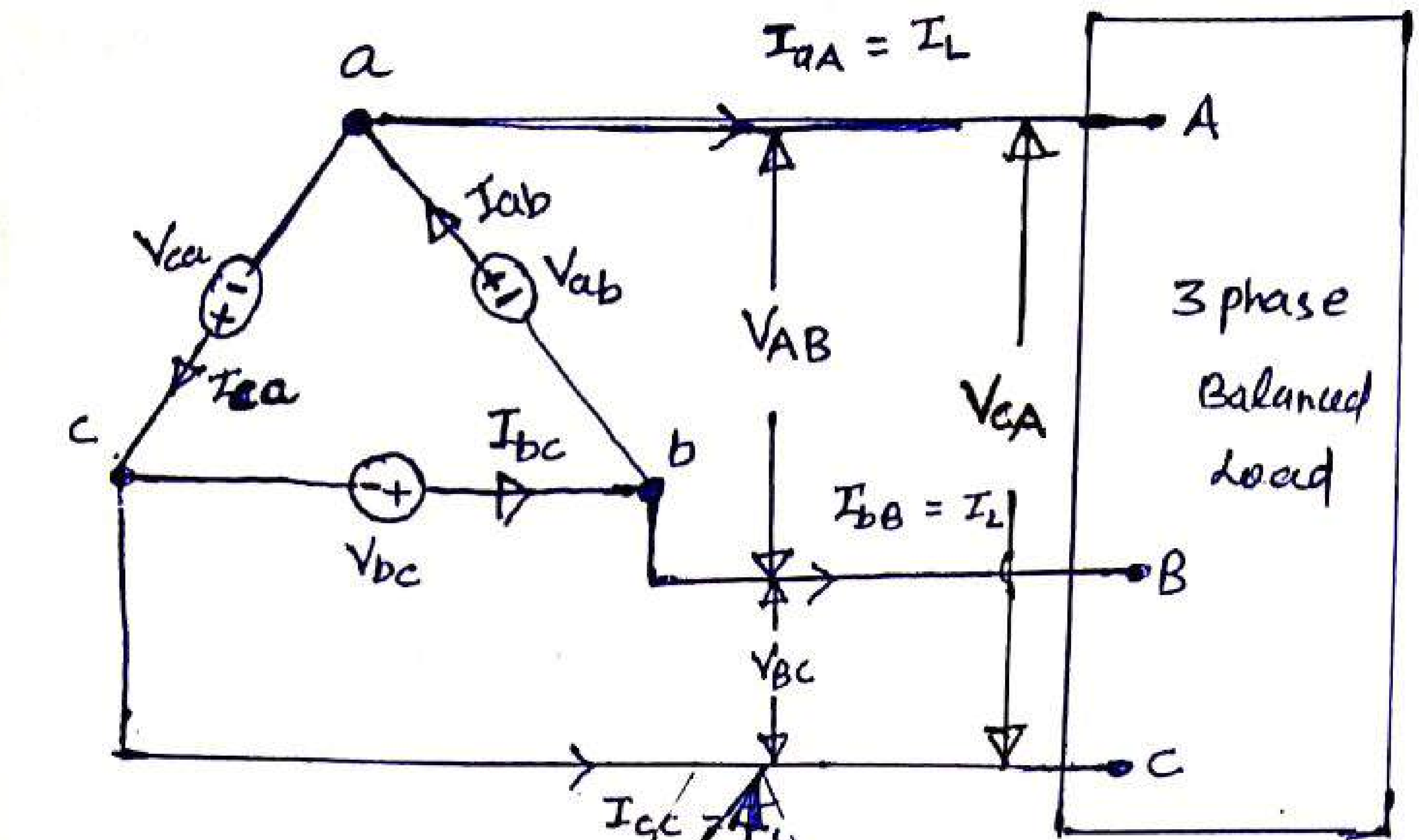
Derivation of V_L & I_L in Delta Connection :-

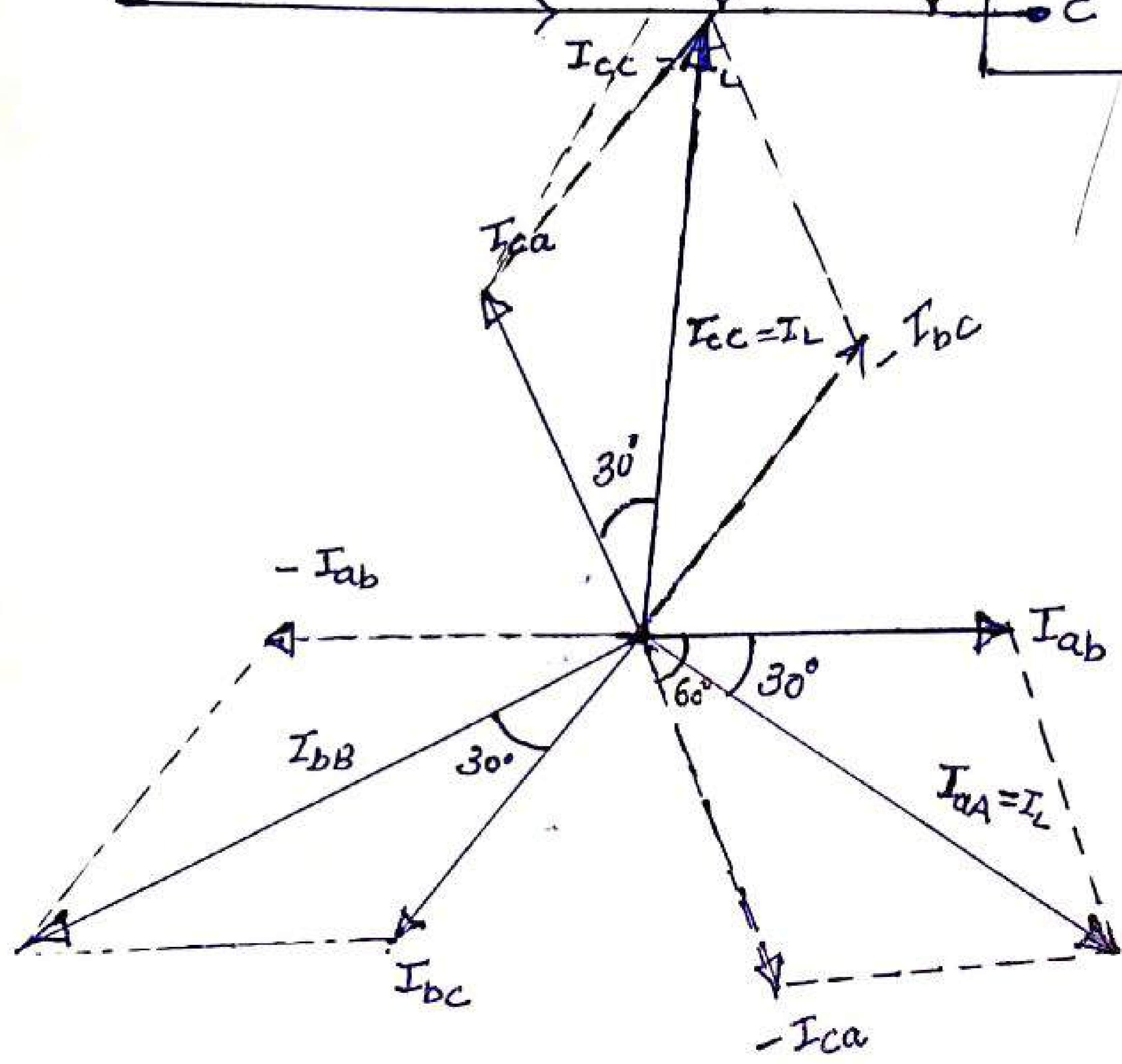


Alternate method from phasor diagram

$$I_{aA} = \sqrt{|I_{ab}|^2 + |-I_{ca}|^2 + 2|I_{ab}||-I_{ca}|\cos 60}$$

$$I_L = \sqrt{I_p^2 + I_p^2 + 2I_p^2 \times \frac{1}{2}}$$

$$I_L = \sqrt{3}\, I_p$$



'Phasor diagram'

I_{ab}, I_{bc}, I_{ca} → Phase current

I_{aA}, I_{bB}, I_{cC} → Line current

V_{ab}, V_{bc}, V_{ca} → phase voltage

V_{AB}, V_{BC}, V_{CA} → Line Voltage

$$I_{ab} = I_p \angle 0^\circ$$

$$I_{bc} = I_p \angle -120^\circ$$

$$I_{ca} = I_p \angle -240^\circ = I_p \angle +120^\circ$$

Applying KCL at Node - a

$$I_{aA} + I_{ca} = I_{ab}$$

$$I_{aA} = I_{ab} - I_{ca} \quad \text{——— (1)}$$

$$I_{aA} = I_p\angle 0^\circ - I_p \angle +120^\circ$$

$$= I_p + j0 - \left(-\frac{1}{2} + j\frac{\sqrt{3}}{2}\right) I_p$$

$$= I_p + \left(\frac{1}{2} - j\frac{\sqrt{3}}{2}\right) I_p$$

$$= I_p \left[1 + \frac{1}{2} - j\frac{\sqrt{3}}{2}\right]$$

$$= I_p \left[\frac{3}{2} - j\frac{\sqrt{3}}{2}\right]$$

$$= \sqrt{3}\, I_p \angle -30^\circ$$

Applying KCL at Node - b

$$I_{bB} = I_{bc} - I_{ab}$$

$$I_{bB} = I_p\angle -120^\circ - I_p \angle 0^\circ$$

$$I_{bB} = I_p\left(-\frac{1}{2} - j\frac{\sqrt{3}}{2}\right) - I_p$$

$$I_{bB} = I_p\left[-\frac{1}{2} - 1 - j\frac{\sqrt{3}}{2}\right]$$

$$I_{bB} = I_p\left[-\frac{3}{2} - j\frac{\sqrt{3}}{2}\right]$$

$$= \sqrt{3}\, I_p \angle 30^\circ$$

Similarly -

$$\boxed{I_{cC} = I_{ca} - I_{bc}} = \sqrt{3}\, I_p$$

V_L & I_L Derivation continued -

if $|I_{aA}| = |I_{bB}| = |I_{cC}| = I_L$

Then $\boxed{I_L = \sqrt{3}\, I_p}$

By Applying KVL -

$V_{AB} = V_{ab}$

$V_{BC} = V_{bc}$

$V_{CA} = V_{ca}$

if $|V_{ab}| = |V_{bc}| = |V_{ca}| = V_p$

& $|V_{AB}| = |V_{BC}| = |V_{CA}| = V_L$

Then $\boxed{V_L = V_p}$

→ Power:-

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

reactive power $Q = \sqrt{3}\, V_L I_L \sin\phi$

Apparent Power $S = \sqrt{3}\, V_L I_L$

→ Impedance :-

$$Z_p = \frac{V_p}{I_p} = \frac{|V_p| \angle \phi_1}{|I_p| \angle \phi_2}$$

→ Summary for Delta connection!-

(I) Line voltage (V_L) = phase voltage (V_p)

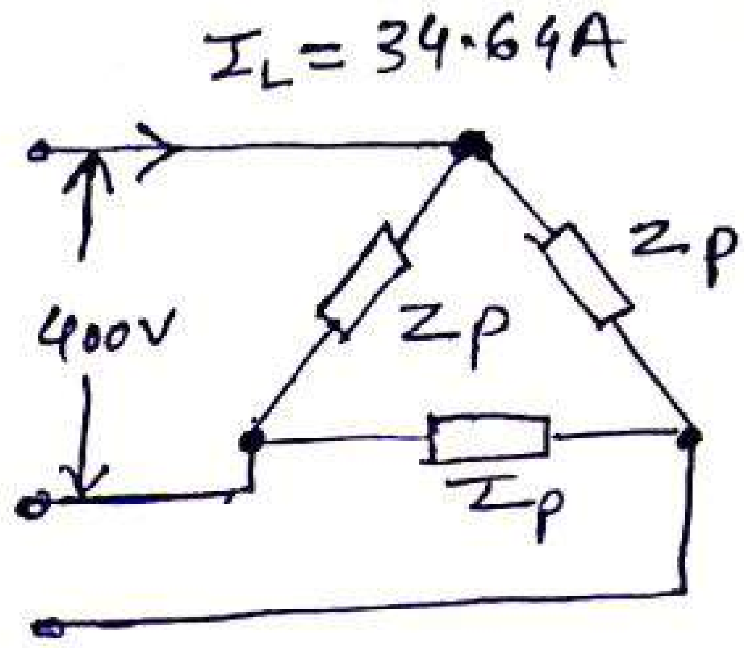
(II) Line Current (I_L) = $\sqrt{3}$ × phase current

$= \sqrt{3}\, I_p$

Probems on Delta Connections :-

Q.1 A delta connected balanced load is connected to a 3 phase 400V supply. The load p.f is 0.8 lagging. The line current is 34.64A. find the (i) R & X_L per phase (ii) active power (iii) total reactive power

Solo



$V_L = 400\,V$, $I_L = 34.64\,A = \sqrt{3}\, I_p$

$\cos\phi = 0.8$ lagging

~~$Z_p = \frac{V_p}{I_p} = \frac{V_L/\sqrt{3}}{\sqrt{3} I_L} = \frac{V_L/\sqrt{3}}{}$~~

let $Z_p = |Z_p|\angle\phi$

$$|Z_p| = \left|\frac{V_p}{I_p}\right| = \left|\frac{V_L}{I_L/\sqrt{3}}\right| = \sqrt{3}\left|\frac{V_L}{I_L}\right| = \sqrt{3} \times \frac{400}{34.64} = 20\,\Omega$$

$$\phi = \cos^{-1}(0.8) = 36.86^\circ$$

$$\therefore Z_p = 20\angle 36.86^\circ = 16 + j12\,\Omega$$

Hence $R = 16$, $X_L = 12\,\Omega$

(ii) $P = \sqrt{3} V_L I_L \cos\phi = \sqrt{3} \times 400 \times 34.64 \times 0.8 = 20\,kW$

$Q = \sqrt{3} V_L I_L \sin\phi = \sqrt{3} \times 400 \times 34.64 \times \sin(36.86^\circ) = 14.4\,KVAr$

Q.2. Three equal impedances each of $10\angle 60^\circ\,\Omega$ are connected in Star across 3 phase 400V, 50 Hz supply. Calculate the active power. If the same three impedances are connected in Delta to same source of supply what is the active power consumed.

Ans. In star, $P = 8\,kW$, in Delta, $P = 24\,kW$

Q.3 A balanced Delta connected load of impedance $60\angle 30^\circ\,\Omega$/phase is connected to 3ϕ supply of 400V, find (i) The phase and line current (ii) Apparent power → 7.97 KVA

3 Phase Power Measurement by Two Wattmeter Method

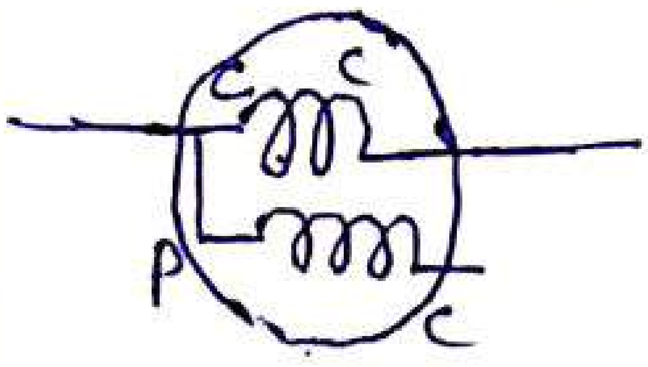
ⓐ Brief points about Wattmeter :-

→ A wattmeter consist of two coils ① Current coil (CC)
② Potential Coil (PC)

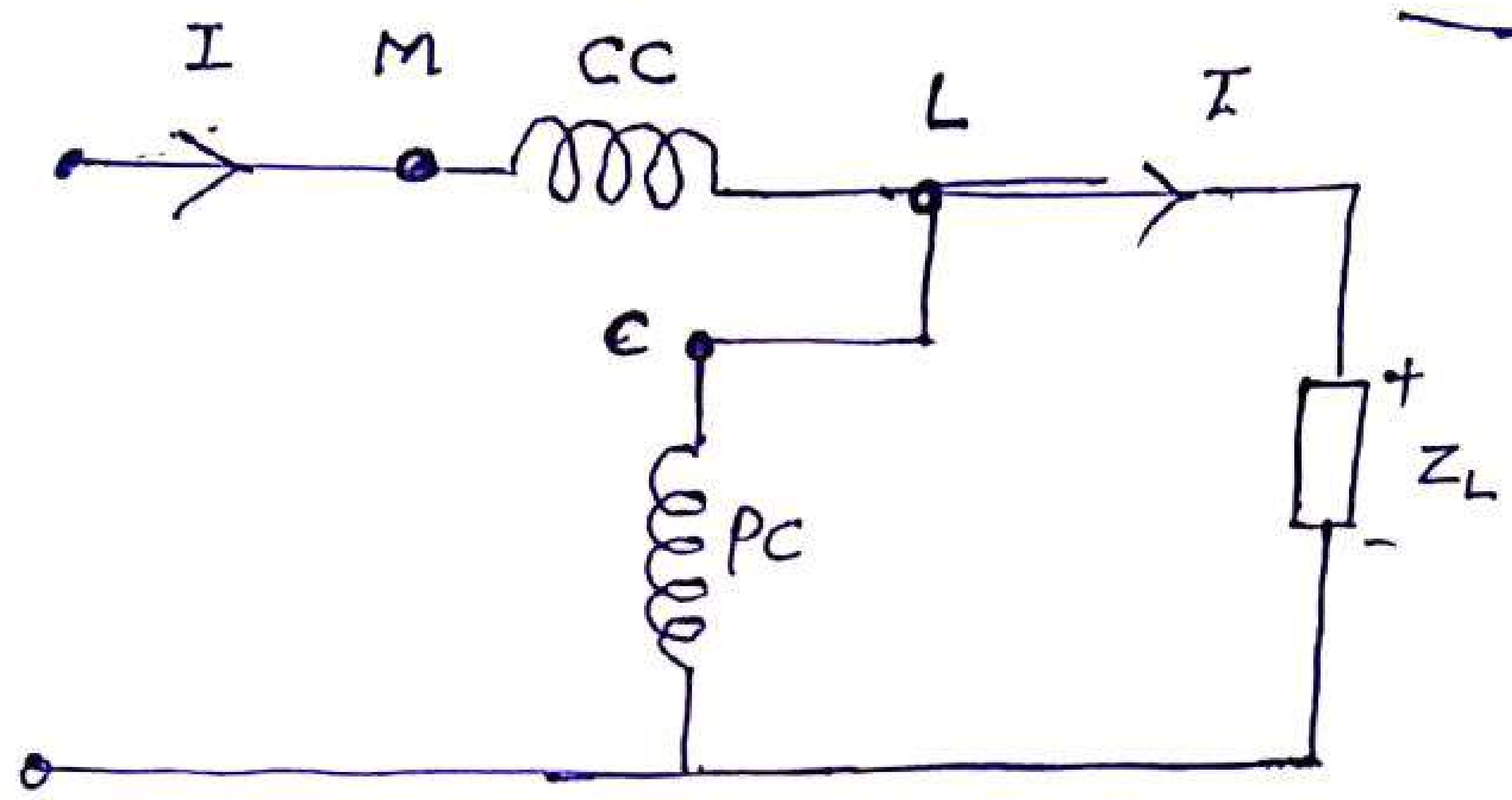
→ The current coil has low impedance while Potential coil has very high impedance.

→ The current coil is connected in series with load and responds to the load current

→ The potential coil is connected in parallel with load and respond to load voltage.



Watt meter symbol



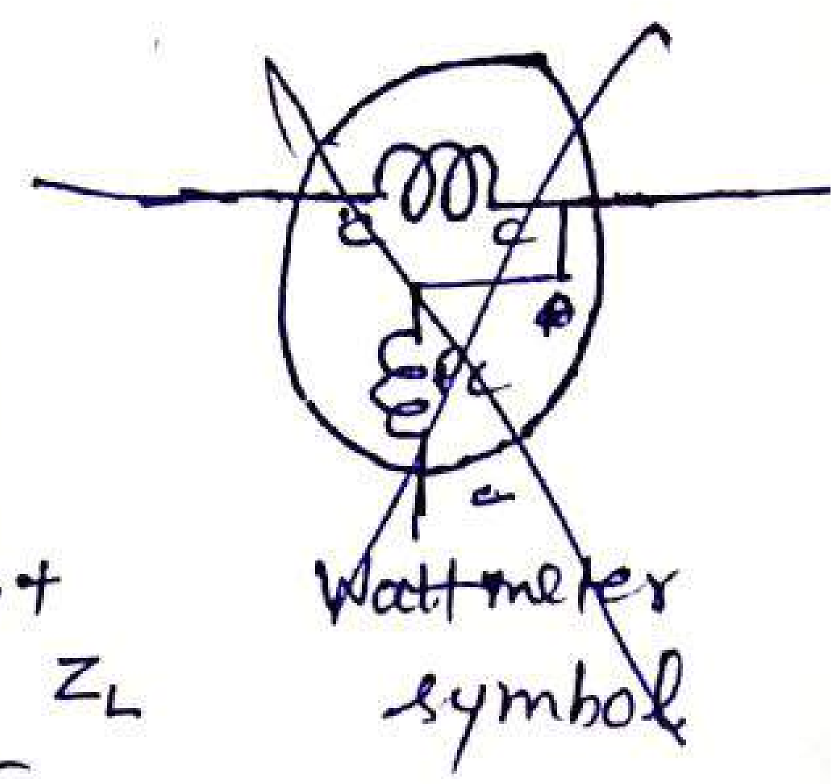


fig. 1 The wattmeter connected to load

ⓑ Two Wattmeter Method :-

→ The two Wattmeter must be properly connected to any two phases, as shown in fig. 2

→ The current coil of each wattmeter measures the line current while, the respective voltage coil is connected between line and ~~thired~~ third line measures the line voltage.

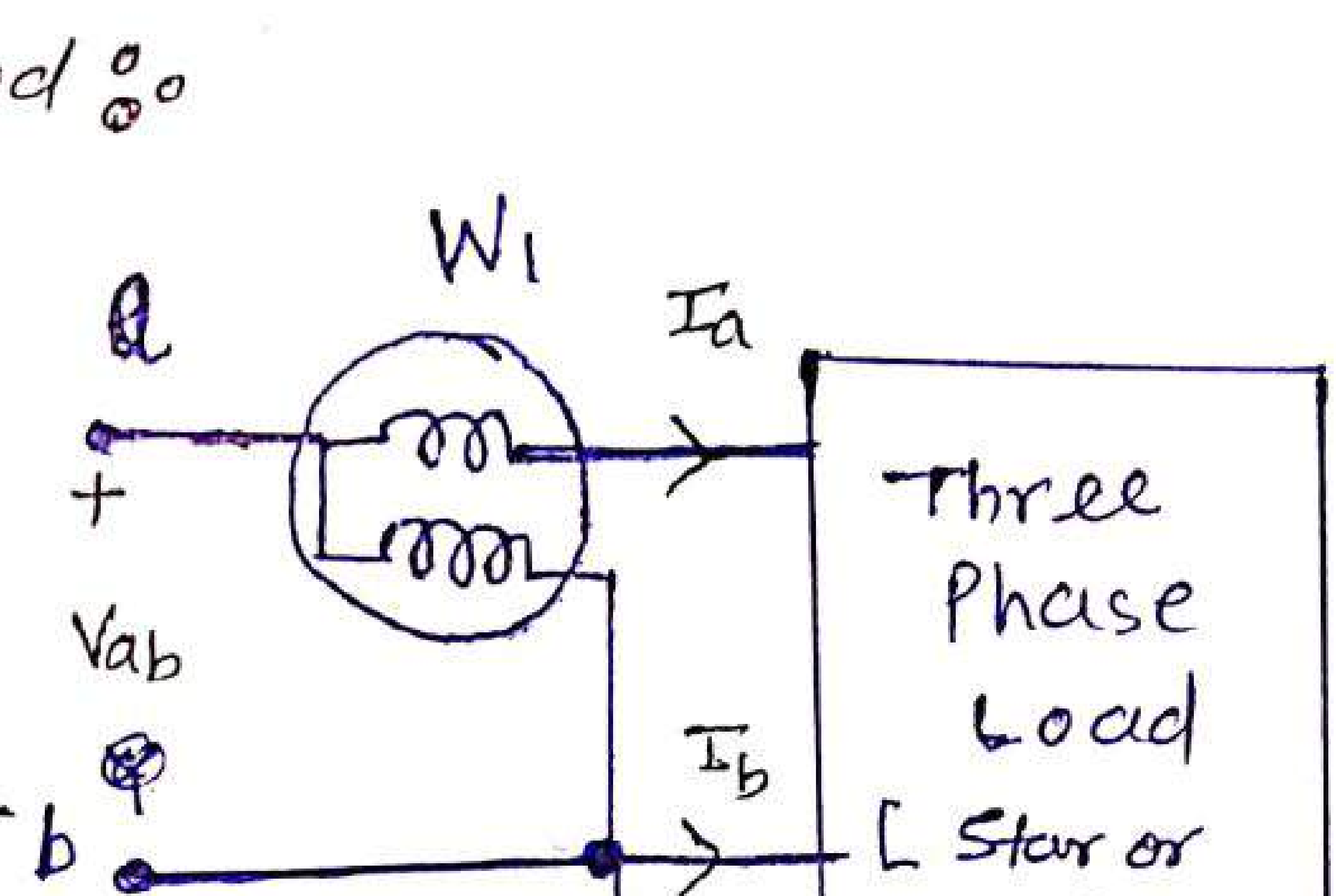


fig. 2

→ The algebraic sum of the two wattmeter reading equals the total power absorbed by the load regardless of whether it is star - or delta connected, balanced, or unbalanced.

$$\boxed{P_T = W_1 + W_2}$$

Derivation :-

→ considered balanced star - connected load.

→ The load impedance of each phase $Z_p = Z \angle \theta$

→ if the load impedance is in RL type then voltage coil leads its current coil by θ, so that power factor is $\cos\theta$.

→ V_{an}, V_{bn}, V_{cn} → Phase Voltage

I_a, I_b, I_c → line current = phase current

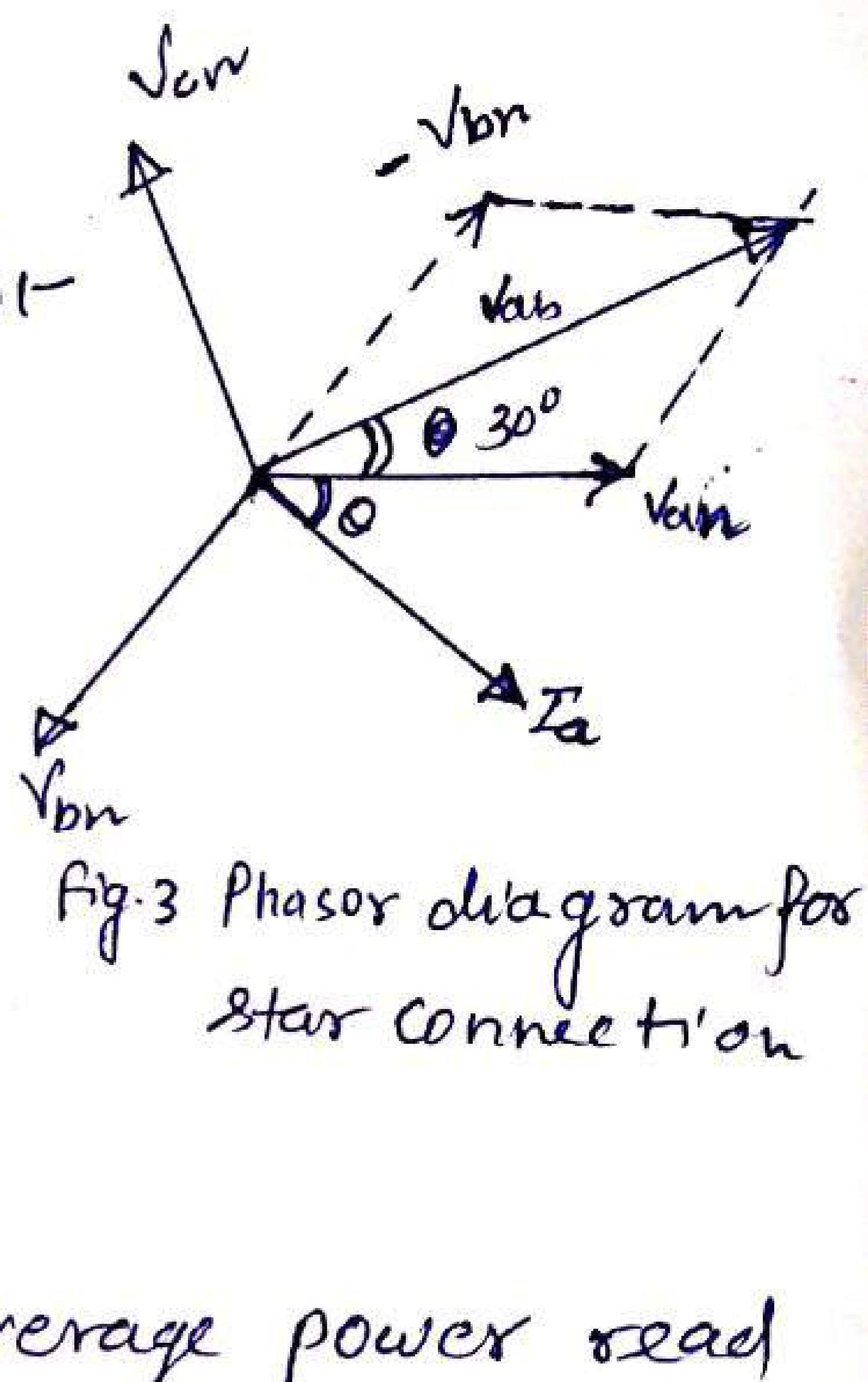


Fig.3 Phasor diagram for star connection

→ The total phase difference between the phase current I_a and line voltage V_{ab} is $(\theta + 30)$, and the average power read by wattmeter W_1 is

$$P_1 = V_{ab} I_a \cos(\theta + 30^\circ)$$

$$P_1 = V_L I_L \cos(\theta + 30^\circ) \quad \text{——— (1)}$$

→ Similarly we can show that the average power read by wattmeter 2 is

$$P_2 = V_{cb} I_c \cos(\theta - 30^\circ) = V_L I_L \cos(\theta - 30^\circ) \quad \text{——— (2)}$$

Total Power $P_T = P_1 + P_2 = V_L I_L [\cos(\theta + 30^\circ) + \cos(\theta - 30^\circ)]$

$$P_T = V_L I_L \, 2 \cos 30^\circ \cdot \cos\theta$$

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

① Power System :-

Electricity is generated at central power stations and then transferred to Domestic, commercial and industrial loads through the transmission and distribution system. A combination of all these systems is collectively known as an Electric Power System.

An Electric Power system consists of three parts -

(I) Generation

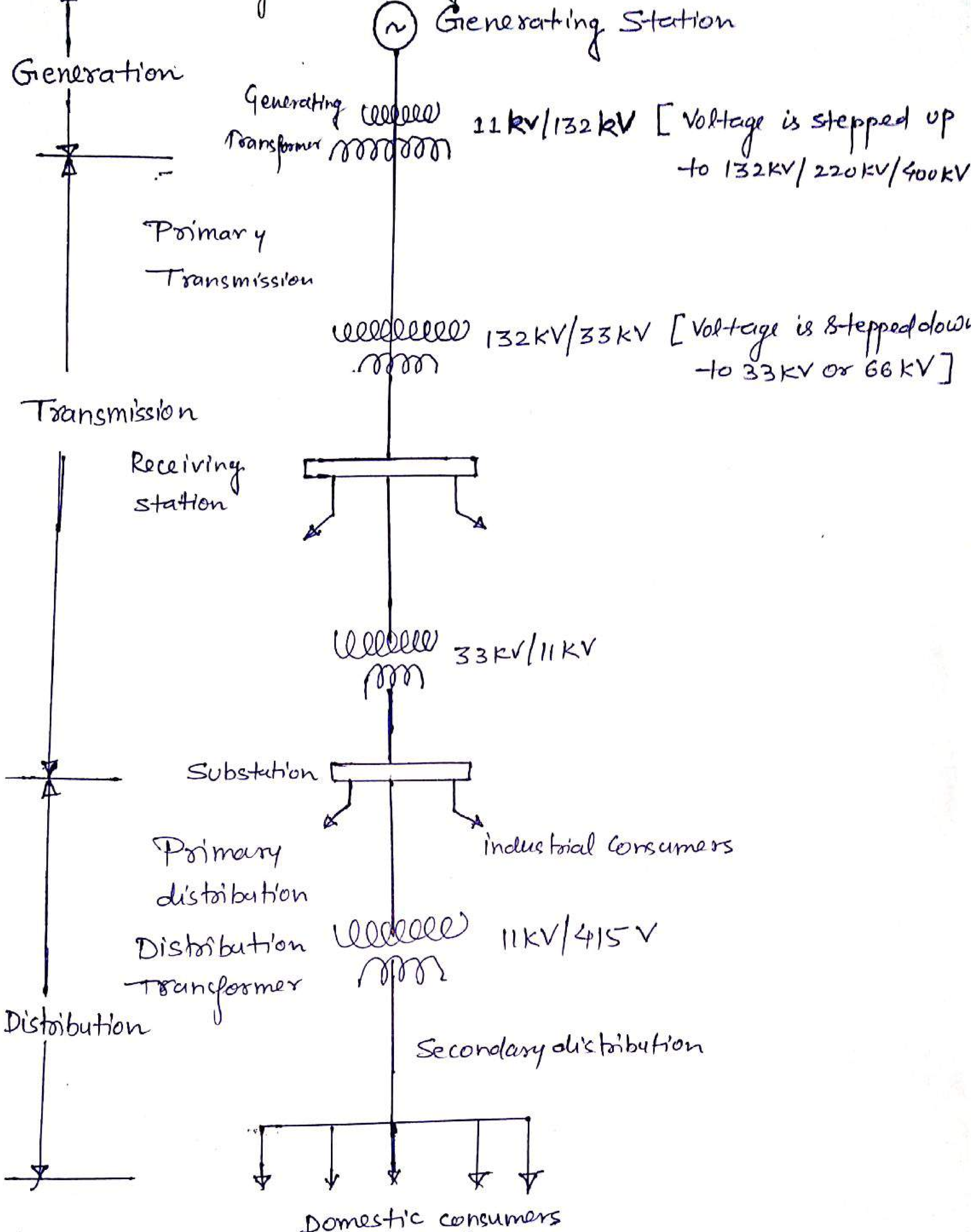
(II) Transmission

(III) Distribution

② Single line diagram or one-line diagram

Theoretically, it is compulsory to have the basic knowledge of about how electricity is produced, transmitted, distributed and reached to the consumers. Therefore, the idea is presented by a graphical symbolic information called single line diagram.

Single Line Diagram of a Power System



Electrical Grid :

A Grid is an electrical network to deliver power from Generating stations to consumers.