Subject Name & Code:

BASIC ELECTRICAL ENGINEERING- BE01R00051

PBL Assignment – 2

Q-1: 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-2: Explain AC circuit containing pure capacitance with phasor diagram.

Answer:

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

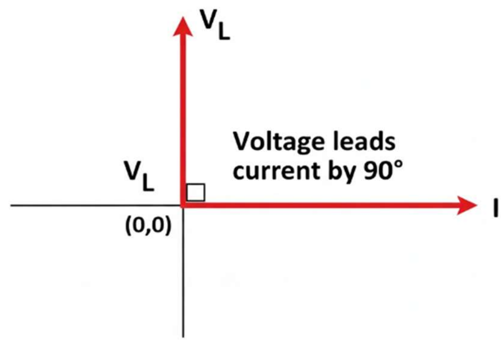
Capacitive reactance:

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

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

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

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



Q-3: 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:

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

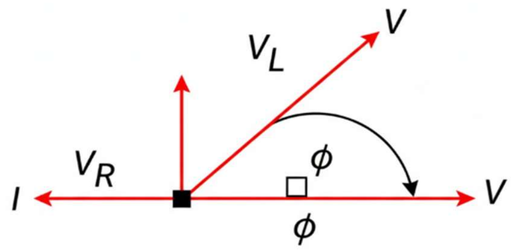
Phase angle:

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

Current:

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

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



Q-4: 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-5: 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-6: 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-7: 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:

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

Q-8: 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:

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

Q-9: A sinusoidal current has peak value of 15 A. Find: (a) RMS value (b) Average value (c) Form factor (d) Peak factor

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Answer:

Given: $I_m = 15$ A

(a) RMS value:

$$I_{rms} = \frac{I_m}{\sqrt{2}} = \frac{15}{\sqrt{2}} \approx 10.61\ \text{A}$$

(b) Average value (full cycle):

$$I_{avg} = \frac{2I_m}{\pi} = \frac{30}{\pi} \approx 9.55\ \text{A}$$

(c) Form factor:

$$FF = \frac{I_{rms}}{I_{avg}} = \frac{10.61}{9.55} \approx 1.111$$

(d) Peak factor:

$$PF = \frac{I_m}{I_{rms}} = \sqrt{2} \approx 1.414$$

Final Answer:

$$\boxed{I_{rms} = 10.61\text{ A}, I_{avg} = 9.55\text{ A}, FF = 1.111, PF = 1.414}$$

Q-10: A current of 10 A leads the voltage by 30°, Represent the voltage and current phasors.

Answer:

Given: $I = 10\text{ A}, \phi = 30°$ (I leads V).

Phasor Diagram Description:

- Draw horizontal reference axis.
- Draw voltage phasor **V** along reference.
- Draw current phasor **I** rotated 30° counterclockwise from **V**.
- Label lengths proportional to magnitudes, indicate angle.

Q-11: A load absorbs 4 kW at a power factor of 0.6 lagging. Find the apparent power and reactive power.

Answer:

Given: $P = 4\text{ kW}, \text{pf} = 0.6$ lagging

Apparent power:

$$S = \frac{P}{\text{pf}} = \frac{4}{0.6} \approx 6.667\text{ kVA}$$

Reactive power:

$$Q = \sqrt{S^2 - P^2} = \sqrt{(6.667)^2 - (4)^2} \approx 5.333\text{ kVAR}$$

Final Answer:

$$\boxed{S \approx 6.67\,\text{kVA}, Q \approx 5.33\,\text{kVAR (lagging)}}$$

Q-12: A pure inductance of 0.2 H and a capacitor of 50 µF is connected to 230 V, 50 Hz supply. Calculate reactance of the circuit and current.

Answer:

Given: $L = 0.2\,\text{H}, C = 50\,\mu\text{F}, V = 230\,\text{V}, f = 50\,\text{Hz}$

Inductive reactance:

$$X_L = 2\pi f L = 2\pi(50)(0.2) = 62.83\,\Omega$$

Capacitive reactance:

$$X_C = \frac{1}{2\pi f C} = \frac{1}{2\pi(50)(50 \times 10^{-6})} \approx 63.66\,\Omega$$

Since L and C are in series:

$$X = X_L - X_C = 62.83 - 63.66 = -0.83\,\Omega$$

(Net capacitive reactance)

Impedance magnitude:

$$|Z| = \sqrt{0^2 + (0.83)^2} \approx 0.83\,\Omega$$

Current:

$$I = \frac{V}{|Z|} = \frac{230}{0.83} \approx 277.11\,\text{A}$$

Final Answer:

$$\boxed{X \approx 0.83\,\Omega\ \text{(capacitive)}, I \approx 277.1\,\text{A}}$$

Q-13: In a series RC circuit, R = 20 Ω and C = 100 µF. Find impedance, current and phase angle.

Answer:

Given: $R = 20\ \Omega, C = 100 \times 10^{-6}$ F
Assume frequency $f = 50$ Hz (typical for such problems unless specified).

Capacitive reactance:

$$X_C = \frac{1}{2\pi(50)(100 \times 10^{-6})} \approx 31.83\ \Omega$$

Impedance:

$$Z = R - jX_C = 20 - j31.83$$

Magnitude:

$$|Z| = \sqrt{20^2 + 31.83^2} \approx 37.59\ \Omega$$

Phase angle:

$$\phi = -\tan^{-1}\left(\frac{31.83}{20}\right) \approx -57.87^\circ$$

Assuming voltage V given, if not, current in terms of V is:

$$I = \frac{V}{|Z|}, \text{leads voltage by } 57.87^\circ.$$

Final Answer:

$$\boxed{|Z| \approx 37.59\ \Omega, \phi \approx -57.87^\circ}$$

Q-14: A resistor of 40 Ω and an inductor of 0.2 H and capacitor of 120 µF are connected in parallel across 230 V, 50 Hz supply. Find (1) the current of each branch (2) the resultant current (3) Power factor of the circuit

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Answer:

Given: $R = 40\ \Omega, L = 0.2\ \text{H}, C = 120\ \mu\text{F}, V = 230\ \text{V}, f = 50\ \text{Hz}$

Branch currents:

$$I_R = \frac{V}{R} = \frac{230}{40} = 5.75\ \text{A (in phase)}$$

$$X_L = 2\pi(50)(0.2) = 62.83\ \Omega, I_L = \frac{230}{62.83} \approx 3.66\ \text{A (lags } 90^\circ)$$

$$X_C = \frac{1}{2\pi(50)(120 \times 10^{-6})} \approx 26.53\ \Omega, I_C = \frac{230}{26.53} \approx 8.67\ \text{A (leads } 90^\circ)$$

Net reactive current:

$$I_X = I_C - I_L = 8.67 - 3.66 = 5.01\ \text{A (leading)}$$

Resultant current:

$$I = \sqrt{I_R^2 + I_X^2} = \sqrt{(5.75)^2 + (5.01)^2} \approx 7.63\ \text{A}$$

Power factor:

$$pf = \frac{I_R}{I} = \frac{5.75}{7.63} \approx 0.754\ \text{leading}$$

Final Answer:

$$\boxed{I_R = 5.75\ \text{A},\ I_L = 3.66\ \text{A},\ I_C = 8.67\ \text{A},\ I = 7.63\ \text{A},\ \text{pf} \approx 0.754\ \text{leading}}$$

Q-15: A circuit consumes a power of 1000 W at 0.6 leading power factor, when connected to 200 V, 50 Hz ac supply. Calculate (a) Current (b) Apparent power (c) Reactive power.

Answer:

Given: $P = 1000$ W,pf $= 0.6$ leading, $V = 200$ V

(a) Current:

$$P = VI\cos\ \phi \Rightarrow I = \frac{P}{V\cos\ \phi} = \frac{1000}{200 \times 0.6} \approx 8.333\ \text{A}$$

(b) Apparent power:

$$S = VI = 200 \times 8.333 \approx 1666.67\ \text{VA}$$

(c) Reactive power:

$$Q = \sqrt{S^2 - P^2} = \sqrt{1666.67^2 - 1000^2} \approx 1333.33\ \text{VAR (leading)}$$

Final Answer:

$$\boxed{I = 8.33\text{ A}, S = 1666.67\text{ VA}, Q \approx 1333.33\text{ VAR (leading)}}$$

Q-16: Two impedances are connected in parallel across a 100 volt, 50 Hz a.c. supply. Impedance no. 1 has resistance of 8 Ω and capacitive reactance of 7 Ω. While impedance no. 2 has resistance of 5 Ω and inductive reactance of 6 Ω. Calculate: (i) Current through each circuit & p.f. of each circuit. (ii) Total current and p.f. of combined circuit. (iii) Power taken by the whole circuit.

Answer:

Given:

$$Z_1 = 8 - j7\,\Omega, Z_2 = 5 + j6\,\Omega, V = 100\text{ V}$$

(i) Current through each circuit & pf:

$$I_1 = \frac{V}{|Z_1|} = \frac{100}{\sqrt{8^2 + 7^2}} = \frac{100}{\sqrt{113}} \approx 9.41\text{ A}$$

pf $_1 = \cos\,\phi_1 = \frac{8}{\sqrt{113}} \approx 0.754$ leading (since capacitive).

$$I_2 = \frac{V}{|Z_2|} = \frac{100}{\sqrt{5^2 + 6^2}} = \frac{100}{\sqrt{61}} \approx 12.81\text{ A}$$

pf $_2 = \frac{5}{\sqrt{61}} \approx 0.64$ lagging (inductive).

(ii) Total current & pf:

Admittances:

$$Y_1 = \frac{1}{Z_1} = \frac{1}{8 - j7} = \frac{8 + j7}{113} \approx 0.0708 + j0.0619\text{ S}$$
$$Y_2 = \frac{1}{Z_2} = \frac{1}{5 + j6} = \frac{5 - j6}{61} \approx 0.0820 - j0.0984\text{ S}$$
$$Y_T = Y_1 + Y_2 \approx 0.1528 - j0.0365\text{ S}$$
$$|Y_T| \approx 0.1565\text{ S}$$
$$I_T = V \times |Y_T| = 100 \times 0.1565 \approx 15.65\text{ A}$$
$$\phi_T = \tan^{-1}\left(\frac{-0.0365}{0.1528}\right) \approx -13.43^\circ$$

pf $_T = \cos\,\phi_T \approx 0.973$ leading.

(iii) Power taken:

$$P = VI_T \cos\ \phi_T = 100 \times 15.65 \times 0.973 \approx 1522.5\ \text{W}$$

Final Answer:

$$\boxed{I_1 \approx 9.41\ \text{A (0.754 leading)},\ I_2 \approx 12.81\ \text{A (0.64 lagging)},\ I_T \approx 15.65\ \text{A},\ \text{pf}_T \approx 0.973\ \text{leading},\ P \approx 1522.5}$$

Q-17: A resistance of 1 Ω and inductance of 0.02 H are connected in series with a capacitor across 200 V supply. Find the value of capacitance, so that current drawn by circuit will be maximum at frequency 50 Hz. Find current and voltage across capacitor.

Answer:

Given: $R = 1\,\Omega, L = 0.02\,\text{H}, V = 200\,\text{V}, f = 50\,\text{Hz}$

For max current at resonance:

$$\omega_r L = \frac{1}{\omega_r C} \Rightarrow C = \frac{1}{\omega_r^2 L} = \frac{1}{(2\pi \times 50)^2 \times 0.02}$$
$$C = \frac{1}{(314.16)^2 \times 0.02} \approx \frac{1}{1973.9} \approx 5.066 \times 10^{-4}\ \text{F} = 506.6\ \mu\text{F}$$

At resonance, $Z = R = 1\,\Omega$

$$I_{\max} = \frac{V}{R} = \frac{200}{1} = 200\ \text{A}$$

Voltage across capacitor:

$$V_C = I \times X_C = 200 \times \frac{1}{2\pi(50)(506.6 \times 10^{-6})}$$
$$X_C = \frac{1}{314.16 \times 5.066 \times 10^{-4}} \approx 6.28\,\Omega$$
$$V_C \approx 200 \times 6.28 = 1256\ \text{V}$$

Final Answer:

$$\boxed{C \approx 506.6\ \mu\text{F}, I_{\max} = 200\ \text{A}, V_C \approx 1256\ \text{V}}$$

Q-18: For 3-φ star connected load consists of non-inductive resistance of 50 Ω in parallel with a capacitance of 15 μF. Calculate the line current, power absorbed, total kVA and power factor when connected to 415 V, 3 phase, 50 Hz supply.

Answer:

Given: Per phase: $R = 50\ \Omega, C = 15\ \mu\text{F}, V_L = 415$ V

Phase voltage:

$$V_{ph} = \frac{V_L}{\sqrt{3}} = \frac{415}{\sqrt{3}} \approx 239.6 \text{ V}$$

Admittance per phase:

$$Y = \frac{1}{R} + j\omega C = \frac{1}{50} + j(2\pi \times 50 \times 15 \times 10^{-6})$$
$$Y = 0.02 + j0.004712 \approx 0.02055\angle 13.24^\circ \text{ S}$$

Phase current:

$$I_{ph} = V_{ph} \times |\ Y\ | = 239.6 \times 0.02055 \approx 4.925 \text{ A}$$

Line current = phase current for star:

$$I_L \approx 4.925 \text{ A}$$

Power absorbed per phase:

$$P_{ph} = V_{ph}^2 \times G = (239.6)^2 \times 0.02 \approx 1148.3 \text{ W}$$

Total power:

$$P_T = 3 \times P_{ph} \approx 3444.9 \text{ W}$$

Total kVA:

$$S_T = 3 \times V_{ph} I_{ph} = 3 \times 239.6 \times 4.925 \approx 3539.6 \text{ VA} = 3.54 \text{ kVA}$$

Power factor:

$$pf = \cos(13.24^\circ) \approx 0.973 \text{ leading}$$

Final Answer:

$$\boxed{I_L \approx 4.925 \text{ A}, P_T \approx 3.445 \text{ kW}, S_T \approx 3.54 \text{ kVA}, \text{pf} \approx 0.973 \text{ leading}}$$

Q-19: In balanced 3-φ, 415 V system, line current is 100 A. When power is measured by two wattmeters, one wattmeter indicates power and other indicates zero. What will be power factor of load & measured power? If the power factor were unity and same load current what would be the reading of each wattmeter?

Answer:

Given: $V_L = 415\text{ V}, I_L = 100\text{ A}, W_1 = \text{some } P, W_2 = 0$

When one wattmeter reads zero:

$$W_2 = 0 \Rightarrow \cos(\phi - 30^\circ) = 0 \Rightarrow \phi - 30^\circ = 90^\circ \Rightarrow \phi = 120^\circ$$

But pf angle ≤ 90° for loads. Actually, for $W_2 = 0$,

$$\phi = 60^\circ (\text{since } W = V_L I_L \cos(\phi \pm 30^\circ))$$

Check:

$$W_2 = V_L I_L \cos(\phi + 30^\circ) = 0 \Rightarrow \phi + 30^\circ = 90^\circ \Rightarrow \phi = 60^\circ$$

Power factor:

$$pf = \cos\ 60^\circ = 0.5 \text{ lagging}$$

Measured power:

$$P_T = W_1 + W_2 = W_1 + 0 = V_L I_L \cos(\phi - 30^\circ) \times 2?$$

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

$$P_T = \sqrt{3} \times 415 \times 100 \times 0.5 \approx 35938.5\text{ W} = 35.94\text{ kW}$$

If pf were unity ($\phi = 0$):
Each wattmeter reading:

$$W = V_L I_L \cos(30^\circ) = 415 \times 100 \times \frac{\sqrt{3}}{2} \approx 35938.5/2?$$

Actually:

$$W_1 = V_L I_L \cos(30^\circ) \approx 35938.5\text{ W}/\sqrt{3}?$$

Let's compute:

$$W = 415 \times 100 \times \cos(30°) \approx 415 \times 100 \times 0.866 \approx 35939 \text{ W}? That\text{'}stoohigh.$$

Wait: For unity pf, total power $P_T = \sqrt{3} \times 415 \times 100 \times 1 \approx 71877$ W.
Each wattmeter reads:

$$W = V_L I_L \cos(30°) = 415 \times 100 \times 0.866 \approx 35938.5 \text{ W}$$

Thus $W_1 = W_2 \approx 35.94$ kW.

Final Answer:

$$\boxed{\text{pf} = 0.5 \text{ lagging}, P_T \approx 35.94 \text{ kW}, \text{At unity pf: each wattmeter reads } \approx 35.94 \text{ kW}}$$

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