Alternating Current

CHAPTER 7

NCERT FOCUS **ANSWERS**

Topic 1

1. (a) : The peak value of a.c. supply is given 300 V.

$E_0 = 300$ V

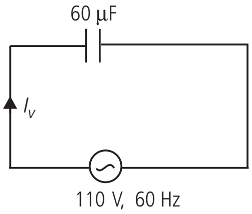
So, rms value of voltage

$$E_v = \frac{E_0}{\sqrt{2}} = \frac{300}{\sqrt{2}} = 150\sqrt{2}\text{ V} = 212.1\text{ V}$$

(b) Here $I_v = 10$ A

Thus, peak current $I_0 = I_v\sqrt{2} = 10\sqrt{2}$ A $= 14.1$ A

2.

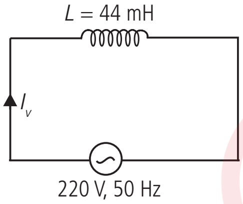


Capacitive reactance $X_C = \frac{1}{2\pi fC}$

$$X_C = \frac{1}{2\times\pi\times 60\times 60\times 10^{-6}} = 44.2\,\Omega$$

The rms current is, $I_v = \frac{E_v}{X_C} = \frac{110}{44.2} = 2.5$ A

3.



The rms current is

$$I_v = \frac{E_v}{X_L} = \frac{220}{2\pi\times 50\times 44\times 10^{-3}} = 15.9\text{ A}$$

Topic 2

1. (a) Condition for resonance is when applied frequency matches with natural frequency.

Resonant frequency $\omega_r = \frac{1}{\sqrt{LC}}$

$$= \frac{1}{\sqrt{5(80\times 10^{-6})}} = 50\text{ rad s}^{-1}$$

(b) At resonance, impedance $Z = R$

as $X_L = X_C$

So, $Z = 40\ \Omega$

rms current, $I_v = \frac{E_v}{R} = \frac{230}{40} = 5.75$ A

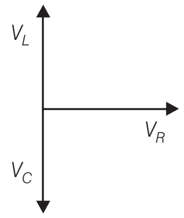
Amplitude of current, $I_0 = I_v\sqrt{2} = 8.13$ A

(c) Potential drop across 'L'

$V_L = I_vX_L = 5.75 \times (\omega L)$

$V_L = 5.75 \times 50 \times 5 = 1437.5$ V

Potential drop across 'C'



$$V_C = I_v \times X_C = 5.75 \times \frac{1}{\omega C}$$

$$= 5.75 \times \frac{1}{50\times 80\times 10^{-6}}$$

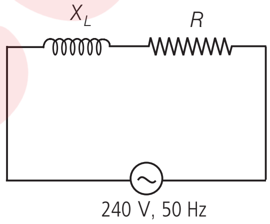
$= 1437.5$ V

Potential drop across R

$V_R = I_vR = 5.75 \times 40 = 230$ V

As $V_L - V_C = 0$, So $E_v = V_R = 230$ V.

2.



Inductive reactance

$X_L = 2\pi fL = 2\pi \times 50 \times 0.5 = 157\ \Omega$

Impedance $Z = \sqrt{R^2 + X_L^2} = \sqrt{(100)^2 + (157)^2}$

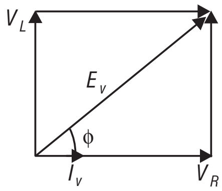
$= 186.14\ \Omega$

(a) Virtual current in the coil

$$I_v = \frac{E_v}{Z} = \frac{240}{186.14} = 1.29\text{ A}$$

Maximum current, $I_0 = I_v\sqrt{2} = 1.82$ A

(b)

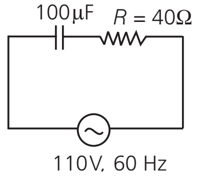


Phase lag, $\tan\phi = \frac{X_L}{R} = 1.57$

$\phi = \tan^{-1}(1.57) = 57.5°$ or $\phi = 0.32\,\pi$ radian

Time lag, $t = \phi/\omega = 3.2$ ms

3.



Capacitive reactance, $X_C = \dfrac{1}{2\pi f C}$

$$X_C = \frac{1}{2\times\pi\times 60\times 100\times 10^{-6}} = 26.54\ \Omega$$

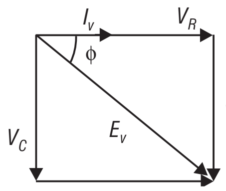
Impedance, $Z = \sqrt{R^2 + X_C^2} = \sqrt{(40)^2 + (26.54)^2} = 48\ \Omega$

(a) Virtual current in the circuit

$$I_v = \frac{E_v}{Z} = \frac{110}{48} = 2.29\ \text{A}$$

Maximum current $I_0 = I_v\sqrt{2} = 3.24$ A

(b)



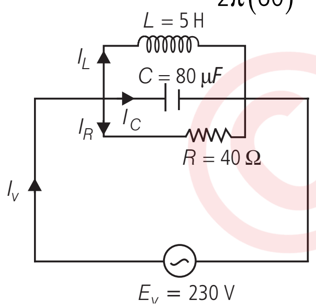
$$\tan\phi = \frac{V_C}{V_R} = \frac{1}{\omega CR}$$

Phase lag $\phi = \tan^{-1}\left(\dfrac{1}{\omega CR}\right) = \tan^{-1}\left(\dfrac{26.54}{40}\right)$

$\phi = 33.56° = 0.186\pi$ radian

Time lag $t = \phi/\omega = \dfrac{0.18\pi}{2\pi(60)} = 1.5$ ms

4.



Resonating angular frequency

$$\omega = \frac{1}{\sqrt{LC}} = \frac{1}{\sqrt{5\times 80\times 10^{-6}}} = 50\ \text{rad s}^{-1}$$

∴ Resonance of L and C in parallel can be calculated

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

Impedance of R and X in parallel is given by

$$\frac{1}{Z} = \sqrt{\frac{1}{R^2} + \frac{1}{X^2}}$$

At resonating frequency of series LCR, $X_L = X_C$

So, $\dfrac{1}{X} = \dfrac{1}{X_L} - \dfrac{1}{X_C} = 0$

Thus, impedances $Z = R$ and will be maximum. Hence, in parallel resonant circuit, current is minimum at resonant frequency.

Current through circuit elements

$$I_R = \frac{E_v}{R} = \frac{230}{40} = 5.75\ \text{A},\quad I_C = \frac{E_v}{X_L} = \frac{230}{\omega L} = \frac{230}{50\times 5} = 0.92\ \text{A}$$

$$I_C = \frac{E_v}{X_L} = \frac{230}{(1/\omega C)}$$

$= 230 \times 50 \times 80 \times 10^{-6} = 0.92$ A

Since, I_L and I_C are opposite in phase, so net current,

$I_v = I_R + I_L + I_C$

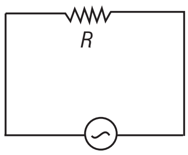
$I_v = 5.75 + 0.92\sqrt{2}\sin(\omega t - \pi/2) + 0.92\sqrt{2}$
$\sin(\omega t + \pi/2)$

$I_v = 5.75 - 0.92\sqrt{2}\cos\omega t + 0.92\sqrt{2}\cos\omega t$

$I_v = 5.75$ A

Topic 3

1. (a) Here virtual a.c. voltage is 220 V at a frequency of 50 Hz. So, rms value of current



$$I_V = \frac{E_V}{R} = \frac{220}{100} = 2.2\ \text{A}$$

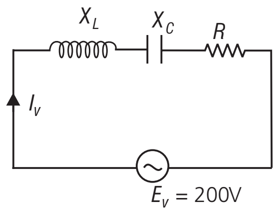
(b) Power in complete cycle

$P = E_v I_v \cos\phi = E_v I_v \cos 0°$

$P = 2.2 \times 220 = 484$ W

2. Power in the complete cycle $P = E_v I_v \cos(-\pi/2) = 0$.

3.



Average power transferred to the circuit in one complete cycle at resonance

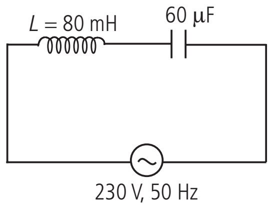
$P = E_v I_v \cos\phi$

$$P = E_v \frac{E_v}{Z}\cos\phi$$

At resonance $Z = R$, $\cos\phi = \cos 0° = 1$

$$P = 200 \times \frac{200}{20} = 2000\ \text{W}$$

4.



(a) Inductive reactance, $X_L = 2\pi fL$

$$X_L = 2\pi(50)\ 80 \times 10^{-3} = 25.12\ \Omega$$

Capacitive reactance, $X_C = \dfrac{1}{2\pi fC}$

$$X_C = \frac{1}{2\times 3.14\times 50\times 60\times 10^{-6}} = 53.05\ \Omega$$

Impedance $= X_C - X_L = 53.05 - 25.12 = 27.93\ \Omega$

rms value of current, $I_v = \dfrac{E_V}{Z} = \dfrac{230}{27.93} = 8.235$ A

Peak value $I_0 = I_v\sqrt{2} = 11.644$ A

(b) Potential drop across L, $V_L = I_v X_L = 206.68$ V

Potential drop across C, $V_C = I_v X_C = 436.87$ V

(c) Average power transferred to inductor is zero, because of phase difference $\pi/2$.

$$P = E_v I_v \cos\phi$$

$$\phi = \pi/2, \quad \therefore \quad P = 0$$

(d) Average power transferred to capacitor is also zero, because of phase difference $\pi/2$.

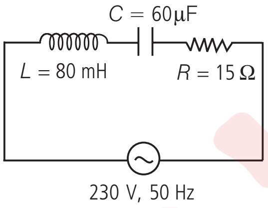
$$P = E_v I_v \cos\phi$$

$$\phi = \pi/2, \quad \therefore \quad P = 0$$

(c) Total power absorbed by the circuit

$$P_{\text{Total}} = P_L + P_C = 0$$

5. If the circuit has a resistance of 15 Ω, now it is *LCR* series resonant circuit.



Now the impedance,

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

$$Z = \sqrt{15^2 + (27.93)^2} = 31.7\ \Omega$$

Virtual current, $I_v = \dfrac{E_V}{Z} = \dfrac{230}{31.7} = 7.26$ A

Average power transferred to '*L*',

$$P_L = I_v E_v \cos\pi/2 = 0$$

Average power transferred to '*C*',

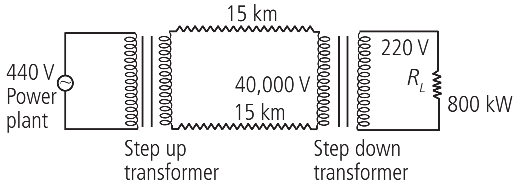
$$P_C = E_v I_v \cos\pi/2 = 0$$

Average power transferred to '*R*',

$$P_R = V_R I_v \cos 0°$$

$$P_R = (I_v R)\ I_v = I_V^2 R = (7.26)^2 \times 15 = 791\ \text{W}$$

6.



Virtual a.c. in the time

$$I_V = \frac{P_{\text{output}}}{E_V} = \frac{800\times 10^3}{40,000} = 20\ \text{A}$$

(a) Line power loss, $P_{\text{loss}} = I_v^2 R = (20)^2 \times 15$

$$= 6\ \text{kW}$$

(b) Power supplied by the plant

$$P_{\text{Total}} = P_{\text{Loss}} + P_{\text{output}} = 6\ \text{kW} + 800\ \text{kW}$$

$$= 806\ \text{kW}$$

(c) Voltage drop in the line,

$$V = I_v R = 20 \times 15 = 300\ \text{V}.$$

Voltage output of step-up transformer at power station

$= 40,000 + 300 = 40,300$ V

So, the step up transformer at the power plant is 220 V - 40,300 V.

Power loss in earlier arrangement,

$$P_1 = \frac{600\times 10^3}{1400\times 10^3}\times 100 = 43\%$$

Power loss in this arrangement,

$$P_2 = \frac{6\times 10^3}{806\times 10^3}\times 100 = 0.74\%$$

So, by supply of electricity at higher voltage, 40,000 V instead by 4000 V the power loss is reduced greatly that is why the electric power is always transmitted at very high voltage.

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