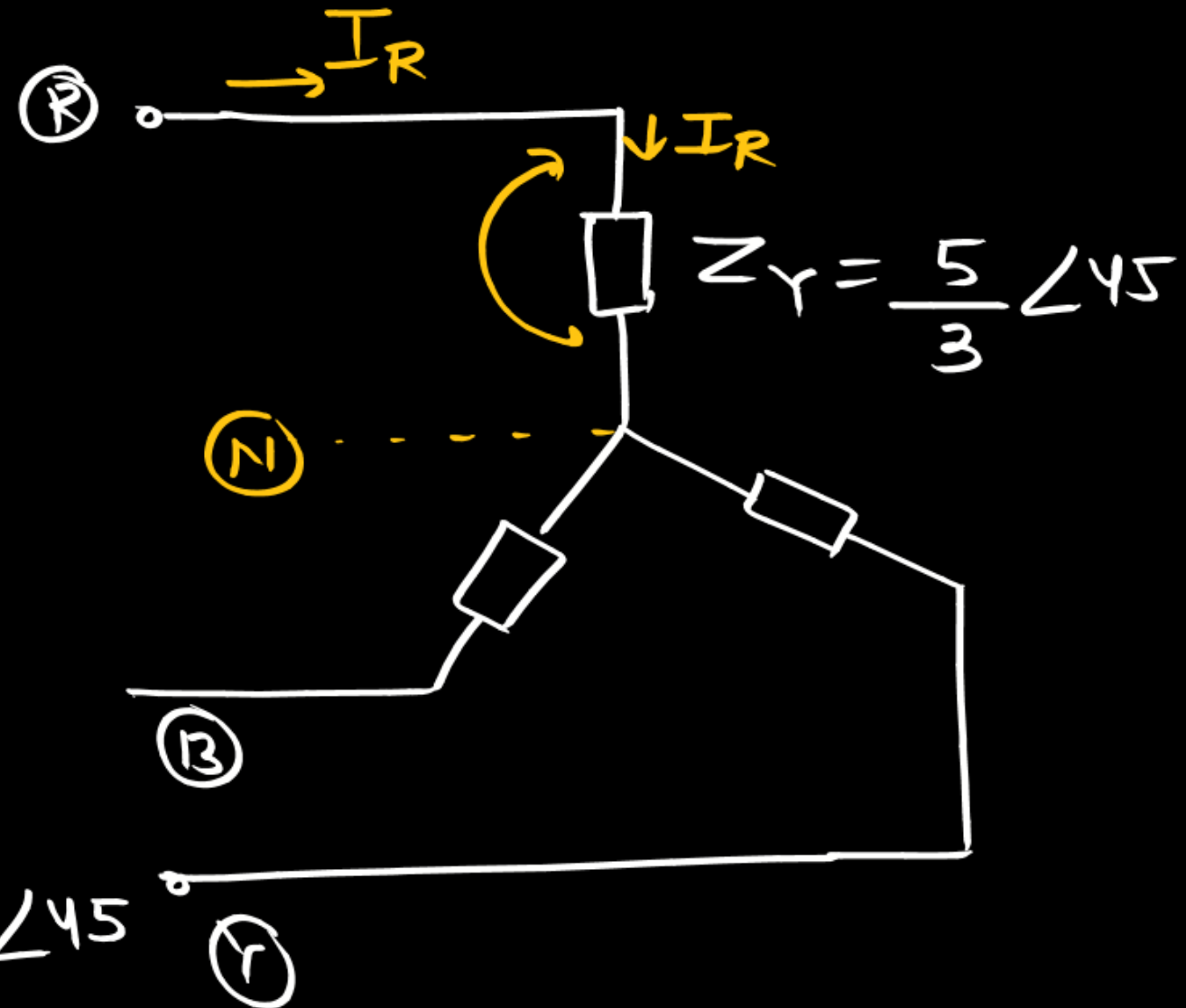
$$I_R = 22\sqrt{3} \angle -45 - 30$$

$$I_R = 38.1 \angle -75$$

Method 3



$\Rightarrow$



$$Z_Y = \frac{Z_D}{3} = \frac{5 \angle 45^\circ}{3} = \frac{5}{3} \angle 45^\circ$$

$$V_{RY} = 110 \angle 0 \quad \Rightarrow \quad V_R = \frac{110}{\sqrt{3}} \angle 0-30 = \frac{110}{\sqrt{3}} \angle -30$$

$$\begin{aligned} \text{In star } I_R &= \frac{V_R}{Z_Y} = \frac{\frac{110}{\sqrt{3}} \angle -30}{\frac{5}{3} \angle 45} = 22\sqrt{3} \angle -75 \\ &= 38.1 \angle -75 \end{aligned}$$

Unbalance Delta connected load :

- ★ In unbalance load the phase impedance are not same



Step : 1

The phase voltage will be equivalent to line voltage.

Step : 2

Now find out phase by dividing phase voltage by respectively phase impedance.

Step : 3

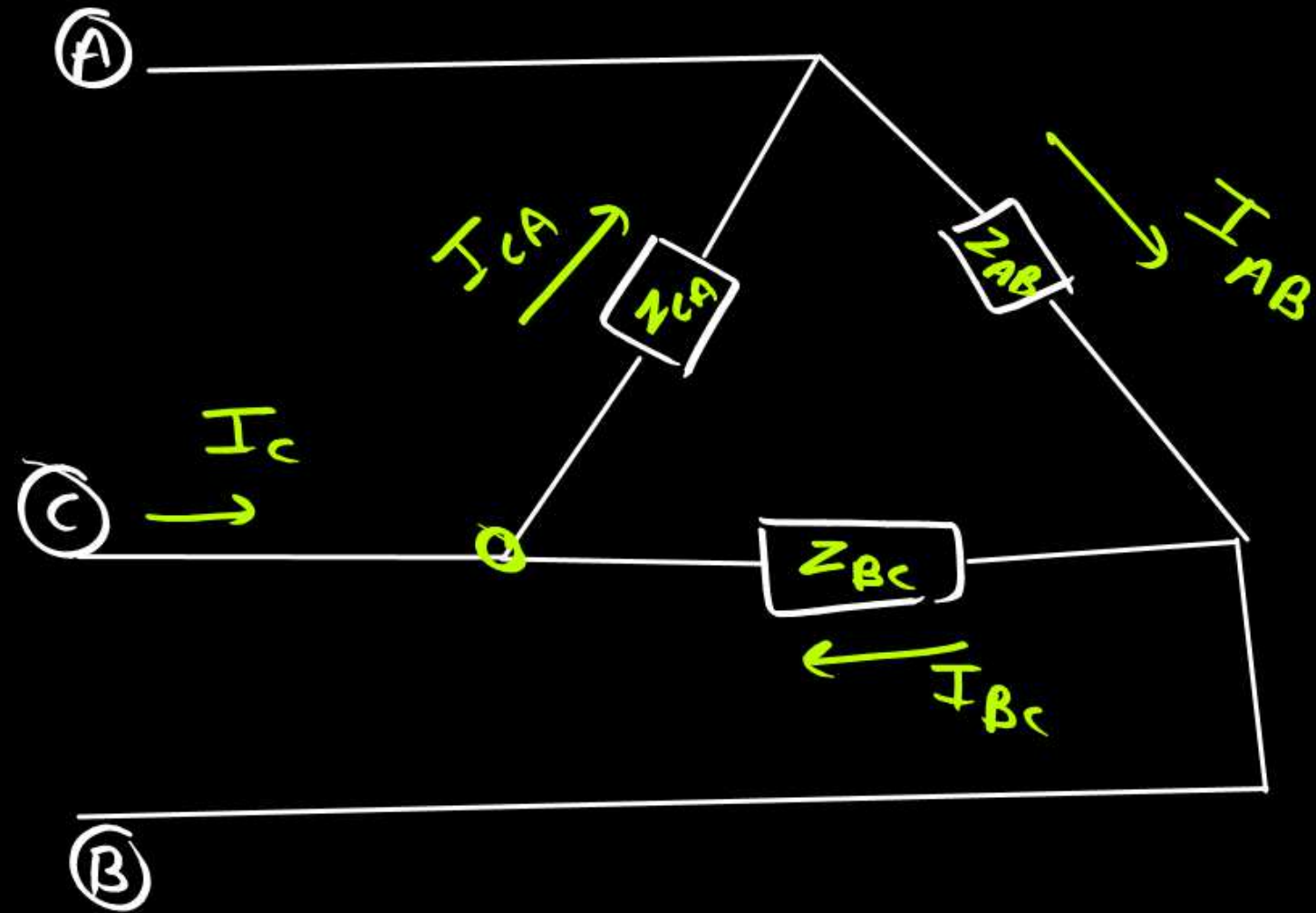
Now using KCL find out line current.

$$I_L \neq \sqrt{3} I_{Pn}$$

Line current magnitude will be different & the phase difference will not be equal to 120°

Q. 3 Phase 3 wire 240 V, ABC has delta connected load $Z_{AB} = 10 \angle 0$,
 $Z_{BC} = 10 \angle 30$, $Z_{CA} = 15 \angle -30$. Find out $I_C = ?$
 $V_{BC} = 240 \angle 0$ $V_{AB} = 240 \angle -120$ $V_{CA} = 240 \angle -240$

- A** $38.7 \angle 108.1$
- B** $46.4 \angle -45$
- C** $40 \angle 150$ ✓
- D** $16 \angle 270$



$$I_{BC} = \frac{V_{BC}}{Z_{BC}} = \frac{240 \angle 0}{10 \angle 30} = \underline{24 \angle -30}$$

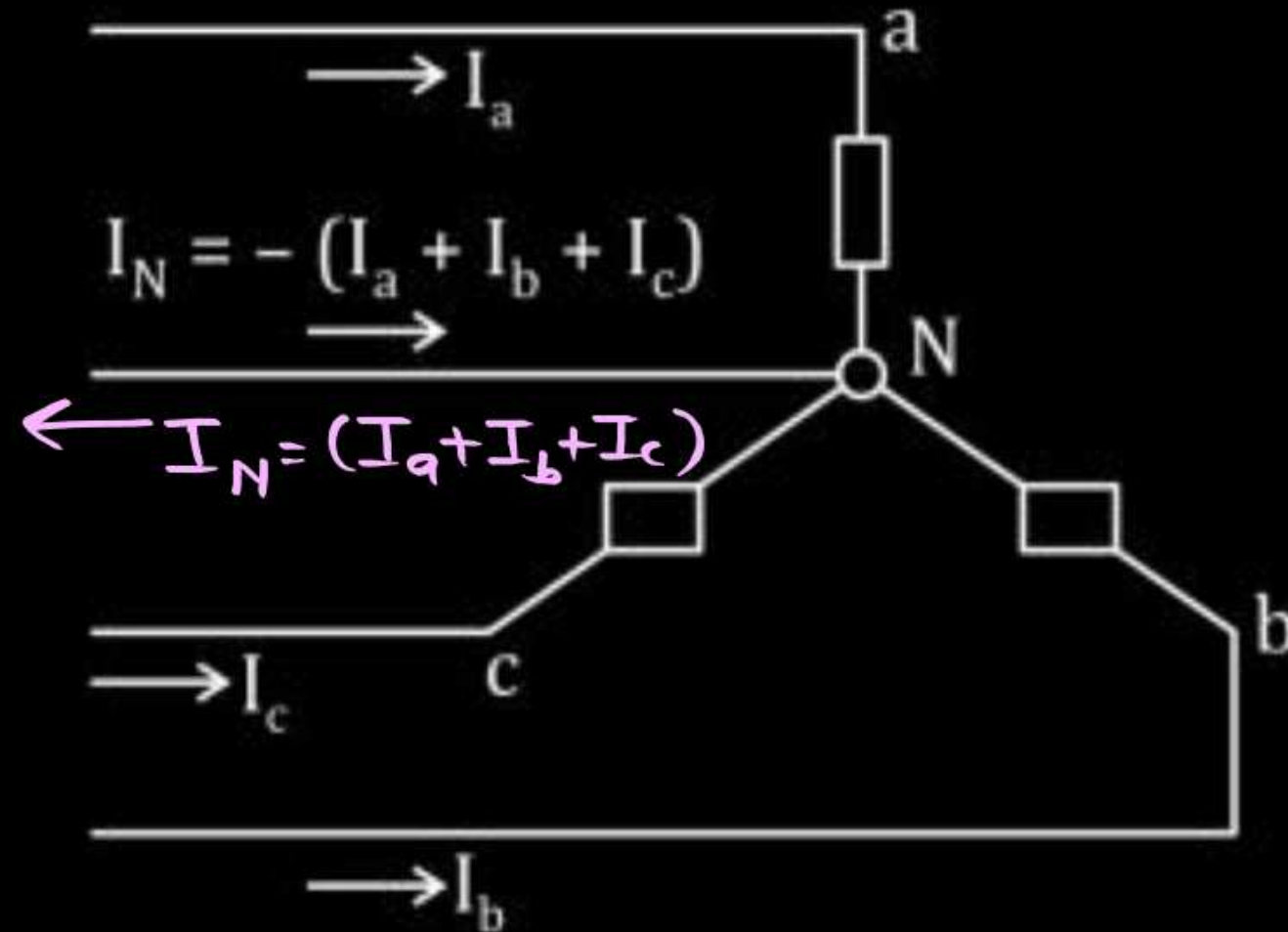
$$I_{CA} = \frac{V_{CA}}{Z_{CA}} = \frac{240 \angle -240}{15 \angle -30} = \underline{16 \angle -210}$$

KCL

$$I_C + I_{BC} = I_{CA}$$

$$\begin{aligned} I_C = I_{CA} - I_{BC} &= [16 \angle -210] - [24 \angle -30] \\ &= 40 \angle 150 \end{aligned}$$

Unbalance Star Connected 3 Phase 4 Wire Load :



Step : 1

First convert line voltage into phase voltage by respective phase impedance to find out phase current.

Step : 2

Now divide phase voltage by respective phase impedance to find out phase current

Step : 3

Now divide phase voltage by respective phase impedance to find out phase current

Step : 4

Now find out neutral current $I_N = -(I_a + I_b + I_c)$

Q.

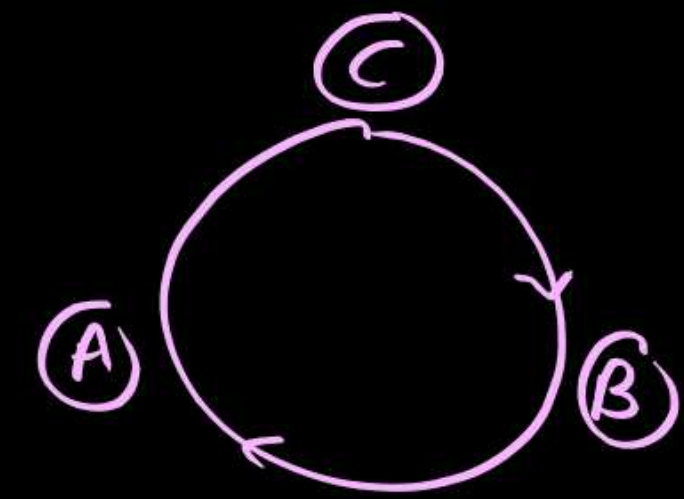
PW

A 3 Phase 4 wire 208 V, CBA system has star connected load $Z_A = 6\angle 0$, $Z_B = 6\angle 30$, $Z_C = 5\angle 45$ find out neutral current

$V_{CB} = \underline{208\angle 0}$

$V_{BA} = 208\angle -120$

$V_{AC} = 208\angle 120$



A $20\angle -90$

$V_{AB} = -V_{BA} = 208\angle -120 + 180 = 208\angle 60$

B $20\angle 0$

C $14.1\angle 13$

$V_{BC} = -V_{CB} = 208\angle 0 + 180 = 208\angle 180$

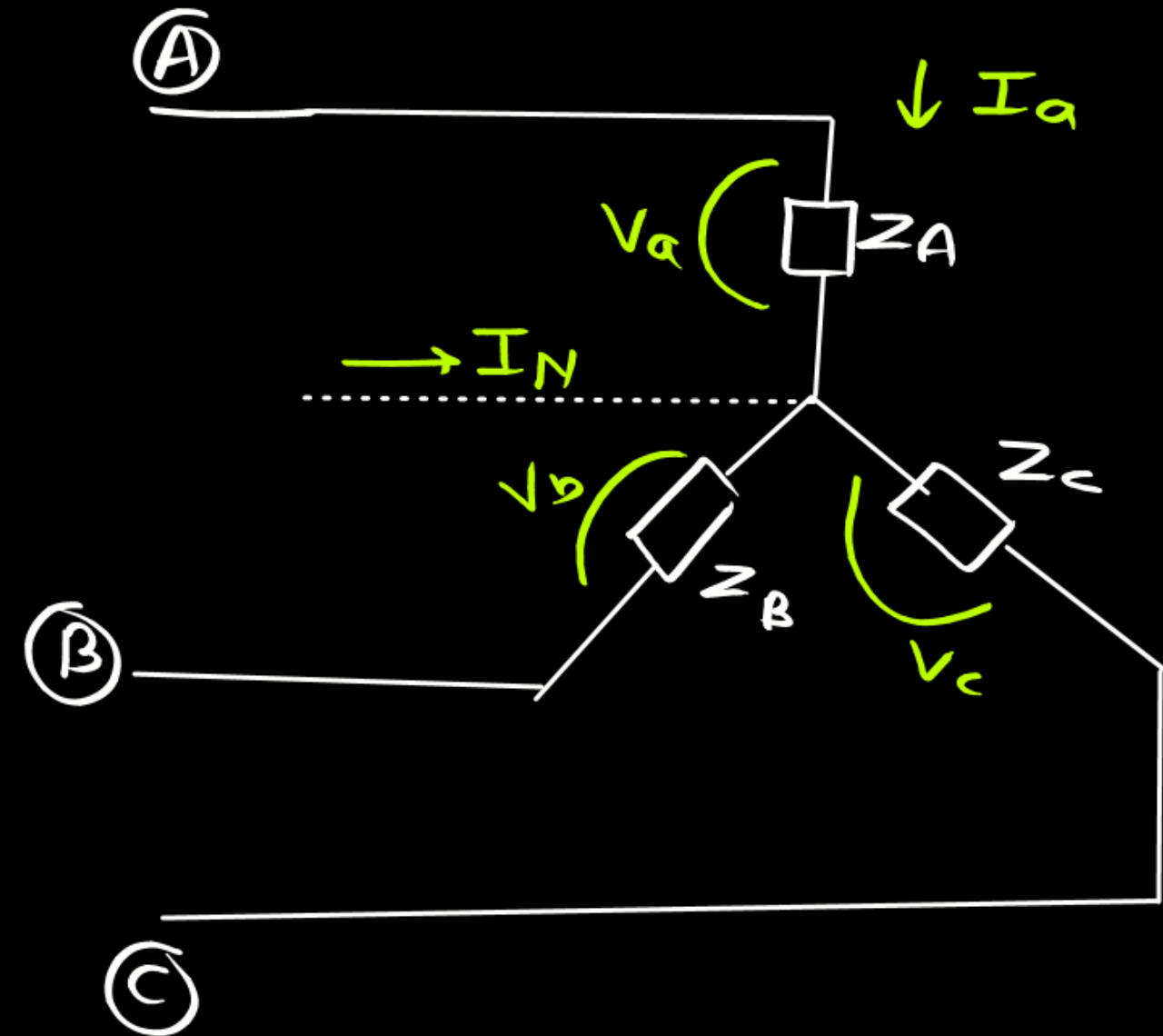
D $14.1\angle 22.6$

$V_{CA} = -V_{AC} = 208\angle 120 = 208\angle 120 + 180 = 208\angle 300$

$$V_a = \frac{208}{\sqrt{3}} \angle 60 + 30 = \frac{208}{\sqrt{3}} \angle 90$$

$$V_b = \frac{208}{\sqrt{3}} \angle 180 + 30 = \frac{208}{\sqrt{3}} \angle 210$$

$$V_c = \frac{208}{\sqrt{3}} \angle 300 + 30 = \frac{208}{\sqrt{3}} \angle 330$$



$$I_a = \frac{V_a}{Z_a} = \frac{\frac{208}{\sqrt{3}} \angle 90}{6 \angle 0} = 20 \angle 90$$

$$I_b = \frac{V_b}{Z_b} = \frac{\frac{208}{\sqrt{3}} \angle 210}{6 \angle 30} = 20 \angle 180$$

$$I_c = \frac{V_c}{Z_c} = \frac{\frac{208}{\sqrt{3}} \angle 330}{5 \angle 45} = 24 \angle 285$$

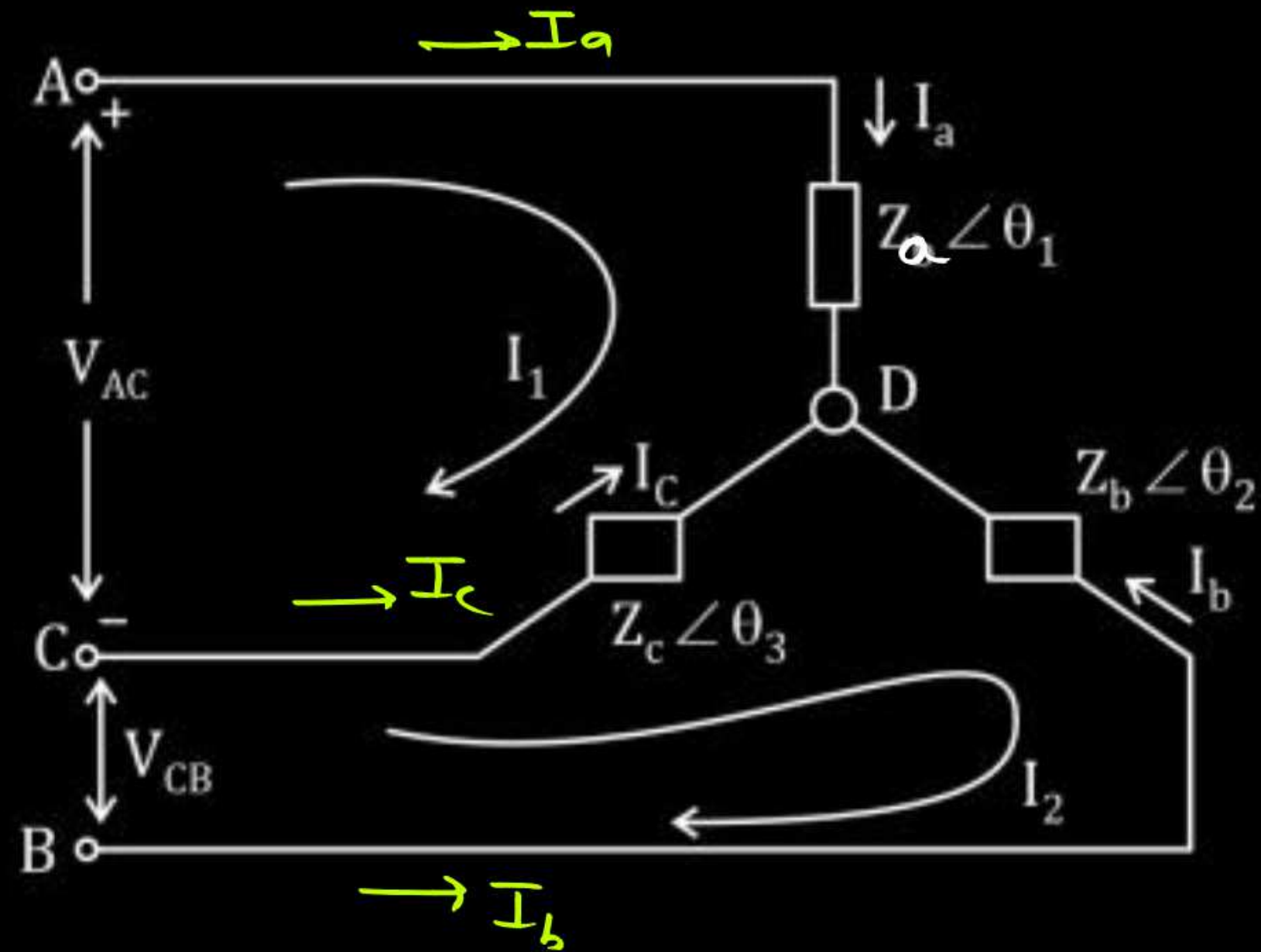
$$I_N = -(I_a + I_b + I_c)$$

$$= -(20 \angle 90^\circ + 20 \angle 180^\circ + 24 \angle 285^\circ)$$

$$I_N = 14.1 \angle 13^\circ$$

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

Unbalance Star Connected 3 Phase 3 Wire Load :



Method : I

Step : 1

Imagine loop current I_1 & I_2 is flowing.

Step : 2

By using direction inspection method write down mesh equation in matrix from

$$\begin{bmatrix} \overset{Z_{11}}{Z_a \angle \theta_1 + Z_c \angle \theta_3} & \overset{Z_{12}}{-Z_c \angle \theta_3} \\ \underset{Z_{21}}{-Z_c \angle \theta_3} & \underset{Z_{22}}{Z_b \angle \theta_2 + Z_c \angle \theta_3} \end{bmatrix} \begin{bmatrix} I_1 \\ I_2 \end{bmatrix} = \begin{bmatrix} V_{AC} \\ V_{CB} \end{bmatrix}$$

Step : 3

Find out I_1 & I_2 .

Step : 4

Now find out line current

$$✓ I_a = I_1$$

$$✓ I_B = -I_2$$

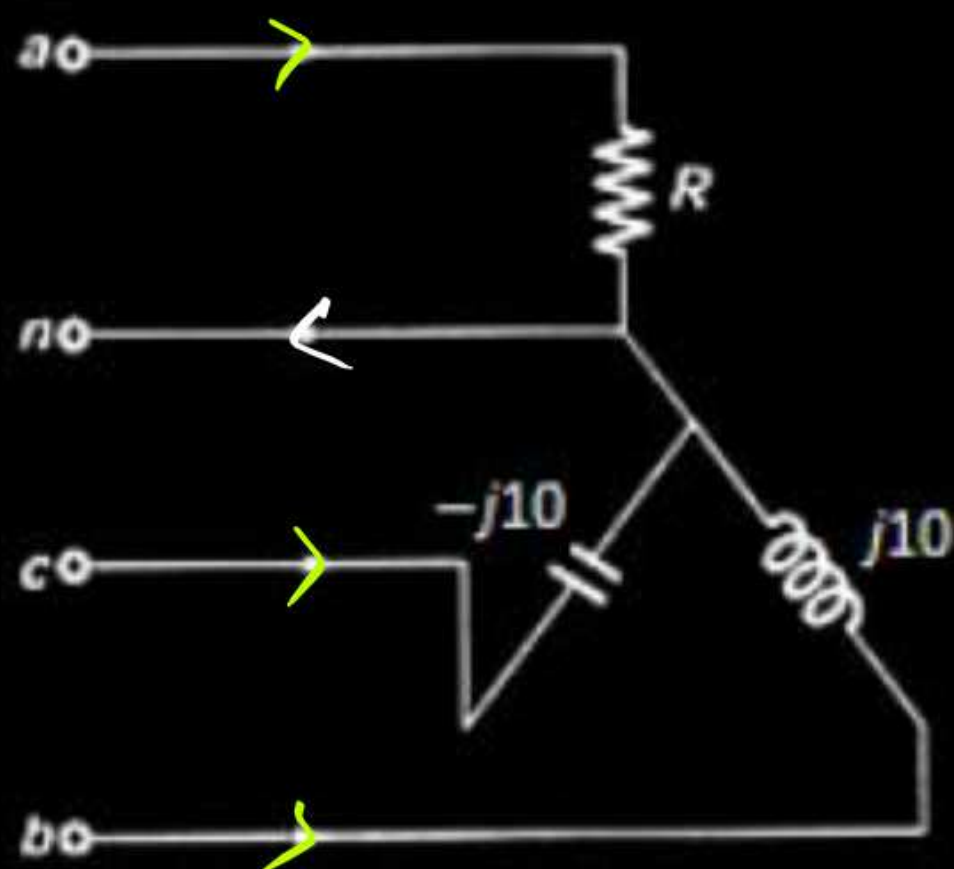
$$I_C = I_2 - I_1$$

NAT

3.57 ≈ 1



A three-phase load is connected to a three-phase balanced supply as shown in the figure. If $V_{an} = 100\angle 0^\circ \text{ V}$, $V_{bn} = 100\angle -120^\circ \text{ V}$ and $V_{cn} = 100\angle -240^\circ \text{ V}$ (angles are considered positive in the anti-clockwise direction), the value of R for zero current in the neutral wire is ____ Ω (upto 2 decimal places). [GATE-2018-EE: 2M]



$$I_n = (I_a + I_b + I_c)$$

$$I_n = \left(\frac{V_a}{R} + \frac{V_b}{j10} + \frac{V_c}{-j10} \right)$$

$$j = 1 \angle 90^\circ$$

$$-j = 1 \angle -90^\circ$$

$$0 = \frac{100}{R} + \frac{100 \angle -120^\circ}{j10} + \frac{100 \angle -240^\circ}{-j10}$$

$$0 = 100 \left[\frac{1}{R} + \frac{1 \angle -210^\circ}{10} + \frac{1 \angle -150^\circ}{10} \right]$$

$$\frac{1}{R} + \frac{1}{10} [1 \cos 210 - j 1 \sin 210] + \frac{1}{10} [1 \cos 150 - j 1 \sin 150]$$

$$\frac{1}{R} + \frac{1}{10} [-0.866 + j0.5 - 0.866 - j0.5] = 0$$

$$\frac{1}{R} = \frac{2 \times 0.866}{10}$$

$$R = \frac{10}{2 \times 0.866} = 5.77$$

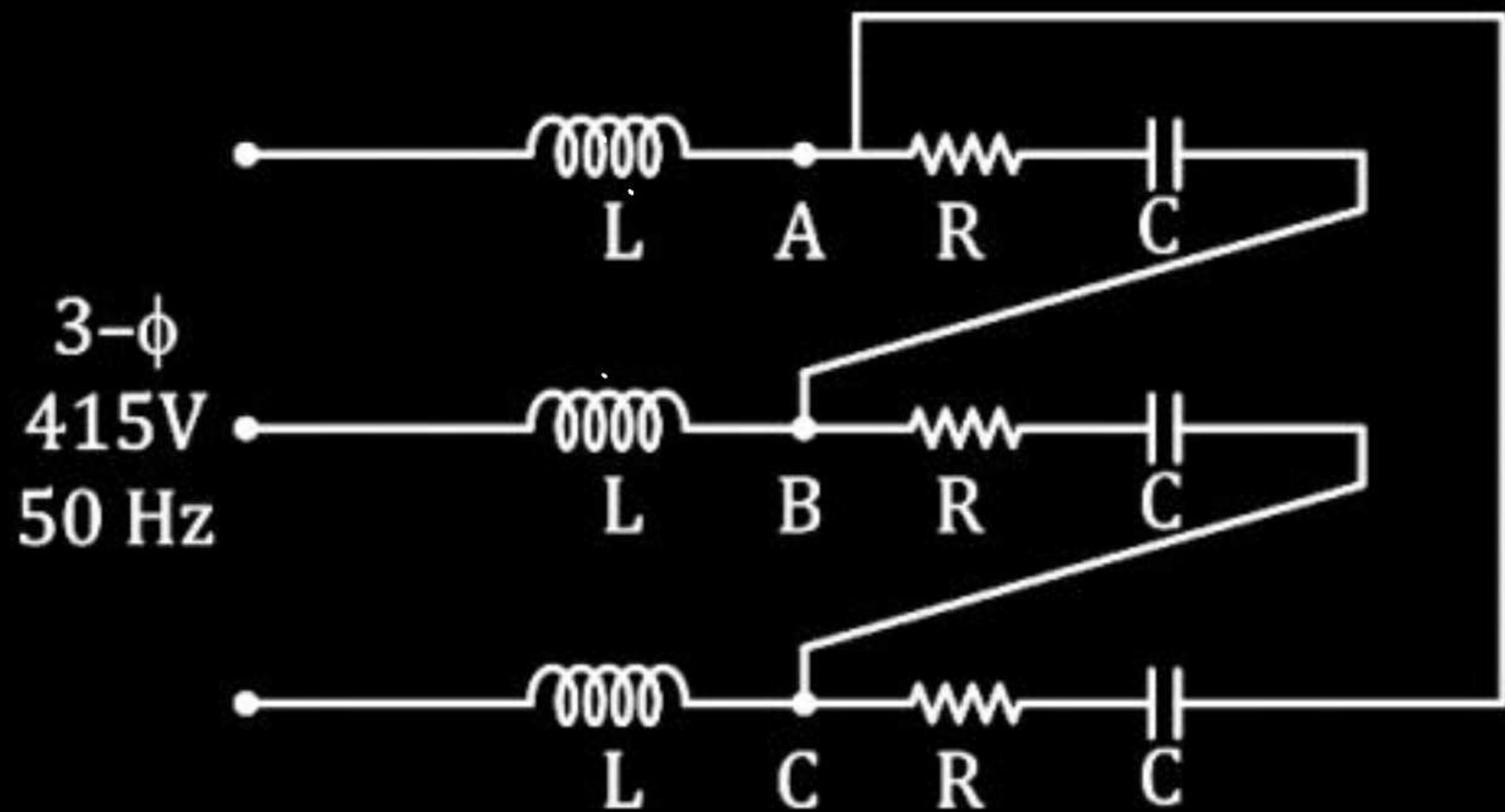
NAT



A balanced delta connected load consisting of the series connection of one resistor ($R = \underline{15\Omega}$) and a capacitor ($C = \underline{212.21\mu\text{F}}$) in each phase is connected to three-phase, 50 Hz, 415 V supply terminals through a line having an inductance of $L = \underline{31.83\text{ mH}}$ per phase, as shown in the figure. Considering the change in the supply terminal voltage with loading to be negligible, the magnitude of the voltage across the terminals V_{AB} in Volts is _____.

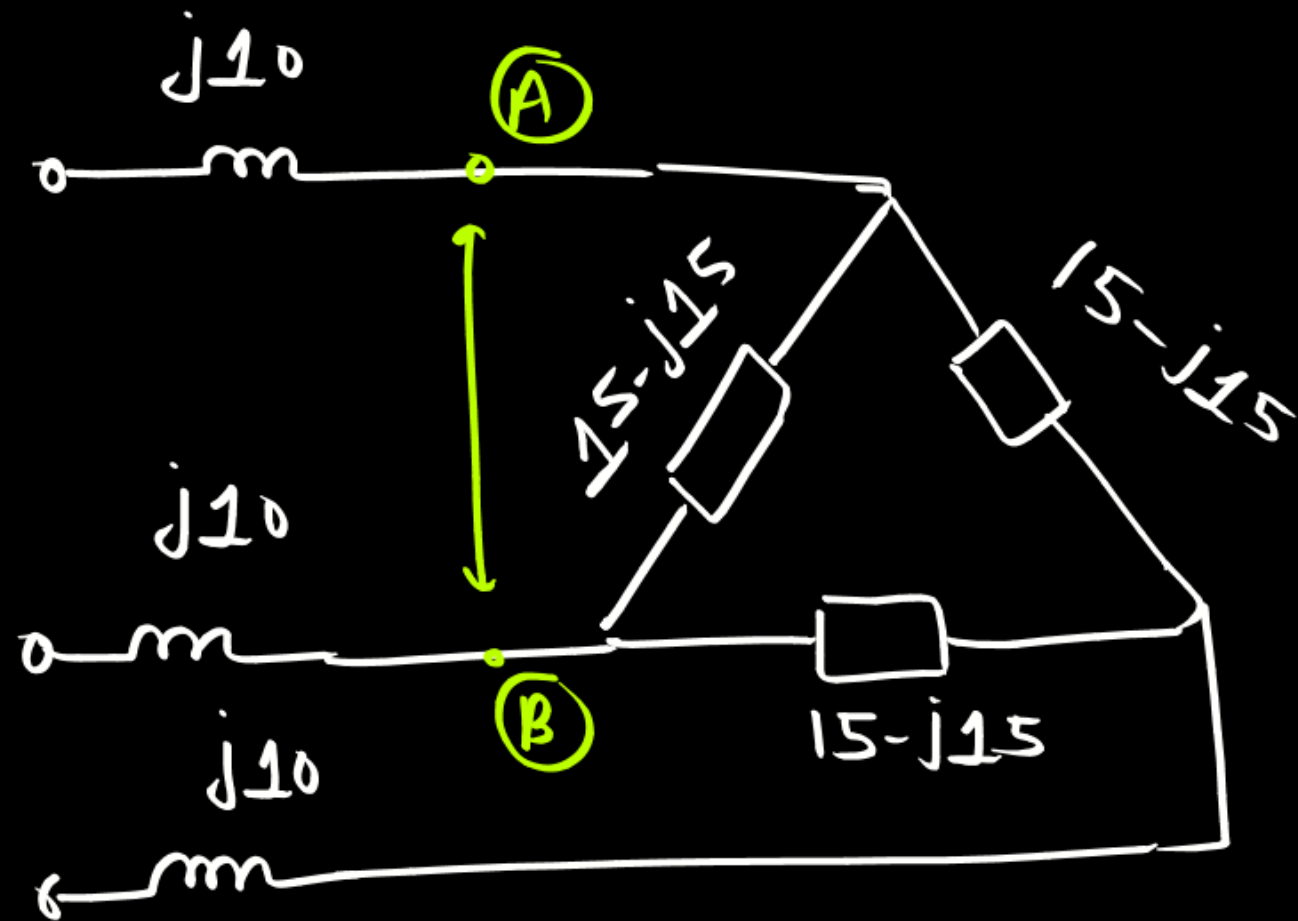
(Round off to the nearest integer).

[GATE-2023: 2M]

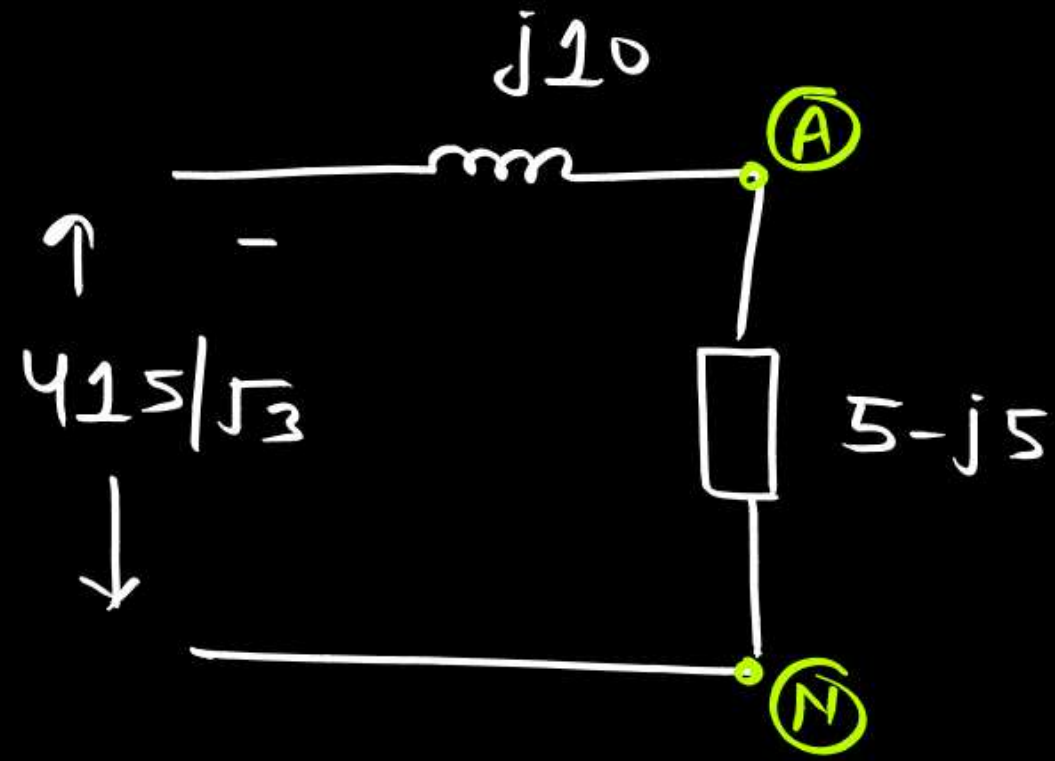
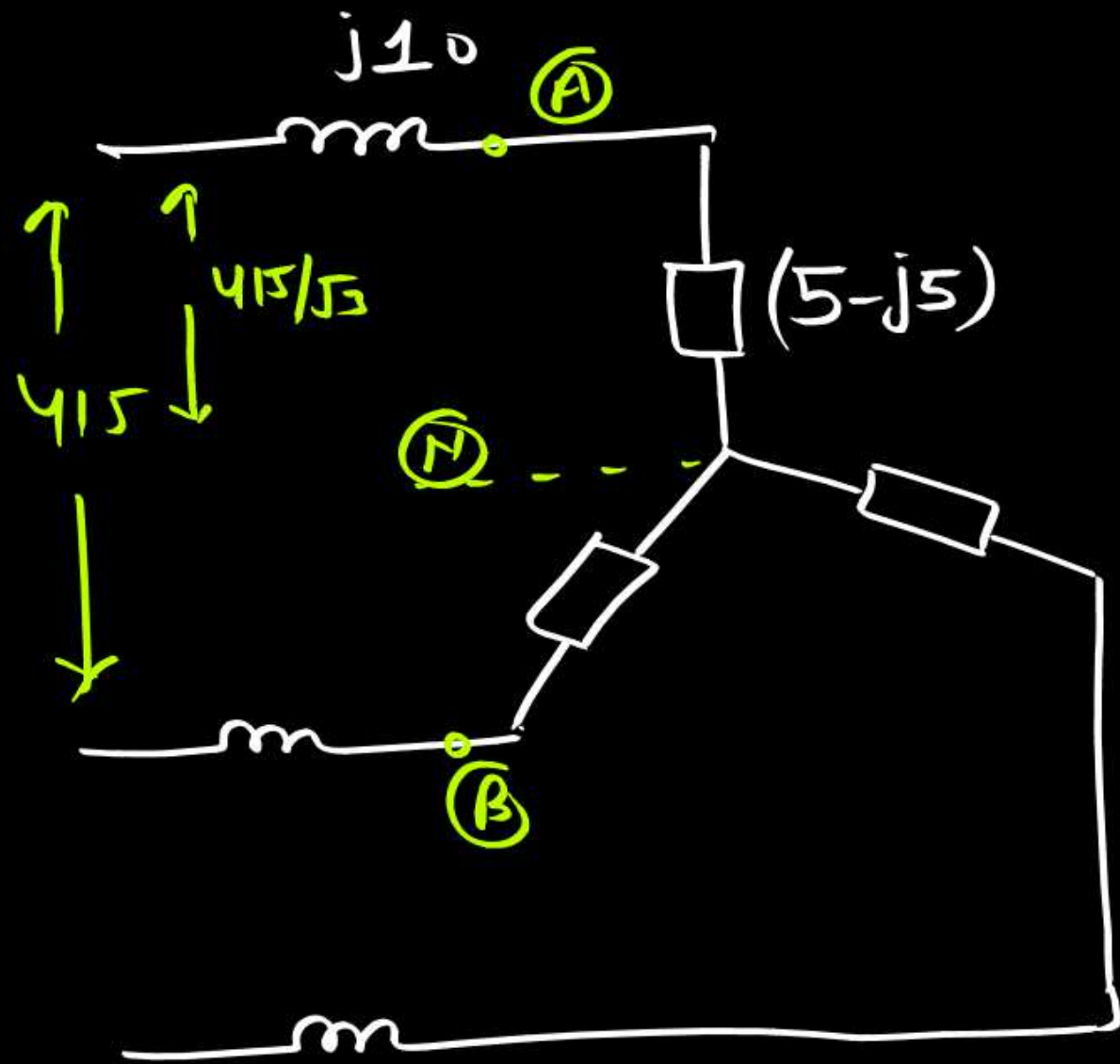


$$X_L = 2\pi fL = 2\pi \cdot 50 \cdot (31.83 \times 10^{-3}) = j10$$

$$X_C = \frac{-j}{\omega C} = \frac{-j}{2\pi \cdot 50 \cdot (212.21 \times 10^{-6})} = -j15$$



$$Z_Y = \frac{Z_\Delta}{3} = \frac{15-j15}{3} = 5-j5$$



$$V_{AN} = \frac{(5-j5)}{j10 + (5-j5)} \times \frac{415}{\sqrt{3}}$$

$$V_{AN} = \frac{5-j5}{5+j5} \times \frac{415}{\sqrt{3}}$$

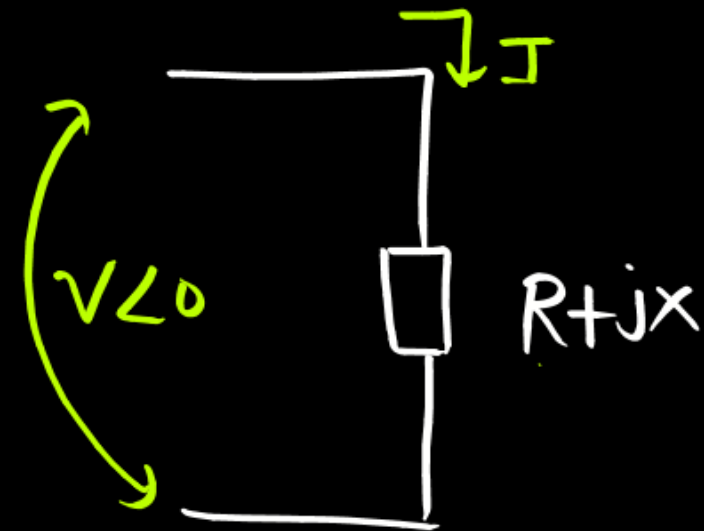

$$|V_{AN}| = \frac{\sqrt{\cancel{5^2} + 5^2}}{\sqrt{\cancel{5^2} + 5^2}} \times \frac{415}{\sqrt{3}}$$

$$|V_{AB}| = \sqrt{3} |V_{AN}| = \sqrt{3} \times \frac{415}{\sqrt{3}} = 415$$

$$R + jX = Z \angle \theta$$

$$Z = \sqrt{R^2 + X^2} \quad \theta = \tan^{-1} \frac{X}{R}$$

$$I = \frac{V \angle 0}{Z \angle \theta} = \frac{V}{Z} \angle -\theta$$



The angle between Voltage and Current is P_f angle. This angle depend upon the R & X of load.

3 Phase Power:

Total power = A phase power + B phase power + C phase power

In a balance system

$$= V_{ph} I_{ph} \cos \theta + V_{ph} I_{ph} \cos \theta + V_{ph} I_{ph} \cos \theta$$

$$P = 3 V_{ph} I_{ph} \cos \theta$$

$$Q = 3 V_{ph} I_{ph} \sin \theta$$

$$S = 3 V_{ph} I_{ph}$$

▫ θ = angle between V_{ph} & I_{ph}

← Valid for γ & Δ Both connection

In star connection:

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

$$I_{ph} = I_L$$

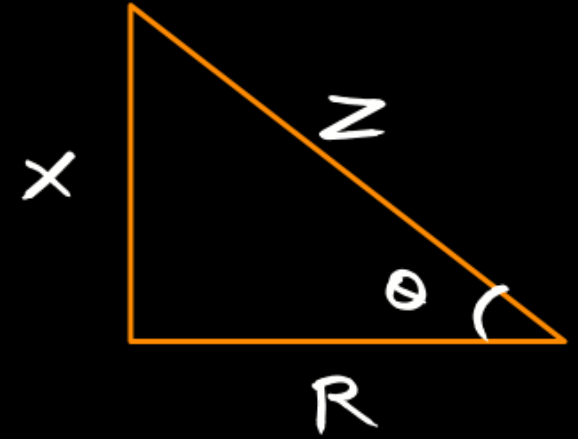
θ is not the angle
between V_L & I_L
↓

$$P = 3 V_{ph} I_{ph} \cos \theta = 3 \left(\frac{V_L}{\sqrt{3}} \right) I_L \cos \theta = \sqrt{3} \underline{V_L} \underline{I_L} \underline{\cos \theta}$$

$$Q = 3 V_{ph} I_{ph} \sin \theta = 3 \left(\frac{V_L}{\sqrt{3}} \right) I_L \sin \theta = \sqrt{3} V_L I_L \sin \theta$$

$$S = 3 V_{ph} I_{ph} = 3 \left(\frac{V_L}{\sqrt{3}} \right) I_L = \sqrt{3} V_L I_L$$

$$P = 3V_{ph} I_{ph} \cos \theta = 3V_{ph} \left(\frac{V_{ph}}{Z} \right) \frac{R}{Z} = \frac{3V_{ph}^2 R}{Z^2} = \frac{V_L^2 R}{Z^2}$$



$$Q = 3V_{ph} I_{ph} \sin \theta = 3V_{ph} \left(\frac{V_{ph}}{Z} \right) \frac{X}{Z} = \frac{3V_{ph}^2 X}{Z^2} = \frac{V_L^2 X}{Z^2}$$

$$S = 3V_{ph} I_{ph} = 3V_{ph} \left(\frac{V_{ph}}{Z} \right) = \frac{3V_{ph}^2}{Z} = \frac{V_L^2}{Z}$$

$$P = \frac{3V_{ph}^2 R}{Z^2} = 3I_{ph}^2 R = 3I_L^2 R$$

$$Q = \frac{3V_{ph}^2 X}{Z^2} = 3I_{ph}^2 X = 3I_L^2 X$$

$$S = \frac{3V_{ph}^2}{Z} = 3I_{ph}^2 Z = 3I_L^2 Z$$

2 Minute Summary

→ Star (Unbalance)

→ Delta (Unbalance)

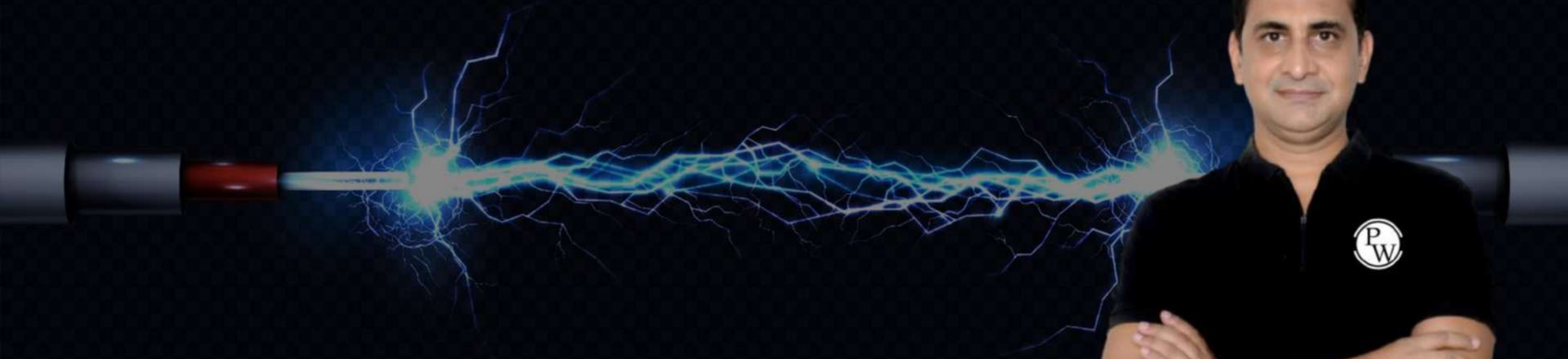
→ 3ph power

THANK
you



Electrical Engineering

POWER SYSTEM



Topic : 3 phase Circuits

Lecture : 2



By- Ajay Gupta Sir



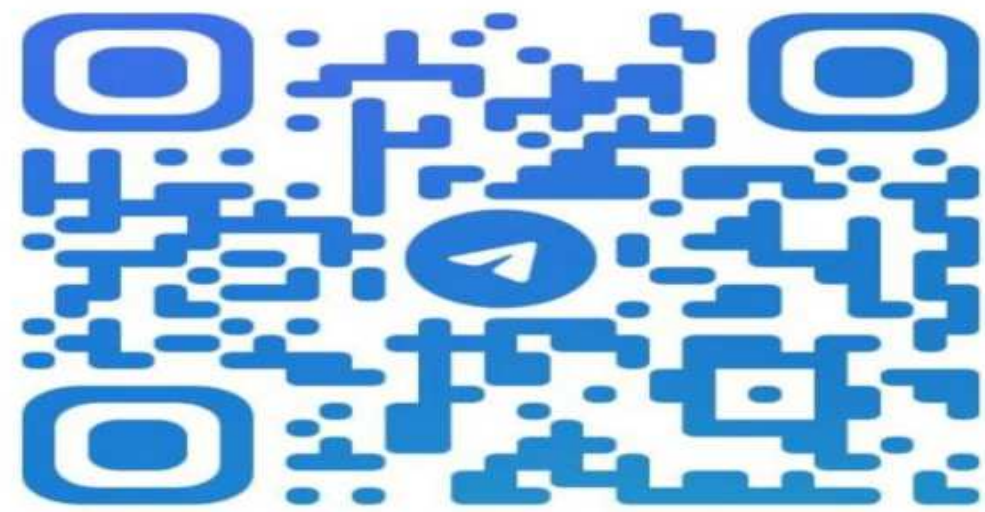
Recap of previous class

- ✓ 1. Unbalance delta load
- ✓ 2. Unbalance star load
- ✓ 3. 3 phase power



Topics to be Covered

- ✓ 1. Measurement of power
- ✓ 2. Single line diagram
- ✓ 3. P.U. System



@AJAYGUPTASIRPW

In delta connection:

$$V_L = V_{ph}$$

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

$$P = 3V_{ph}I_{ph}\cos\phi = 3(V_L)\left(\frac{I_L}{\sqrt{3}}\right)\cos\phi = \sqrt{3}V_LI_L\cos\phi$$

$$Q = \sqrt{3}V_LI_L\sin\phi$$

$$S = \sqrt{3}V_LI_L$$

$$P = \frac{3 V_{ph}^2 R}{Z^2} = \frac{3 V_L^2 R}{Z^2}$$

$$Q = \frac{3 V_{ph}^2 X}{Z^2} = \frac{3 V_L^2 X}{Z^2}$$

$$S = \frac{3 V_{ph}^2}{Z} = \frac{3 V_L^2}{Z}$$

$$P = 3 I_{ph}^2 R = I_L^2 R$$

$$Q = 3 I_{ph}^2 X = I_L^2 X$$

$$S = 3 I_{ph}^2 Z = I_L^2 Z$$

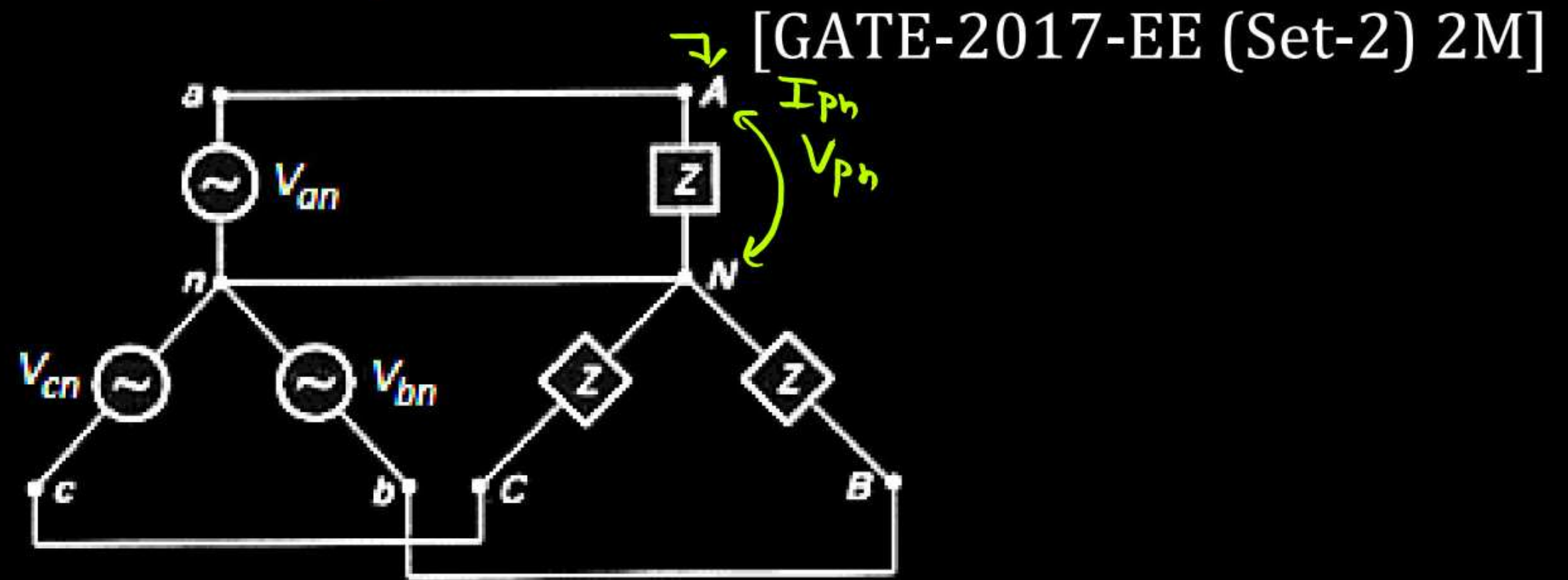
MCQ



For the balanced Y-Y connected 3-phase circuit shown in the figure below, the line-line voltage is 208 V rms and the total power absorbed by the load is 432 W at a power factor of 0.6 leading.

The approximate value of the impedance Z is

- A $33 \angle -53.1^\circ \Omega$
- B $60 \angle 53.1^\circ \Omega$
- C $60 \angle -53.1^\circ \Omega$
- D $180 \angle -53.1^\circ \Omega$



$$Z = \frac{V_{ph}}{I_{ph}}$$

$$V_{ph} = \frac{208}{\sqrt{3}}$$

$$Z = \frac{\frac{208}{\sqrt{3}} \angle 0^\circ}{2 \angle 53.13^\circ}$$

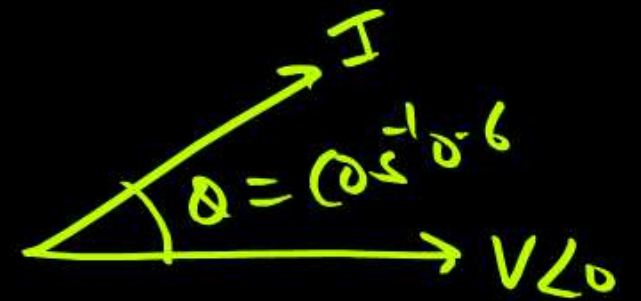
$$= 60 \angle -53.13^\circ$$

$$P = 3 V_{ph} I_{ph} \cos \theta$$

$$432 = 3 \cdot \frac{208}{\sqrt{3}} \cdot I_{ph} \times 0.6$$

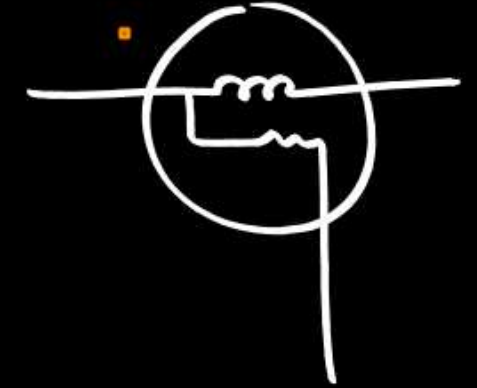
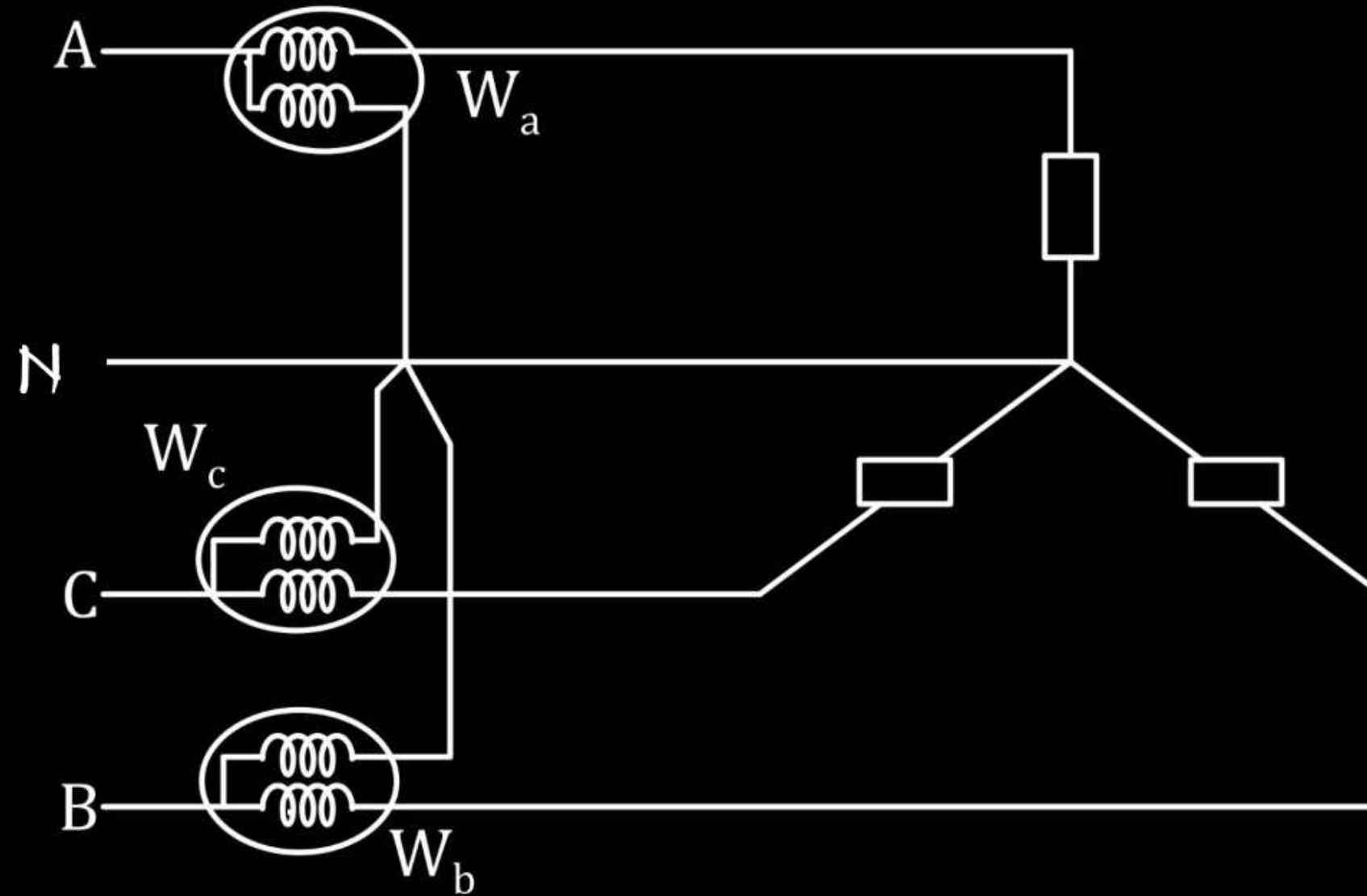
$$|I_{ph}| = 2$$

$$I_{ph} = 2 \angle 53.13^\circ$$



Measurement of 3 Phase Power

1. 3 Watt meter method :



3 phase 4 wire system.



$$W_a = V_{a(Ph)} I_{a(Ph)} \cos \theta$$

$$W_b = V_{b(Ph)} I_{b(Ph)} \cos \theta$$

$$W_c = V_{c(Ph)} I_{c(Ph)} \cos \theta$$

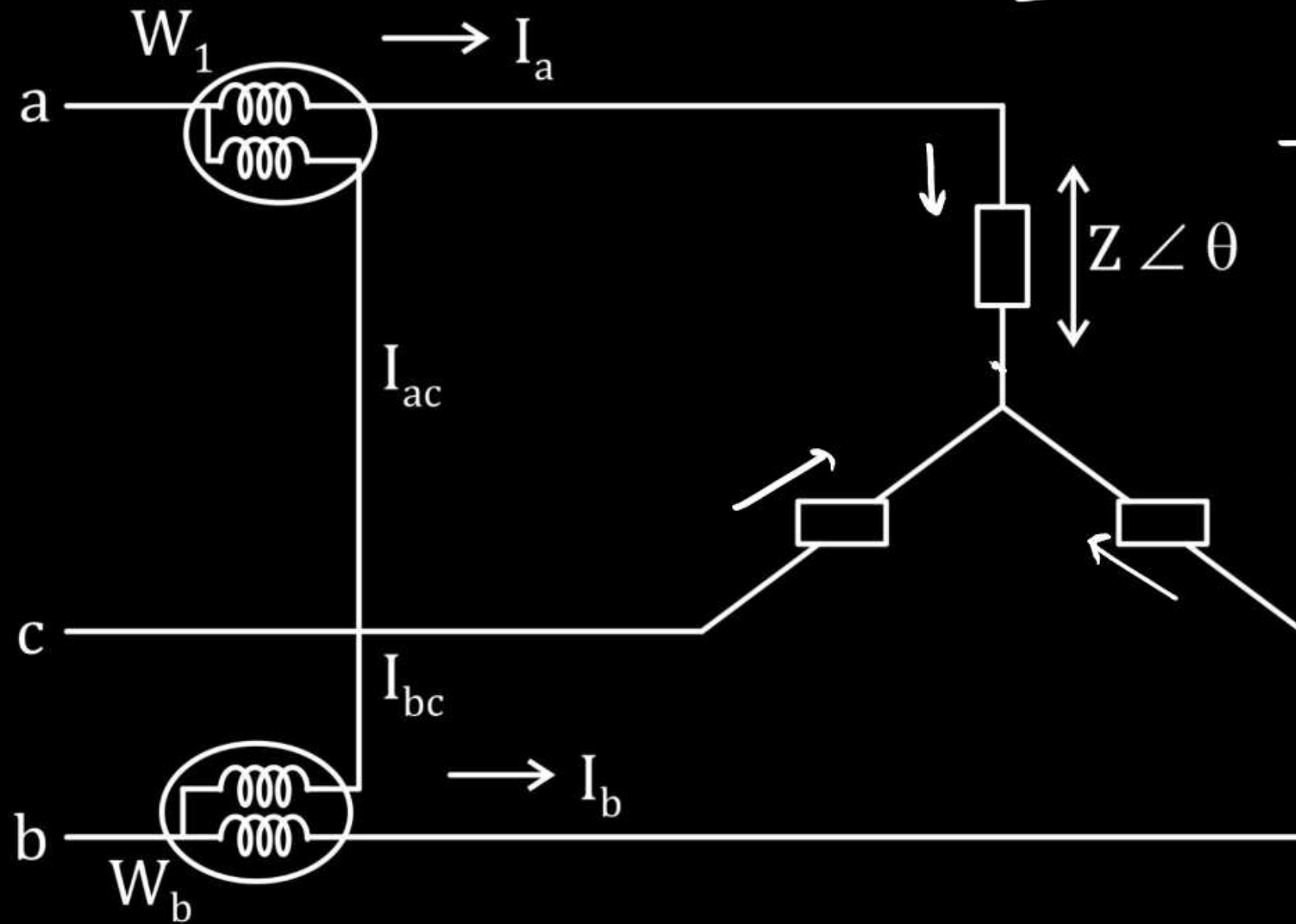
$$W = W_a + W_b + W_c = 3V_{Ph} I_{Ph} \cos \theta$$

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

|

2 Wattmeter method :

$$\underline{I}_{ph} = \frac{V_{ph} \angle 0}{Z \angle \theta} = \frac{V_{ph}}{Z} \angle -\theta$$

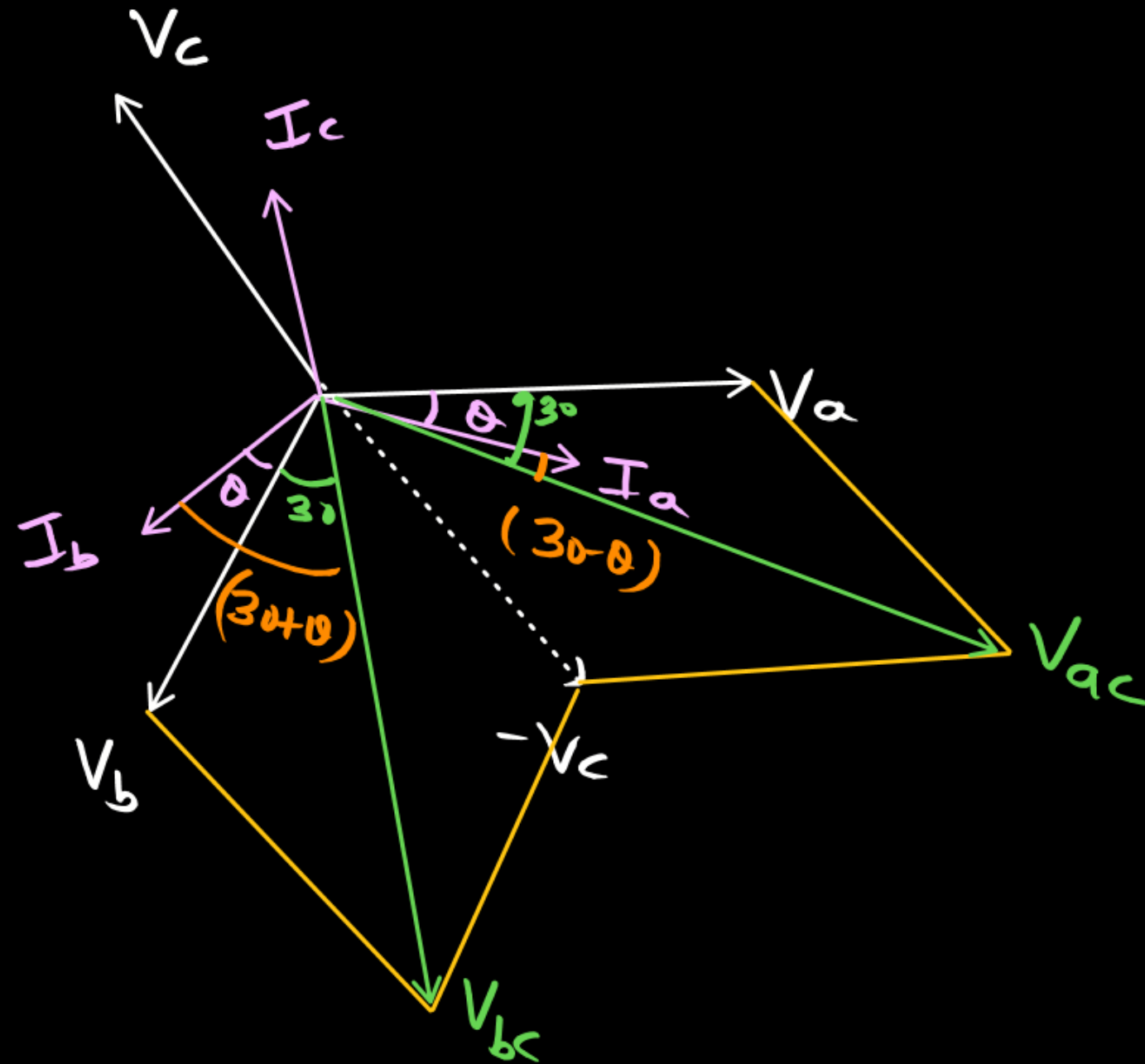


$$\rightarrow W_1 = V_{ac} I_a \cos(\angle V_{ac} - I_a)$$

$$W_1 = V_L I_L \cos(\angle V_{ac} - I_a)$$

$$\rightarrow W_2 = V_{bc} I_b \cos(\angle V_{bc} - I_b)$$

$$W_2 = V_L I_L \cos(\angle V_{bc} - I_b)$$



$$W_1 = V_L I_L \cos(30 - \theta)$$

$$W_2 = V_L I_L \cos(30 + \theta)$$

$$\rightarrow W_1 = V_L I_L \cos(30^\circ - 0)$$

$$W_1 = V_L I_L [\cos 30^\circ \cos 0 + \sin 30^\circ \sin 0] \quad - (1)$$

$$\rightarrow W_2 = V_L I_L \cos(30^\circ + 0)$$

$$= V_L I_L [\cos 30^\circ \cos 0 - \sin 30^\circ \sin 0] \quad - (2)$$

Add eqⁿ (1) and (2)

$$W_1 + W_2 = V_L I_L [2 \cos 30^\circ \cos 0]$$

$$= V_L I_L \cdot 2 \cdot \frac{\sqrt{3}}{2} \cdot \cos 0$$

$$= \sqrt{3} V_L I_L \cos 0 = P$$

$$P = W_1 + W_2 = \sqrt{3} V_L I_L \cos \theta \quad - (3)$$

$$\text{eqn (1)} - \text{eqn (2)}$$

$$W_1 - W_2 = V_L I_L [2 \sin 30 \sin \theta]$$

$$= V_L I_L \left[2 \cdot \frac{1}{2} \cdot \sin \theta \right]$$

$$W_1 - W_2 = V_L I_L \sin \theta$$

$$\sqrt{3} (W_1 - W_2) = \sqrt{3} V_L I_L \sin \theta = Q$$

$$Q = \sqrt{3} (W_1 - W_2) = \sqrt{3} V_L I_L \sin \theta \quad - (4)$$

$$\frac{e_{qn}(4)}{e_{qn}(3)} = \frac{\sqrt{3}(W_1 - W_2)}{(W_1 + W_2)} = \frac{\cancel{\sqrt{3}V_L I_L} \sin \phi}{\cancel{\sqrt{3}V_L I_L} \cos \phi} = \tan \phi$$

$$\phi = \tan^{-1} \frac{\sqrt{3}(W_1 - W_2)}{(W_1 + W_2)}$$

$$P = W_1 + W_2$$

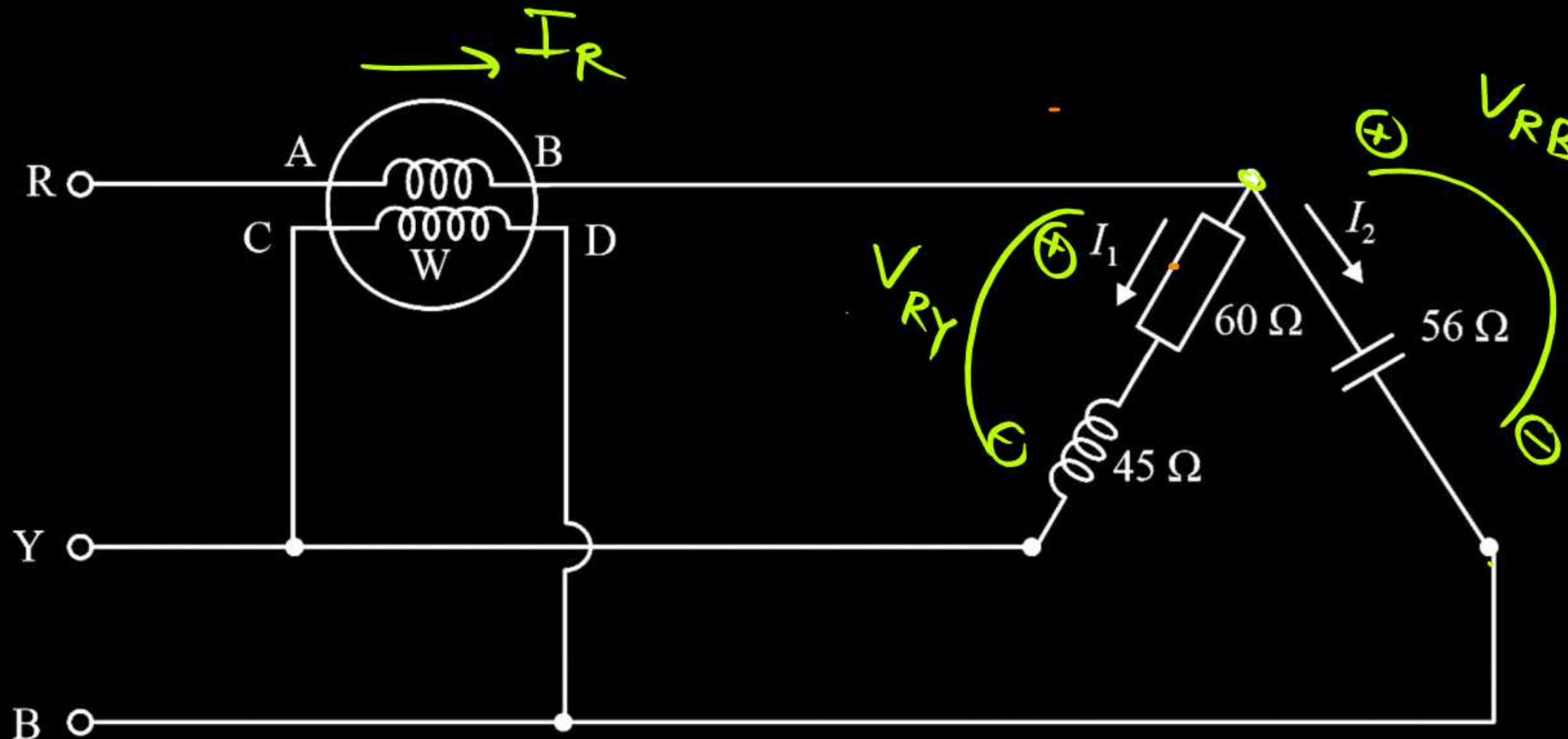
$$Q = \sqrt{3}(W_1 - W_2)$$

$$\tan \theta = \frac{\sqrt{3}(W_1 - W_2)}{(W_1 + W_2)}$$

Same result, we can find out in delta 3 phase 3 wire line.

Question:

Two impedances, one of resistance 60Ω in series with an inductive reactance 45Ω and the other of capacitive reactance 56Ω are connected across a 3- ϕ , 440-V supply with phase sequence RYB, as shown in Figure. Find the reading of the wattmeter connected in phase R, as shown in the figure.



$$V_{RY} = 440 \angle 0$$

$$V_{YB} = 440 \angle -120$$

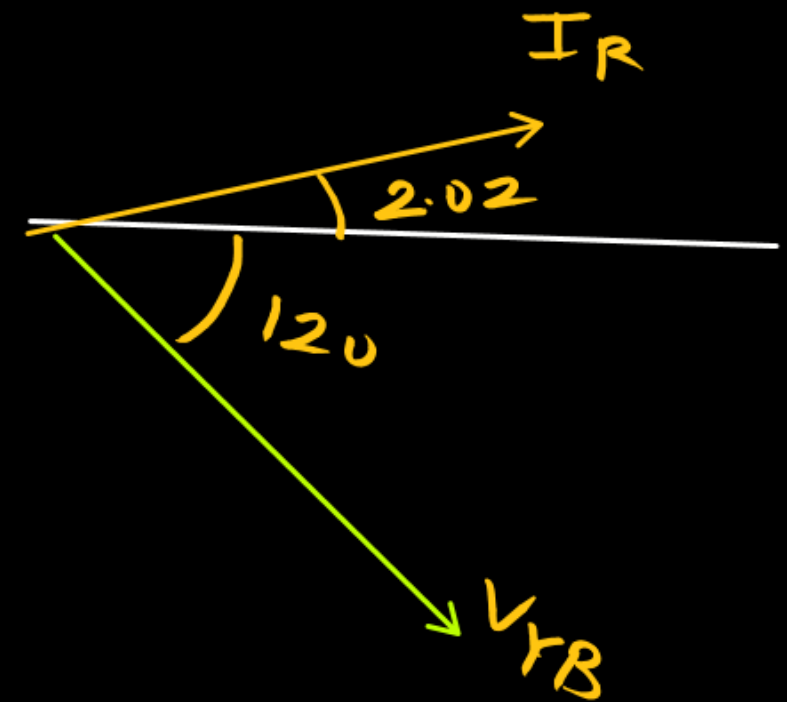
$$V_{BR} = 440 \angle -240 \Rightarrow V_{RB} = 440 \angle -240 + 180 = 440 \angle -60$$

$$I_1 = \frac{V_{RY}}{60 + j45} = \frac{440}{60 + j45} = \frac{440}{75 \angle 36.87} = 5.87 \angle -36.87$$

$$I_2 = \frac{V_{RB}}{-j56} = \frac{440 \angle -60}{56 \angle -90} = 7.857 \angle 30$$

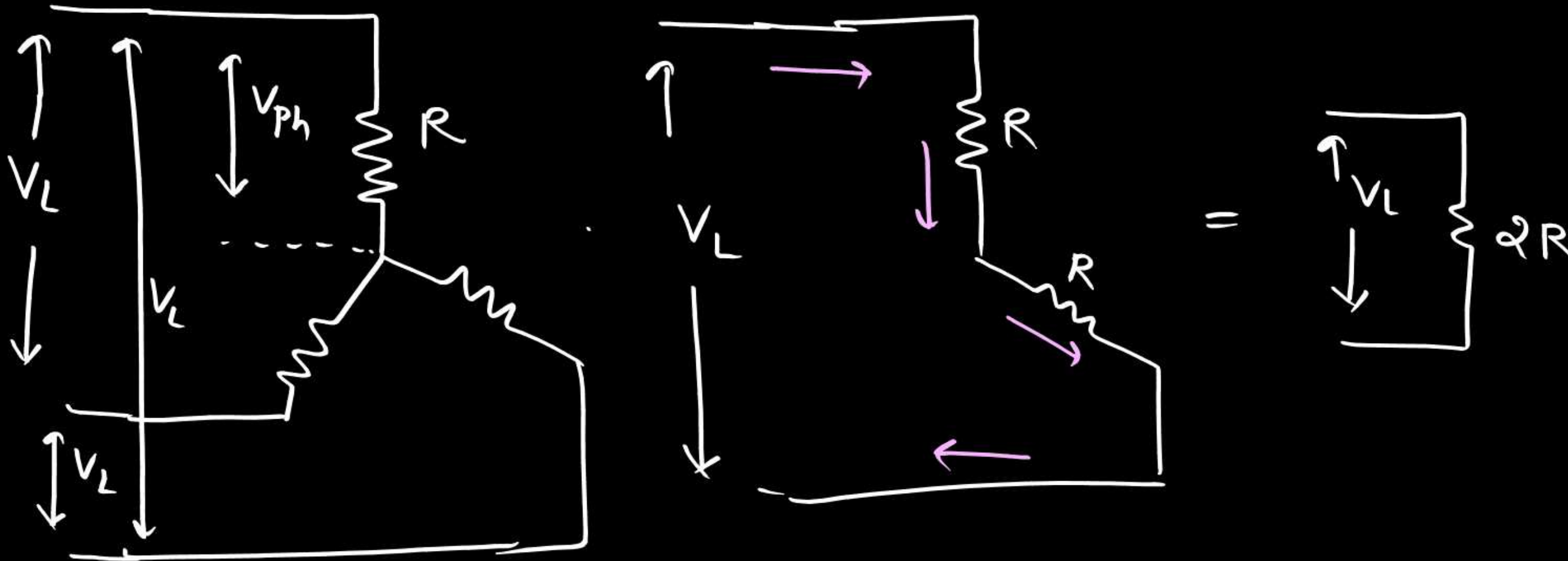
$$I_R = I_1 + I_2 = 11.50 \angle 2.024$$

$$\begin{aligned} W &= V_{YB} I_R \cos(\angle V_{YB} I_R) \\ &= (440)(11.5) \cos 122.02^\circ \\ &= -2696 \end{aligned}$$



Question:

Three identical resistances are connected in a star fashion against a balanced three phase voltage supply. If one of the resistances be removed, by how much percent the power be reduced?



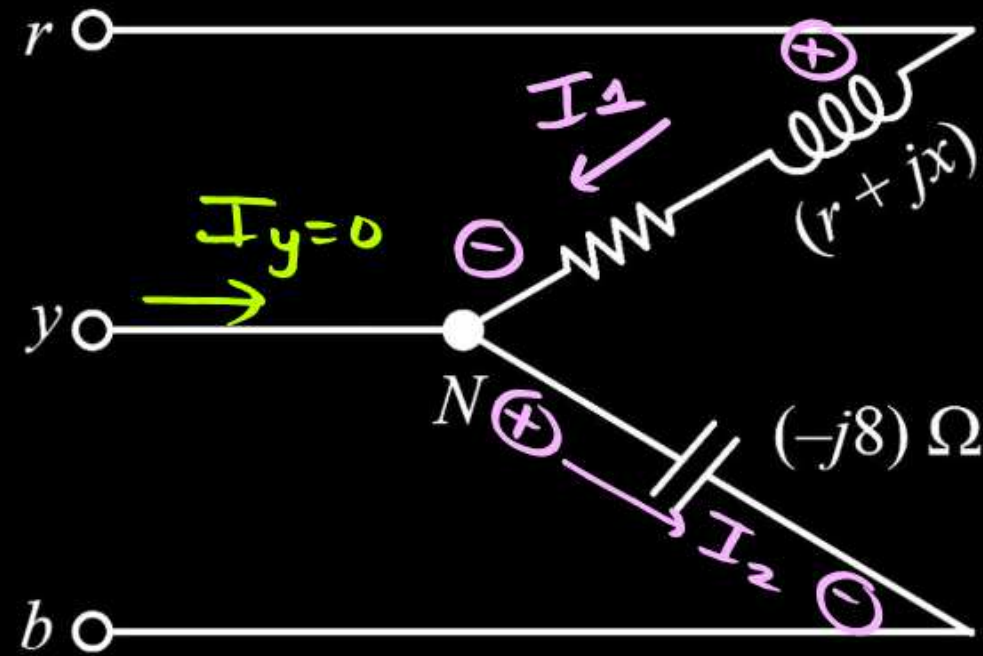
$$P_1 = 3 \frac{V_{Ph}^2}{R} = \frac{3 \left(\frac{V_L}{\sqrt{3}} \right)^2}{R} = \frac{V_L^2}{R}$$

$$P_2 = V_L^2 / 2R$$

$$\% \text{ change } \frac{P_1 - P_2}{P_1} \times 100 = \frac{\frac{V_L^2}{R} - \frac{V_L^2}{2R}}{\frac{V_L^2}{R}} \times 100 = 50\%$$

Question:

In the given circuit of Figure. Find the value of the unknown impedance provided no current flows in branch y .



$$I_y = 0 \Rightarrow I_1 = I_2$$

$$V_{ry} = V \angle 0^\circ$$

$$V_{yb} = V \angle -120^\circ$$

$$V_{br} = V \angle -240^\circ$$

Ⓐ $3 + j2$

Ⓑ $6.94 + j4$

Ⓒ $3.3 + j4$

Ⓓ $4 + j6.94$

$$I_1 = \frac{V_{ay}}{8+jx} = \frac{V}{8+jx}$$

$$I_2 = \frac{V_{yb}}{-j8} = \frac{V \angle -120}{8 \angle -90} = \frac{V}{8 \angle 30}$$

$$I_1 = I_2$$

$$\frac{V}{8+jx} = \frac{V}{8 \angle 30}$$

$$8+jx = 8 \angle 30$$

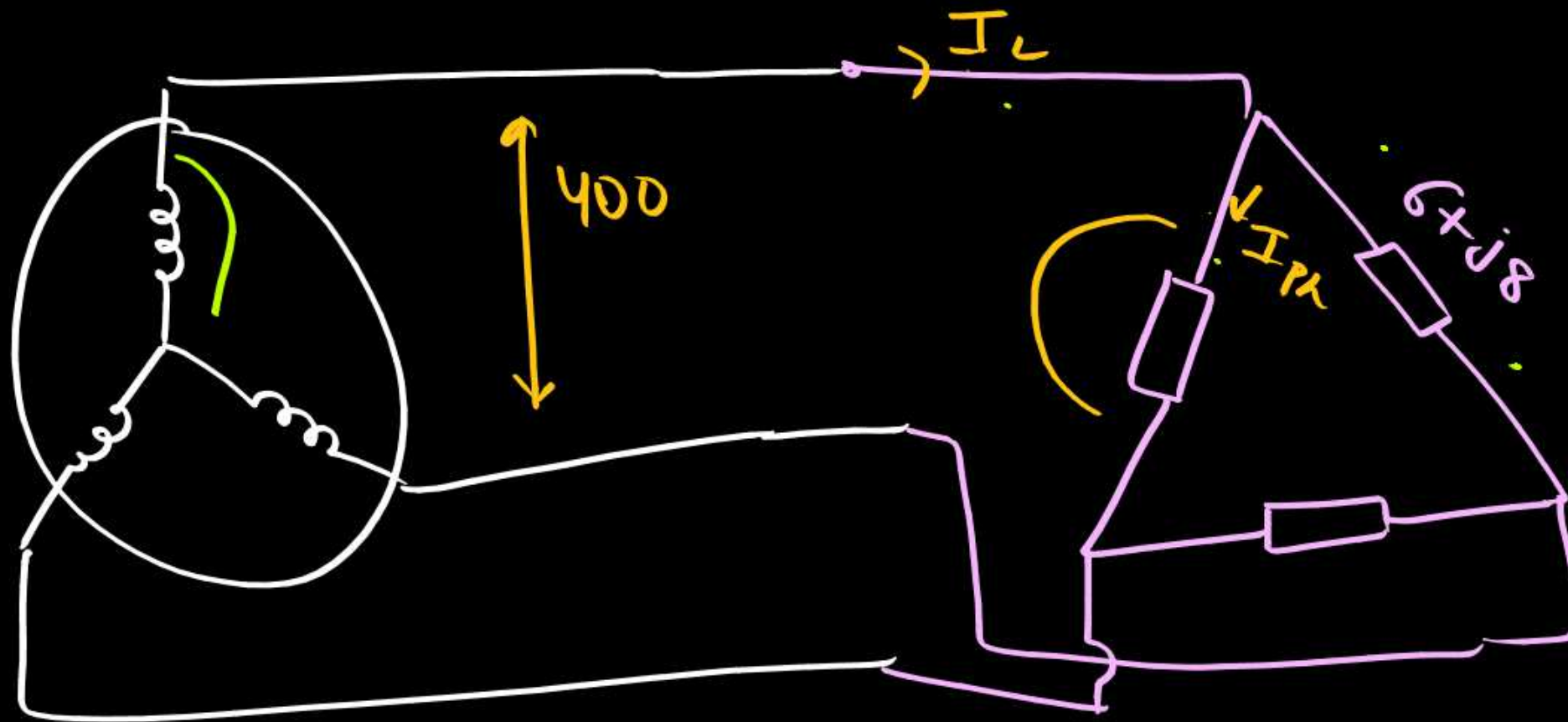
$$8+jx = 6.928+j4$$

$$8 = 6.928$$

$$x = 4$$

Question:

A star connected alternator supplies a delta connected load. The impedance of each branch is $(6 + j8) \Omega$. The line voltage is 400 V. Obtain the current in phase of the load. Also find the current in each phase of the alternator. What is the power drawn by the load and its power factor? Determine the reactive power of the load. (KVAR)



$$V_{ph} = V_L = 440$$

$$I_{ph} = \frac{440 \angle 0}{6 + j8} = \frac{440}{10 \angle 53.1} = 44 \angle -53.1$$

$$|I_{ph}| = 44$$

$$P.f \text{ angle} = 53.1$$

$$|I_L| = \sqrt{3}(44)$$

$$P.f = \cos 53.1 = 0.6$$

$$P = 3 I_{ph}^2 R$$

$$P = 3(44)^2(6) = 28,800 = 28.8 \text{ kW}$$

$$Q = 3 I_{ph}^2 X$$

$$= 3(44)^2(8)$$

$$= 38400$$

$$= 38.4 \text{ kV}$$

Single Line Diagram:



- Single line diagram is the representation of power system using symbol for each component. It show connection and arrangement along with their data.
- Generator & transformer connection are also indicated in single line diagram.
- 3 Phase system is represented as single line.

Real Name

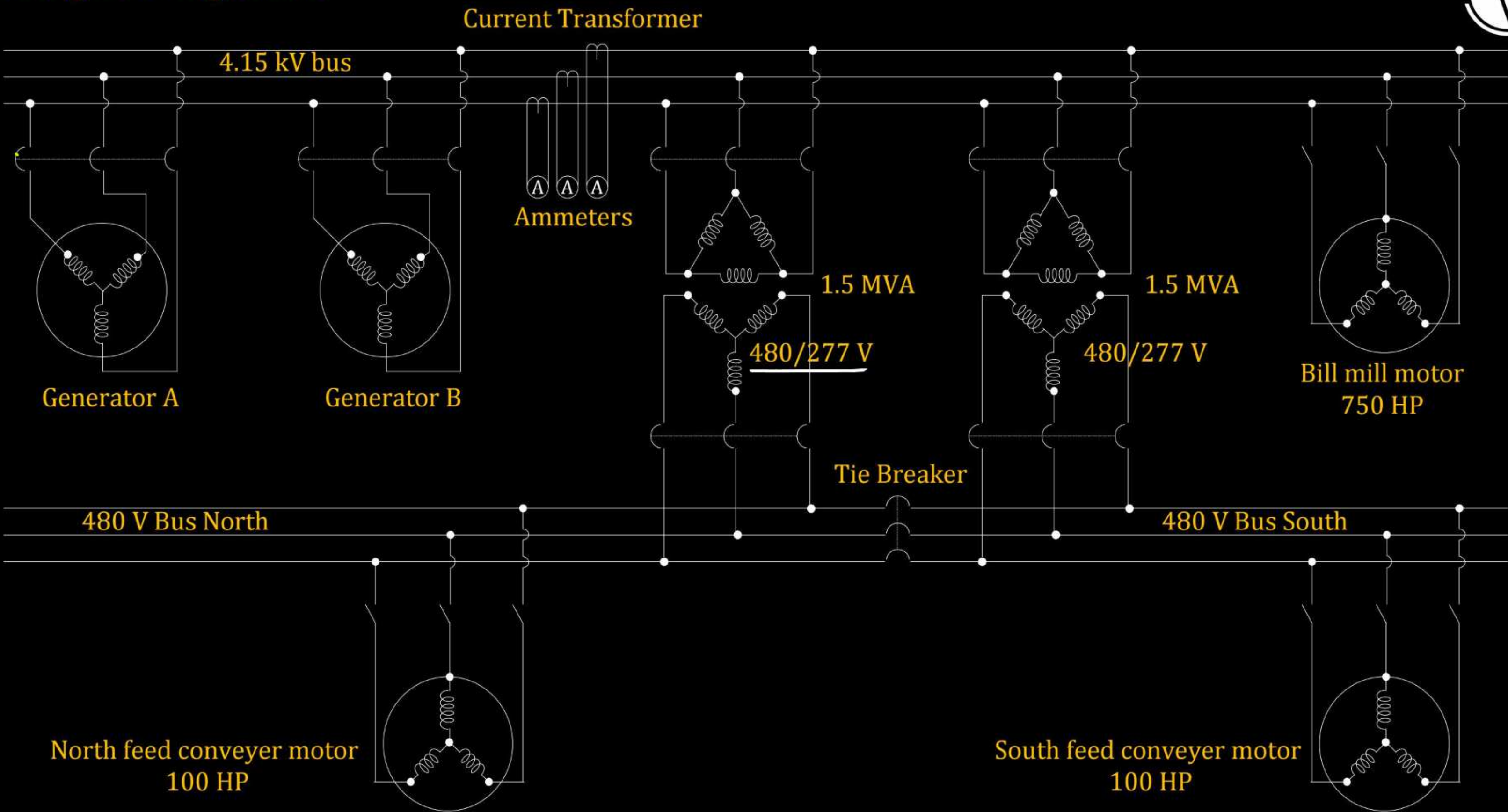
Karona Kapoor Khan

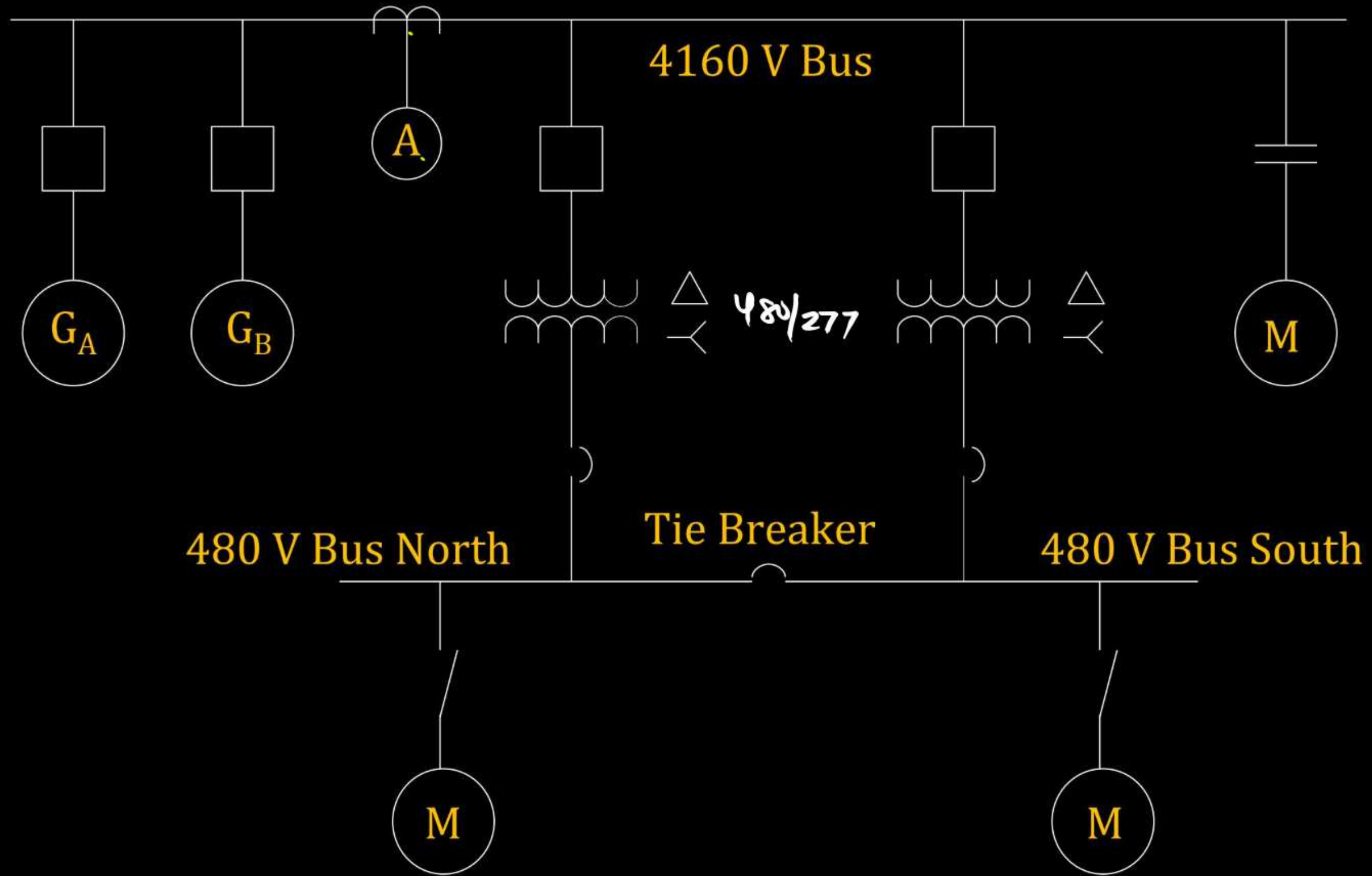


Nick Name

Bebo

Single Diagram:





2 Minute Summary

→ Measurement of 3 ph power

→ P, Q, Q .

→ Question

THANK
you

PRACTICE SHEET-1

EE POWER SYSTEM 3 phase Circuits

Q 1 Three phase voltages of a balanced three phase system are V_{an} , V_{bn} and V_{cn} . If $V_{an} = 120\angle 10^\circ$ V and $V_{bn} = 120\angle -110^\circ$ V, then phase sequence of the system is :

- (A) abc (B) acb
(C) cba (D) bac

Q 2 A balanced Y - connected source with $V_{an} = 220\angle 0^\circ$ V is connected to a delta connected balanced $(12 + j16) \Omega$ /phase. The magnitude of the line current is _____A. (Assume positive phase sequence)

Q 3 A balanced delta connected load absorb a total power of 24 kVA at a lagging power factor of 0.8 when connected to a line voltage of 400 V. The magnitude of the phase current is _____A.

Q 4 The three-phase sequence of the voltages given below,

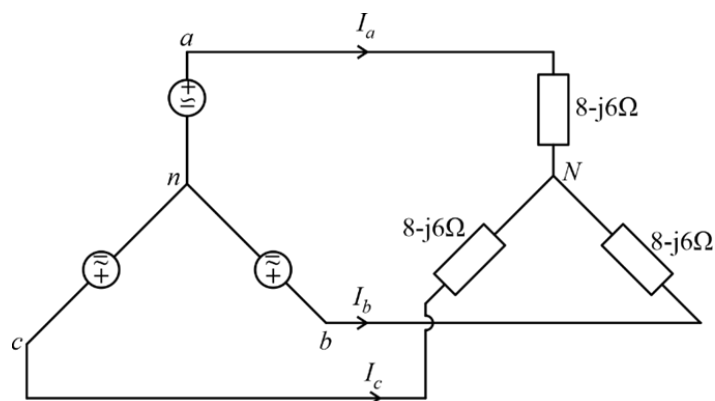
$$V_{an} = 230 \cos (wt + 50^\circ)$$

$$V_{bn} = 230 \cos (wt - 190^\circ)$$

$$V_{cn} = 230 \cos (wt - 70^\circ)$$

- (A) abc (B) acb
(C) Positive (D) Negative

Q 5 In the given balanced circuit, the value of the line current I_B is, if $V_{an} = 239.6\angle 0^\circ$.

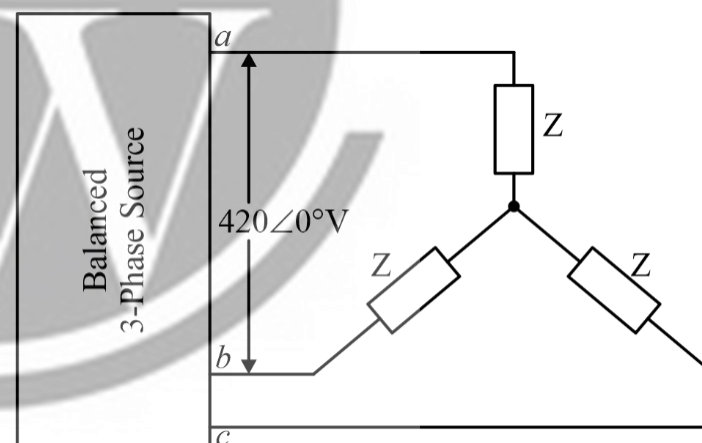


- (A) $41.5\angle -83.13^\circ$
(B) $41.5\angle 83.13^\circ$
(C) $23.96\angle -83.13^\circ$
(D) $23.96\angle 83.13^\circ$

Q 6 If $V_{an} = 230\angle 60^\circ$ V, assuming a positive (abc) sequence. Then the value of voltage V_{cb} is :

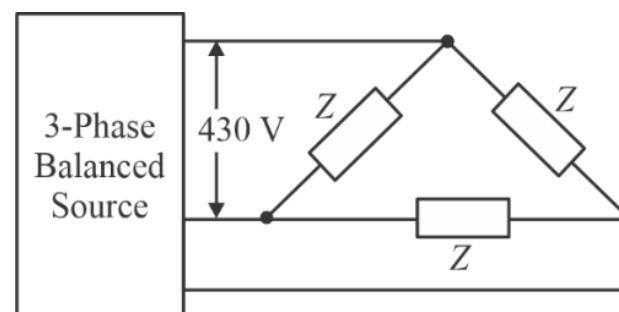
- (A) $398.37\angle -210^\circ$
(B) $398.37\angle -90^\circ$
(C) $398.37\angle -150^\circ$
(D) $398.37\angle 90^\circ$

Q 7 In the three-phase circuit of figure, load is balanced and $Z = 10 + j17.32 \Omega$. The phase difference between line voltage V_{ab} and line current I_a is _____ degree.



Q 8 A balanced Δ -connected source having positive phase sequence is connected to a Y-connected load. If $V_{ab} = 420 \angle 0^\circ$ V and $Z_Y = 3 + j4 \Omega$, then the active power consumed by the load is _____W.

Q 9 In the three-phase circuit of figure shown below, the magnitude of line current is _____A. If $Z = 5\angle 30^\circ \Omega$.



Q 10 The phase impedance of a star connected load is $(12 + j12) \Omega$. The reactive power of the load (in VAR) if the applied line voltage is 420 V.

Answer Key

Q1	A	Q6	A,C
Q2	32~34	Q7	89~91
Q3	19~20	Q8	21160~21171
Q4	B,D	Q9	147~150
Q5	C	Q10	7348~7352





Power System

Practice Sheet Discussion – 01

3 phase Circuits

By – Ajay Gupta Sir

Three phase voltages of a balanced three phase system are V_{an} , V_{bn} and V_{cn} . If $V_{an} = 120 \angle 10^\circ \text{ V}$ and $V_{bn} = 120 \angle -110^\circ \text{ V}$, then phase sequence of the system is

A

abc

B

acb

C

cba

D

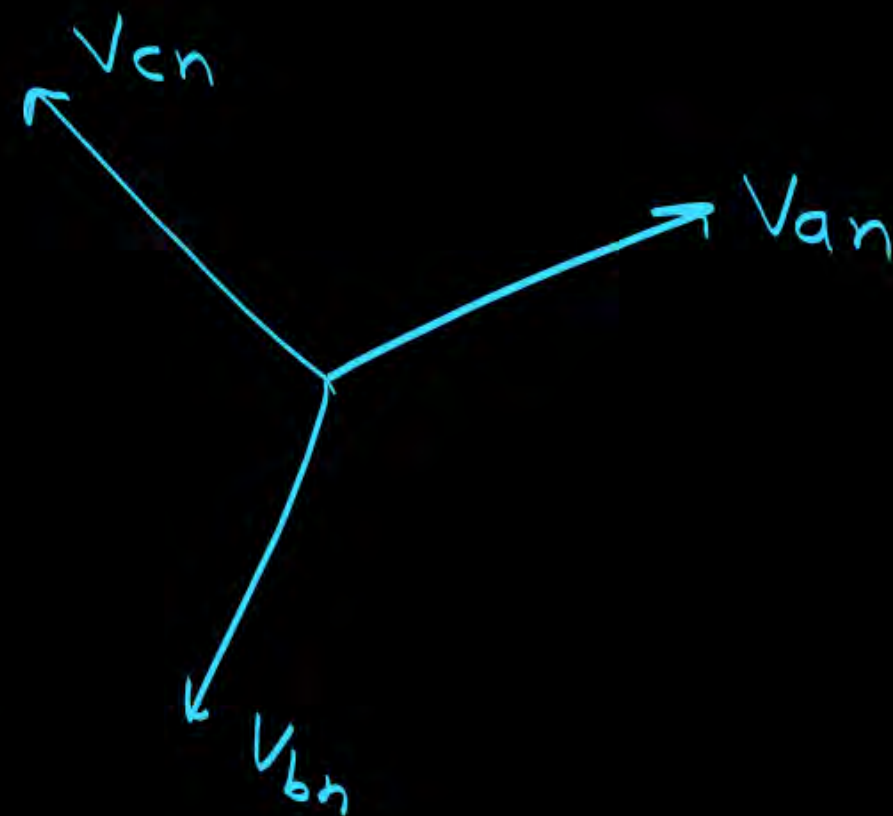
bac

$$V_{an} = 120 \angle 10^\circ$$

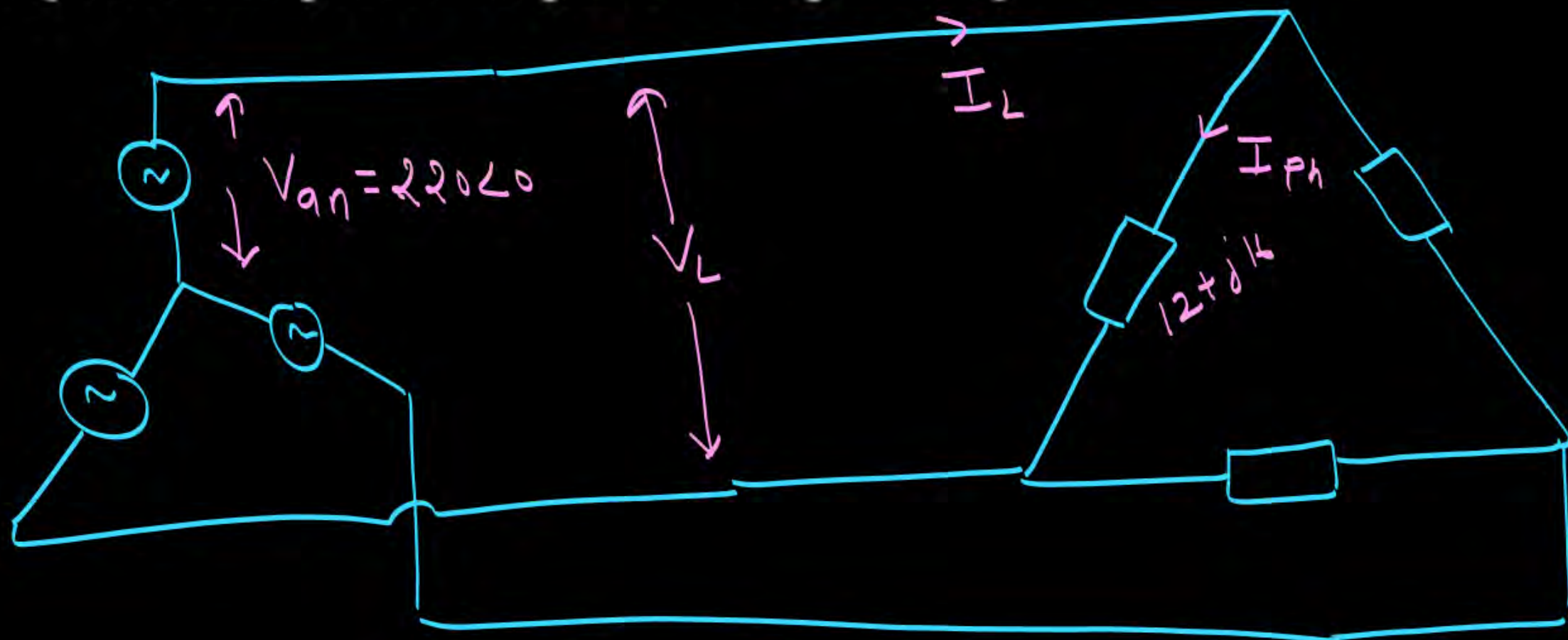
$$V_{bn} = 120 \angle -110^\circ$$

→ V_{bn} lag the V_{an} by 120°

So phase sequence is abc



A balanced Y-connected source with $V_{an} = 220\angle 0^\circ$ V is connected to a delta connected balanced $(12 + j16) \Omega/\text{phase}$. The magnitude of the line current is ____A. (Assume positive phase sequence).



$$|I_{pn}| = \frac{220\sqrt{3}}{\sqrt{12^2 + 16^2}} = \frac{220\sqrt{3}}{20}$$

$$|I_L| = \sqrt{3} |I_{pn}|$$

$$= \sqrt{3} \times \frac{220\sqrt{3}}{20} = 33 \text{ Amp}$$

A balanced delta connected load absorb a total power of 24 kVA at a lagging power factor of 0.8, when connected to a line voltage of 400 V. The magnitude of the phase current is ____A.

$$S = 3 V_{ph} I_{ph}$$

$$24 \times 1000 = 3 \times 400 \times I_{ph}$$

$$I_{ph} = \frac{24 \times 1000}{3 \times 400} = 20 \text{ Amp.}$$

for delta connected load

$$V_L = V_{ph} = 400$$

The three-phase sequence of the voltages given below,

$$V_{an} = 230 \cos(\omega t + 50^\circ)$$

$$V_{bn} = 230 \cos(\omega t - 190^\circ)$$

$$V_{cn} = 230 \cos(\omega t - 70^\circ)$$

A

abc

 $\rightarrow V_{cn}$ lag V_{an} by 120° **B**

acb ✓

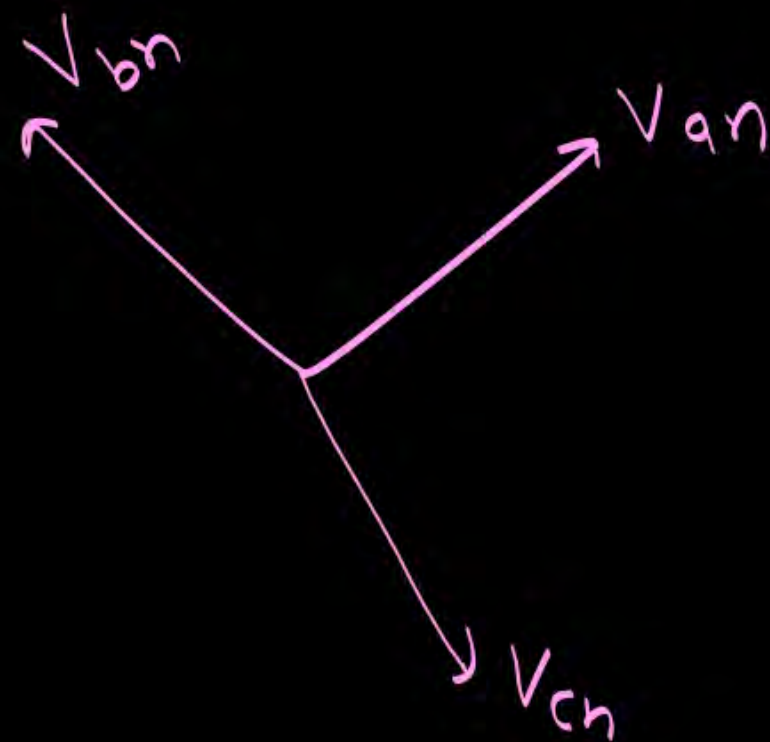
 $\rightarrow V_{bn}$ lag V_{cn} by 120° **C**

Positive

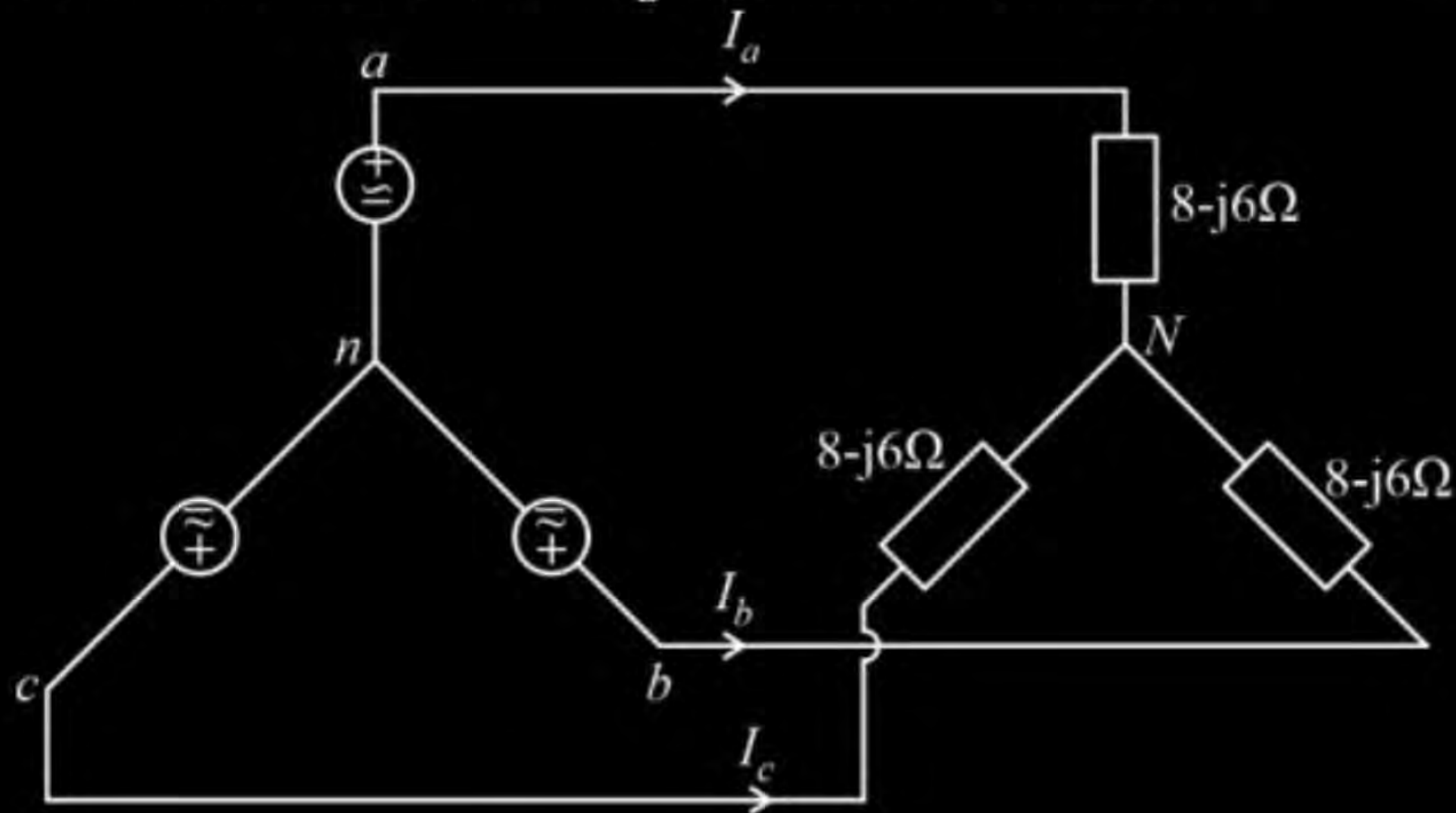
So phase sequence is acb

D

Negative ✓



In the given circuit, the value of the line current I_B is, if $V_{an} = 239.6 \angle 0^\circ$.



A $41.5 \angle -83.13^\circ$

B $41.5 \angle 83.13^\circ$

C $23.96 \angle -83.13^\circ$

D $23.96 \angle 83.13^\circ$

$$V_{bn} = 239.6 \angle -120$$

$$I_b = \frac{V_{bn}}{8-j6} = \frac{239.6 \angle -120}{8-j6} = 23.96 \angle -83.13$$

If $V_{an} = 230 \angle 60^\circ \text{V}$, assuming a positive (abc) sequence. Then the value of voltage V_{cb} is

A ✓ $398.37 \angle -210^\circ \text{V}$

B $398.37 \angle -90^\circ \text{V}$

C ✓ $398.37 \angle 150^\circ \text{V}$

D $398.37 \angle 90^\circ \text{V}$

$$V_{bn} = 230 \angle -60^\circ$$

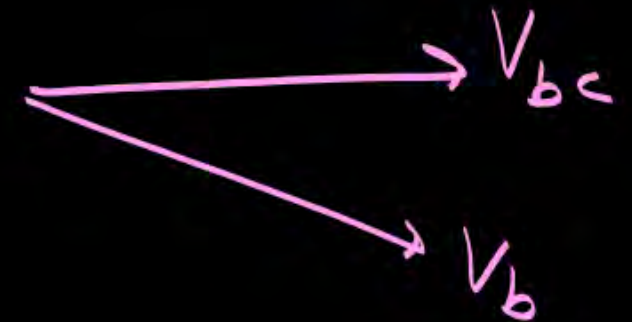
$$V_{bc} = 230\sqrt{3} \angle -60 + 30$$

$$V_{bc} = 398.37 \angle -30$$

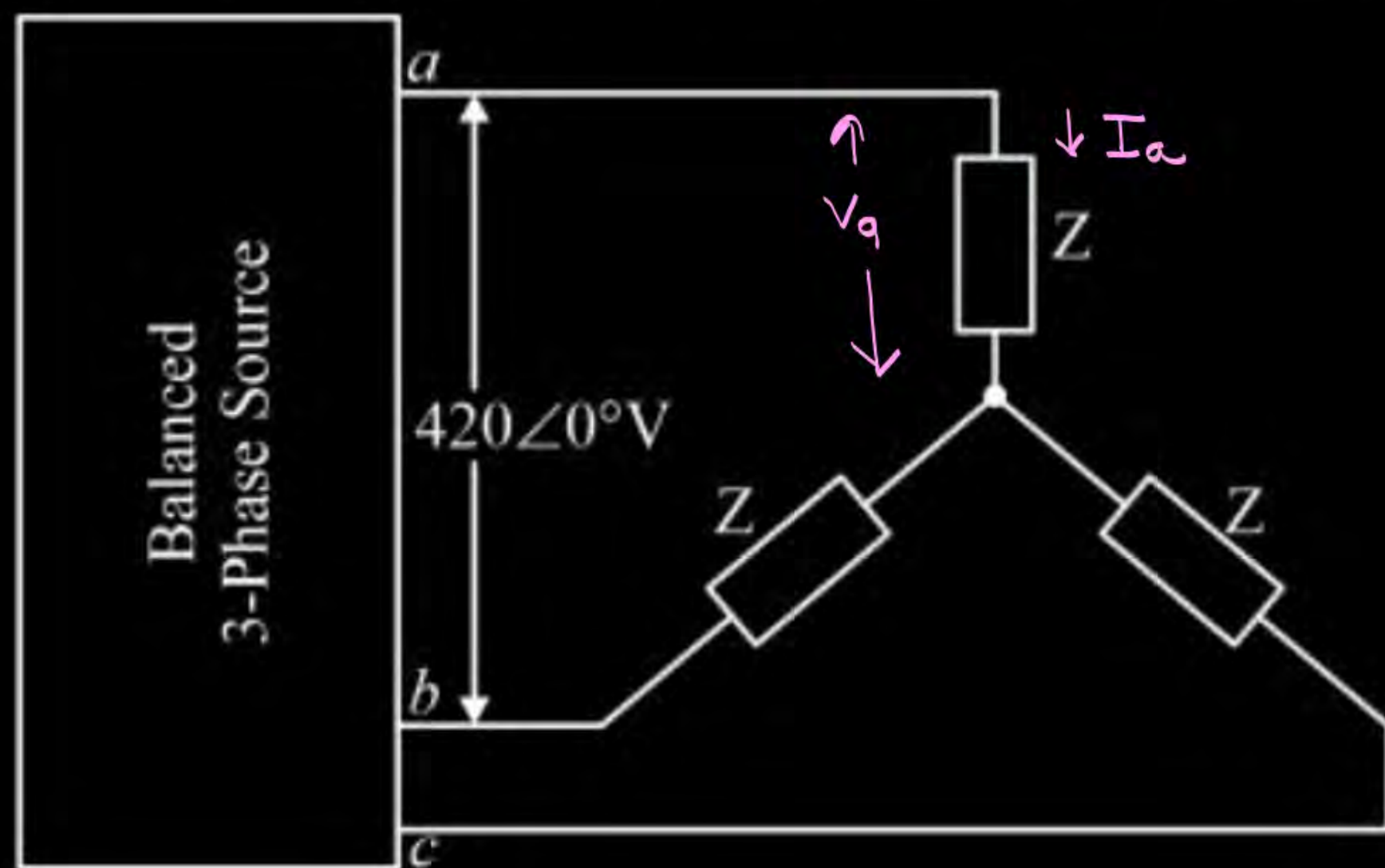
$$V_{cb} = -V_{bc} = 398.37 \angle -30 \pm 180$$

$$= 398.37 \angle -210$$

$$= 398.37 \angle 150$$



In the three-phase circuit of figure, load are balanced and $Z = 10 + j17.32 \Omega$. The phase difference between line voltage V_{ab} and line current I_a is ____ degree.



V_a lag V_{ab} by 30°

$$V_a = \frac{420}{\sqrt{3}} \angle -30^\circ$$

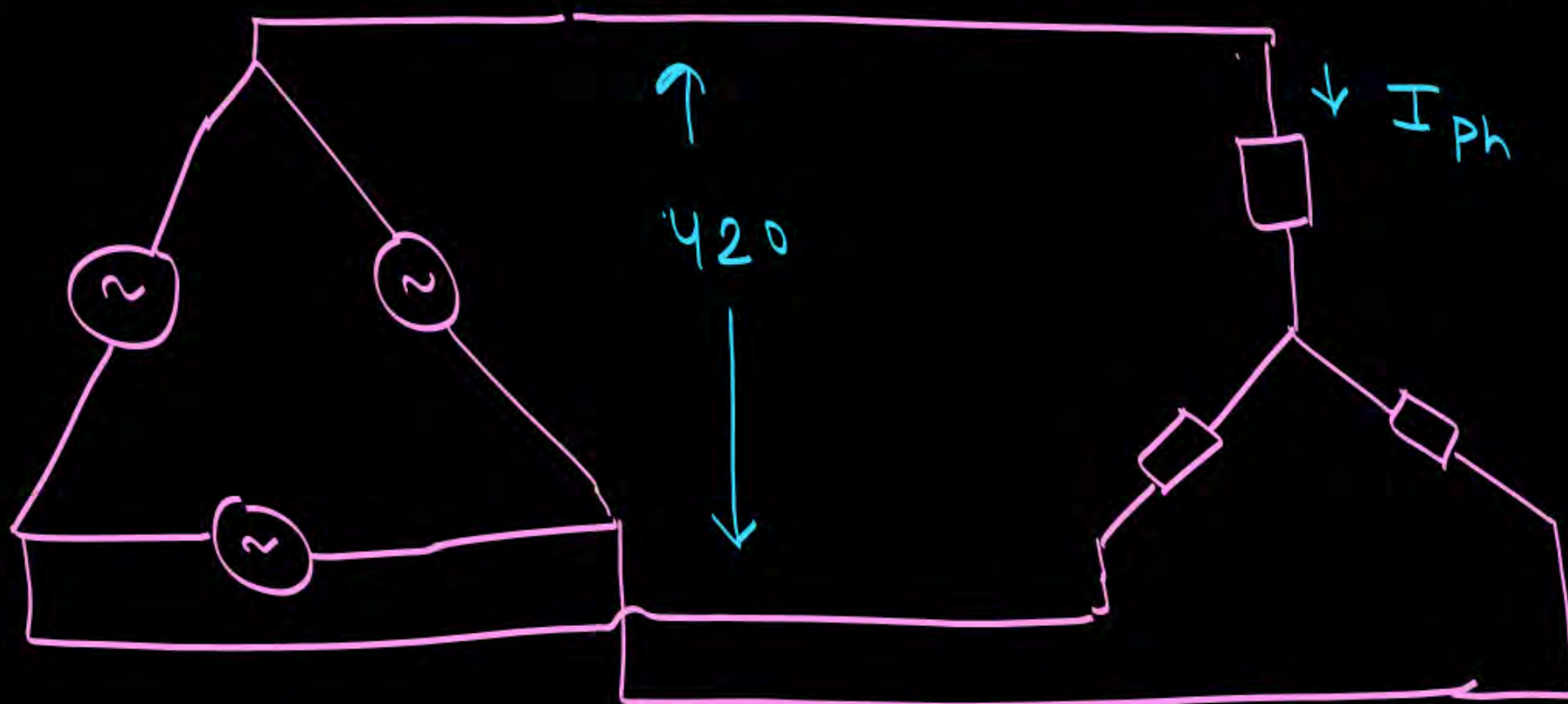
$$I_a = \frac{420/\sqrt{3}}{10 + j17.32} \angle -30^\circ$$

$$I_a = 12.12 \angle -90^\circ$$

So phase difference is 90°

A balanced Δ -connected source having positive phase sequence is connected to a Y-connected load.

If $V_{ab} = 420 \angle 0^\circ$ V and $Z_Y = 3 + j4 \Omega$, then the active consumed by the load is _____ W.



$$V_{ph} = \frac{420}{\sqrt{3}}$$

$$|I_{ph}| = \frac{420/\sqrt{3}}{|3+j4|} = 48.5 \text{ Amp}$$

$$P = \sqrt{3} V_L I_L \cos \theta = 3 V_{ph} I_{ph} \cos \theta$$

$$= 3 \times \frac{420}{\sqrt{3}} \times 48.5 \times \frac{3}{5}$$

$$= 21169$$

$$Z = 3 + j4$$

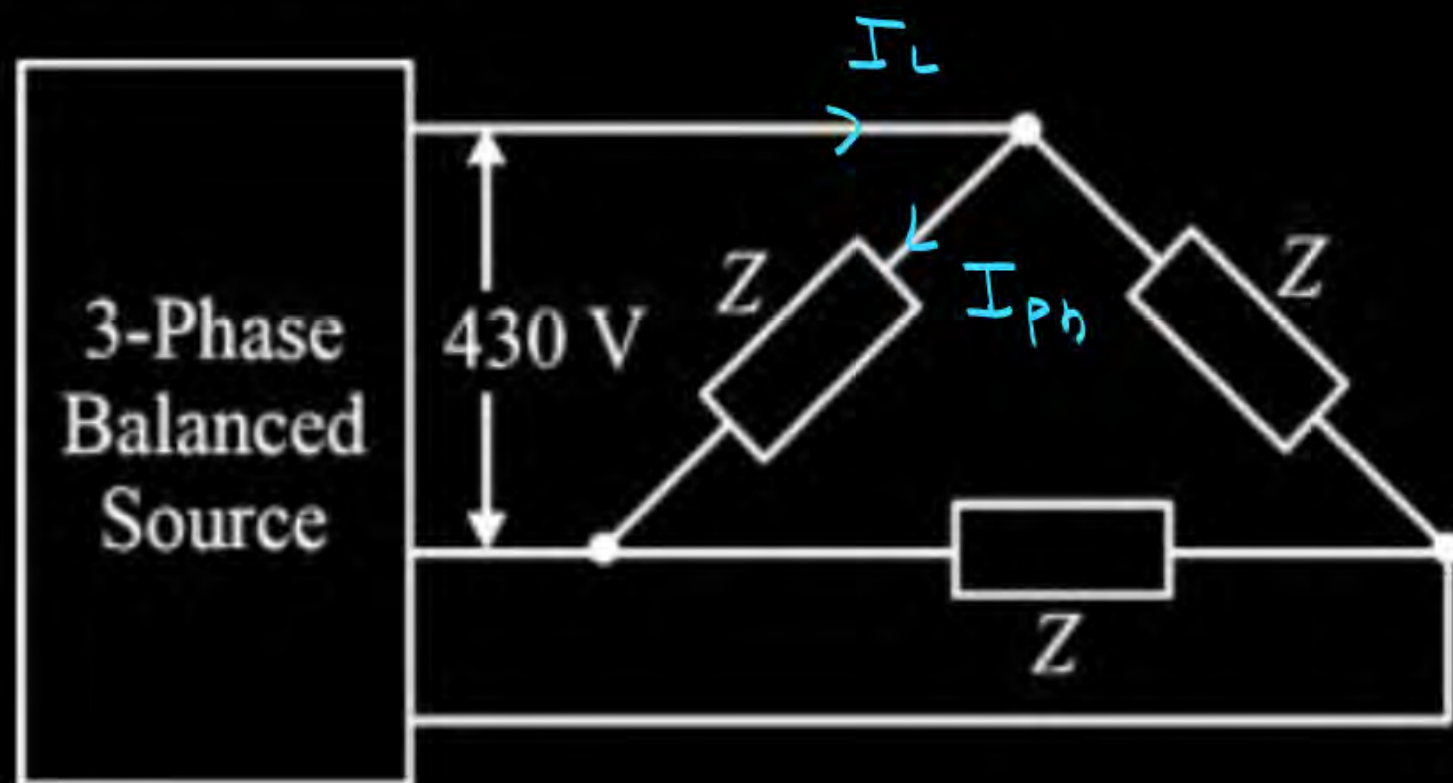
$$\theta = \tan^{-1} \frac{4}{3}$$

$$\cos \theta = 3/5$$

In the three-phase circuit of figure shown below, the magnitude of line current is _____A. If $Z = 5\angle 30^\circ \Omega$.

$$|I_{ph}| = \frac{430}{5}$$

$$|I_L| = \sqrt{3} \times \frac{430}{5} \\ = 148.95$$



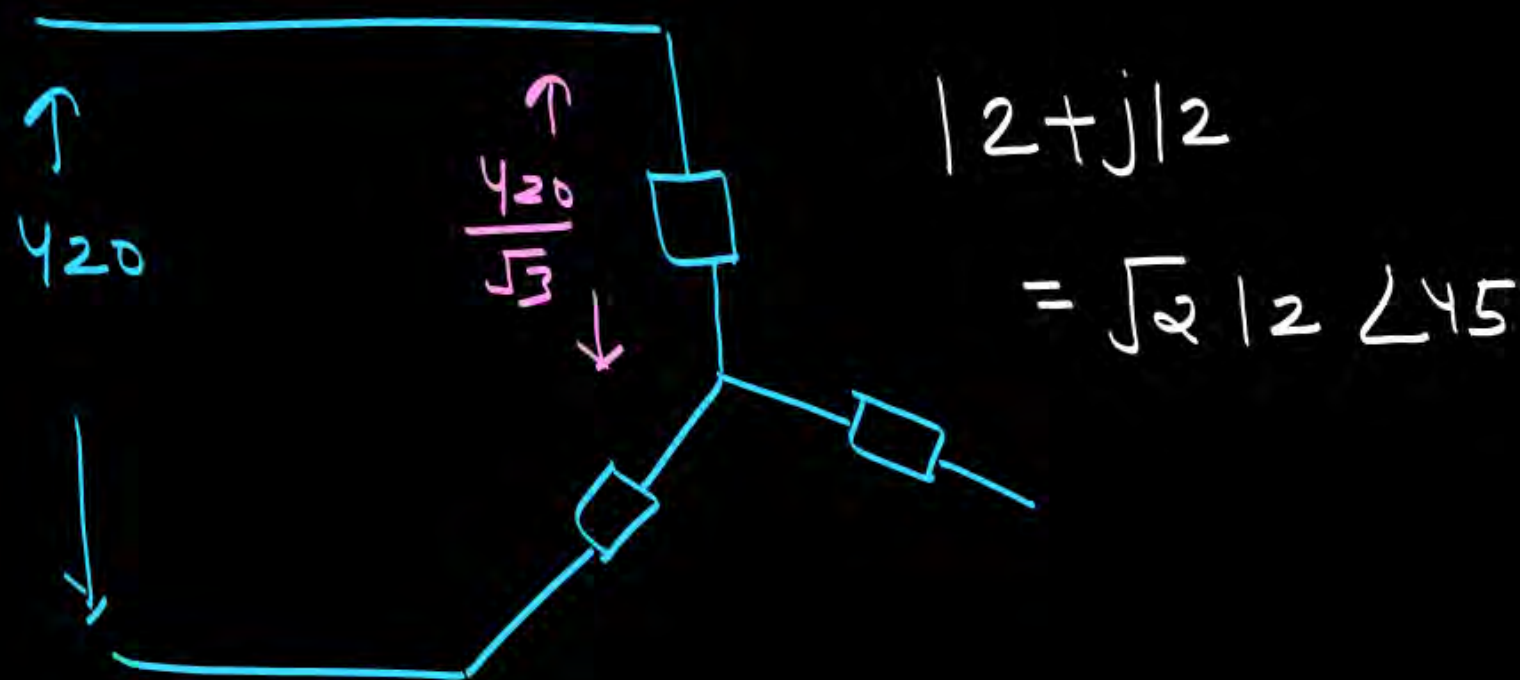
The phase impedance of a star connected load is $(12 + j12) \Omega$. What is the reactive power of the load (in VAR), if the applied line voltage is 420 V.

$$Q = 3 V_{ph} I_{ph} \sin \phi$$

$$= 3 V_{ph} \cdot \frac{V_{ph}}{Z} \cdot \frac{x}{Z}$$

$$= \frac{3 V_{ph}^2 x}{Z^2}$$

$$= 3 I_{ph}^2 x = 3 \times \left[\frac{420/\sqrt{3}}{\sqrt{2} \times 12} \right]^2 \times 12 = \underline{7350}$$



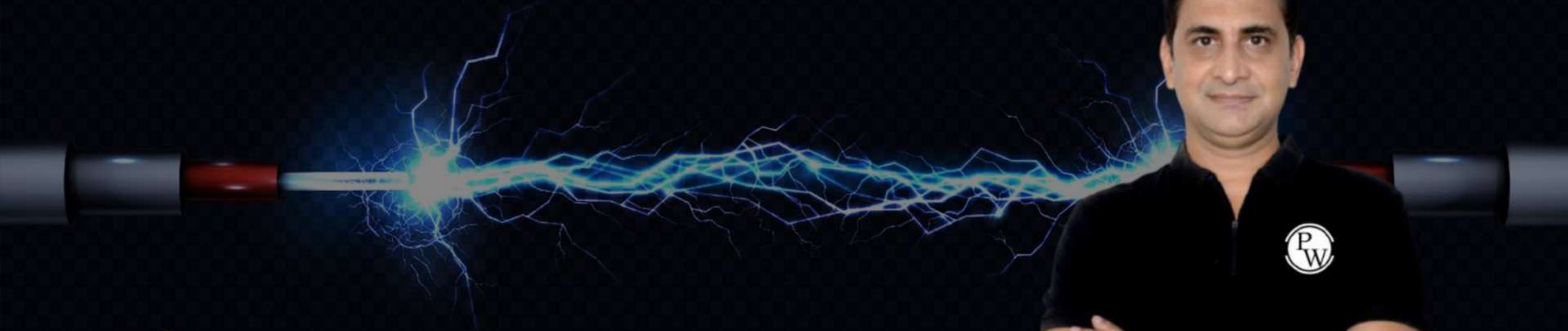
Thank you

GW
Soldiers !



Electrical Engineering

Power System



Lecture No.-01

Per unit System

By- Ajay Gupta Sir



Recap of previous class

- ✓ 1. Single line diagram
- ✓ 2. Measurement of 3 phase power

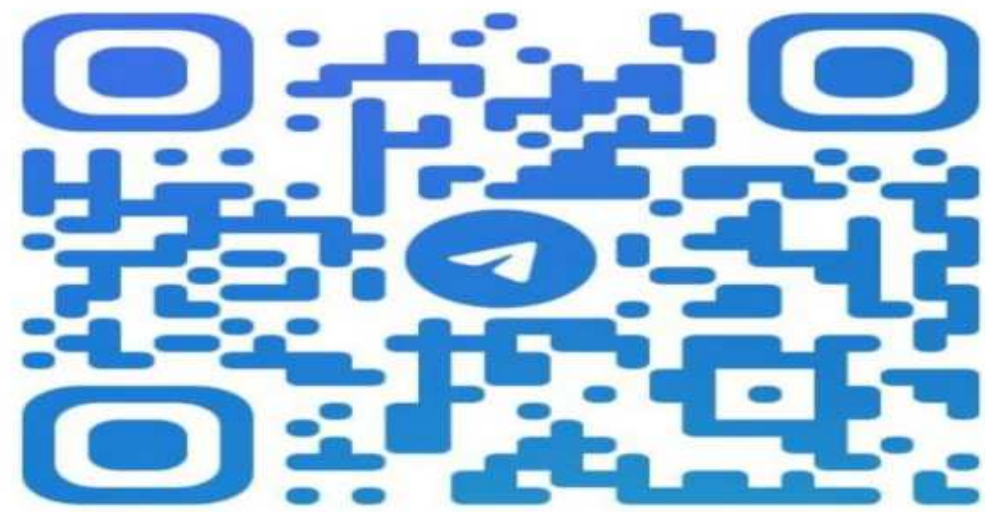


Topics to be Covered

1. P.U. System

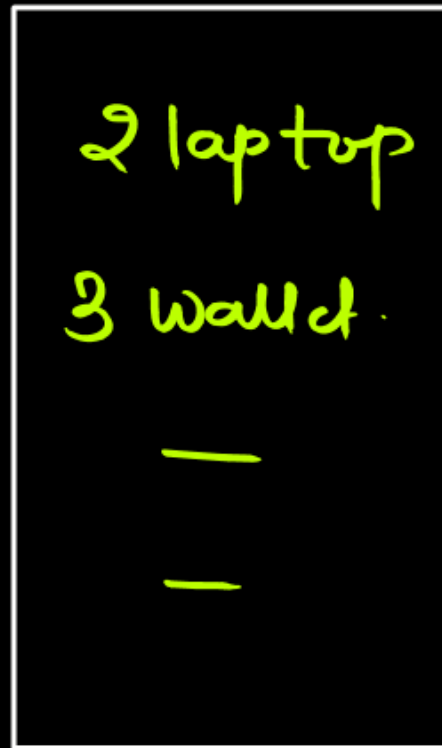
2. Base quantity

3. 3 phase p.u power

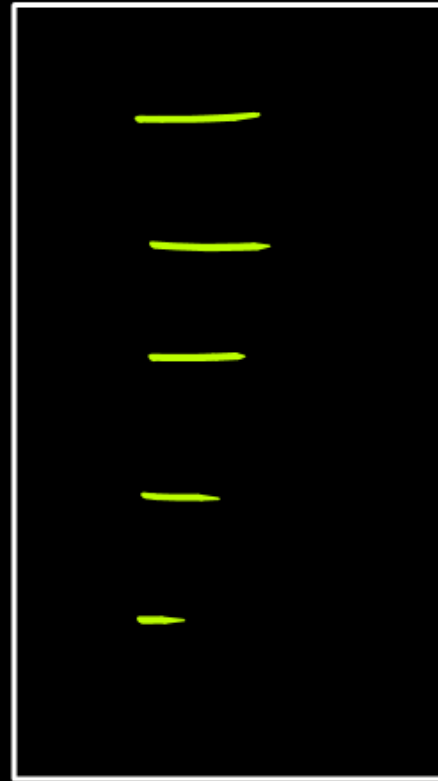


@AJAYGUPTASIRPW

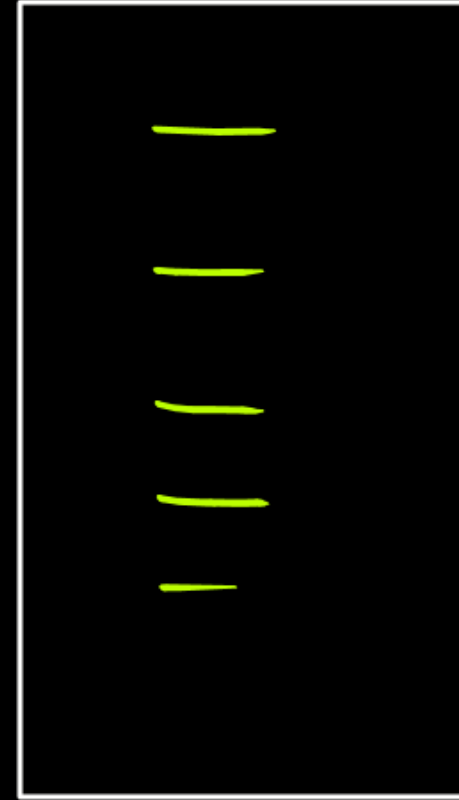




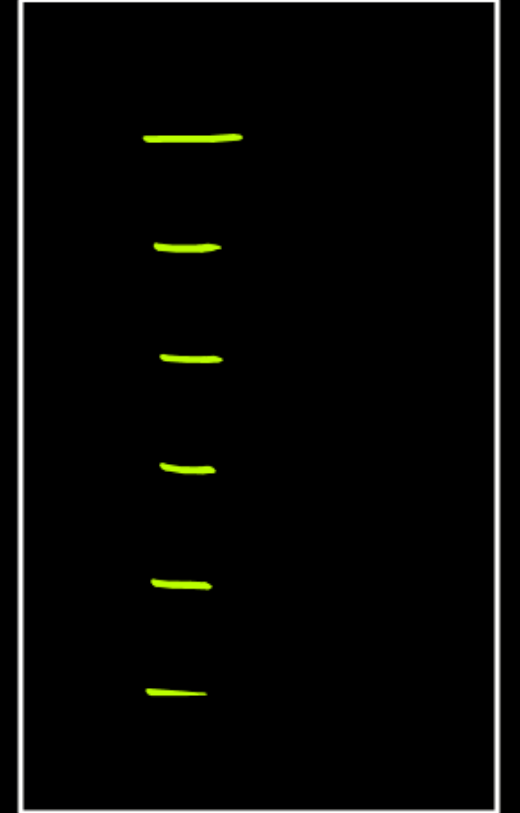
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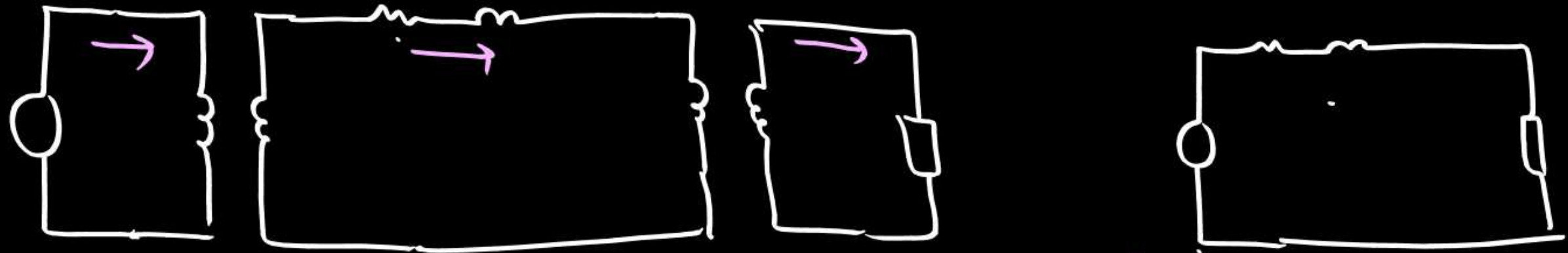
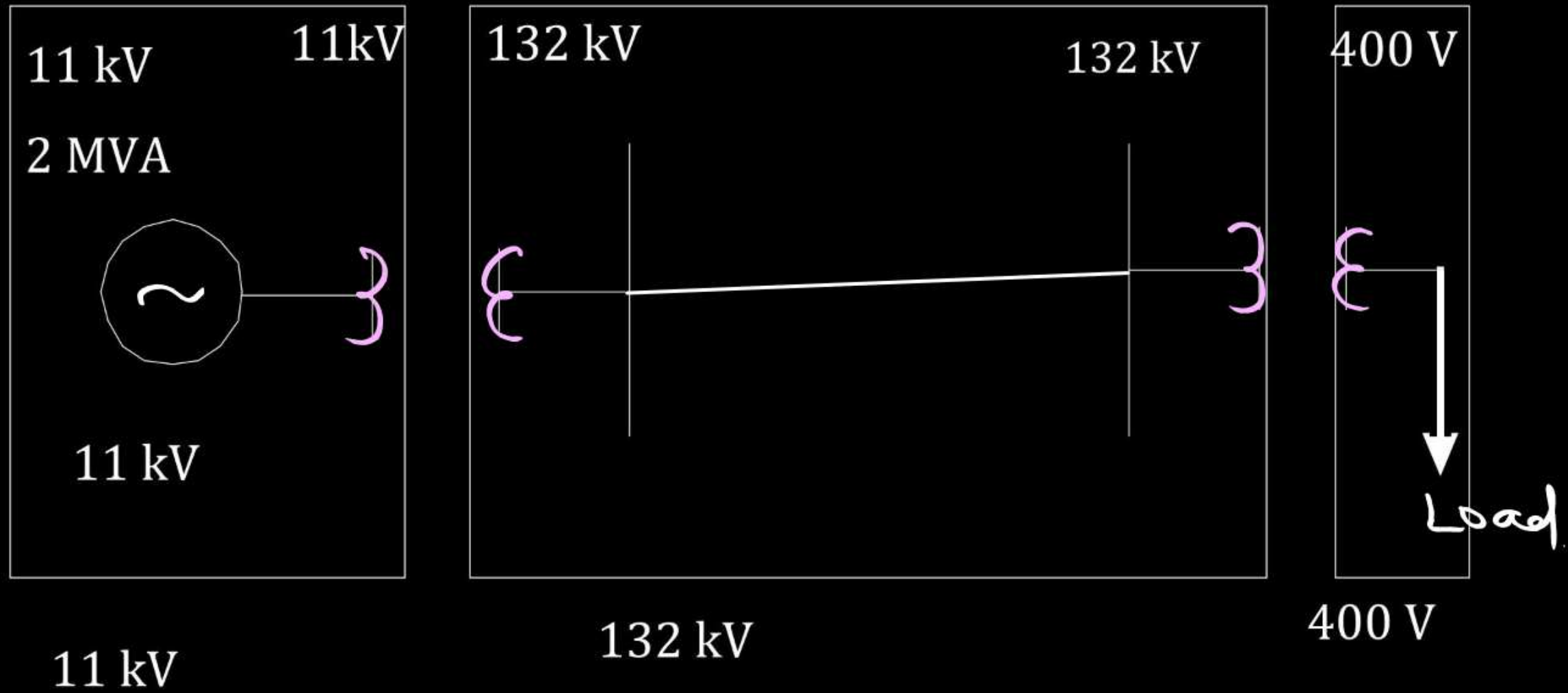


Australia
(AUS Dollar)



U.S.
\$

Per unit system





- The total number of equation required to analysis a power system is equal to number of voltage level.
- The modern power system network operate at many voltage level. So number of equation increase and calculation time is also increased. So now absolute system is replaced by P.U system.

Absolute System		P.U System	
1.	Number of equation <u>depend</u> upon number of <u>voltage level</u>	1.	Number of equation does not depend on voltage <u>level</u> .
2.	All electrical quantities has its own unit.	2.	P.U quantities are <u>unit less</u> quantities
<u>IMP</u> 3.	The both side quantities of transformer are different	3.	All the quantities is become same both side of transformer
<u>LMP</u> 4.	The line quantities & phase quantities are different	4.	The line & phase quantities are same in per unit
5.	The analysis time are more	5.	The analysis time is less
6.	All parameter lies within broad range.	6.	All parameter lies within narrow range.

$$\text{P. U. quantity} = \frac{\text{Actual quantity}}{\text{Base quantity}}$$

$$\begin{array}{lll} P = VI & \cos \theta & W \\ Q = VI & \sin \theta & \text{VAR} \\ S = VI & & VA \end{array}$$



$$\% \text{ value} = 100 \times \text{P. U. quantity}$$

➤ We have four quantities

✓(i) Voltage

(ii) Current

✓(iii) Power (S, P, Q)

(iv) Impedance (R, X)

$$Z = R + jX$$

$$\frac{Z}{Z_B} = \frac{R + jX}{Z_B}$$

$$Z_{p.u.} = R_{p.u.} + jX_{p.u.}$$

$$S = P + jQ$$

$$\frac{S}{S_B} = \frac{P}{S_B} + j \frac{Q}{S_B}$$

➤ We will take voltage & power base as a independent quantities and will derive current & impedance base quantity.

$$\frac{VI}{X}$$

Single Phase :

- Base voltage
- Base Power (VA)
- Base Current
- Base Impedance

$$\begin{aligned}
 &= V_b \\
 &= S_b \quad \left. \begin{array}{l} \\ \end{array} \right\} \text{Independent} \\
 &= (I_b) = \frac{(VA)_b}{V_b} = \frac{S_b}{V_b} \\
 &= \frac{V_b}{I_b} = \frac{V_b}{S_b / V_b} = \frac{V_b^2}{S_b} = \frac{V_b^2}{(VA)_b}
 \end{aligned}$$

$$Z_b = \frac{V_b^2}{(VA)_b} = \frac{V_b^2 / 10^6}{(VA)_b / 10^6} = \frac{\left(\frac{V_b}{10^3}\right)^2}{\frac{(VA)_b}{10^6}} = \frac{(KV_b)^2}{(MVA)_b}$$

$$Z_b = \frac{(kV_b)^2}{MVA_b}$$

- We may choose any quantities as a base quantity. But it is always convenient to take rated quantities as base quantities
 - ◆ Base impedance is Applicable for R & X

$$R_{p.u} = \frac{R}{Z_b} \quad X_{p.u} = \frac{X}{Z_b}$$

IMP Base voltage & base current at both side of transformer is related by their turn ratio. 

➤ Base S_b (VA) is same at both side of transformer.

$$400/220 \text{ kV}$$

➤ Base impedance will be different both side of transformer.

$$315 \text{ MVA}$$

◆ Base VA = it is applicable for all power

$$\text{Primary side Base voltage} = V_{1b}$$

$$\text{Primary side Base Current} = I_{1b}$$

$$\text{Secondary side Base voltage} = \frac{N_2}{N_1} \cdot V_{1b}$$

$$\text{Secondary side Base} = \frac{N_1}{N_2} \times I_{1b}$$

$$\text{Primary Base Impedance} = Z_{1b}$$

$$\text{Secondary Base Impedance} = \left(\frac{N_2}{N_1}\right)^2 Z_{1b}$$

3 Phase system :

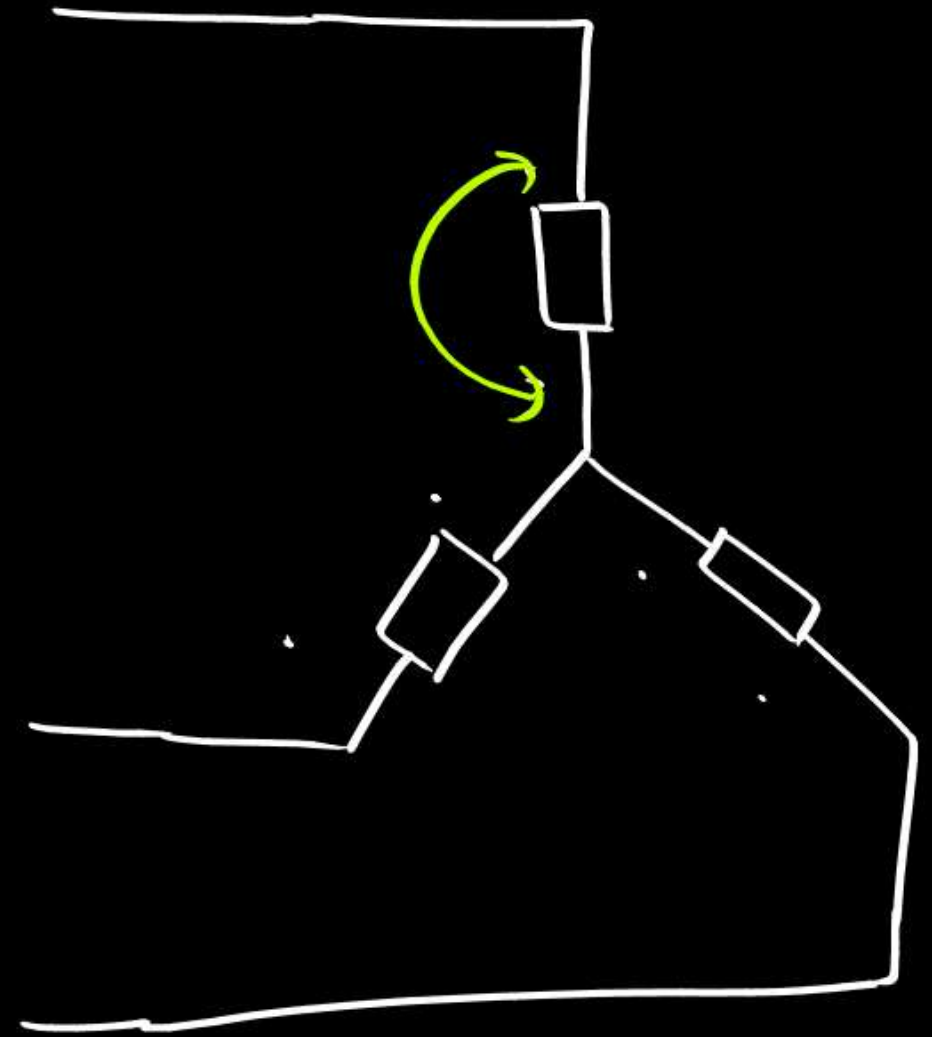
- In 3 phase, the data given is always line voltage, line current & 3 phase power.

Star Connection :

- Line base voltage = V_{Lb}
- 3 phase base VA = $S_{3\phi}$

$$\text{Line current (Base)} = \frac{S_{3\phi}}{\sqrt{3} \cdot V_{Lb}}$$

$$S_{3\phi} = \sqrt{3} V_{Lb} I_{Lb}$$



$$\text{Base impedance} = \frac{\text{Per phase voltage}}{\text{Per phase current}}$$

$$= \frac{\frac{V_{Lb}}{\sqrt{3}}}{\frac{S_{3\phi}}{\sqrt{3} \cdot V_{Lb}}} = \frac{V_{Lb}^2}{S_{3\phi}}$$

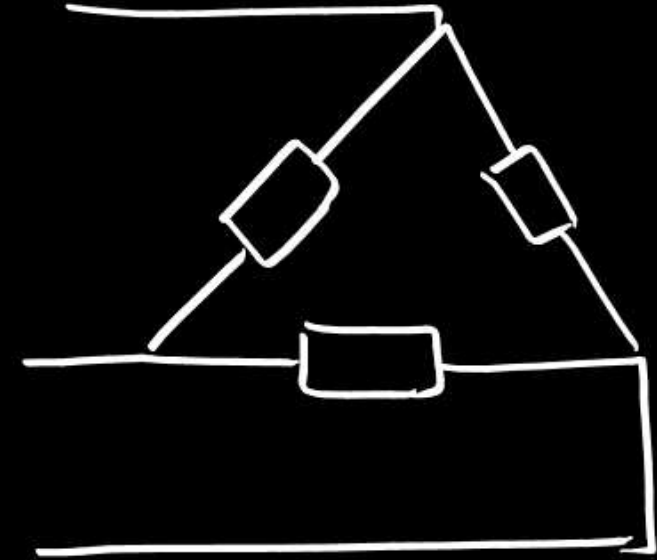
$$Z_b = \frac{V_{Lb}^2}{S_{3\phi}}$$

Delta Connection :

Line voltage (Base) = V_{Lb}

3 ϕ VA (Base) = $S_{3\phi}$.

- Line current I_{LB} (Base) = $\frac{S_{3\phi}}{\sqrt{3} V_{Lb}}$
- Impedance (Base) = $\frac{\text{Per phase } V}{\text{Per phase } I}$



$$= \frac{V_{Lb}}{I_{Lb} / \sqrt{3}} = \frac{\sqrt{3} V_{Lb}}{I_{Lb}} = \frac{\sqrt{3} V_{Lb} \cdot \sqrt{3} V_{Lb}}{S_{3\phi}} = \frac{3 V_{Lb}^2}{S_{3\phi}}$$

$$Z_b = \frac{3 V_{Lb}^2}{S_{3\phi}}$$

◆

$$\text{P.u. Voltage} = \frac{\text{Actual line voltage}}{\text{Base line voltage}} = \frac{\text{Actual phase voltage}}{\text{Base phase voltage}}$$

$$\text{P.u. Current} = \frac{\text{Actual line current}}{\text{Base line current}} = \frac{\text{Actual phase current}}{\text{Base phase current}}$$

$$\text{P.u. power} = \frac{\text{Actual 3}\phi \text{ Power}}{\text{Base 3}\phi \text{ Power}} = \frac{\text{Actual per phase power}}{\text{Base per phase power}}$$

P.U. Active Power in 3 Phase :

$$\text{Actual power } P = \sqrt{3} V_L I_L \cos \phi$$

$$\text{Base (3}\phi\text{) kVA} = \sqrt{3} V_{Lb} I_{Lb}$$

$$(\text{Active Power})_{p.u} = \frac{\text{Actual Power}}{\text{Base Power}} = \frac{\cancel{\sqrt{3}} V_L I_L \cos \phi}{\cancel{\sqrt{3}} V_{Lb} I_{Lb}}$$

$$= \frac{V_L}{V_{Lb}} \cdot \frac{I_L}{I_{Lb}} \cdot \cos \phi$$

$$P (p. u) = V_{(p. u)} I_{(p. u)} \cos \phi$$

P.U. Reactive Power in 3 Phase :

Actual Reactive power $Q = \sqrt{3} V_L I_L \sin \phi$

Base (3 ϕ) kVA = $\sqrt{3} V_{Lb} I_{Lb}$.

$$(\text{Reactive Power})_{p.u} = \frac{\text{Actual Power}}{\text{Base Power}} = \frac{\cancel{\sqrt{3}} V_L I_L \sin \phi}{\cancel{\sqrt{3}} V_{Lb} I_{Lb}} = \frac{V_L}{V_{Lb}} \cdot \frac{I_L}{I_{Lb}} \sin \phi$$

$$Q (p. u) = V_{(p. u)} I_{(p. u)} \sin \phi$$

P.U. Apparent Power in 3 Phase :

Actual Apparent power $Q = \sqrt{3} V_L I_L$

Base (3 ϕ) kVA = $\sqrt{3} V_{Lb} I_{Lb}$

$$(\text{Apparent Power})_{p.u} = \frac{\text{Actual Power}}{\text{Base Power}} = \frac{\cancel{\sqrt{3}} V_L I_L}{\cancel{\sqrt{3}} V_{Lb} I_{Lb}} = \frac{V_L}{V_{Lb}} \cdot \frac{I_L}{I_{Lb}}$$

$$S (p. u) = V_{(p. u)} I_{(p. u)}$$

Note : Do not use $\sqrt{3}$ in p.u. power

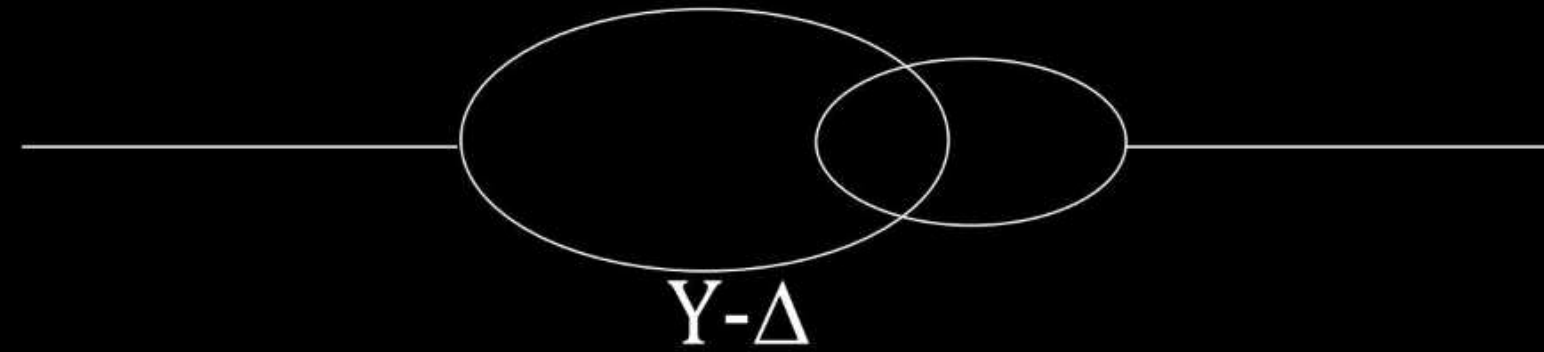
Note: Do not use $\sqrt{3}$ or 3 with Three phase p.u power

$$P = V_{p.u} I_{p.u} \cos \phi$$

$$Q = V_{p.u} I_{p.u} \sin \phi$$

$$S = V_{p.u} I_{p.u}$$

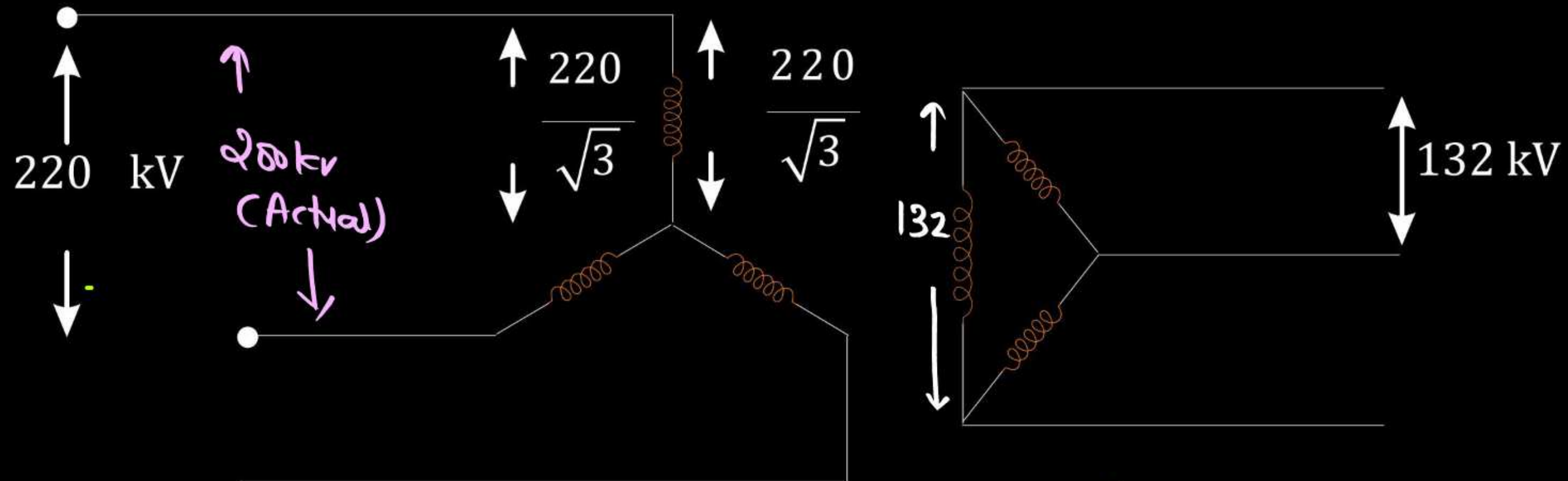
Transformer



220 / 132 kV
200 MVA

Rating

$$\frac{N_2}{N_1} = \frac{132}{220/\sqrt{3}} = 1.039$$



Line



3 ϕ Base(primary) (γ)

(secondary) (Δ)

$$V_{LB} = 220 \text{ kV}$$

$$V_{LB} = 132 \text{ kV}$$

$$S_{3\phi} = 200 \text{ MVA} (200 \times 10^3 \text{ kVA})$$

$$S_{3\phi} = 200 \text{ MVA} (200 \times 10^3 \text{ kVA})$$

$$I_{LB} = \frac{200 \times 10^3}{\sqrt{3} \times 220} = 524.86 \text{ Amp}$$

$$I_{Lb} = \frac{200 \times 10^3}{\sqrt{3} \times 132} = 874.77$$

$$Z_B = \frac{V_{Lb}^2}{S_{3\phi}} \Omega = \frac{(220)^2}{200} = 242$$

$$Z_B = \frac{3V_{Lb}^2}{S_{3\phi}} = \frac{3(132)^2}{200} = 261.36$$

3 ϕ Actual(primary)	(secondary)
$V_L = 200 \text{ kV (Imaginc)}$	$V_L = \frac{132}{220} \times 200 = 120 \text{ kV}$
$S_{3\phi} = 100 \text{ MVA (Imagine)}$	$S_{3\phi} = 100 \text{ MVA}$
$I_L = \frac{100 \times 10^3}{\sqrt{3} \times 200} = 288.67$	$I_L = \frac{100 \times 10^3}{\sqrt{3} \times 120} = 481.12$
$Z = 25 \Omega \text{ (Imagine)}$	$Z_2 = \left(\frac{N_2}{N_1}\right)^2 Z_1 = (1.039)^2 (25) = 27$

P.u from line quantities

$$V_{p.u} = \frac{V_L}{V_{LB}} = \frac{200}{220} = 0.909 \text{ p.u.}$$

$$V_{p.u} = \frac{V_L}{V_{LB}} = \frac{120}{132} = 0.909 \text{ p.u.}$$

$$I_{p.u} = \frac{I_L}{I_{LB}} = \frac{288.67}{524.86} = 0.549 \text{ p.u.}$$

$$I_{p.u} = \frac{481.12}{874.77} = 0.549 \text{ p.u.}$$

$$Z_{p.u} = \frac{25}{242} = 0.103$$

$$Z_{p.u} = \frac{27}{261.36} = 0.103 \text{ p.u.}$$

(Phase quantities)



Per phase Base(primary) Υ	(secondary) Δ
$V_{pB} = \frac{220}{\sqrt{3}} = 127.01 \text{ kV}$	$V_{pB} = 132 \text{ kV}$
$S_{1\phi} = \frac{200}{3} \text{ MVA}$	$S_{1\phi} = \frac{200}{3} \text{ MVA}$
$I_{pB} = \frac{\frac{200}{3} \times 10^3}{127.01} = 524.89$	$I_{pB} = \frac{\frac{200}{3} \times 10^3}{132} = 505.05$
$Z_B = \frac{V_{pb}^2}{S_{1\phi}} \Omega = \frac{(127.01)^2}{200/3} = 241.97$	$Z_B = \frac{V_{pb}^2}{S_{1\phi}} = \frac{(132)^2}{200/3} = 261.36$

Per phase Actual(primary) (γ)	(secondary) (Δ)
$V_p = \frac{200}{\sqrt{3}} \text{ kV}$	$V_p = 120 \text{ kV}$
$S_{1\phi} = \frac{100}{3} \text{ MVA}$	$S_{1\phi} = \frac{100}{3} \text{ MVA}$
$I_p = \frac{\frac{100}{3} \times 10^3}{200/\sqrt{3}} = 288.67$	$I_p = \frac{\frac{100}{3} \times 10^3}{120} = 277.77$
$Z = 25$	$Z = 27$

Per Phase ✓ (p.u)	Secondary.
➤ $V_{pu} = \frac{280/\sqrt{3}}{127.01} = 0.909$	$V_{pu} = \frac{120}{132} = 0.909.$
➤ $I_{pu} = \frac{288.67}{524.89} = 0.549$	$I_{pu} = \frac{277.77}{505.05} = 0.549$
➤ $Z_{pu} = \frac{25}{241.97} = 0.103$	$Z_{pu} = \frac{27}{261.36} = 0.103$

Q.



A 400/100V, 2KVA transformer is having p.u impedance of 0.25 p.u.
What will be ohmic (actual) impedance of transformer referred to H.V Side?.

$$P.u = \frac{\text{Actual}}{\text{Base}}$$

- a) 40 ohm
- b) 10 ohm
- c) 80 ohm
- d) None

$$\text{Actual quantity} = \text{Base quantity} \times P.u \text{ quanti}$$

H.V
400V, 2000 VA

$$Z_B = \frac{V^2}{VA} = \frac{400 \times 400}{\frac{2000}{5}} = 80$$

$$\begin{aligned}\text{Actual quantity} &= 80 \times 0.25 \\ &= 20 \Omega.\end{aligned}$$

LV

$$100 \text{ V}, 2000 \text{ VA}$$

$$Z_B = \frac{V^2}{VA} = \frac{100 \times 100}{2000} = 5.$$

$$\text{Actual quantity} = 5 \times 0.25 = 1.25.$$



2 Minutes Summary

→ p.u. quantity

→ 3 phase p.u quantity

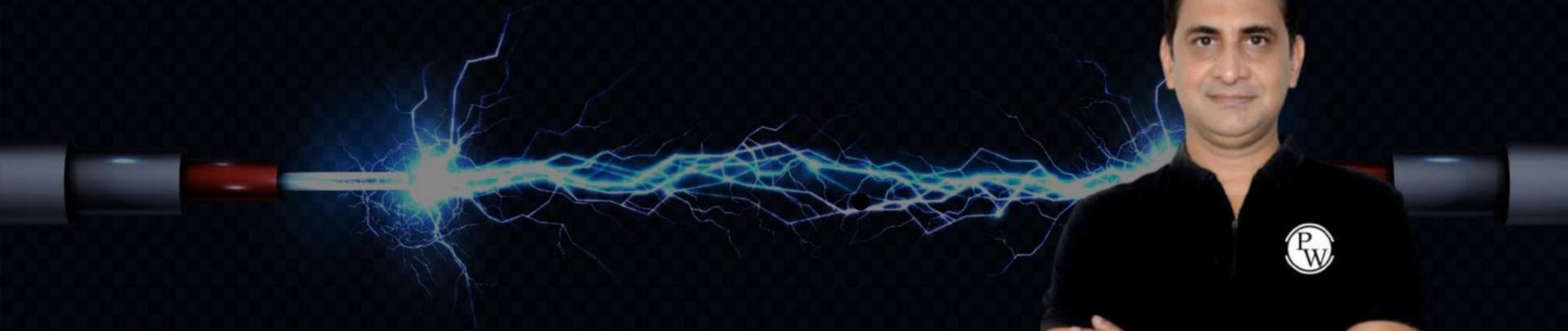
Thank you

GW
Soldiers !



Electrical Engineering

Power System



Lecture No.-02

Per unit system

By- Ajay Gupta Sir



Recap Of previous class

1. P.U system

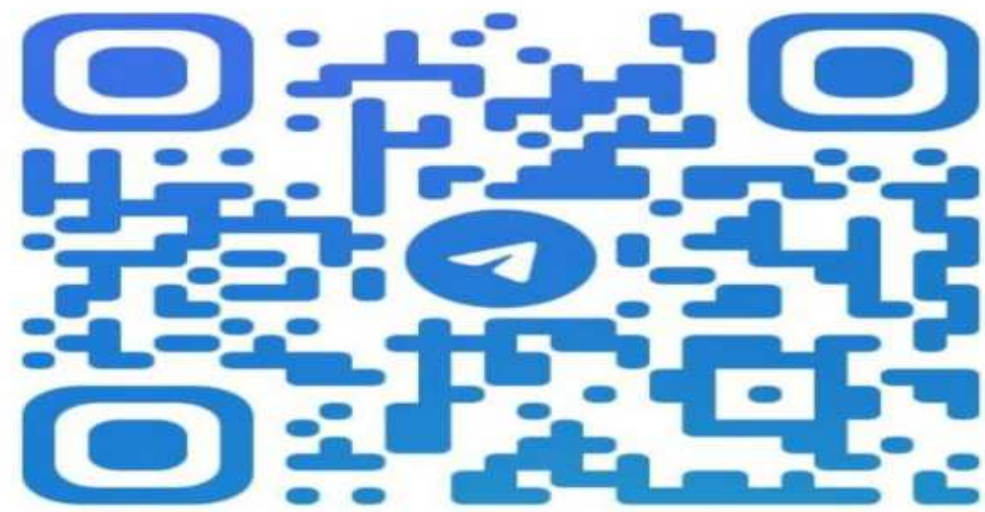
2. Base Quantity



Topics to be Covered

1. P.U OF 3 PHASE SYSTEM

2. Inductance



@AJAYGUPTASIRPW

$$S_{3\phi} = \sqrt{3} \underline{V}_{Lb} I_{Lb}$$

$$S_{3\phi} = 3 V_{Pb} I_{Pb}$$

$$S = \sqrt{3} V_L I_L$$

$$S = 3 V_{Ph} I_{Ph}$$

Q A 3 phase $400/\underline{220}$ kV ($\overset{Y}{-}\overset{\Delta}{}$), 300 MVA X-mcr is having P.u. Impedance of 0.3 p.u. find out Actual Impedance referred to LV Side.

Ans: LV Side 220 kV, 300 MVA (Δ Connected)

$$Z_b = \frac{3 V_{Lb}^2}{S_{3\phi}} = \frac{3 (220)^2}{300} = 484 \Omega$$

$$\begin{aligned}\text{Actual} &= \text{Base quantity} \times \text{P.U. quantity} \\ &= 484 \times 0.3 \\ &= 145.2 \Omega.\end{aligned}$$

II Method 200 kV, 300 MVA (Δ)

$$V_{Ph} = 200 \text{ kV}$$

$$S_{1\phi} = \frac{300}{3} = 100 \text{ MVA}$$

$$Z_B = \frac{kV^2}{MVA} = \frac{(200)^2}{100} = 400$$

(ii) find out actual Impedance referred to HV Side

HV Side 400 kV, 300 MVA (Y)

$$Z_B = \frac{V_{LB}^2}{S_{3\phi}} = \frac{(400)^2}{300} = 533.33$$

$$\begin{aligned}\text{Actual Impedance} &= Z_B \times P.U. \\ &= 533.33 \times 0.3 \\ &= 160\end{aligned}$$

II Method

400 kV, 300 MVA (Y)

$$V_{ph} = \frac{400}{\sqrt{3}}$$

$$S_{1\phi} = \frac{300}{3} \text{ MVA}$$

$$Z_B = \frac{V_{ph}^2}{S_{1\phi}} = \frac{\left(\frac{400}{\sqrt{3}}\right)^2}{\frac{300}{3}} = 533.33$$

Q.



The Three phase motor draw 8 kw power at 0.8 power factor lagging
From 200 V, 10 MVA Generator. The P.U. Reactive power drawn by
motor on generator base is ?

A 0.2×10^{-3}

B 0.5×10^{-3}

C $.3 \times 10^{-3}$

D None

$$Q_{p.u} = V_{p.u} I_{p.u} \sin \phi$$

$$P_{p.u} = V_{p.u} I_{p.u} \cos \phi$$

$$0.8 \times 10^{-3} = V_{p.u} I_{p.u} (0.8)$$

$$V_{p.u} I_{p.u} = 1 \times 10^{-3}$$

$$\cos \phi = 0.8$$

$$\sin \phi = \sqrt{1 - (0.8)^2} \\ = 0.6$$

$$\text{Base Power} = 10 \times 10^3 \text{ kVA}$$

$$P_{p.u} = \frac{8}{10 \times 10^3} = 0.8 \times 10^{-3}$$

$$Q_{p.u} = (V_{p.u} I_{p.u}) \sin \phi$$

$$Q_{p.u} = (1 \times 10^{-3}) (0.6)$$

$$Q_{p.u} = 0.6 \times 10^{-3} \text{ p.u.}$$

II Method

$$Q_{p.u} = \frac{Q(\text{Actual})}{\text{Base VA}}$$

$$\text{Base MVA} = 10$$

$$= 10 \times 10^3 \text{ kVA}$$

$$P = \sqrt{3} V I \cos \phi$$

$$8 = \sqrt{3} V I (0.8)$$

$$\sqrt{3} V I = 10 \text{ kVA}$$

$$Q = \underline{\sqrt{3} V I \sin \phi} = \underline{10 \times 0.6} = 6 \text{ kVAR}$$

$$Q_{p.u.} = \frac{6 \text{ kVAR}}{10 \times 10^3} = 0.6 \times 10^{-3} \text{ p.u.}$$

Change in p.u. from one base to another base:-

$$\text{Old Base Voltage} = (KV)_{old}$$

$$\text{Old Base VA} = (MVA)_{old}$$

$$(Z_B)_{old} = \frac{(KV)_{old}^2}{MVA_{old}}$$

$$\text{Actual Impedance} = Z$$

$$(Z_{p.u})_{old} = \frac{Z}{(Z_B)_{old}} = \frac{Z}{(KV)_{old}^2} \times (MVA)_{old} \quad \text{---(1)}$$

$$\text{New Base Voltage} = (KV)_{\text{new}}$$

$$\text{New Base VA} = (MVA)_{\text{new}}$$

$$(Z_B)_{\text{new}} = \frac{(KV)_{\text{new}}^2}{(MVA)_{\text{new}}}$$

$$\text{Actual Impedance} = Z$$

$$(Z_{p.u})_{\text{new}} = \frac{Z}{(Z_B)_{\text{new}}} = \frac{Z}{(KV)_{\text{new}}^2} \times (MVA)_{\text{new}} \quad \text{--- (2)}$$

$$\frac{eq^n(2)}{eq^n(1)} = \frac{(Z_{p.u})_{new}}{(Z_{p.u})_{old}} = \frac{(MVA)_{new}}{(kv)^2_{new}} \times \frac{(kVA)_{old}}{(MVA)_{old}}$$

$$(Z_{p.u})_{new} = (Z_{p.u})_{old} \times \frac{(MVA)_{new}}{(MVA)_{old}} \times \frac{(kv)^2_{old}}{(kv)^2_{new}}$$

$$\text{if } (MVA)_{\text{new}} = (MVA)_{\text{old}}$$

$$(Z_{\text{p.u}})_{\text{new}} = (Z_{\text{p.u}})_{\text{old}} \times \frac{(Kv)_{\text{old}}^2}{(Kv)_{\text{new}}^2}$$

Q.



The impedance of generator is 0.25 p.u at the base of 13.8 KV 30 MVA.
The P.U Impedance at the base of 20 KV , 50 MVA will be?.

$$(KV)_{old} = 13.8$$

$$(KV)_{new} = 20$$

$$(MVA)_{old} = 30$$

$$(MVA)_{new} = 50$$

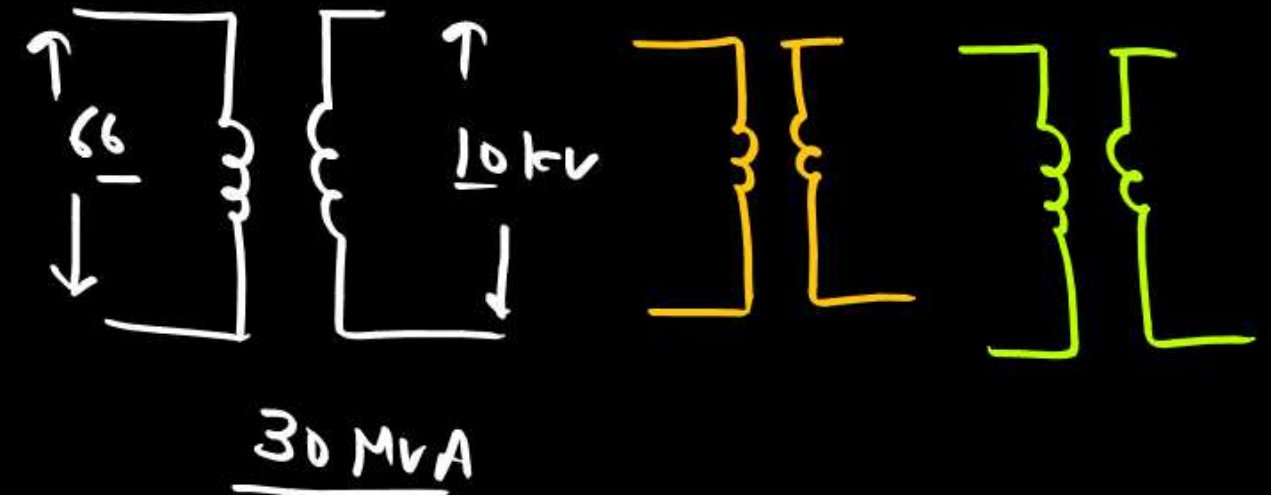
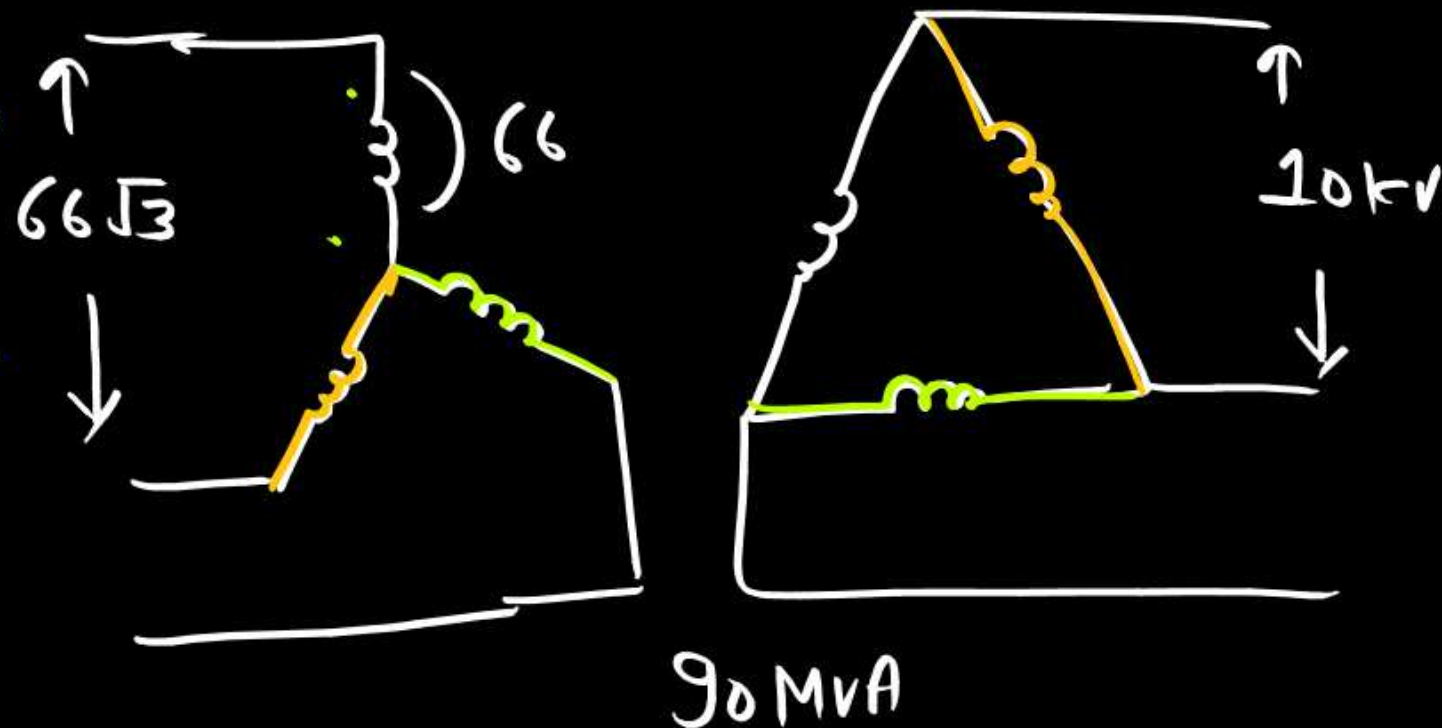
$$(Z_{p.u})_{new} = (Z_{p.u})_{old} \times \left(\frac{MVA_{new}}{MVA_{old}} \right) \times \left(\frac{KV_{old}}{KV_{new}} \right)^2$$

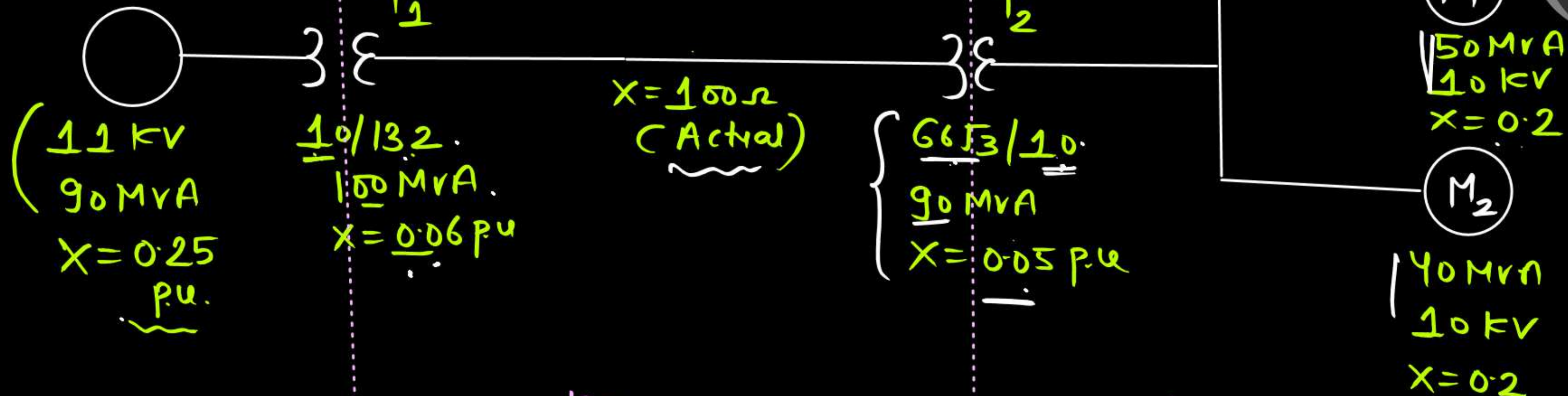
$$= 0.25 \times \frac{50}{30} \times \left(\frac{13.8}{20} \right)^2$$

$$= 0.198 \text{ p.u.}$$

Q.

A 90 MVA, 11 kV, 3 ϕ generator has reactance of 25%. The generator supply 2 motor through transformers & T.L. The transformers T_1 is 3 phase transformers 100 MVA, 10/132 kV, 6% reactance. transformers T_2 is composed of three, 1 ϕ transformers unit each rated at 30 MVA, 66/10 kV with 5% reactance. The motor is rated at 50 MVA & 40 MVA both at 10 kV & 20% reactance. Take the generator rating as a base the reactance of line is 100Ω . Find p.u. reactance of all component.





$$\begin{cases} \text{Base KV} = 11 \\ \text{Base MVA} = 90 \end{cases}$$

$$\text{Base KV} = \frac{13.2}{10} \times 11 = 14.52 \text{ KV}$$

$$\text{Base MVA} = 90$$

$$\text{Base KV} = \frac{10 \times 14.52}{66\sqrt{3}} = 12.70$$

$$\text{Base MVA} = 90$$

→ P.u reactance of alternator = 0.25 p.u.

P.u reactance of T_1

$$\rightarrow (kV)_{old} = 10 \text{ kV}$$

$$(kV)_{new} = 11$$

$$(MVA)_{old} = 150$$

$$(MVA)_{new} = 90$$

$$(Z_{p.u})_{new} = (Z_{p.u})_{old} \times \frac{(MVA)_{new}}{(MVA)_{old}} \times \frac{(kV)_{old}^2}{(kV)_{new}^2}$$

$$= 0.06 \times \frac{90}{150} \times \left(\frac{10}{11}\right)^2 = 0.0446$$

→ P.u reactance of T.L.

$$Z_B = \frac{KV^2}{MVA} = \frac{(145.2)^2}{90} = 234.256$$

$$Z_{p.u} = \frac{Z_{actual}}{Z_B} = \frac{100}{234.256} = 0.426 \text{ p.u.}$$

→ P.u reactance of T₂

$$(kv)_{old} = 10 \quad (kv)_{new} = 12.7$$

$$(MVA)_{old} = 90 \quad (MVA)_{new} = 90$$

$$(Z_{p.u})_{new} = (Z_{p.u})_{old} \times \frac{(MVA)_{new}}{(MVA)_{old}} \times \frac{(kv)_{old}^2}{(kv)_{new}^2}$$

$$= 0.05 \times \frac{90}{90} \times \frac{(10)^2}{(12.7)^2}$$

$$= 0.031$$

→ P.u reactance of M_1

$$(KV)_{old} = 10$$

$$(KV)_{new} = 12.7$$

$$(MVA)_{old} = 40$$

$$(MVA)_{new} = 90$$

$$(Z_{p.u})_{new} = (Z_{p.u})_{old} \times \left(\frac{MVA_{new}}{MVA_{old}} \right) \times \left(\frac{KV_{old}}{KV_{new}} \right)^2$$

$$= 0.2 \times \frac{90}{40} \times \left(\frac{10}{12.7} \right)^2$$

$$= 0.279$$

→ P.u reactance of M_2

$$(KV)_{old} = 10$$

$$(KV)_{new} = 12.7$$

$$(MVA)_{old} = 50$$

$$(MVA)_{new} = 90$$

$$(Z_{p.u})_{new} = (Z_{p.u})_{old} \times \left(\frac{MVA_{new}}{MVA_{old}} \right) \times \left(\frac{KV_{old}}{KV_{new}} \right)^2$$

$$= 0.2 \times \frac{90}{50} \times \left(\frac{10}{12.7} \right)^2$$

$$= 0.223 \text{ p.u.}$$

2 Minute Summary.



→ P.u power 3 phase

→ Question.

Thank you

GW
Soldiers !



PRACTICE SHEET-1

EE POWER SYSTEM Per unit system

- Q 1** A three phase 100 MVA, 11 kV generator has a reactance of 0.6 ohm per phase. The per unit value of the reactance on a base of 240 MVA, 30 kV will be :
 (A) 0.10 (B) 0.16
 (C) 0.24 (D) 0.30
- Q 2** The per unit reactance of a 50 MVA, 22 kV alternator is 0.5625 p.u. The p.u value of the reactance for a base voltage of 33 kV and 20 MVA will be.
 (A) 0.05 (B) 0.10
 (C) 0.15 (D) 0.20
- Q 3** The impedance value of generator is 0.245 pu on a base value of 13.8 kV, 40 MVA. The impedance value for a base value of 21.6 kV, 100 MVA is :
 (A) 0.10 pu (B) 0.15 pu
 (C) 0.20 pu (D) 0.25 pu
- Q 4** The per unit impedance of a generator in an interconnected power system, corresponding to its own voltage and kVA rating is 0.5 p.u.. Its per unit impedance corresponding to a new common base voltage and kVA rating, which are 125% of the generator base values selected for the whole system will be _____p.u.
- Q 5** A 66 kV, 500 MVA generator has a reactance of 1.21 Ω . The p.u. value of reactance on base values of 11 kV and 100 MVA will be _____p.u.
- Q 6** A 250 MVA, 15 kV alternator has a reactance of 0.3 p.u. The ohmic value of the reactance of the alternator will be _____ Ω .
- Q 7** A generator has its rated values as base voltage and base VA, and on this base value its per unit impedance value is X p.u. If the value of voltage base is tripled and value of VA base is doubled. Then its new per unit impedance will be :
 (A) 0.22X p.u. (B) 0.28X p.u.
 (C) 0.34X p.u. (D) Remain Unchanged
- Q 8** A three-phase motor draws 6 kVAR at power factor of 0.8 lagging from a 400 V, 10 kVA generator through a transmission line, then p.u. value of the active power drawn by the motor on generator base, will be _____p.u.
- Q 9** A balanced positive sequence Y-connected source with $V_{an} = 230.94 \angle 0^\circ \text{V}$ is connected to a Δ connected balanced $(10 + j5) \Omega$ per phase. Then the p.u. value of line current will be _____p.u. Assume base as 400 V, 50 kVA.
- Q 10** A balanced star connected load absorbs a total power of 12 kW at a leading power factor of 0.8, when connected to a line voltage of 420 V. Then the impedance of each phase will be _____p.u. Assume line voltage and line current as base quantity.
 (A) $(0.8 - j0.6)$
 (B) $(0.4 - j0.3)$
 (C) $(0.16 - j0.12)$
 (D) $(0.12 - j0.9)$

Answer Key

Q1	B	Q6	(0.27)
Q2	B	Q7	A
Q3	D	Q8	(0.8)
Q4	(0.4)	Q9	(0.86)
Q5	(1)	Q10	A





Power System

Practice Sheet Discussion – 01

Per unit system

By- Ajay Gupta Sir

A three phase 100 MVA, 11 kV generator has a reactance of 0.6 ohm per phase. The per unit value of the reactance on a base of 240 MVA, 30 kV will be:

$$X(\text{Actual}) = 0.6 \Omega/\text{phase}$$

$$X_{\text{p.u.}} = \frac{X(\text{Actual})}{Z_B}$$

$$Z_B = \frac{\text{kV}^2}{\text{MVA}} = \frac{(30)^2}{240}$$

$$X_{\text{p.u.}} = \frac{0.6}{(30)^2} \times 240 = 0.16 \text{ p.u.}$$

A 0.10

B 0.16

C 0.24

D 0.30

The per unit reactance of a 50 MVA, 22 kV alternator is 0.5625 p.u. The p.u value of the reactance for a base voltage of 33 kV and 20 MVA will be

A 0.05

B 0.10

C 0.15

D 0.20

$$(X_{p.u})_{new} = (X_{p.u})_{old} \times \left(\frac{MVA_{new}}{MVA_{old}} \right) \times \left(\frac{KV_{old}}{KV_{new}} \right)^2$$

$$= 0.5625 \times \frac{20}{50} \times \left(\frac{22}{33} \right)^2$$

$$= 0.1 \text{ p.u.}$$

The impedance value of generator is 0.245 pu on a base value of 13.8 kV, 40 MVA. The impedance value for a base value of 21.6 kV, 100 MVA is

A 0.10 pu

B 0.15 pu

C 0.20 pu

D 0.25 pu

$$(Z_{p.u})_{new} = (Z_{p.u})_{old} \times \left(\frac{MVA_{new}}{MVA_{old}} \right) \times \left(\frac{KV_{old}}{KV_{new}} \right)^2$$

$$= 0.245 \times \left(\frac{100}{40} \right) \times \left(\frac{13.8}{21.6} \right)^2$$

$$= 0.25 \text{ p.u.}$$

The per unit impedance of a generator in an interconnected power system, corresponding to its own voltage and kVA rating is 0.5 p.u. Its per unit impedance corresponding to a new common base voltage and kVA rating, which are 125% of the generator base values selected for the whole system will be _____ p.u.

$$(Z_{p.u})_{new} = (Z_{p.u})_{old} \times \left(\frac{MVA_{new}}{MVA_{old}} \right) \times \left(\frac{KV_{old}}{KV_{new}} \right)^2$$

$$= 0.5 \times \left(\frac{1.25 MVA}{1 MVA} \right) \times \left(\frac{1 KV}{1.25 KV} \right)^2$$

$$= \frac{0.5}{1.25} = 0.4 \text{ p.u.}$$

A 66 kV, 500 MVA generator has a reactance of 1.21 Ω . The p.u. value of reactance on base values of 11 kV and 100 MVA will be _____ p.u.

$$Z_B = \frac{kV^2}{MVA} = \frac{(11)^2}{100}$$

$$Z_{p.u.} = \frac{Z(\text{Actual})}{Z_B} = \frac{1.21}{(11)^2} \times 100 = 1 \text{ p.u.}$$

A 250 MVA, 15 kV alternator has a reactance of 0.3 p.u. The ohmic value of the reactance of the alternator will be _____ Ω .

$$Z_B = \frac{kV^2}{MVA} = \frac{(15)^2}{250}$$

$$\begin{aligned} Z(\text{Actual}) &= Z_{p.u} \times Z_B \\ &= 0.3 \times \frac{(15)^2}{250} \\ &= 0.27 \Omega \end{aligned}$$

A generator has its rated values as base voltage and base V_A , and on this base value its per unit impedance value is X p.u. If the value of voltage base is tripled and value of V_A base is doubled. Then its new per unit impedance will be

$$\begin{aligned}(Z_{p.u})_{new} &= (Z_{p.u})_{old} \times \frac{MVA_{new}}{MVA_{old}} \times \left(\frac{kV_{old}}{kV_{new}} \right)^2 \\ &= X \left(\frac{2 MVA}{MVA} \right) \times \left(\frac{1 kV}{3 kV} \right)^2 \\ &= 0.2222 X\end{aligned}$$

A~~0.22X p.u~~**B**

0.28X p.u

C

0.34X p.u

D

Remain Unchanged

A three-phase motor draws 6 kVAR at power factor of 0.8 lagging from a 400 V, 10 MVA generator through a transmission line, then p.u. value of the active power drawn by the motor on generator base, will be _____ p.u.

$$Q = 6 \text{ kVAR} = \sqrt{3} V_L I_L \sin \phi$$

$$\cos \phi = 0.8$$

$$Q = S \sin \phi$$

$$\sin \phi = 0.6$$

$$S = \frac{6}{0.6} = 10 \text{ kVA}$$

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

$$= S \cos \phi$$

$$= 10 \times 0.8$$

$$P = 8 \text{ kW}$$

$$P(\text{p.u.}) = \frac{8 \text{ kW}}{10} = 0.8 \text{ p.u.}$$

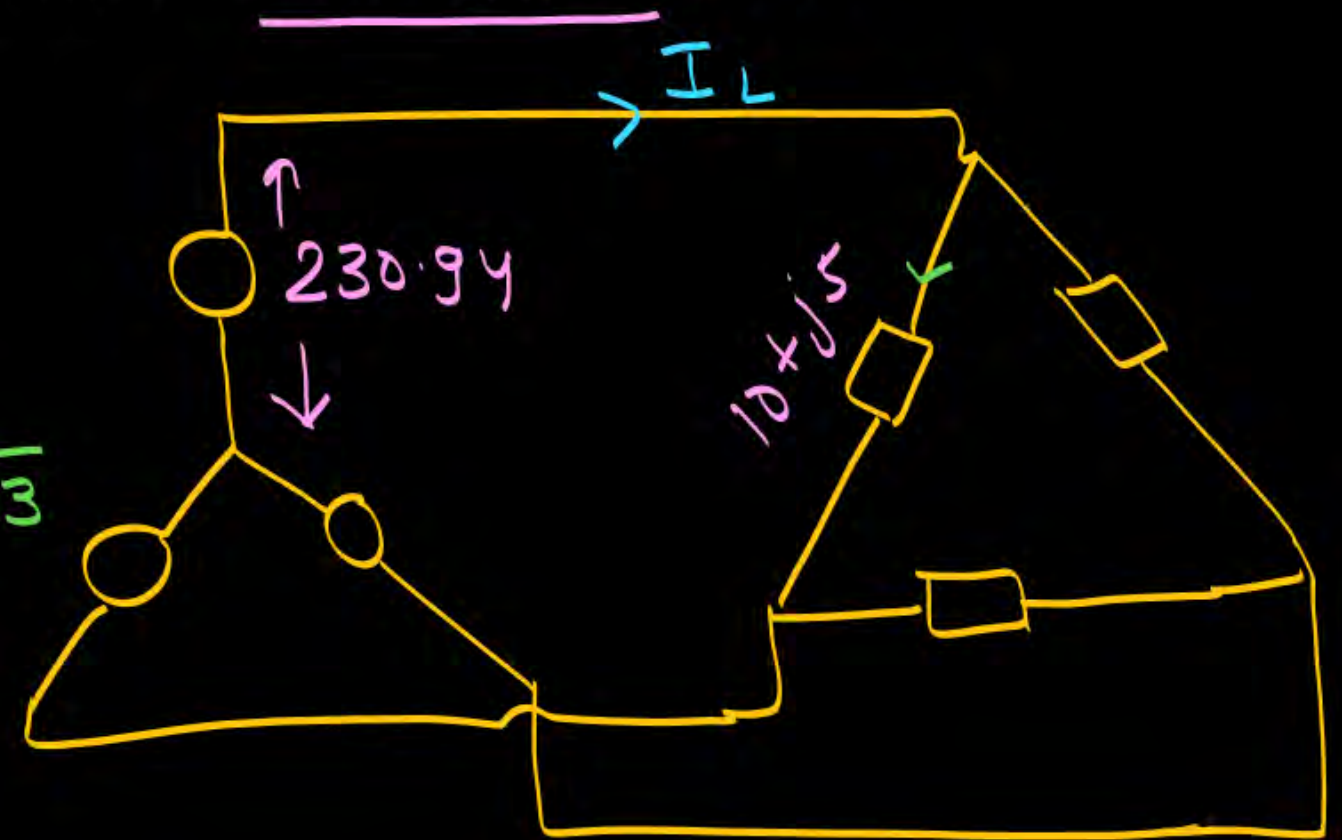
A balanced positive sequence Y-connected source with $V_{an} = 230.94 \angle 0^\circ \text{V}$ is connected to a Δ connected balanced $(10 + j5) \Omega$ per phase. Then the p.u. value of line current will be _____ p.u. Assume base as 400 V, 50 kVA.

$$I_B = \frac{50,000/3}{400/\sqrt{3}} = \frac{500/3}{4/\sqrt{3}} \text{ Amp} = \frac{125}{\sqrt{3}}$$

$$\text{Voltage Across Impedance} = V_L = 230.94 \times \sqrt{3}$$

$$I_{ph} = \frac{230.94 \times \sqrt{3}}{\sqrt{10^2 + 5^2}}$$

$$I_L = \sqrt{3} I_{ph} = \frac{3 \times 230.94}{11.18}$$



$$(I_L)_{p.u} = \frac{3 \times 230.94}{11.18} \times \frac{\sqrt{3}}{125}$$

$$= 0.8586 \text{ p.u.}$$

A balanced star connected load absorbs a total power of 12 kW at a leading power factor of 0.8, when connected to a line voltage of 420 V. Then the impedance of each phase will be _____ p.u. Assume line voltage and line current as base quantity.

Rated quantity = Base quantity

$$S(\text{p.u.}) = V(\text{p.u.}) I(\text{p.u.})$$

$$1 = 1 \times I(\text{p.u.})$$

$$I = 1 \text{ p.u.}$$

$$Z = \frac{V_{\text{p.u.}}}{I_{\text{p.u.}}} = \frac{1}{1} = 1$$

$$Z \cos \theta - j Z \sin \theta$$

$$0.8 - j0.6$$

A (0.8 - j0.6) ✓

B (0.4 - j0.3)

C (0.16 - j0.12)

D (0.12 - j0.9)

Thank you

GW
Soldiers !

