related expressions & Problems

UNIT-II- AC Circuits

1. Derive the expression for RMS and Average value of Sine wave.
2. Define i) form factor ii) Peak factor iii) phase iv) phase difference v) Line voltage vi) phase voltage vii) line current viii) phase current.
3. Draw the phasor diagram for AC through pure resistor, pure inductor and pure capacitor.
4. Derive the expression for Current , power factor and power in Series R-L circuit
5. Derive the expression for Current , power factor and power in Series R-C circuit.
6. Derive the expression for Current , power factor and power in Series R-L-C circuit
7. Explain the operation of a series RLC circuit, when excited by AC supply with neat diagram
8. Derive the voltage and current relations in star and delta connected systems.
9. Explain the two wattmeter method with neat diagram? And draw the phasor diagram.
10. Define Active, Reactive and Apparent power in AC circuits . What do you understand by Balanced loads.

1) Derive Average & Rms value of Sinusoidal / Ac waveform

Average value

$$V_{average} = \frac{1}{T}\int_0^{\pi} V(t)\,dt$$

$$= \frac{1}{\pi}\int_0^{\pi} V_m \sin\omega t$$

$$= \frac{V_m}{\pi}\int_0^{\pi} \sin\omega t$$

$$V_{avg} = \frac{V_m}{\pi}\left[-\cos\omega t\right]_0^{\pi} = \frac{2V_m}{\pi}$$

$$V_{rms} = \frac{1}{T}\int_0^{\pi} V^2(t)\,dt$$

$$= \frac{1}{2\pi}\int_0^{2\pi} V_m^2 \sin^2\omega t\,(d\omega t)$$

$$= \frac{V_m^2}{2\pi}\int_0^{2\pi} \sin^2\omega t\,dt$$

$$V_{rms} = \frac{V_m^2}{2\pi}\left[\frac{1-\cos 2(\omega t)}{2}\right]_0^{2\pi} = \frac{V_m}{\sqrt{2}}$$

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✅ 1. RMS Value of a Sine Wave

Definition:

The RMS value of a periodic waveform is the **square root of the average of the square of the waveform** over one full cycle.

$$V_{rms} = \sqrt{\frac{1}{T}\int_0^T [v(t)]^2 dt}$$

Substitute $v(t) = V_m \sin(\omega t)$, and since a sine wave is periodic, we can take the limits over one period $T = \frac{2\pi}{\omega}$:

$$V_{rms} = \sqrt{\frac{1}{T}\int_0^T V_m^2 \sin^2(\omega t) dt} = V_m \sqrt{\frac{1}{T}\int_0^T \sin^2(\omega t) dt}$$

Use identity:

$$\sin^2(\omega t) = \frac{1 - \cos(2\omega t)}{2}$$

$$V_{rms} = V_m \sqrt{\frac{1}{T}\int_0^T \frac{1 - \cos(2\omega t)}{2} dt} = V_m \sqrt{\frac{1}{2T}\int_0^T [1 - \cos(2\omega t)] dt}$$

Since $\int_0^T \cos(2\omega t) dt = 0$ over one full period:

$$V_{rms} = V_m \sqrt{\frac{1}{2T} \cdot T} = V_m \sqrt{\frac{1}{2}}$$

Final RMS Value:

$$\boxed{V_{rms} = \frac{V_m}{\sqrt{2}} \approx 0.707 V_m}$$

✅ 2. Average Value of a Sine Wave (over Half Cycle)

Definition:

The average value of a sine wave over **one full cycle is zero**, so we take it over **half cycle (0 to π)**:

$$V_{avg} = \frac{1}{\pi}\int_0^\pi V_m \sin(\theta) d\theta$$

$$= \frac{V_m}{\pi}[-\cos(\theta)]_0^\pi = \frac{V_m}{\pi}[-\cos(\pi) + \cos(0)]$$

$$= \frac{V_m}{\pi}[-(-1) + 1] = \frac{V_m}{\pi}[2]$$

Final Average Value (half cycle):

$$\boxed{V_{avg} = \frac{2V_m}{\pi} \approx 0.637 V_m}$$

📌 Summary Table:

Quantity	Expression	Approx. Value
RMS Value	$\frac{V_m}{\sqrt{2}}$	$\approx 0.707 V_m$
Average Value	$\frac{2V_m}{\pi}$	$\approx 0.637 V_m$

2 Form Factor

Definition:

Form factor is the ratio of the **RMS (Root Mean Square) value** to the **average value** (mean value) of an alternating waveform.

$$\text{Form Factor} = \frac{\text{RMS Value}}{\text{Average Value}}$$

- For a sine wave:

$$\text{Form Factor} = \frac{0.707V_m}{0.637V_m} = 1.11$$

Peak Factor (also called Crest Factor)

Definition:

Peak factor is the ratio of the **maximum (peak) value** to the **RMS value** of an alternating waveform.

$$\text{Peak Factor} = \frac{\text{Peak Value}}{\text{RMS Value}}$$

- For a sine wave:

$$\text{Peak Factor} = \frac{V_m}{0.707V_m} \approx 1.414$$

Phase

Definition:

Phase refers to the **position of a point** in time on a waveform cycle. It tells us the **timing** of a wave relative to a reference.

- Represented in **degrees** (°) or **radians**.
- For example, if a sine wave starts at zero, it has **0° phase**.

Phase Difference

Definition:

Phase difference is the **angular displacement** between two waveforms having the same frequency.

- It indicates **how much one wave leads or lags behind** the other.
- Expressed in degrees or radians.

📌 Example: If Wave A leads Wave B by 90°, the phase difference is **+90°**.

Line Voltage (in 3-phase systems)

Definition:

Line voltage is the voltage measured **between any two lines** (or phases) in a 3-phase system.

🟦 Line Voltage (in 3-phase systems)

Definition:
Line voltage is the voltage measured **between any two lines (or phases) in a 3-phase** system.

- For a star (Y) connection:

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

🟦 Phase Voltage

Definition:
Phase voltage is the voltage measured **across a single phase** (i.e., between a line and neutral) in a 3-phase system.

- In **star connection**, phase voltage is:

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

- In **delta connection**, phase voltage = line voltage.

🟦 Line Current

Definition:
Line current is the current flowing through **each line conductor** in a 3-phase system.

- In **star connection**, line current = phase current.
- In **delta connection:**

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

🟦 Phase Current

Definition:
Phase current is the current flowing through **each phase winding or load** in a 3-phase system.

- In **star** connection:
  $I_{ph} = I_L$
- In **delta** connection:
  $I_{ph} = \frac{I_L}{\sqrt{3}}$

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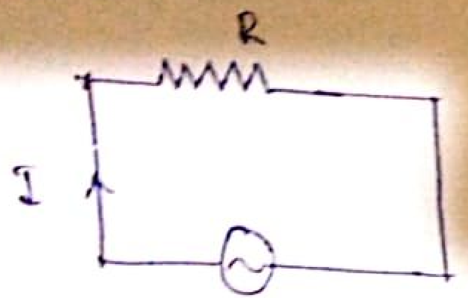
3)

AC through pure Resistance

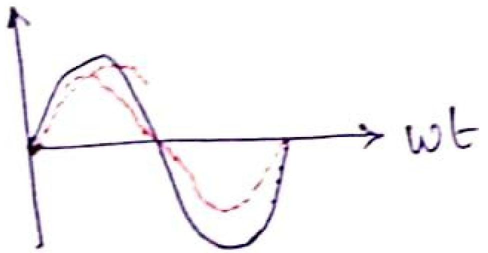


$V = V_m \sin \omega t$

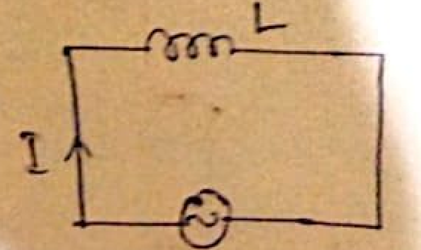
$I = I_m \sin \omega t$

$I_m = \frac{V_m}{R}$, $V = (V_m \angle 0)\,V$

$I = (I_m \angle 0)\,A$



AC through pure Inductance



$V = V_m \sin \omega t$

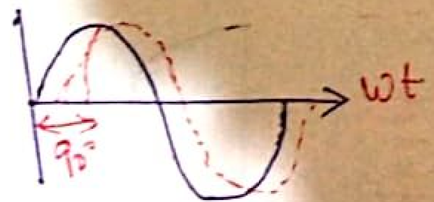
$I = I_m \sin(\omega t - 90^\circ)$

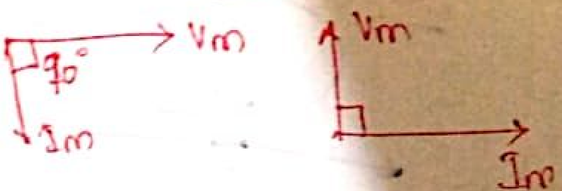
$I_m = \frac{V_m}{X_L}$

$V = (V_m \angle 0)\,V$

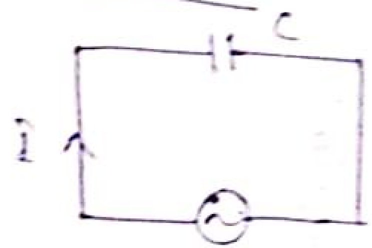
$I = (I_m \angle -90^\circ)\,A$

$X_L = \omega L$ | $\omega = 2\pi f$ | $X_L = 2\pi f L$





AC through pure Capacitance



$V = V_m \sin \omega t$

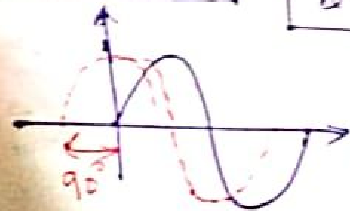
$I = I_m \sin(\omega t + 90^\circ)$

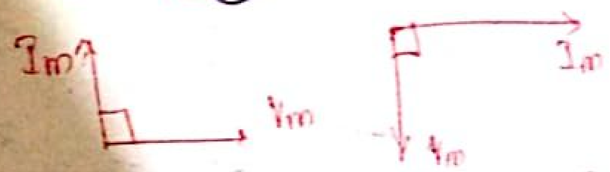
$I_m = \frac{V_m}{X_C}$

$V = (V_m \angle 0)\,V$

$I = (I_m \angle 90^\circ)\,A$

$X_C = \frac{1}{\omega C}$, $\frac{1}{2\pi f C} = X_C$





🔷 4. Derive the expression for Current, Power Factor and Power in a Series R–L Circuit

- **Given:**

An AC supply is connected to a **resistor** (R) and **inductor** (L) in series.

- **Voltage equation:**

$$V = V_R + V_L$$

- **Current is same through both:**

$$I = \text{same in R and L (series)}$$

- **Voltage across resistor:**

$$V_R = IR$$

- **Voltage across inductor:**

$$V_L = IX_L, \quad \text{where } X_L = \omega L$$

- **Total Impedance:**

$$Z = \sqrt{R^2 + X_L^2}$$

✅ Expression for Current:

$$I = \frac{V}{Z} = \frac{V}{\sqrt{R^2 + X_L^2}}$$

✅ Power Factor:

$$\cos\phi = \frac{R}{Z} = \frac{R}{\sqrt{R^2 + X_L^2}}$$

> Here, ϕ is the phase angle between voltage and current.

✅ Power:

$$P = VI\cos\phi = I^2R$$

Only **resistor consumes power**, inductor stores and returns it (no power loss).

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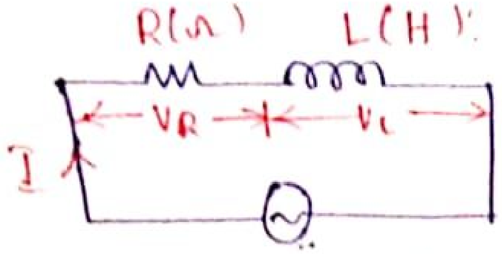
4) Series AC Circuit : Series R-L Circuit



$V = V_m \sin\omega t$

$I = I_m \sin(\omega t - \phi)$

$V = (V_m \angle 0)\,V$

$I = (I_m \angle -\phi)\,A$

$I = \frac{V}{Z}$ Amps

where, Z = Impedance (Ω)

$Z = R + jX_L$

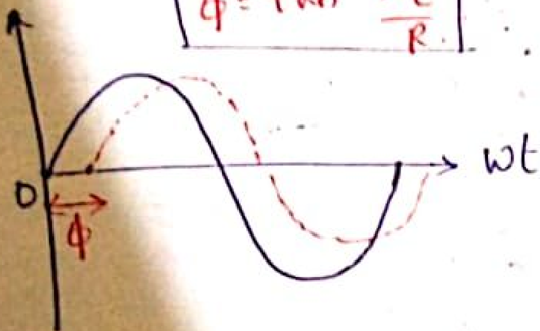
or

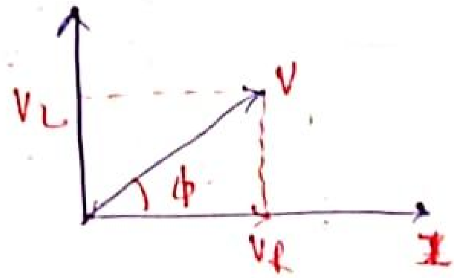
$Z = \sqrt{R^2 + X_L^2}$

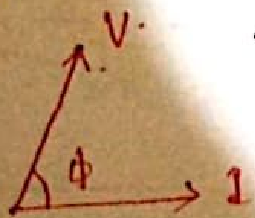
$X_L = \omega L \quad \{\because \omega = 2\pi f$

$X_L = 2\pi f L$; $\phi = \tan^{-1} \frac{X_L}{R}$

$\phi = \tan^{-1} \frac{X_L}{R}$







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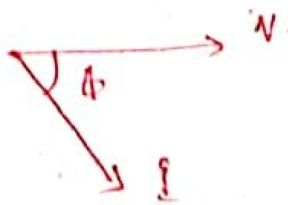


🔷 5. Derive the expression for Current, Power Factor and Power in a Series R–C Circuit

- **Given:**

An AC source is connected to **resistor (R) and capacitor (C) in series.**

- **Capacitive Reactance:**

$$X_C = \frac{1}{\omega C}$$

- **Total Impedance:**

$$Z = \sqrt{R^2 + X_C^2}$$

✅ Expression for Current:

$$I = \frac{V}{Z} = \frac{V}{\sqrt{R^2 + X_C^2}}$$

✅ Power Factor:

$$\cos\phi = \frac{R}{Z} = \frac{R}{\sqrt{R^2 + X_C^2}}$$

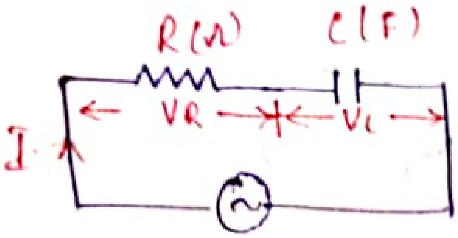
> Current leads voltage in a capacitive circuit.

✅ Power:

$$P = VI\cos\phi = I^2 R$$

Only the resistor consumes power. Capacitor just stores and releases energy.

Series AC Circuit : Series R-C Circuit



$$\boxed{I = \frac{V}{Z} \text{ Amps}}$$

where, Z = Impedance (Ω).

$V = V_m \sin \omega t$

$I = I_m \sin(\omega t + \phi)$.

$$\boxed{Z = R - jX_C}$$

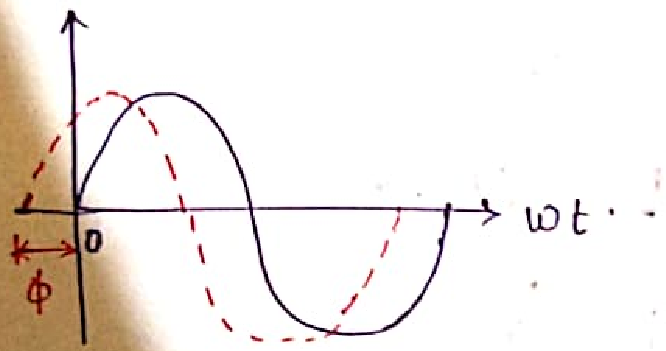
or

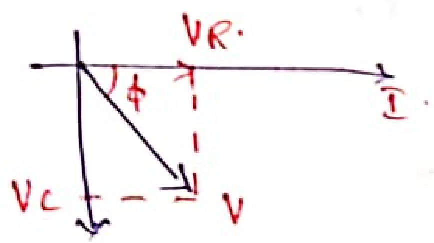
$$\boxed{Z = \sqrt{R^2 + X_C^2}}$$

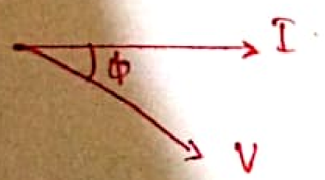
$$\boxed{\begin{aligned} V &= (V_m \angle 0)\ V \\ I &= I_m (\angle + \phi)\ A \end{aligned}}$$

$X_C = \frac{1}{\omega C}$ $\{\because \omega = 2\pi f$

$X_C = \frac{1}{2\pi f C}$; $\boxed{\phi = \tan^{-1}\left(\frac{-X_C}{R}\right)}$







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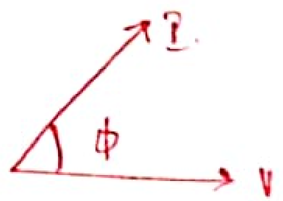


🔷 6. Derive the expression for Current, Power Factor and Power in Series R–L–C Circuit

- **Components: Resistor (R), Inductor (L), Capacitor (C) in series with AC supply.**
- **Inductive Reactance:**

$$X_L = \omega L$$

- **Capacitive Reactance:**

$$X_C = \frac{1}{\omega C}$$

- **Net Reactance:**

$$X = X_L - X_C$$

✅ Total Impedance:

$$Z = \sqrt{R^2 + (X_L - X_C)^2}$$

✅ Expression for Current:

$$I = \frac{V}{Z} = \frac{V}{\sqrt{R^2 + (X_L - X_C)^2}}$$

✅ Power Factor:

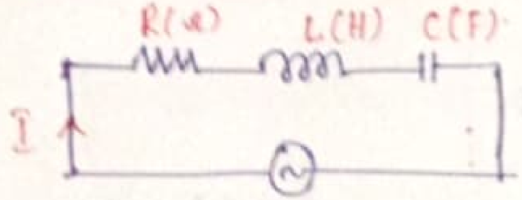
$$\cos\phi = \frac{R}{Z}$$

> - "If $X_L > X_C$: Inductive, current lags."
> - "If $X_C > X_L$: Capacitive, current leads."
> - "If $X_L = X_C$: Resonance, PF = 1."

✅ Power:

$$P = VI\cos\phi = I^2R$$

Series RLC Circuit



$V = V_m \sin \omega t$

$I = I_m \sin(\omega t \pm \phi)$

$V = (V_m \angle 0)\,V$

$I = (I_m \angle \pm \phi)\,A$

$I = \frac{V}{Z}$ Amp

where Z = Impedance.

$Z = R + j(X_L - X_C)\ (\Omega)$

(or)

$Z = \sqrt{R^2 + (X_L - X_C)^2}$

$X_L = \omega L; \quad X_C = \frac{1}{\omega C}$

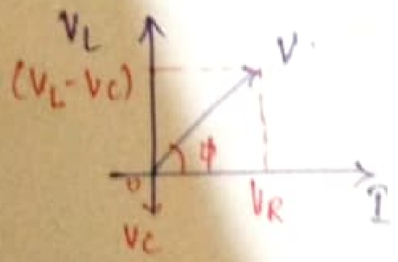
$\because \omega = 2\pi f$

$X_L = 2\pi f L\ (\Omega)$

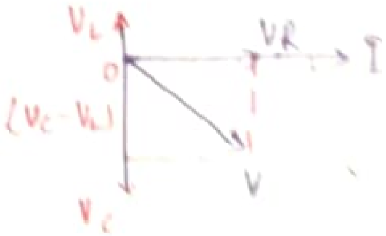
$X_C = \frac{1}{2\pi f C}\ (\Omega)$

$\phi = \tan^{-1}\left(\frac{X_L - X_C}{R}\right)$

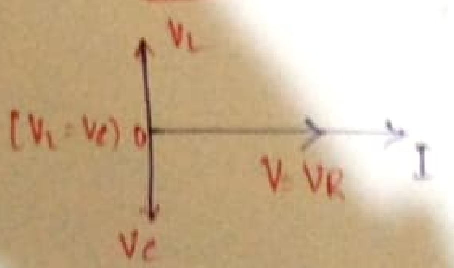
(i) $X_L > X_C$



(ii) $X_C > X_L$



(iii) $X_L = X_C$



🔷 7. Explain the Operation of Series RLC Circuit with AC Supply (with Neat Diagram)

🔹 Circuit Description:

A resistor R, inductor L, and capacitor C are connected in series to an AC source.

✅ Operation:

- The total **impedance (Z)** determines the current.
- The circuit can behave **resistive, inductive,** or **capacitive** depending on the values of X_L and X_C.
- **The current varies based on the net reactance:**

$$X = X_L - X_C$$

✅ Cases:

1. If $X_L > X_C$:
   - Net reactance is inductive
   - Current **lags** voltage
   - Power factor is **lagging**
2. If $X_C > X_L$:
   - Net reactance is capacitive
   - Current **leads** voltage
   - Power factor is **leading**
3. If $X_L = X_C$ (Resonance):
   - Net reactance = 0
   - Impedance is minimum = R
   - **Current is maximum**
   - **Power factor is unity (1)**

✅ Phasor Diagram (at Resonance):

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↑
|          → V and I (in phase)
|
|
|
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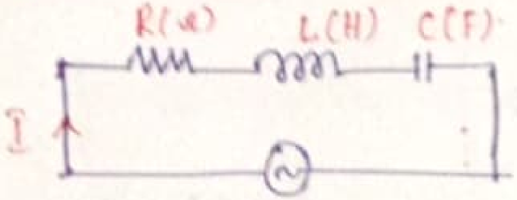
Series RLC Circuit



$$V = V_m \sin \omega t$$

$$I = I_m \sin(\omega t \pm \phi)$$

$$V = (V_m \angle 0)\, V$$

$$I = (I_m \angle \pm \phi)\, A$$

$$I = \frac{V}{Z} \text{ Amp}$$

where Z = Impedance.

$$Z = R + j(X_L - X_C)\ (\Omega)$$

(or)

$$Z = \sqrt{R^2 + (X_L - X_C)^2}$$

$$X_L = \omega L; \quad X_C = \frac{1}{\omega C}$$

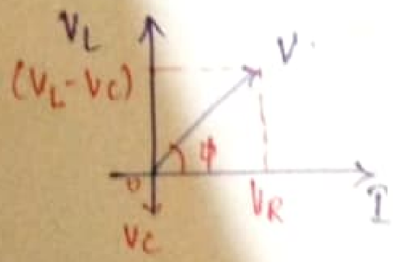
$\because \omega = 2\pi f$

$$X_L = 2\pi f L\ (\Omega)$$

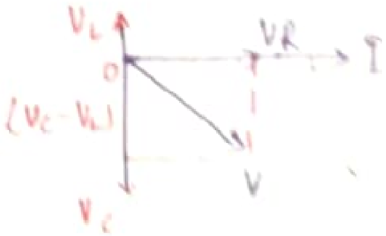
$$X_C = \frac{1}{2\pi f C}\ (\Omega)$$

$$\phi = \tan^{-1}\left(\frac{X_L - X_C}{R}\right)$$

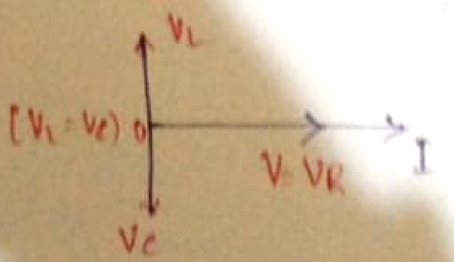
(i) $X_L > X_C$



(ii) $X_C > X_L$



(iii) $X_L = X_C$



RL load

$R = 180\Omega$

$X_L = 120\Omega$

$V = 230V$

$f = 50Hz$

$Z = \sqrt{R^2 + X_L^2} = \sqrt{180^2 + 120^2} = 216.33\Omega$

(1) $\cos\phi = \frac{R}{Z} = \frac{180}{216.33} = 0.83$ lagging

(2) $I = \frac{V}{Z} = \frac{230}{216.33} = 1.06A$

(3) $P = VI\cos\phi = 230 \times 1.06 \times 0.83 = 202.35$ watts

(4) $Q = VI\sin\phi = 230 \times 1.06 \times 0.55 = 134.09$ VAR

$\sin\phi = \sin(\cos^{-1}(0.83)) = 0.55$

(5) $S = VI = 230 \times 1.06 = 243.8$ VA

RC load

$R = 170\Omega$

$X_c = 50\Omega$

$V = 225V$

$f = 50Hz$

$Z = \sqrt{R^2 + X_c^2} = 196.46\Omega$

(1) $\cos\phi = \frac{R}{Z} = \frac{190}{196.46} = 0.96$ lagging

(2) $I = \frac{V}{Z} = \frac{225}{196.46} = 1.14$ A

(3) $P = VI\cos\phi = 225 \times 1.14 \times 0.96 = 246.24$ watts

(4) $Q = VI\sin\phi = \sout{230}$ 225 $\times 1.14 \times 0.28 = 71.82$ VAR

$\sin\phi = \sin(\cos^{-1}(0.96)) = 0.28$

(5) $S = VI = 225 \times 1.14 = 256.5$ VA

RLC load

$R = 50\Omega$

$L = 80mH$

$C = 90.4$ F

$V = 230V$

$f = 50Hz$

$Z = \sqrt{R^2 + (X_L - X_c)^2} = \sqrt{50^2 + (25.1 - 35.36)^2} = 51.04\Omega$

(1) $\cos\phi = \frac{R}{Z} = \frac{50}{51.04} = 0.979$ leading.

$X_L = 2\pi fL = 2\pi \times 50 \times 80 \times 10^{-3} = 25.1\Omega$

$X_c = \frac{1}{2\pi f c} = \frac{1}{2\pi \times 50 \times 90 \times 10^{-6}} = 35.36\Omega$

(2) $I = \frac{V}{Z} = \frac{230}{51.04} = 4.5A$.

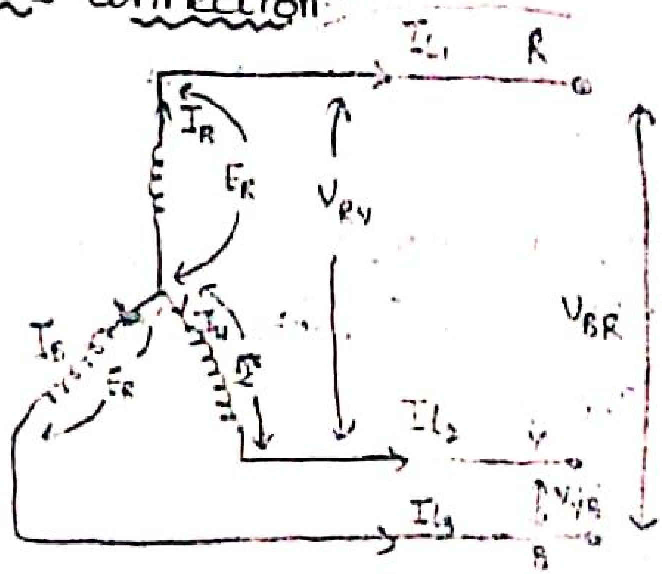
(3) $P = VI\cos\phi = 230 \times 4.5 \times 0.97 = 1003.95$ watts

(4) $Q = VI\sin\phi = 230 \times 4.5 \times 0.24 = 248.4$ VAR

$\sin\phi = \sin(\cos^{-1}(0.97)) = 0.24$

(5) $S = VI = 230 \times 4.5 = 1035$ VA

8) Star connection (Y): (A)



$I_{L_1}, I_{L_2}, I_{L_3}$ - Line currents = I_L

I_R, I_Y, I_B - phase currents = I_{ph}

E_R, E_Y, E_B - phase voltages = E_{ph}

V_{RY}, V_{YB}, V_{BR} - line voltages = V_L

In Y-connection

Apply KCL

$I_R = I_{L_1}$

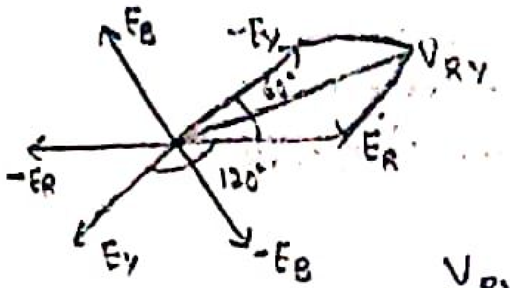
$I_Y = I_{L_2}$

$I_B = I_{L_3}$

In Y-connected system

line current = phase current

Relation b/w I_L & I_{ph} V_L & V_{ph}



$V_{RY} = E_R - E_Y$

$V_{YB} = E_Y - E_B$

$V_{BR} = E_B - E_R$

$$V_{RY} = \sqrt{E_R^2 + E_Y^2 + 2E_R E_Y \cos\theta}$$

$$= \sqrt{E_{ph}^2 + E_{ph}^2 + 2 E_{ph} E_{ph} \cos 60}$$

$$= \sqrt{E_{ph}^2 + E_{ph}^2 + 2 E_{ph}^2 \tfrac{1}{2}} = \sqrt{3 E_{ph}^2}$$

$$\boxed{V_{RY} = \sqrt{3} E_{ph}}$$

$V_{Line} = \sqrt{3}$ phase voltage

In a 3 phase Star connected System having $R = 150\,\Omega$, $C = 120\,\mu F$, $V = 420V$ and $f = 50\,Hz$. Find $\cos\phi$, I_L, I_{ph}, V_L, V_{ph}, P, Q & S

Sol:

① $\cos\phi = \frac{R}{Z} = \frac{150}{152.3} = 0.98$ leading.

$Z = \sqrt{R^2 + X_C^2} = \sqrt{150^2 + 26.5^2} = 152.3\,\Omega$

$X_C = \frac{1}{2\pi f C} = \frac{1}{2\pi \times 50 \times 120 \times 10^{-6}} = 26.5\,\Omega$

example problem

② $V_{ph} = \frac{V_L}{\sqrt{3}} = \frac{420}{\sqrt{3}} = 242.4\ V$

③ $I_{ph} = \frac{V_{ph}}{Z_{ph}} = \frac{420}{152.3} = 1.59\ A$ $\quad I_{ph} = I_L$

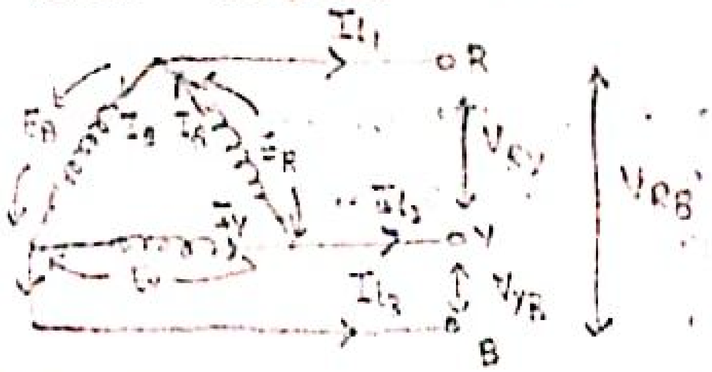
④ $P = \sqrt{3} V_L I_L \cos\phi = \sqrt{3} \times 420 \times 1.59 \times 0.98 = 1133$ watts

⑤ $Q = \sqrt{3} V_L I_L \sin\phi = \sqrt{3} \times 420 \times 1.59 \times 0.19 = 229\ VAR$

$\sin\phi = \sin(\cos^{-1}(0.98)) = 0.19$

⑥ $S = \sqrt{3} V_L I_L = \sqrt{3} \times 420 \times 1.59 = 1156\ VA$

Delta Connection (Δ)



$V_{RY} = E_R$

$V_{YB} = E_Y$

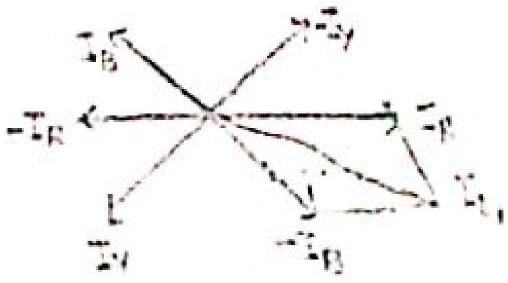
$V_{BR} = E_B$

Line voltage = phase voltage

$I_{L_1} = I_R - I_B$

$I_{L_2} = I_Y - I_R$

$I_{L_3} = I_B - I_Y$



$I_{L_1} = \sqrt{I_R^2 + I_B^2 + 2 I_R I_B \cos 60^\circ} \Rightarrow I_{L_1} = \sqrt{I_{ph}^2 + I_{ph}^2 + 2 I_{ph} I_{ph} \cdot \frac{1}{2}}$

$I_{L_1} = \sqrt{I_{ph}^2 + I_{ph}^2 + I_{ph}^2} \Rightarrow I_{L_1} = \sqrt{3 I_{ph}^2} \Rightarrow \boxed{I_{L_1} = \sqrt{3} I_{ph}}$

∴ Line current = $\sqrt{3}$ phase current

2022 3-phase delta circuit having $R = 100\Omega$, $L = 30mH$, $V = 415$ and $f = 50Hz$. Calculate power factor $\cos\phi$, I_L, I_{ph}, V_L, V_{ph}, P, Q & S.

Sol: ① $\cos\phi = \frac{R}{Z} = \frac{100}{100.44} = 0.99$ lagging

$Z = \sqrt{R^2 + X_L^2} = \sqrt{100^2 + 9.42^2} = 100.44\Omega$

$X_L = 2\pi f L = 2\pi \times 50 \times 30 = 9.42\Omega$

② $I_{ph} = \frac{V_{ph}}{Z_{ph}} = \frac{415}{100.44} = 4.13A$ example problem

③ $I_L = \sqrt{3} I_{ph} = \sqrt{3} \times 4.13 = 7.15A$

④ $P = 3 V_{ph} I_{ph} \cos\phi = 3 \times 415 \times 4.13 \times 0.99 =$ ~~8819~~ 5090 watts

⑤ $Q = 3 V_{ph} I_{ph} \sin\phi = 3 \times 415 \times 4.13 \times 0.14 =$ ~~1246~~ 719 VAR

$\sin\phi = \sin(\cos^{-1}(0.99)) = 0.14$

⑥ $S = 3 V_{ph} I_{ph} = 3 \times 415 \times 4.13 =$ ~~890~~ 5141.85 VA

9. Explain the Two Wattmeter Method with Neat Diagram. Draw the Phasor Diagram.

Introduction:

The **two wattmeter method** is used to measure the **power in a 3-phase system**, especially when the system is **balanced or unbalanced**. It works for both **star (Y)** and **delta (Δ)** connected loads.

Circuit Diagram:

(Please draw this diagram for your notes)

- Two wattmeters W_1 and W_2
- Current coils of both wattmeters are connected in **Line 1** and **Line 2**
- Pressure (voltage) coils are connected between:
  - W_1: Line 1 to Line 3
  - W_2: Line 2 to Line 3
- Load is connected in a 3-phase system.

Working:

- Each wattmeter measures the power in its respective line.
- **The total power** in the 3-phase system is:

$$P_{total} = W_1 + W_2$$

Phasor Diagram:

For a **balanced inductive load**, the current lags the voltage. The phasor diagram shows:

- Three phase voltages at 120° apart
- Current vectors lagging behind voltages by the power factor angle (φ)
- The angle between voltage across pressure coil and current through current coil determines wattmeter reading

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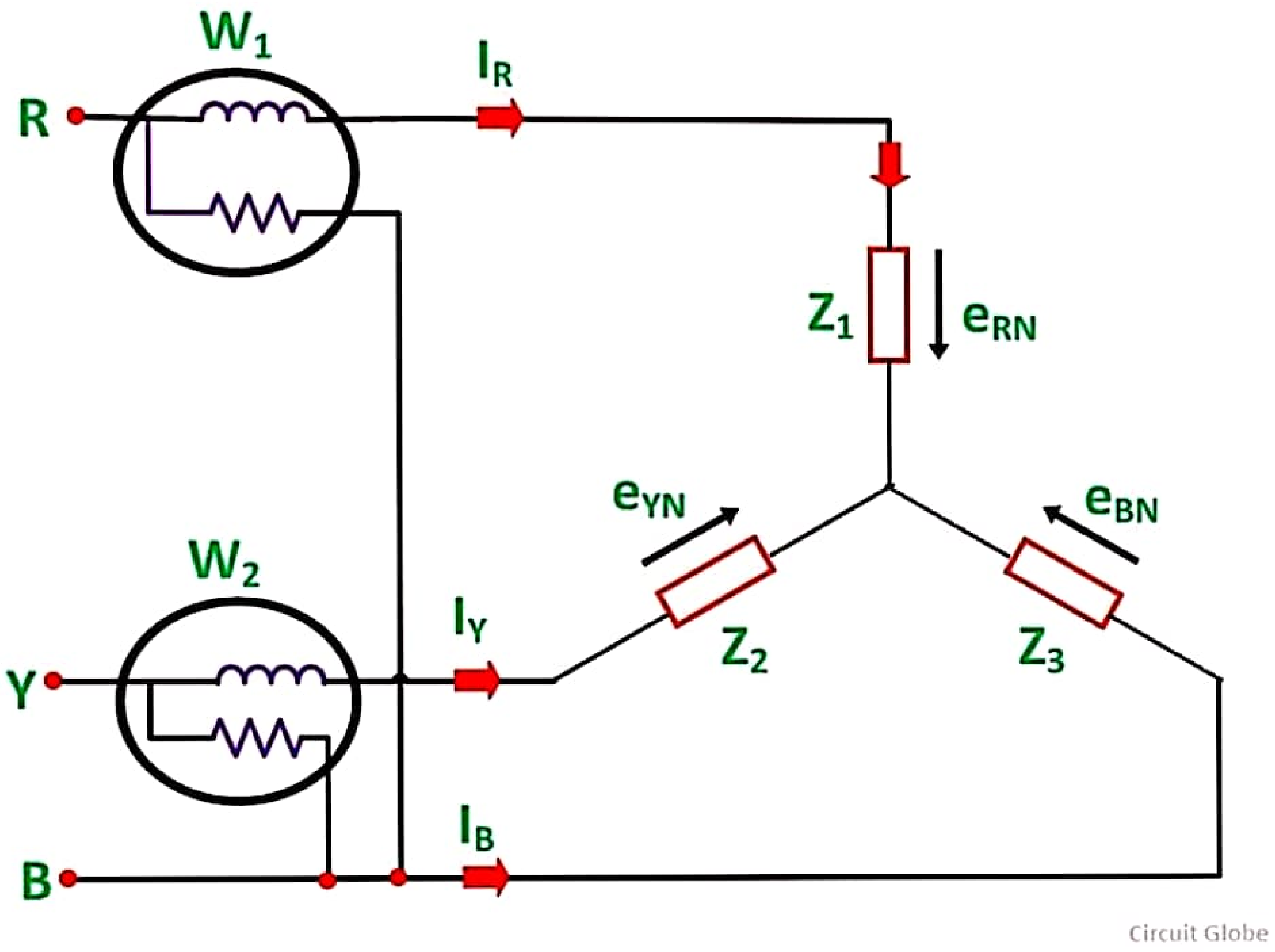
Conditions:

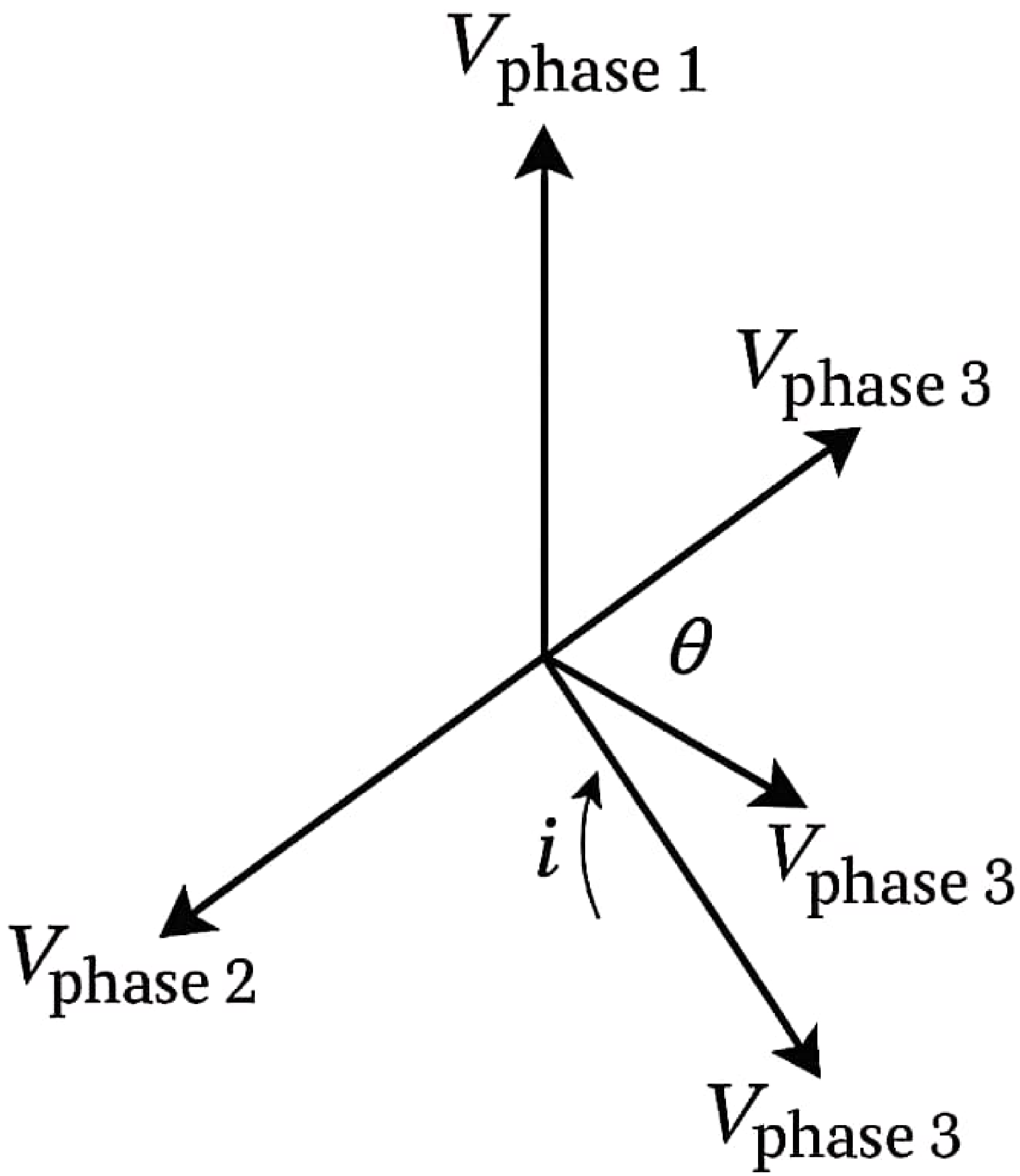
- If power factor is **unity**, both wattmeters show equal reading.
- If power factor is **lagging**, W_1 shows more than W_2.
- If one wattmeter reads negative, **power factor < 0.5** (one needs to reverse connection to get a positive reading).
- **Power factor angle** φ can be found by:

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

Advantages:

- Only two wattmeters needed
- Works for both balanced and unbalanced loads


W1
IR
R
Z1
eRN
eYN
eBN
W2
IY
Y
Z2
Z3
IB
B
Circuit Globe



$V_{\text{phase 1}}$
$V_{\text{phase 3}}$
θ
i
$V_{\text{phase 3}}$
$V_{\text{phase 2}}$
$V_{\text{phase 3}}$

10. Define Active, Reactive, and Apparent Power in AC Circuits. What Do You Understand by Balanced Loads?

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1. Active Power (P):

- Also called **Real Power or True Power**
- It is the power actually **consumed or used** by the load to do useful work like lighting, heating, etc.
- Measured in **Watts (W)**
- Formula:

$$P = VI\cos\phi$$

where $\cos\phi$ is the power factor.

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2. Reactive Power (Q):

- Power that **flows back and forth** between source and load.
- It **does not do any useful work**, but is needed for maintaining electric and magnetic fields in inductive or capacitive loads.
- Measured in **VAR (Volt-Ampere Reactive)**
- Formula:

$$Q = VI\sin\phi$$

---

3. Apparent Power (S):

- Total power supplied by the source to the circuit.
- It is the vector sum of Active and Reactive power.
- Measured in **VA (Volt-Ampere)**
- Formula:

$$S = VI$$

Or,

$$S = \sqrt{P^2 + Q^2}$$

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4. Balanced Loads:

- A load is said to be **balanced** when:
  - All three phases have **equal impedance**
  - The currents in all three lines are **equal in magnitude** and **120° apart**
- In a balanced load:
  - The system is **symmetrical**
  - **Neutral current = 0**
  - Power calculations become simpler