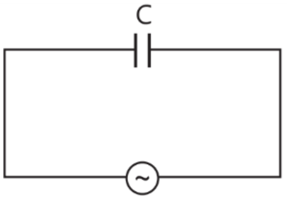
Alternating Current

Case Study Based Questions

Case Study 1

Let a source of alternating emf $E = E_0 \sin\omega t$ be connected to a capacitor of capacitance C. If 'I' is the instantaneous value of current in the circuit as instant t, then $I = \frac{E_0}{1/\omega C}\sin\left(\omega t + \frac{\pi}{2}\right)$.

The capacitive reactance limits the amplitude of current in a purely capacitive circuit and it is given by $X_C = \frac{1}{\omega C}$.



Read the given passage carefully and give the answer of the following questions:

Q1. What is the unit of capacitive reactance?

a. Farad

b. Ampere

c. Ohm

d. Ohm^{-1}

Q2. The capacitive reactance of a 5μF capacitor for a frequency of 10^6 Hz is:

a. 0.032 Ω

b. 2.52 Ω

c. 1.25 Ω

d. 4.51 Ω

Q3. In a capacitive circuit, resistance to the flow of current is offered by:

a. resistor

b. capacitor

c. inductor

d. frequency

Q4. In a capacitive circuit, by what value of phase angle does alternating current leads the emf?

a. 45°

b. 90°

c. 75°

d. 60°

Q5. One microfarad capacitor is joined to a 200 V, 50 Hz alternator. The rms current through capacitor is:

a. 6.28×10^{-2} A

b. 7.5×10^{-4} A

c. 10.52×10^{-2} A

d. 15.25×10^{-2} A

Solutions

1. (c) Ohm

Ohm is the unit of capacitive reactance.

2. (a) 0.032 Ω

Capacitive reactance,

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

$$= \frac{1}{2\pi \times 10^6 \times 5 \times 10^{-6}} = 0.032\Omega$$

3. (b) capacitor

In capacitive circuit, resistance to the flow of current is offered by the capacitor.

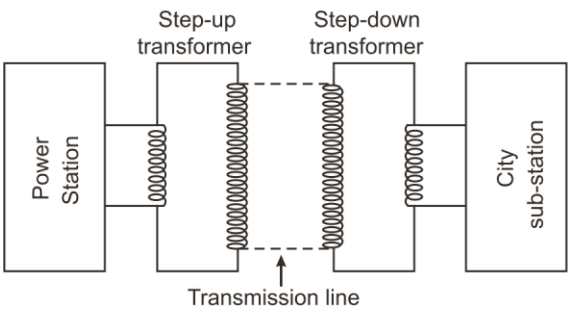
4. (b) 90°

5. (a) 6.28×10^{-2} A

$$\text{Current, } I_V = \frac{E_V}{X_C} = \frac{E_V}{1/2\pi\nu C} = (2\pi\nu C)E_V$$

$$I_V = 2 \times 3.14 \times 50 \times 1 \times 10^{-6} \times 200 = 6.28 \times 10^{-2}\text{A}$$

Case Study 2



Long distance power transmissions

The large-scale transmission and distribution of electrical energy over long distances is done with the use of transformers. The voltage output of the generator is stepped-up. It is then transmitted over long distances to an area sub-station near the consumers. Then the voltage is stepped-down. It is further stepped-down at distributing sub-stations and utility poles before a power supply of 240 V reaches our homes. (CBSE SQP 2021 Term-1)

Read the given passage carefully and give the answer of the following questions:

Q1. Which of the following statement is true?

a. Energy is created when a transformer steps-up the voltage

b. A transformer is designed to convert an AC voltage to DC voltage

c. Step-up transformer increases the power for transmission

d. Step-down transformer decreases the AC voltage

Q2. If the secondary coil has a greater number of turns than the primary:

a. the voltage is stepped-up ($V_s > V_p$) and arrangement is called a step-up transformer

b. the voltage is stepped-down ($V_s < V_p$) and arrangement is called a step-down transformer

c. the current is stepped-up ($I_s > I_p$) and arrangement is called a step-up transformer

d. the current is stepped-down ($I_s < I_p$) and arrangement is called a step-down transformer

Q3. We need to step-up the voltage for power transmission, so that:

a. the current is reduced and consequently, the I^2R loss is cut down

b. the voltage is increased the power losses are also increased

c. the power is increased before transmission is done

d. the voltage is decreased so V^2/R losses are reduced

Q4. A power transmission line feeds input power at 2300 V to a step-down transformer with its primary windings having 4000 turns. The number of turns in the secondary in order to get output power at 230 V are:

a. 4 b. 40

c. 400 d. 4000

Solutions

1. (d) Step-down transformer decreases the AC voltage.

2. (a) the voltage is stepped-up ($V_s > V_p$) and the arrangement is called a step-up transformer.

$$\because \quad \frac{N_S}{N_P} = \frac{E_S}{E_P}$$

If number of turns in secondary coil (N_s) are greater than number of turns in primary (N_p), then voltage is increased or stepped-up in secondary, so the arrangement is called step-up transformer.

3. (a) The current is reduced and consequently, the I^2R loss is cut down.

4. (c) 400

Given, $E_i = 2300$ V

$E_o = 230$ V

$N_P = 4000$

$N_S = ?$

We know, $\frac{E_i}{E_o} = \frac{N_P}{N_S}$

$$\therefore \quad \frac{2300}{230} = \frac{4000}{N_S}$$

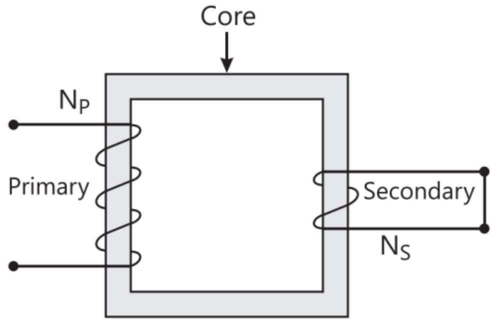
$$\therefore \quad N_S = 400$$

Number of turns in secondary coil, $N_S = 400$

Case Study 3

Step-down transformers are used to decrease or step-down voltages. These are used when voltages need to be lowered for use in homes and factories.

A small town with a demand of 800 kW of electric power at 220 V is situated 15 km away from an electric plant generating power at 440 V. The resistance of the two wire line carrying power is 0.5 Ω per km. The town gets power from the line through a 4000-220 V step-down transformer at a sub-station in the town.



Read the given passage carefully and give the answer of the following questions:

Q1. The value of total resistance of the wire is:

a. 25 Ω b. 30 Ω

c. 35 Ω d. 15 Ω

Q2. The line power loss in the form of heat is:

a. 550 kW b. 650 kW

c. 600 kW d. 700 kW

Q3. How much power must the plant supply, assuming there is negligible power loss due to leakage?

a. 600 kW b. 1600 kW

c. 500 W d. 1400 kW

Q4. The voltage drop in the power line is:

a. 1700 V b. 3000 V

c. 2000 V d. 2800 V

Q5. The total value of voltage transmitted from the plant is:

a. 500 V b. 4000 V

c. 3000 V d. 7000 V

Solutions

1. (d) 15 Ω

Resistance of the two wire lines carrying power = 0.5 Ω /km

Total resistance = (15+15) 0.5 = 15 Ω

2. (c) 600 kW

Line power loss = I^2R

rms current in the coil,

$$I = \frac{P}{V_i} = \frac{800 \times 10^3}{4000} = 200 \text{A}$$

∴ Power loss = $(200)^2 \times 15$ = 600 kW

3. (d) 1400 kW

Assuming that the power loss is negligible due to the leakage of the current.

The total power supplied by the plant = 800 kW + 600 kW 1400 kW

4. (b) 3000 V

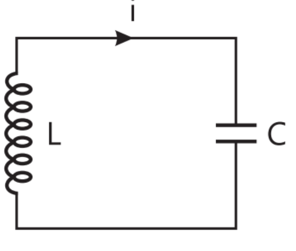
Voltage drop in the power line = IR = 200 × 15 = 3000 V

5. (d) 7000 V

Total voltage transmitted from the plant = 3000 V + 4000 V = 7000 V

Case Study 4

An LC circuit also called a resonant circuit or tank circuit or tuned circuit, is an electric circuit consisting of an inductor represented by the letter L and a capacitor, represented by the letter C connected together. An LC circuit is an idealised model since it assumes there is no dissipation of energy due to resistance.



An LC circuit contains a 20 mH inductor and a 50 μF capacitor with an initial charge of 10 mC. The resistance of the circuit is negligible. Let the instant of circuit is closed be t = 0.

Read the given passage carefully and give the answer of the following questions:

Q1. What will be the total energy stored initially?

Q2. What will be the natural frequency of the circuit?

Q3. At what time is the energy stored completely electrical?

Q4. At what time is the energy stored completely magnetic?

Q5. Calculate the value of X_L.

Solutions

1. Energy, $E = \frac{1}{2}\frac{Q^2}{C} = \frac{(10\times10^{-3})^2}{2\times50\times10^{-6}} = 1\text{ J}$

2. Frequency, $\nu = \frac{1}{2\pi\sqrt{LC}} = \frac{1}{2\pi\sqrt{20\times10^{-3}\times50\times10^{-6}}}$

$$= \frac{10^3}{2\pi} = 159.24\text{Hz}$$

3. Total time period,

$$T = \frac{1}{\nu} = \frac{1}{159.24} = 6.28\text{ ms}$$

Total charge on capacitor at time, t

$$Q' = Q\cos\frac{2\pi}{T}t$$

For energy stored in electrical, we can write $Q' = \pm Q$. Hence, energy stored in the capacitor is completely electrical at $t = 0, \frac{T}{2}, T, \frac{3T}{2}, \ldots$.

4. Magnetic energy is maximum when electrical energy is equal to zero.

Hence, $t = \frac{T}{4}, \frac{3T}{4}, \frac{5T}{4}, \ldots$.

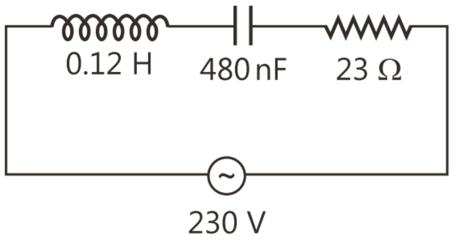
5. $X_L = \omega L = 2\pi\nu L$

$= 2 \times 3.14 \times 159.24 \times 20 \times 10^{-3}$

$\Rightarrow$ $X_L = 20\ \Omega$

Case Study 5

When the frequency of AC supply is such that the inductive reactance and capacitive reactance become equal, the impedance of the series LCR circuit is equal to the ohmic resistance in the circuit. Such a series LCR circuit is known as resonant series LCR circuit and the frequency of the AC supply is known as resonant frequency.



Resonance phenomenon is exhibited by a circuit only if both L and C are present in the circuit. We cannot have resonance in an RL or RC circuit. A series LCR circuit with L = 0.12 H, C = 480 nF, R = 23 Ω is connected to a 230V variable frequency supply.

Read the given passage carefully and give the answer of the following questions:

Q1. Find the value of source frequency for which current amplitude is maximum.

Q2. Calculate the value of maximum current.

Q3. Calculate the value of maximum power.

Q4. At resonance, which physical quantity is maximum?

Solutions

1. Here, $L = 0.12\text{ H},\ C = 480\text{ nF} = 480 \times 10^{-9}\text{F}$

$$R = 23\Omega,\ V = 230\text{V}$$

$$V_0 = \sqrt{2} \times 230 = 325.22\text{V}$$

$$I_0 = \frac{V_0}{\sqrt{R^2 + \left(\omega L - \frac{1}{\omega C}\right)^2}}$$

At resonance, $\omega L - \frac{1}{\omega C} = 0$

$$\omega = \frac{1}{\sqrt{LC}} = \frac{1}{\sqrt{0.12 \times 480 \times 10^{-9}}}$$

$$= 4166.67\text{ rad s}^{-1}$$

$$\nu_R = \frac{4166.67}{2 \times 3.14} = 663.48\text{ Hz} \qquad [\because \omega = 2\pi\nu_R]$$

2. Current, $I_0 = \frac{V_0}{R} = \frac{325.22}{23} = 14.14$ A

3. Maximum power, $P_{max} = \frac{1}{2}(I_0)^2 R$

$$= \frac{1}{2} \times (14.14)^2 \times 23 = 2299.3 \text{ W}$$

4. At resonance, current is maximum. A circuit in which inductance L, capacitance C and resistance R are connected and the circuit admits maximum current corresponding to a given frequency of AC is called resonance circuit.

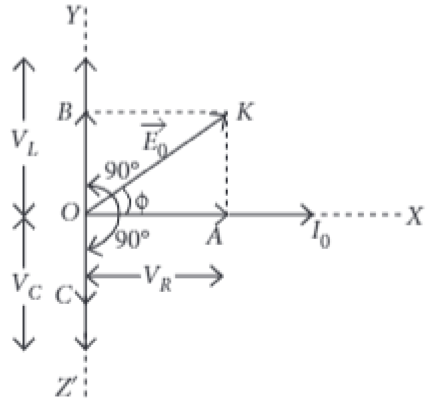
Solutions for Questions 6 to 15 are Given Below

Case Study 6

LCR Circuit

When a pure resistance R, pure inductor L and an ideal capacitor of capacitance C is connected in series to a source of alternating e.m.f., then current at any instant through the three elements has the same amplitude and is represented as $I = I_0 \sin\omega t$. However, voltage across each element has a different phase relationship with the current as shown in graph.

The effective resistance of RLC circuit is called impedance (Z) of the circuit and the voltage leads the current by a phase angle ϕ.



A resistor of 12 Ω, a capacitor of reactance 14 Ω and a pure inductor of inductance 0.1 H are joined in series and placed across 200 V, 50 Hz a.c. supply.

(i) The value of inductive reactance is
(a) 15 Ω (b) 31.4 Ω (c) 20 Ω (d) 30 Ω

(ii) The value of impedance is
(a) 20 Ω (b) 15 Ω (c) 30 Ω (d) 21.13 Ω

(iii) What is the value of current in the circuit?
(a) 5 A (b) 15 A (c) 10 A (d) 9.46 A

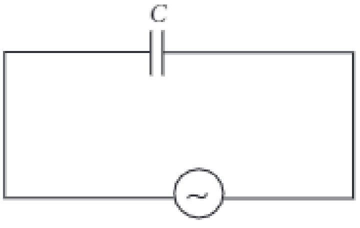
(iv) What is the value of the phase angle between current and voltage?
(a) 53°9′ (b) 63°9′ (c) 55°4′ (d) 50°

(v) From graph, which one is true from following?
(a) $V_L \geq V_C$ (b) $V_L < V_C$ (c) $V_L > V_C$ (d) $V_L = V_C$

Case Study 7

AC Voltage Applied to a Capacitor

Let a source of alternating e.m.f. $E = E_0 \sin\omega t$ be connected to a capacitor of capacitance C. If 'I' is the instantaneous value of current in the circuit at instant t, then $I = \frac{E_0}{1/\omega C}\sin\left(\omega t + \frac{\pi}{2}\right)$. The capacitive reactance limits the amplitude of current in a purely capacitive circuit and it is given by $X_C = \frac{1}{\omega C}$.



(i) What is the unit of capacitive reactance?
(a) farad (b) ampere (c) ohm (d) ohm^{-1}

(ii) The capacitive reactance of a 5 μF capacitor for a frequency of 10^6 Hz is
(a) 0.032 Ω (b) 2.52 Ω (c) 1.25 Ω (d) 4.51 Ω

(iii) In a capacitive circuit, resistance to the flow of current is offered by
(a) resistor (b) capacitor (c) inductor (d) frequency

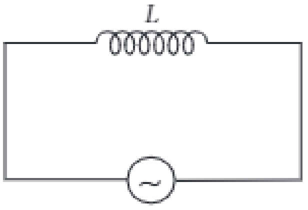
(iv) In a capacitive circuit, by what value of phase angle does alternating current leads the e.m.f?
(a) 45° (b) 90° (c) 75° (d) 60°

(v) One microfarad capacitor is joined to a 200 V, 50 Hz alternator. The rms current through capacitor is
(a) 6.28×10^{-2} A (b) 7.5×10^{-4} A (c) 10.52×10^{-2} A (d) 15.25×10^{-2} A

Case Study 8

AC Voltage Applied to an Inductor

Let a source of alternating e.m.f. $E = E_0 \sin\omega t$ be connected to a circuit containing a pure inductance L. If I is the value of instantaneous current in the circuit, then $I = I_0 \sin\left(\omega t - \frac{\pi}{2}\right)$. The inductive reactance limits the current in a purely inductive circuit and is given by $X_L = \omega L$.



(i) A 100 hertz a.c. is flowing in a 14 mH coil. The reactance is

(a) 15 Ω (b) 7.5 Ω (c) 8.8 Ω (d) 10 Ω

(ii) In a pure inductive circuit, resistance to the flow of current is offered by

(a) resistor (b) inductor (c) capacitor (d) resistor and inductor

(iii) In a inductive circuit, by what value of phase angle does alternating current lags behind e.m.f.?

(a) 45° (b) 90° (c) 120° (d) 75°

(iv) How much inductance should be connected to 200 V, 50 Hz a.c. supply so that a maximum current of 0.9 A flows through it?

(a) 5 H (b) 1 H (c) 10 H (d) 4.5 H

(v) The maximum value of current when inductance of 2 H is connected to 150 volt, 50 Hz supply is

(a) 0.337 A (b) 0.721 A (c) 1.521 A (d) 2.522 A

Case Study 9

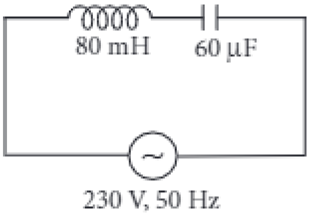
Average Power Associated with an Inductor and Capacitor

The power averaged over one full cycle of a.c. is known as average power. It is also known as true power.

$P_{av} = V_{rms} I_{rms} \cos\phi = \dfrac{V_0 I_0}{2} \cos\phi$.

Root mean square or simply rms watts refer to continuous power.

A circuit containing a 80 mH inductor and a 60 μF capacitor in series is connected to a 230 V, 50 Hz supply. The resistance of the circuit is negligible.



(i) The value of current amplitude is

(a) 15 A (b) 11.63 A (c) 17.65 A (d) 6.33 A

(ii) Find rms value.

(a) 6 A (b) 5.25 A (c) 8.23 A (d) 7.52 A

(iii) The average power transferred to inductor is

(a) zero (b) 7 W (c) 2.5 W (d) 5 W

(iv) The average power transferred to the capacitor is

(a) 5 W (b) zero (c) 11 W (d) 15 W

(v) What is the total average power absorbed by the circuit?

(a) zero (b) 10 W (c) 2.5 W (d) 15 W

Case Study 10

Transformer

A transformer is essentially an a.c. device. It cannot work on d.c. It changes alternating voltages or currents. It does not affect the frequency of a.c. It is based on the phenomenon of mutual induction. A transformer essentially consists of two coils of insulated copper wire having different number of turns and wound on the same soft iron core.

The number of turns in the primary and secondary coils of an ideal transformer are 2000 and 50 respectively. The primary coil is connected to a main supply of 120 V and secondary coil is connected to a bulb of resistance 0.6 Ω.

(i) The value of voltage across the secondary coil is

(a) 5 V (b) 2 V (c) 3 V (d) 10 V

(ii) The value of current in the bulb is

(a) 7 A (b) 15 A (c) 3 A (d) 5 A

(iii) The value of current in primary coil is

(a) 0.125 A (b) 2.52 A (c) 1.51 A (d) 3.52 A

(iv) Power in primary coil is

(a) 20 W (b) 5 W (c) 10 W (d) 15 W

(v) Power in secondary coil is

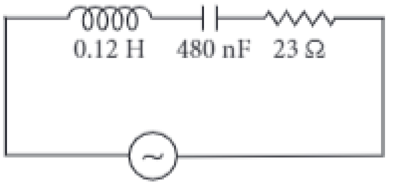
(a) 15 W (b) 20 W (c) 7 W (d) 8 W

Case Study 11

Resonant Series LCR Circuit

When the frequency of ac supply is such that the inductive reactance and capacitive reactance become equal, the impedance of the series *LCR* circuit is equal to the ohmic resistance in the circuit. Such a series *LCR* circuit is known as resonant series *LCR* circuit and the frequency of the ac supply is known as resonant frequency. Resonance phenomenon is exhibited by a circuit only if both *L* and *C* are present in the circuit. We cannot have resonance in a *RL* or *RC* circuit.

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



(i) Find the value of source frequency for which current amplitude is maximum.

(a) 222.32 Hz (b) 550.52 Hz (c) 663.48 Hz (d) 770 Hz

(ii) The value of maximum current is

(a) 14.14 A (b) 22.52 A (c) 50.25 A (d) 47.41 A

(iii) The value of maximum power is

(a) 2200 W (b) 2299.3 W (c) 5500 W (d) 4700 W

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

(a) 25 (b) 42.21 (c) 35.42 (d) 21.74

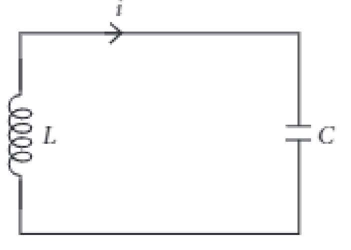
(v) At resonance which of the following physical quantity is maximum?

(a) Impedance (b) Current (c) Both (a) and (b) (d) Neither (a) nor (b)

Case Study 12

LC Circuit

An LC circuit also called a resonant circuit, tank circuit or tuned circuit is an electric circuit consisting of an inductor represented by the letter L and a capacitor, represented by the letter C connected together. An LC circuit is an idealized model since it assumes there is no dissipation of energy due to resistance.
An LC circuit contains a 20 mH inductor and a 50 μF capacitor with an initial charge of 10 mC. The resistance of the circuit is negligible. Let the instant the circuit is closed be $t = 0$.



(i) The total energy stored initially is

(a) 5 J (b) 3 J (c) 10 J (d) 1 J

(ii) The natural frequency of the circuit is

(a) 159.24 Hz (b) 200.12 Hz (c) 110.25 Hz (d) 95 Hz

(iii) At what time is the energy stored completely electrical?

(a) $T, 5T, 9T$ (b) $\frac{T}{2}, \frac{5T}{2}, \frac{9T}{2}$ (c) $0, T, 2T, 3T$ (d) $0, \frac{T}{2}, T, \frac{3T}{2}$

(iv) At what time is the energy stored completely magnetic?

(a) $\frac{T}{2}, \frac{3T}{2}, \frac{T}{4}$ (b) $\frac{T}{3}, \frac{T}{9}, \frac{T}{12}$ (c) $0, 2T, 3T$ (d) $\frac{T}{4}, \frac{3T}{4}, \frac{5T}{4}$

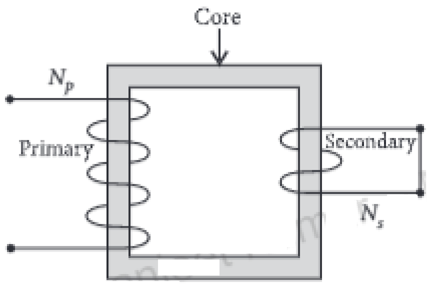
(v) The value of X_L is

(a) 20 Ω (b) 40 Ω (c) 60 Ω (d) 50 Ω

Case Study 13

Step-down Transformer in the Transmission of Electric Power

Step-down transformers are used to decrease or step-down voltages. These are used when voltages need to be lowered for use in homes and factories.
A small town with a demand of 800 kW of electric power at 220 V is situated 15 km away from an electric plant generating power at 440 V. The resistance of the two wire line carrying power is 0.5 Ω per km. The town gets power from the line through a 4000 - 220 V step-down transformer at a sub-station in the town.



(i) The value of total resistance of the wires is
(a) 25 Ω (b) 30 Ω (c) 35 Ω (d) 15 Ω

(ii) The line power loss in the form of heat is
(a) 550 kW (b) 650 kW (c) 600 kW (d) 700 kW

(iii) How much power must the plant supply, assuming there is negligible power loss due to leakage?
(a) 600 kW (b) 1600 kW (c) 500 W (d) 1400 kW

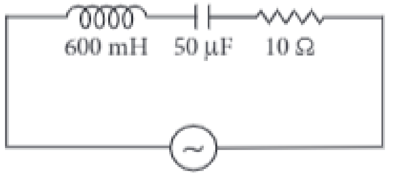
(iv) The voltage drop in the power line is
(a) 1700 V (b) 3000 V (c) 2000 V (d) 2800 V

(v) The total value of voltage transmitted from the plant is
(a) 500 V (b) 4000 V (c) 3000 V (d) 7000 V

Case Study 14

Power Associated with LCR Circuit

In an a.c. circuit, values of voltage and current change every instant. Therefore, power of an a.c. circuit at any instant is the product of instantaneous voltage (E) and instantaneous current (I). The average power supplied to a pure resistance R over a complete cycle of a.c. is $P = E_v I_v$. When circuit is inductive, average power per cycle is $E_v I_v \cos\phi$.



230 V, 60 Hz

In an a.c. circuit, 600 mH inductor and a 50 μF capacitor are connected in series with 10 Ω resistance. The a.c. supply to the circuit is 230 V, 60 Hz.

(i) The average power transferred per cycle to resistance is
(a) 10.42 W (b) 15.25 W (c) 17.42 W (d) 13.45 W

(ii) The average power transferred per cycle to capacitor is
(a) zero (b) 10.42 W (c) 17.42 W (d) 15 W

(iii) The average power transferred per cycle to inductor is
(a) 25 W (b) 17.42 W (c) 16.52 W (d) zero

(iv) The total power transferred per cycle by all the three circuit elements is

(a) 17.42 W (b) 10.45 W (c) 12.45 W (d) zero

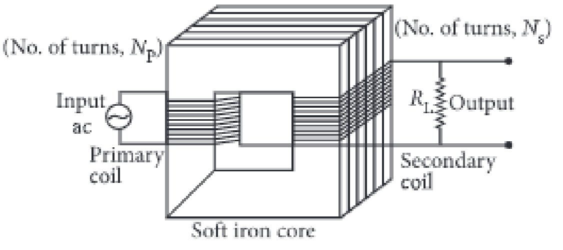
(v) The electrical energy spend in running the circuit for one hour is

(a) 7.5×10^5 Joule (b) 10×10^3 Joule (c) 9.4×10^3 Joule (d) 6.2×10^4 Joule

Case Study 15

Transformer

A transformer is an electrical device which is used for changing the a.c. voltages. It is based on the phenomenon of mutual induction *i.e.* whenever the amount of magnetic flux linked with a coil changes, an e.m.f. is induced in the neighbouring coil. For an ideal transformer, the resistances of the primary and secondary windings are negligible.



It can be shown that $\frac{E_s}{E_p} = \frac{I_p}{I_s} = \frac{n_s}{n_p} = k$

where the symbols have their standard meanings.

For a step up transformer, $n_s > n_p$; $E_s > E_p$; $k > 1$; $\therefore$ $I_s < I_p$

For a step down transformer, $n_s < n_p$; $E_s < E_p$; $k < 1$

The above relations are on the assumptions that efficiency of transformer is 100%.

Infact, efficiency $\eta = \frac{\text{output power}}{\text{intput power}} = \frac{E_s I_s}{E_p I_p}$

(i) Which of the following quantity remains constant in an ideal transformer?

(a) Current (b) Voltage (c) Power (d) All of these

(ii) Transformer is used to

(a) convert ac to dc voltage (b) convert dc to ac voltage

(c) obtain desired dc power (d) obtain desired ac voltage and current

(iii) The number of turns in primary coil of a transformer is 20 and the number of turns in a secondary is 10. If the voltage across the primary is 220 ac V, what is the voltage across the secondary?

(a) 100 ac V (b) 120 ac V (c) 110 ac V (d) 220 ac V

(iv) In a transformer the number of primary turns is four times that of the secondary turns. Its primary is connected to an a.c. source of voltage V. Then

(a) current through its secondary is about four times that of the current through its primary.

(b) voltage across its secondary is about four times that of the voltage across its primary.

(c) voltage across its secondary is about two times that of the voltage across its primary.

(d) voltage across its secondary is about $\frac{1}{2\sqrt{2}}$ times that of the voltage across its primary.

(v) A transformer is used to light 100 W–110 V lamp from 220 V mains. If the main current is 0.5 A, the efficiency of the transformer is

(a) 95% (b) 99% (c) 90% (d) 96%

HINTS & EXPLANATIONS

6. (b): Given : $R = 12\ \Omega$, $X_C = 14\ \Omega$, $L = 0.1$ H
$X_L = \omega L = 2\pi \upsilon L = 2 \times 3.14 \times 50 \times 0.1 = 31.4\ \Omega$

(ii) (d): Impedance, $Z = \sqrt{R^2 + (X_L - X_C)^2}$

$= \sqrt{(12)^2 + (31.4 - 14)^2} = 21.13\ \Omega$

(iii) (d): $I_v = \dfrac{E_v}{Z} = \dfrac{200\text{ V}}{21.13} = 9.46$ A

(iv) (c): $\tan\phi = \dfrac{X_L - X_C}{R} = \dfrac{31.4 - 14}{12} = 1.45$

$\phi = \tan^{-1}(1.45) = 55°4'$

(v) (c)

7. (i) (c): Ohm is the unit of capacitive reactance.

(ii) (a): Capacitive reactance, $X_C = \dfrac{1}{\omega C} = \dfrac{1}{2\pi\upsilon C}$

$= \dfrac{1}{2\pi \times 10^6 \times 5 \times 10^{-6}} = 0.032\ \Omega$

(iii) (b): In capacitive circuit, resistance to the flow of current is offered by the capacitor.

(iv) (b)

(v) (a): Current, $I_v = \dfrac{E_v}{X_C} = \dfrac{E_v}{1/2\pi\upsilon C} = (2\pi\upsilon C)E_v$

$I_v = 2 \times 3.14 \times 50 \times 10^{-6} \times 200 = 6.28 \times 10^{-2}$ A

8. (i) (c) : Inductive reactance,
$X_L = \omega L = 2\pi\upsilon L = 2\pi \times 100 \times 14 \times 10^{-3}$
$X_L = 8.8\ \Omega$

(ii) (b)

(iii) (b): In an inductor voltage leads the current by $\dfrac{\pi}{2}$ or current lags the voltage by $\dfrac{\pi}{2}$.

(iv) (b): The current in the inductor coil is given by

$I_0 = \dfrac{E_0}{X_L} = \dfrac{\sqrt{2}E_v}{2\pi\upsilon L}$

$L = \dfrac{\sqrt{2}E_v}{2\pi\upsilon I_0} = \dfrac{1.414 \times 200}{2 \times 3.14 \times 50 \times 0.9} = 1\text{ H}$

(v) (a): Inductive reactance,
$X_L = \omega L = 2\pi\upsilon L = 2 \times 3.14 \times 50 \times 2 = 628\ \Omega$

$I_0 = \dfrac{E_0}{X_L} \Rightarrow I_0 = \dfrac{\sqrt{2} \times E_v}{X_L} = \dfrac{\sqrt{2} \times 150}{628} = 0.337$ A

9. (i) (b): Inductance, $L = 80$ mH $= 80 \times 10^{-3}$ H
Capacitance, $C = 60\ \mu$F $= 60 \times 10^{-6}$ F, $V = 230$ V
Frequency, $\upsilon = 50$ Hz
$\omega = 2\pi\upsilon = 100\pi$ rad s^{-1}

Peak voltage, $V_0 = V\sqrt{2} = 230\sqrt{2}$ V

Maximum current is given by, $I_0 = \dfrac{V_0}{\left(\omega L - \dfrac{1}{\omega C}\right)}$

$$I_0 = \frac{230\sqrt{2}}{\left(100\pi \times 80 \times 10^{-3} - \dfrac{1}{100\pi \times 60 \times 10^{-6}}\right)}$$

$$I_0 = \frac{230\sqrt{2}}{\left(8\pi - \dfrac{1000}{6\pi}\right)} = -11.63\text{ A}$$

Amplitude of maximum current, $I_0 = 11.63$ A

(ii) (c) : rms value of current,

$$I = \frac{I_0}{\sqrt{2}} = \frac{-11.63}{\sqrt{2}} = -8.23 \text{ A}$$

Negative sign appears as $\omega L < \frac{1}{\omega C}$.

(iii) (a) : Average power consumed by the inductor is zero because of phase difference of $\frac{\pi}{2}$ between voltage and current through inductor.

(iv) (b): Average power consumed by the capacitor is zero because of phase difference of $\frac{\pi}{2}$ between voltage and current through capacitor.

(v) (a)

10. (i) (c) : As $\frac{E_s}{E_p} = \frac{n_s}{n_p} \Rightarrow E_s = E_p \cdot \frac{n_s}{n_p}$

$$= \frac{120 \times 50}{2000} = 3 \text{ V}$$

(ii) (d): $I_s = \frac{E_s}{R} \Rightarrow I_s = \frac{3}{0.6} = 5 \text{ A}$

(iii) (a) : As $\frac{I_p}{I_s} = \frac{E_s}{E_p}$

$$\Rightarrow I_p = \frac{E_s}{E_p} \times I_s = \frac{3}{120} \times 5 = 0.125 \text{ A}$$

(iv) (d): Power in primary, $P_p = E_p \times I_p = 120 \times 0.125 = 15 \text{ W}$

(v) (a) : Power in secondary coil, $P_s = E_s \times I_s = 3 \times 5 = 15 \text{ W}$

11. (i) (c) : Here, $L = 0.12$ H, $C = 480$ nF $= 480 \times 10^{-9}$ F
$R = 23\ \Omega$, $V = 230$ V

$$V_0 = \sqrt{2} \times 230 = 325.22 \text{ V}$$

$$I_0 = \frac{V_0}{\sqrt{R^2 + \left(\omega L - \frac{1}{\omega C}\right)^2}}$$

At resonance, $\omega L - \frac{1}{\omega C} = 0$

$$\omega = \frac{1}{\sqrt{LC}} = \frac{1}{\sqrt{0.12 \times 480 \times 10^9}} = 4166.67 \text{ rad s}^{-1}$$

$$\upsilon_R = \frac{4166.67}{2 \times 3.14} = 663.48 \text{ Hz}$$

(ii) (a) : Current, $I_0 = \frac{V_0}{R} = \frac{325.22}{23} = 14.14 \text{ A}$

(iii) (b): Maximum power, $P_{max} = \frac{1}{2}(I_0)^2 R$

$$= \frac{1}{2} \times (14.14)^2 \times 23 = 2299.3 \text{ W}$$

(iv) (d): Quality factor $Q = \frac{X_L}{R} = \frac{\omega_r L}{R}$

$$= \frac{4166.67 \times 0.12}{23} = 21.74$$

(v) (b)

12. (i) (d): Energy, $E = \frac{1}{2}\frac{Q^2}{C} = \frac{(10 \times 10^{-3})^2}{2 \times 50 \times 10^{-6}} = 1 \text{ J}$

(ii) (a) : Frequency, $\upsilon = \frac{1}{2\pi\sqrt{LC}}$

$$= \frac{1}{2\pi\sqrt{20 \times 10^{-3} \times 50 \times 10^{-6}}} = \frac{10^3}{2\pi} = 159.24 \text{ Hz}$$

(iii) (d): Total time period, $T = \frac{1}{\upsilon} = \frac{1}{159.24} = 6.28 \text{ ms}$

Total charge on capacitor at time t, $Q' = Q\cos\frac{2\pi}{T}t$

For energy stored is electrical, we can write $Q' = \pm Q$. Hence, energy stored in the capacitor is completely electrical at, $t = 0, \frac{T}{2}, T, \frac{3T}{2}, ...$

(iv) (d): Magnetic energy is maximum when electrical energy is equal to zero.

Hence $t = \frac{T}{4}, \frac{3T}{4}, \frac{5T}{4}, ...$

(v) (a) : $X_L = \omega L = 2\pi\upsilon L = 2 \times 3.14 \times 159.24 \times 20 \times 10^{-3}$

$$\Rightarrow X_L = 20\ \Omega$$

13. (i) (d): Resistance of the two wire lines carrying power = 0.5 Ω/km
Total resistance = (15 + 15)0.5 = 15 Ω

(ii) (c) : Line power loss = I^2R
RMS current in the coil,

$$I = \frac{P}{V_1} = \frac{800 \times 10^3}{4000} = 200 \text{ A}$$

$\therefore$ Power loss $= (200)^2 \times 15 = 600$ kW

(iii) (d): Assuming that the power loss is negligible due to the leakage of the current.
The total power supplied by the plant
= 800 kW + 600 kW = 1400 kW

(iv) (b): Voltage drop in the power line = IR
= 200 × 15 = 3000 V

(v) (d): Total voltage transmitted from the plant
= 3000 V + 4000 V = 7000 V

14. (i) (c): Average power transferred per cycle to resistance is $P_v = I_v^2 R$

As $X_L = \omega L = 2\pi\upsilon L = 2\times\frac{22}{7}\times 60\times 0.6 = 226.28\ \Omega$

$$X_C = \frac{1}{\omega C} = \frac{1}{2\pi\upsilon C} = \frac{1}{2\times 22/7\times 60\times 50\times 10^{-6}}$$

$= 53.03\ \Omega$

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

$$= \sqrt{(10)^2 + (226.28 - 53.03)^2} = 173.53\ \Omega$$

$$I_v = \frac{E_v}{Z} = \frac{230}{173.53} = 1.32\ \text{A}$$

$P_v = I_v^2 R = (1.32)^2 \times 10 = 17.42$ W

(ii) (a): $P_C = E_v I_v \cos\phi$
In a capacitor, phase difference, $\phi = 90°$
$\therefore\ P_L = E_v I_v \cos 90° =$ zero

(iii) (d): $P_L = E_v I_v \cos\phi$
In an inductor, phase difference, $\phi = 90°$
$P_L = E_v I_v \cos 90° =$ zero

(iv) (a): Total power absorbed per cycle
$P = P_R + P_C + P_L = 17.42 + 0 + 0 = 17.42$ W

(v) (d): Energy spent = power × time
= 17.42 × 60 × 60 = 6.2×10^4 Joule

15. (i) (c): In an ideal transformer, there is no power loss. The efficiency of an ideal transformer is $\eta = 1$ (*i.e* 100%) *i.e.* input power = output power.

(ii) (d): Transformer is used to obtain desired ac voltage and current.

(iii) (c): For a transformer, $\frac{V_s}{V_p} = \frac{N_s}{N_p}$
where N denotes number of turns and V = voltage.

$$\therefore\ \frac{V_s}{220} = \frac{10}{20}\quad \therefore\ V_s = 110\ \text{ac V}$$

(iv) (a): In a transformer the primary and secondary currents are related by

$$I_s = \left(\frac{N_p}{N_s}\right) I_p$$

and the voltages are related by

$$V_s = \left(\frac{N_s}{N_p}\right) V_p$$

where subscripts p and s refer to the primary and secondary of the transformer.

Here, $V_p = V$, $\frac{N_p}{N_s} = 4\quad \therefore\ I_s = 4I_p$

and $V_s = \left(\frac{1}{4}\right)V = \frac{V}{4}$

(v) (c): The efficiency of the transformer is

$$\eta = \frac{\text{Output power}(P_{out})}{\text{Input power}(P_{in})} \times 100$$

Here, $P_{out} = 100$ W, $P_{in} = (220\ \text{V})(0.5\ \text{A}) = 110$ W

$$\therefore\ \eta = \frac{100\ \text{W}}{110\ \text{W}} \times 100 \approx 90\%$$