Subject Name & Code:

BASIC ELECTRICAL ENGINEERING- BE01R00051

Assignment – 2

Q-1: Define following terms (i) Cycle, (ii) Time period, (iii) Frequency, (iv) RMS Value, (v) Average value, (vi) Peak factor, (vii) Form factor, (viii) Line Voltage/Current, (ix) Active power. (x) Power factor.

Answer:

(i) Cycle
A *cycle* in an alternating quantity (e.g., voltage or current) refers to one complete set of positive and negative values, repeating identically over time.

(ii) Time Period (T)
The *time period* is the duration in seconds required to complete one full cycle of the waveform. It is denoted by T and measured in seconds (s).

(iii) Frequency (f)
Frequency is the number of cycles completed per second. It is the reciprocal of the time period:

$$f = \frac{1}{T}$$

The unit is Hertz (Hz).

(iv) RMS Value
The *Root Mean Square (RMS) value* of an alternating quantity is the equivalent steady (DC) value that produces the same heating effect in a resistive load. For a sinusoidal waveform:

$$V_{\text{rms}} = \frac{V_{\text{max}}}{\sqrt{2}}$$

(v) Average Value
The *average value* of an alternating quantity over one complete cycle is zero for a symmetrical waveform. For a half-cycle of a sine wave:

$$V_{\text{avg}} = \frac{2V_{\text{max}}}{\pi}$$

(vi) Peak Factor (Crest Factor)
Peak factor is the ratio of the peak (maximum) value to the RMS value:

$$\text{Peak Factor} = \frac{V_{\text{max}}}{V_{\text{rms}}}$$

For a sine wave, this equals $\sqrt{2} \approx 1.414$.

(vii) Form Factor
Form factor is the ratio of the RMS value to the average value (over a half-cycle):

$$\text{Form Factor} = \frac{V_{\text{rms}}}{V_{\text{avg}}}$$

For a sine wave, this equals $\frac{\pi}{2\sqrt{2}} \approx 1.11$.

(viii) Line Voltage/Current
In polyphase systems, *line voltage* is the voltage between any two line conductors, and *line current* is the current flowing in each line conductor.

(ix) Active Power (P)
Active power is the real power consumed in a circuit, measured in watts (W). It is given by:

$$P = V_{\text{rms}} I_{\text{rms}} \cos\ \phi$$

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

(x) Power Factor
Power factor is the ratio of active power to apparent power:

$$\text{PF} = \frac{P}{S} = \cos\ \phi$$

It indicates the phase relationship between voltage and current.

Q-2: Derive the current and voltage relation in a purely resistive AC circuit.

Answer:

In a purely resistive AC circuit, the voltage $v(t)$ and current $i(t)$ are in phase. Let the supply voltage be:

$$v(t) = V_m \sin\,(\omega t)$$

By Ohm's law,

$$i(t) = \frac{v(t)}{R} = \frac{V_m}{R}\sin(\omega t)$$

Let $I_m = \frac{V_m}{R}$. Then:

$$i(t) = I_m \sin(\omega t)$$

Both waveforms reach their maximum, minimum, and zero points at the same instant. The phasor representation shows **V** and **I** aligned along the same direction, with a phase difference of 0°.

Q-3: Explain AC circuit containing pure inductance with phasor diagram.

Answer:

In a purely inductive AC circuit, only inductance L is present (resistance and capacitance are negligible). The voltage across the inductor leads the current by 90°.

Relationship:

$$v_L = L\frac{di}{dt}$$

For sinusoidal current $i = I_m \sin(\omega t)$:

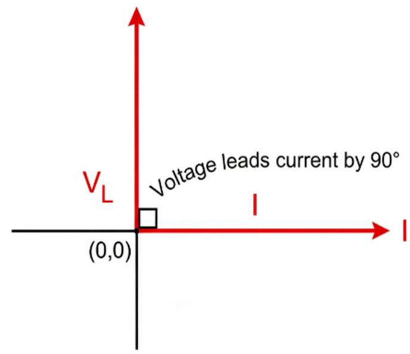
$$v_L = \omega L I_m \sin\left(\omega t + \frac{\pi}{2}\right)$$

Thus, $V_L = I \cdot X_L$, where $X_L = \omega L$ is the inductive reactance.

Phasor Diagram Description:

- Draw a horizontal reference axis representing the current phasor I.
- Draw the voltage phasor V_L perpendicular upward from the origin (leading by 90°).
- Label magnitudes $V_L = IX_L$ and show the 90° angle.

Diagram: (**Diagram is AI generated and only for reference)**



Q-4: Explain AC circuit containing pure capacitance with phasor diagram.

Answer:

In a pure capacitive circuit, current leads voltage by 90°.

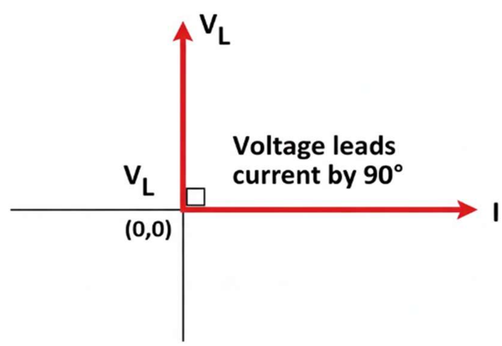
Capacitive reactance:

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

If $v(t) = V_m \sin(\omega t)$, then:

$$i(t) = C\frac{dv}{dt} = \omega C V_m \cos(\omega t) = I_m \sin\left(\omega t + \frac{\pi}{2}\right)$$

Phasor Diagram: (Diagram is AI generated and only for reference)



Q-5: Analyze series RL circuit with phasor diagram and equation.

Answer:

A series RL circuit consists of resistance R and inductance L connected in series across an AC supply V.

Impedance:

$$Z = R + jX_L = \sqrt{R^2 + X_L^2} \angle \tan^{-1}\left(\frac{X_L}{R}\right)$$

Current:

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

Phasor Diagram:

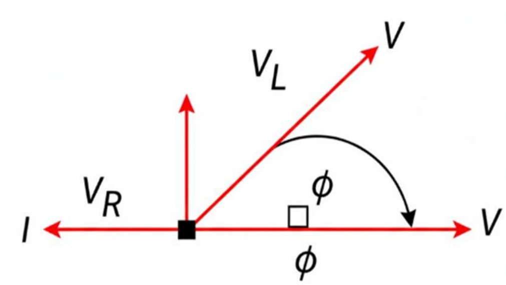
- Voltage across R, $V_R = IR$, is in phase with current I.
- Voltage across L, $V_L = IX_L$, leads I by 90°.
- Supply voltage V is the phasor sum of V_R and V_L, lagging I by angle ϕ.

Equation for Voltage:

$$V = \sqrt{V_R^2 + V_L^2}$$

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

Diagram: (Diagram is AI generated and only for reference)



Q-6: Analyze series RC circuit with phasor diagram.

Answer:

Impedance of series RC:

$$Z = R - jX_C \text{where} X_C = \frac{1}{\omega C}$$

Magnitude:

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

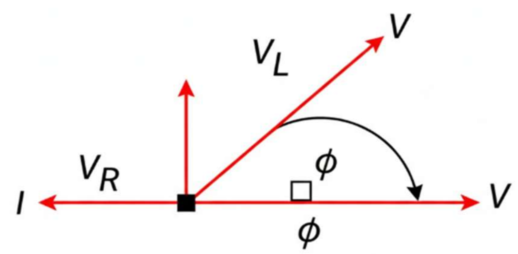
Phase angle:

$$\phi = -\tan^{-1}\left(\frac{X_C}{R}\right) \text{(current leads voltage)}$$

Current:

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

Phasor Diagram: (Diagram is AI generated and only for reference)



Q-7: Explain series RLC circuit and obtain expression for impedance.

Answer:

A series RLC circuit contains resistance R, inductance L, and capacitance C in series.

Voltages:

- $V_R = IR$ (in phase with I)
- $V_L = IX_L$ (leads I by 90°)
- $V_C = IX_C$ (lags I by 90°)

Net Reactance:

$$X = X_L - X_C = \omega L - \frac{1}{\omega C}$$

Impedance:

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

Magnitude:

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

Phase angle:

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

Phasor Sum: Supply voltage $V = \sqrt{V_R^2 + (V_L - V_C)^2}$.

Q-8: Explain parallel RLC circuit with phasor diagram.

Answer:

For parallel R, L, C across same AC voltage V:

- $I_R = \frac{V}{R}$ (in phase with V)
- $I_L = \frac{V}{X_L}$ (lags V by 90°)
- $I_C = \frac{V}{X_C}$ (leads V by 90°)

Net reactive current:

$$I_X = I_C - I_L$$

Resultant current:

$$I = \sqrt{I_R^2 + (I_C - I_L)^2}$$

Phase angle:

$$\phi = \tan^{-1}\left(\frac{I_C - I_L}{I_R}\right)$$

Q-9: What is resonance in AC circuits? Explain its significance.

Answer:

Resonance in an AC circuit occurs when the inductive reactance X_L equals the capacitive reactance X_C, causing the circuit to behave purely resistively.

Condition:

$$X_L = X_C \Rightarrow \omega L = \frac{1}{\omega C}$$
$$f_r = \frac{1}{2\pi\sqrt{LC}}$$

where f_r is the resonant frequency.

Significance:

- Impedance is minimum ($Z = R$), current is maximum.
- Voltage across L and C can be much higher than supply voltage (voltage magnification).
- Used in tuning circuits (radio receivers), filters, and induction heating.
- Power factor becomes unity.

Q-10: Explain series resonance and derive resonant frequency.

Answer:

In series RLC, impedance is:

$$Z = R + j\left(\omega L - \frac{1}{\omega C}\right)$$

Resonance occurs when imaginary part = 0:

$$\omega L = \frac{1}{\omega C}$$
$$\omega_r = \frac{1}{\sqrt{LC}}$$
$$f_r = \frac{1}{2\pi\sqrt{LC}}$$

At resonance:

- Impedance is minimum ($Z = R$).
- Current is maximum ($I = V/R$).
- Voltage across L and C can be higher than supply voltage (Q-factor effect).
- Power factor = 1.

Q-11: Explain parallel resonance and its characteristics.

Answer:

In parallel resonance (often in a parallel LC circuit with a resistor in series with L or C), the susceptances cancel, resulting in maximum impedance.

Condition:

$$B_L = B_C \Rightarrow \frac{1}{X_L} = \frac{1}{X_C}$$

Same resonant frequency as series: $f_r = \frac{1}{2\pi\sqrt{LC}}$.

Characteristics:

- Total impedance is maximum, line current is minimum.
- Circuit acts as a rejector circuit (high impedance at f_r).
- Current through L and C can be large (circulating currents).
- Power factor is unity at resonance.
- Used in radio frequency filters and oscillator circuits.

Q-12: Explain advantages of three-phase system over single-phase system.

Answer:

1. **Power Delivery:** Constant instantaneous power in balanced 3-phase, leading to smoother motor operation.
2. **Efficiency:** Higher power-to-weight ratio for generators, motors, and transformers.
3. **Economy:** Less conductor material for same power transmission compared to single-phase.
4. **Flexibility:** Can supply both single-phase and three-phase loads.
5. **Self-starting:** Three-phase induction motors are self-starting without extra starting devices.

Q-13: Derive voltage and current relation in star and delta connection.

Answer:

Star (Y) Connection:

- Line voltage $V_L = \sqrt{3} \times$ Phase voltage V_{ph}
- Line current $I_L =$ Phase current I_{ph}

Delta (Δ) Connection:

- Line voltage $V_L =$ Phase voltage V_{ph}
- Line current $I_L = \sqrt{3} \times$ Phase current I_{ph}

Derivation for Star:
Consider three phases with voltages V_{RN}, V_{YN}, V_{BN}. Voltage between lines R and Y:

$$V_{RY} = V_{RN} - V_{YN} = V_{ph}\angle 0^\circ - V_{ph}\angle - 120^\circ$$

Using phasor algebra:

$$| V_{RY} |= \sqrt{3}V_{ph}$$

Derivation for Delta:
Each phase carries current I_{ph}. At each node, line current is the difference of two phase currents:

$$I_R = I_{RY} - I_{BR}$$

Phasor subtraction yields $| I_R |= \sqrt{3}I_{ph}$.

Q-14: Explain power measurement in three-phase balanced circuits.

Answer:

For balanced three-phase systems:

- **Two-wattmeter method** is commonly used (for 3-wire systems).
- Total power:

$$P_T = W_1 + W_2$$

- Power factor:

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

- Each wattmeter reads:

$$W = V_L I_L \cos(\phi \mp 30^\circ)$$

Q-15: Explain two-wattmeter method of power measurement.

Answer:

Used to measure total power in a 3-phase, 3-wire system (balanced or unbalanced).

Connection:
Two wattmeters W_1 and W_2 are connected with their current coils in two lines (say R and Y) and voltage coils between those lines and the third line (B).

Readings:

$$W_1 = V_{RB} I_R \cos(\angle V_{RB} \& I_R)$$
$$W_2 = V_{YB} I_Y \cos(\angle V_{YB} \& I_Y)$$

Total Power:

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

Power Factor (balanced load):

$$\tan\phi = \sqrt{3}\frac{W_1 - W_2}{W_1 + W_2}$$
$$\text{PF} = \cos\phi$$

Q-16: Derive expression for total power in a three-phase balanced system.

Answer:

Let phase voltage = V_{ph}, phase current = I_{ph}, power factor angle = ϕ.

Power per phase:

$$P_{ph} = V_{ph} I_{ph} \cos\phi$$

For star: $V_L = \sqrt{3} V_{ph}, I_L = I_{ph}$
For delta: $V_L = V_{ph}, I_L = \sqrt{3} I_{ph}$

In both cases:

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

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