ELEMENTS OF ELECTRICAL ENGINEERING (UE24EE141B)

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Unit 2 – Lecture 25 - Analysis of Series RL and Series RC Circuits

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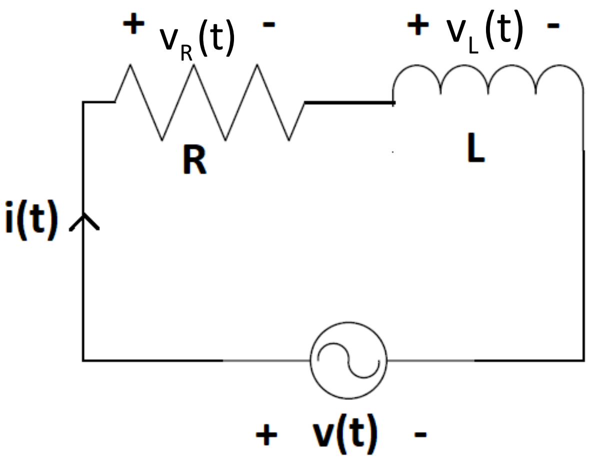
Series RL Circuit



By KVL, $v(t) = v_R(t) + v_L(t)$

In Phasor form, $\overline{V} = \overline{V_R} + \overline{V_L}$

In general for any element,

(Voltage Phasor) = (Current Phasor)*(Impedance)

$$\overline{V_R} = \bar{I} * R$$

$$\overline{V_L} = \bar{I} * (jX_L)$$

$$\overline{V} = \bar{I} * (R + jX_L)$$

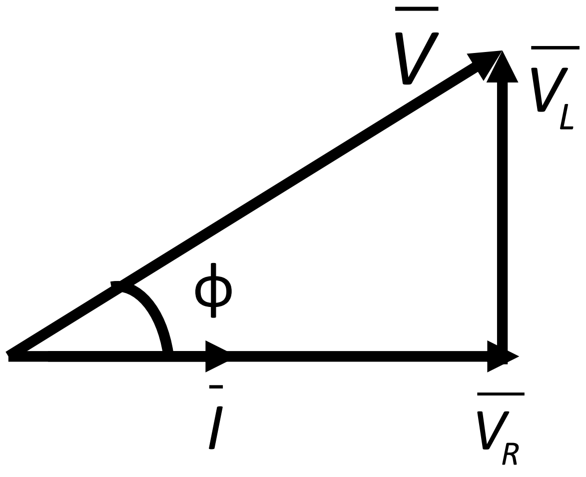
Series RL Circuit

$$Z_T = \frac{\bar{V}}{\bar{I}} = (R+jX_L) = \sqrt{R^2+X_L^2}\angle Tan^{-1}(\frac{X_L}{R})$$

It can be observed that the total impedance of a series AC network is equal to the sum of individual element impedances.

Phasor Diagram:

Note: While drawing phasor diagram for a series AC network, considering current phasor as reference is preferable.

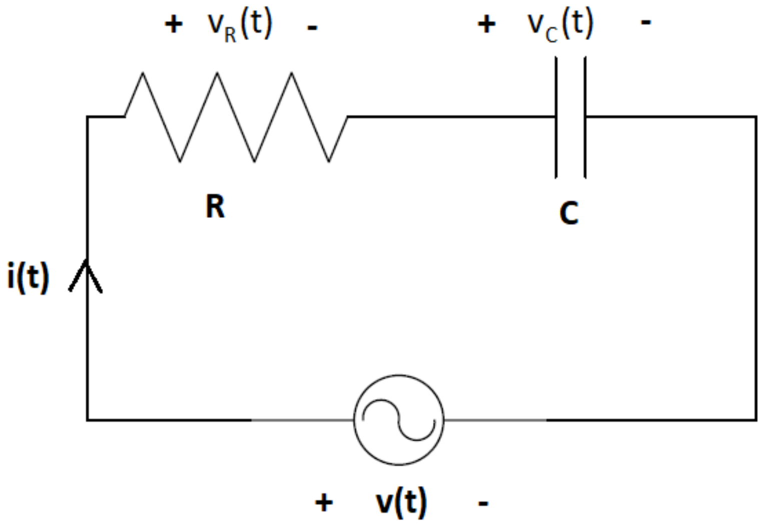


$$\phi = Tan^{-1}(\frac{|\bar{V}_L|}{|\bar{V}_R|}) = Tan^{-1}(\frac{V_L}{V_R})$$

$$= Tan^{-1}(\frac{X_L}{R})$$

+ve phase angle means voltage leads current.

Series RC Circuit



By KVL, $v(t) = v_R(t) + v_C(t)$

In Phasor form, $\overline{V} = \overline{V_R} + \overline{V_C}$

$$\overline{V_R} = \bar{I} * R$$

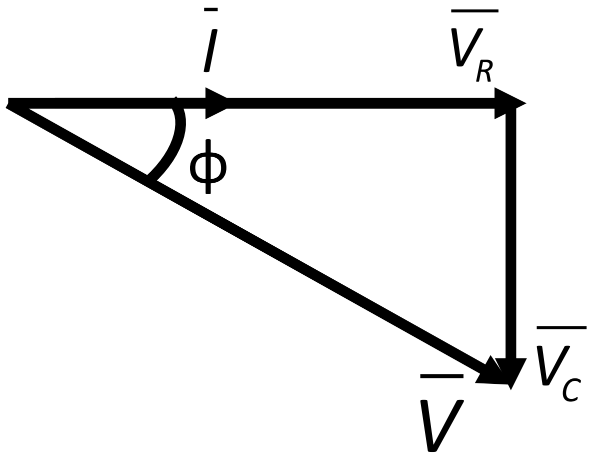
$$\overline{V_C} = \bar{I} * (-jX_C)$$

$$\overline{V} = \bar{I} * (R\text{-}jX_C)$$

Series RC Circuit

$$Z_T = \frac{\bar{V}}{\bar{I}} = (R - jX_C) = \sqrt{R^2 + X_C^2}\angle -\mathrm{Tan}^{-1}\left(\frac{X_C}{R}\right)$$

Phasor Diagram:



Phase angle of a network is found as

$$\phi = \angle\bar{V} - \angle\bar{I}$$

$$\phi = -\mathrm{Tan}^{-1}\left(\frac{|\bar{V}_C|}{|\bar{V}_R|}\right) = -\mathrm{Tan}^{-1}\left(\frac{V_C}{V_R}\right) = -\mathrm{Tan}^{-1}\left(\frac{X_C}{R}\right)$$

Negative phase angle means voltage lags current.

In series AC networks, phase angle = Impedance angle.

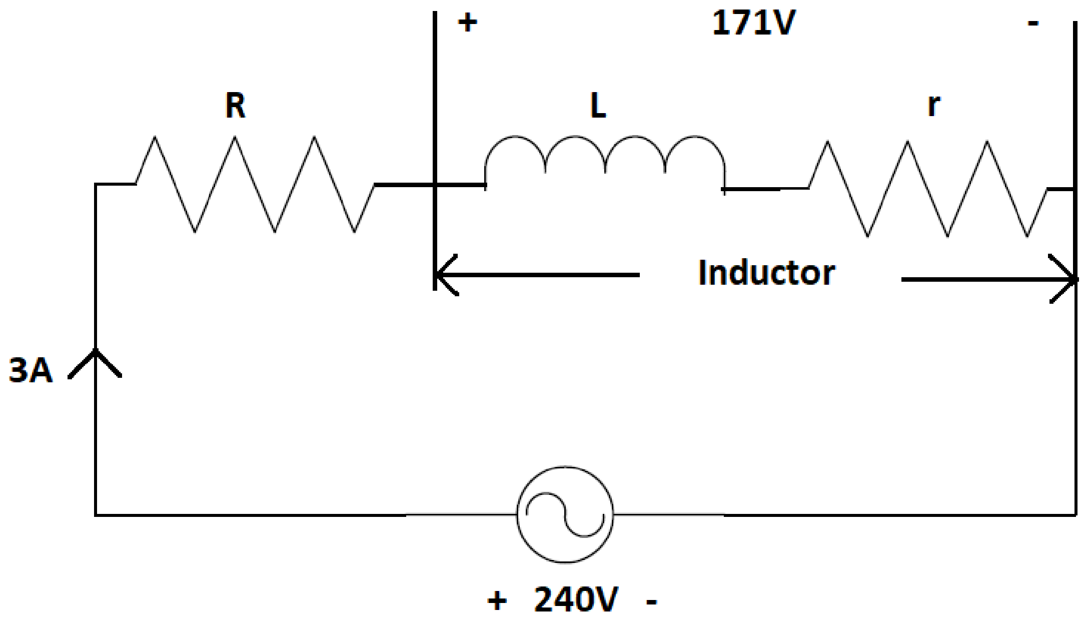
Numerical Example

Question:

When a resistor and an inductor in series are connected to a 240V supply, a current of 3A flows lagging 37^0 behind the supply voltage, while the voltage across the inductor is 171V. Find the resistance of the resistor, and the resistance and reactance of the inductor. Find the power factor of the circuit.

Numerical Example

Solution:



Note: In AC systems, if voltage and current are given as numerical values, they represent RMS values.

Let us consider current as reference.

i.e., $\bar{I} = 3\angle 0° \text{A}$

Therefore, supply voltage phasor, $\bar{V} = 240\angle 37° \text{ V}$

Numerical Example

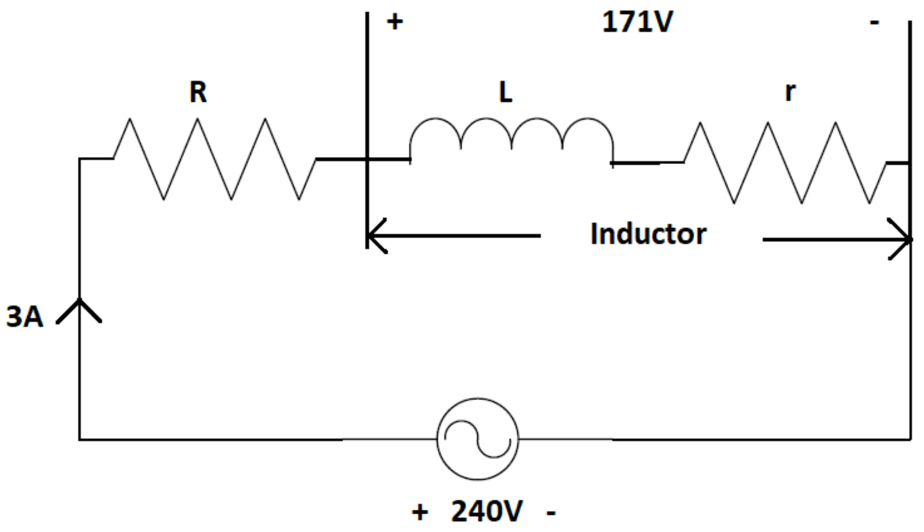
Solution (Continued…):

$$Z_T = \frac{\bar{V}}{\bar{I}} = \frac{240\angle 37^\circ}{3\angle 0^\circ}$$

$= 80\angle 37^\circ\ \Omega$

$= (63.89 + j48.14)\ \Omega$ ---- (1)

$= R + (r + jX_L)$ ---(2)



Comparing Real and Imaginary parts in (1) & (2), $X_L = 48.14\Omega$

Also, $(R+r) = 63.89\Omega$ --- (3)

Across Inductor, $\left|\bar{V}_{inductor}\right| / \left|\bar{I}\right| = \frac{171}{3} = \sqrt{r^2 + X_L^2}$ ---(4)

Solving (3) & (4), $r = 30.52\Omega$; $R = 33.37\Omega$

Power factor $= (R+r) / \left|Z_T\right| = 0.798$ Lag

Numerical Example

Question:

2. A series RC circuit, with $R=4\Omega, C=120\mu F$ is connected across 230V, 50 Hz supply. Calculate the current drawn by the circuit. Draw the phasor Diagram.

Numerical Example

Q2. 3 coils A,B and C are connected in series. When a current of 3A is passed through the circuit, the voltage drops are respectively 12V, 6V and 9V on direct current and 15V, 9V and 12Von alternating current. Find for each of the coils i) internal parameters, ii) power dissipated when alternating current flows through the circuit, (iii)the applied voltage across it. Draw the phasor diagram. Find the overall power factor of the circuit.

Numerical Example

Q4. Power dissipated in a series RC circuit is 25 W, while the current and voltage being 0.4A and 230 V respectively. Find the value of capacitance.(Assume supply frequency of 50 Hz)

Numerical Example

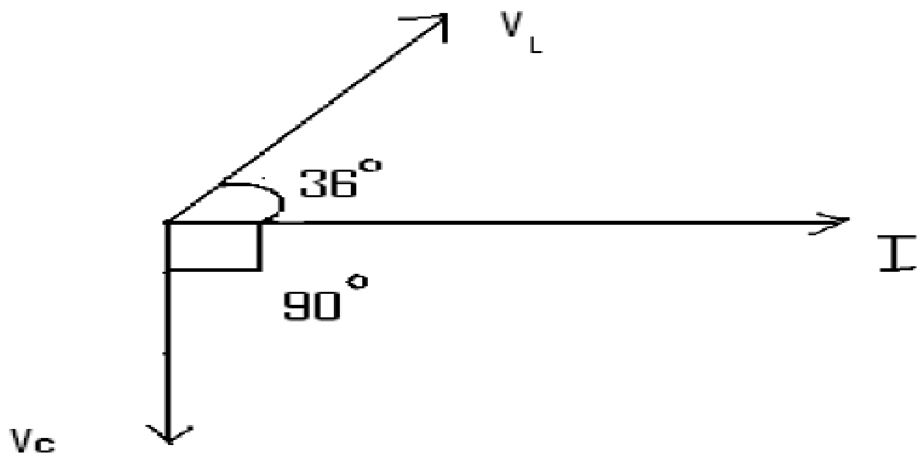
Q6. The following phasor diagram find the following.

(i) Power Factor of the circuit

(ii) Reactive power in the circuit

(iii) Magnitude of supply voltage

Also, Redraw the phasor diagram by taking supply voltage as reference, mentioning all the voltages and current. Current phasor is 10 A , V_C is 6V and V_L is 10 V.



Text Book & References

Text Book:

"Electrical and Electronic Technology" E. Hughes (Revised by J. Hiley, K. Brown & I.M Smith), 11th Edition, Pearson Education, 2012.

Reference Books:

1. "Basic Electrical Engineering - Revised Edition", D. C. Kulshreshta, Tata- McGraw-Hill, 2012.
2. "Basic Electrical Engineering", K Uma Rao, Pearson Education, 2011.
3. "Engineering Circuit Analysis", William Hayt Jr., Jack E. Kemmerly & Steven M. Durbin, 8th Edition, McGraw-Hill, 2012.

THANK YOU

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