NCERT 12.7. Q20

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QUESTION A series LCR circuit with L = 0.12 H, C = 480 nF, R=23Ω is connected to a 230 V variable frequency supply.

(a) What is the source frequency for which current amplitude is maximum. Obtain this maximum value.

(b) What is the source frequency for which average power absorbed by the circuit is maximum. Obtain the value of this maximum power.

(c) For which frequencies of the source is the power transferred to the circuit half the power at resonant frequency? What is the current amplitude at these frequencies?

(d) What is the Q-factor of the given circuit?

Given Data:

Inductance $L = 0.12\,\text{H}$
Capacitance $C = 480\,\text{nF}$
Resistance $R = 23\,\Omega$
Supply voltage $V = 230\,\text{V}$

(a)

$$V_o = \sqrt{2}V = 325.2\,\text{volts}$$

At resonance, $\omega_{RL} = \frac{1}{\omega RC}$
We know that,

$$\Rightarrow \omega_R = \frac{1}{\sqrt{LC}} = 4166.67\,\text{rad/s}$$

Resonant frequency,

$$\nu_R = \frac{\omega_R}{2\pi} = 663.48\,\text{Hz}$$

$I_o = \frac{V_o}{R} = 14.14\,\text{A}$

(b) Maximum power absorbed

$$P = \frac{1}{2}I_o^2 R = \frac{1}{2}(14.14)^2 \times 23 \Rightarrow 2299.3\,\text{W}$$

(c) The angular frequencies at which the power would be half of the power at resonant frequency will be:

$$\omega' = \omega_R \pm \Delta\omega$$

Here, $\Delta\omega = R^2 L$

$$\Rightarrow \Delta\omega = 23^2 \times 0.12 \Rightarrow 95.83\,\text{rad/s}$$

So,

$$\omega_1' = 4166.67 + 95.83 = 4262.3\,\text{rad/s}$$

$$\omega_2' = 4166.67 - 95.83 = 4070.87\,\text{rad/s}$$

The amplitude of current at these frequencies will be the RMS value.

$$I = I_0\sqrt{2} \Rightarrow \frac{14.14}{1.414} \Rightarrow 10\,\text{A}$$

(d) Q factor is given by

$$Q = \frac{1}{R}\sqrt{LC} = \frac{1}{23}\sqrt{0.12480 \times 10^{-9}} = 21.74$$