Unit 20

AC Circuit

Teaching Periods 15 **Weightage %** 10

The Jamshoro grid station is the sole transit point for affordable power from K2, K3, China Power Hub, and Hubco to meet northern demand. It is also the only transit point for evacuating wind power from Jhimpir/Gharo. Grid stations, are critical components for the distribution and utilization of AC (Alternating Current) circuits.

In this unit student should be able to:

- Define the terms time period, frequency, instantaneous peak value and root mean square value of an alternating current and voltage.
- Represent a sinusoidal alternating current or voltage by an equation of the form $x = x_o \sin \omega t$.
- Describe the phase of A.C and how phase lags and leads in A.C Circuits.
- Explain the flow of A.C through Resistors, Calculate the resistance of resistors
- Construct phasor diagrams and carry out calculations on circuits including resistive components
- Explain the flow of A.C through capacitors
- Calculate the reactance of capacitors
- Construct phasor diagrams and carry out calculations on circuits including reactive components
- Explain Ac through inductors.
- Identify inductors as important components of A.C circuits termed as chokes
- Construct phasor diagrams and carry out calculations on circuits including inductive components
- Describe impedance as vector summation of resistances and reactance
- Construct phasor diagrams and carry out calculations on circuits including resistive reactive and inductive components in series and parallel.
- Solve the problems using the formulae of A.C Power.
- Explain resonance in an A.C circuit and carry out calculations using the resonant frequency formulae.
- Describe that maximum power is transferred when the impedances of source and load match to each other.
- Illustrate the principle of metal detectors used for security checks.
- State the principle of electro-cardiograph in medical diagnostic.
- Describe the importance of oscillator circuit as broadcaster of radio waves.
- Describe the principle of resonance in tuning circuits of a radio.

Introduction:

Alternating current is the back bone of electrical engineering and physics. In addition, we will explore the dynamic nature of AC current, which is quite different when comparing with its counterpart, Direct Current (DC).

There is great contribution of many scientists, like Nikola Tesla and George Westinghouse in better understanding of alternating current. Their groundbreaking work in the late 19th and early 20th centuries laid the foundation for the widespread use of AC power, revolutionizing the way electricity is generated, transmitted, and utilized.

In this chapter we will discuss essential concepts such as frequency, amplitude, and the sinusoidal waveform that characterizes AC current. We will use the mathematics behind AC circuits and study the principles governing the behavior of resistors, capacitors, and inductors when connected with alternating current source. Also, the practical applications of AC current, from the power distribution grid that lights up our cities to the metal detector that have become integral to our daily lives.

20.1 Alternating Current

A graphical representation, such as the one depicted in Figure 20.1, shows the nature of an alternating current. This graph visually demonstrates the cyclic variation of the current, depicting a pattern where, during one half of the cycle, the current is positive, while during the other half, it is negative. Consequently, the current alternates its direction in the wires it traverses, flowing first in one direction and then in the opposite direction.

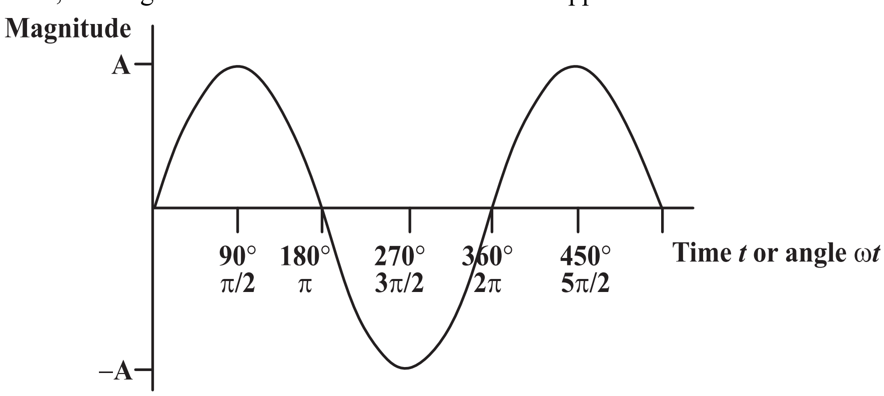


Figure 20.1 A graphical representation of sinusoidal alternating current.

In the context of utilizing household appliances connected to the mains, the current continuously oscillates back and forth along the wires connecting the user to the power station generating the electricity. At any given moment, the current possesses a specific magnitude and direction, as indicated by the graph.

Alternating current (AC) varies in a sinusoidal pattern and follows the shape of a sine wave. This pattern is characterized by a smooth, periodic oscillation that changes direction between positive and negative. While any current that alternates direction could be considered AC, the term typically refers to currents that exhibit this regular, sinusoidal pattern. This sinusoidal nature is fundamental to how AC is generated and utilized in power systems.

20.1.1 AC terminologies

Cycle:

One complete set of both positive and negative values of an alternating quantity is known as a cycle as shown in figure 20.2.

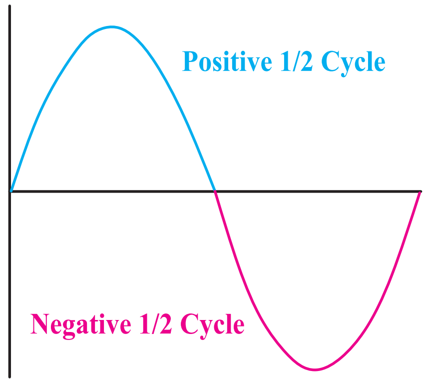


Figure 20.2 One cycle of ac current

Time Period (T):

The time period of an alternating current (AC) or voltage wave is the duration it takes to complete one full cycle. It is typically denoted by the symbol T. The relationship between time period and frequency (f) is given by the equation: $= \frac{1}{f}$, where T is in second.

Frequency (f):

It refers to the number of complete cycles of the current waveform that occur in one second. It is a measure of how many times the direction of the current reverses per second. Frequency is typically expressed in hertz (Hz), where one hertz equals one cycle per second. In practical terms, the frequency of AC current determines how rapidly the current alternates its direction and is crucial for the operation of electrical devices that rely on AC power. The relationship between frequency and time period is expressed as $f = \frac{1}{T}$

Instantaneous Peak Value:

The instantaneous peak value refers to the maximum amplitude of the alternating current or voltage at any specific point in time. For a sine wave, this is the highest positive or negative value reached during a cycle. It is usually denoted as I_{peak} for current or V_{peak} for voltage.

Root Mean Square (rms) Value:

The average value of voltage or current is not used in electric power calculations. The reason being that the AC cycle consists of positive and negative half cycles so the average value is zero. However, there exists a mathematical relation between the peak value V_0 of alternating voltage and a direct current (d.c) voltage that yields an equivalent average electrical power. This constant d.c. voltage is referred to as the root-mean-square (r.m.s) value of the alternating voltage V_{rms}. The d.c voltage is approximately 70% of V_{peak} as shown in figure 20.3. For a sinusoidal wave, the rms value is approximately 0.707 times the peak value. Mathematically,

$V_{rms} = 0.707 \times V_{peak}$ for voltage

and $I_{rms} = 0.707 \times I_{peak}$ for current.

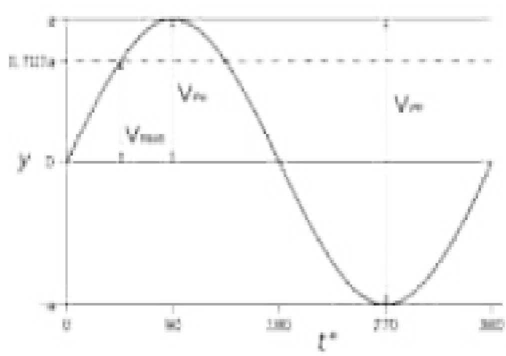


Figure 20.3 Cycle of ac current

20.1.2 Alternating Current OR voltage equation:

When a coil undergoes constant rotation at a uniform angular velocity within a magnetic field, it generates an alternating voltage. Alternating Current (AC) or Voltage refers to the type of electrical flow or potential difference that periodically changes direction and magnitude over time. The fundamental equation describing AC voltage or current in a sinusoidal waveform is:

$V = V_0 Sin\omega t$............ (20.1)

$I = I_0 Sin\omega t$............ (20.2)

Where,

V, I represent the instantaneous value of the voltage and alternating current respectively

V_0, I_0 is the amplitude of the waveform, which represents the maximum value of alternating voltage and alternating current respectively

ω is the angular frequency, given by $\omega = 2\pi f$

Worked Example 20.1

If an alternating current is flowing through a circuit with an amplitude of 5 amps, with frequency of 60 Hz, write its equation:

Solution:

Step 1: Write the known quantities and point out quantities to be found

Vo = 5A,

f = 60 Hz

Step 2: Write the formula and rearrange if necessary

$$I = I_0 Sin\omega t$$

Step 3: Now, substitute the values into the formula:

$$I=5\ Sin2\pi\times60\times t$$

Result: The sine function will oscillate between -5 and 5 Amps.

20.1.3 Phase of AC:

The phase difference between two waves carries more important than their magnitudes. The phase describes the relative positions of these waveforms. Hence in alternating current (A.C.) circuits, the concept of phase refers to the relationship between different waveforms as time passes. Now we discuss different states of phase within AC circuit.

In-phase:

When two waveforms have the same frequency and reach their peak values or zero values at the same time, they are said to be in phase as shown in figure 20.4.

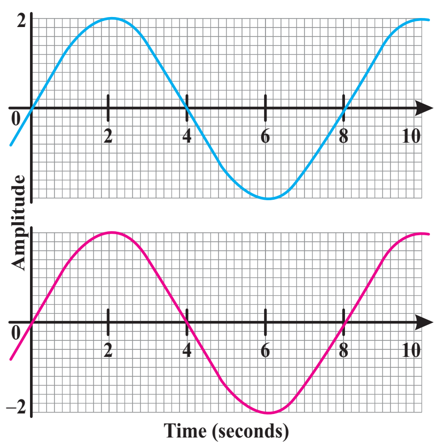


Figure 20.4 Two waves are in a phase

Phase Lag:

If one waveform reaches its peak or zero value after the other, there is a phase difference, and the second waveform is said to lag the first. It is shown by figure 20.5 where a wave shown by dotted line lags the wave shown by solid line. It can be said that the dotted wave form lags the solid line waveform by 90^0 or $\frac{\pi}{2}$ radians.

Phase Lead:

Conversely, if one waveform reaches its peak or zero value before the other, the second waveform is said to lead the first. It is shown by figure 20.5 where a wave shown by solid line leads the wave shown by dotted line by phase difference of 90^0 or $\frac{\pi}{2}$ radians.

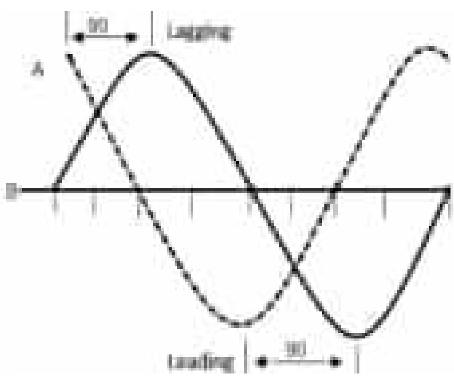


Figure 20.5
The two waves are 90° out of phase.

The representation of phase lead and lag between two alternating quantities is effectively demonstrated by showing the two AC quantities as vectors also known as "Phasor".

Vector Representation of an Alternating quantity:

To solve AC problems effectively, it is beneficial to represent a sinusoidal quantity, such as voltage or current, using a line of specific length that rotates in a counterclockwise direction with the same angular velocity as the sinusoidal quantity. This rotating line is commonly referred to as a phasor.

Let's consider a line denoted as OA, referred to as a phasor, which accurately represents, to scale, the maximum value of an alternating quantity, such as electromotive force (emf). In this representation, OA equals the maximum emf value and rotates counterclockwise at an angular velocity of ω radians per second around the point O, as illustrated in Figure 20.6. An arrowhead is placed at the outer end of the phasor, serving both to indicate the assumed direction of movement and to specify the precise length of the phasor, especially when multiple phasors coincide.

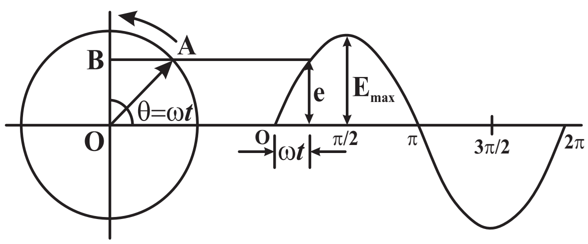


Figure 20.6 The propagation of sinusoidal wave and its vector (phasor) representation

In Figure 20.6, OA represents the phasor after it has rotated through an angle θ, equivalent to ωt, from its initial position when the emf was at its zero value. The projection of OA on the Y-axis, denoted as OB, equals OA multiplied by sin θ, which is equivalent to Emax sin ωt, representing the instantaneous value of the emf, denoted as 'e,' at that particular moment. Therefore, the projection of OA on the vertical axis accurately portrays, to scale, the instantaneous value of the emf.

Self-Assessment Questions:

1. Explain the concept of reactance in AC circuits and how it differs from resistance.
2. How does the phase angle affect the relationship between voltage and current in AC circuits?

20.2 AC through a resistor

Consider a circuit comprising a pure resistor (R) connected to an alternating voltage source, as depicted in figure 20.7(a).

The alternating voltage induces oscillatory motion of free electrons within the resistor, constituting the alternating current. At any given time 't,' the potential difference across the resistor's terminals is expressed as

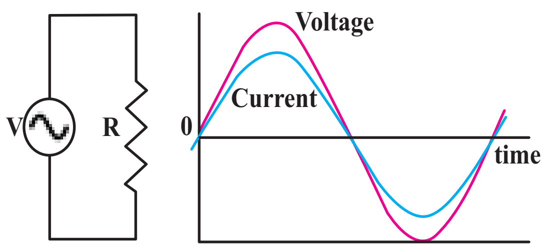


Figure 20.7(a) resistor connected to an AC source and 20.7(b)the voltage and current wave are in a phase

$$V = V_0 sin\omega t$$

where V_0 signifies the peak value of the alternating voltage. The circuit's current (I) is governed by Ohm's law: $I = \frac{V}{R} = \frac{V_0}{R}\, Sin\omega t$

Or $I = I_0 Sin\omega t$…………….. (20.3)

The current achieves its maximum value when $Sin\omega t = 1$. From equations (20.2) and (20.3), it is evident that the applied voltage and the current in the circuit are in phase with each other as shown in figure 20.7 (b). This phase relationship is further illustrated by the phasor diagram as shown in figure 20.8.

20.2.3 Phasor diagram of Resistive circuit

The current I_R flowing through a resistor R is in phase with the voltage V_R across the resistor. This alignment can be visually represented on a phasor diagram by depicting a vector (I_R) that coincides with the voltage (V_R)

The power loss in a resistor in an AC circuit is a result of the conversion of electrical energy into heat due to the resistance of the resistor. The instantaneous power in the resistance is can be expressed using the formula

$P = I^2R$…… (20.4)

$P = V_{rms}I_{rms}$…….. (20.5)

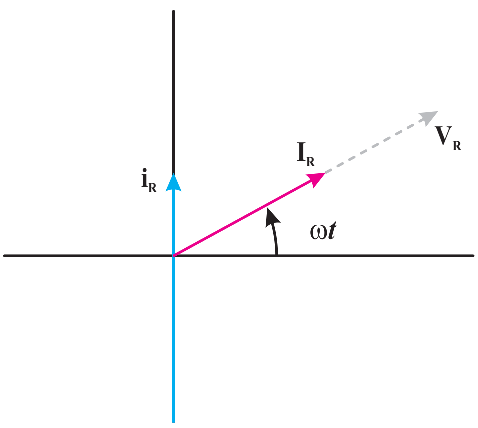


Figure 20.8 phasor diagram of resistive circuit

Worked Example 20.2

A 200Ω resistor is connected with AC supply of 36V with frequency 60 Hz. Calculate
(i) Current flowing through the circuit
(ii) Power dissipated in the resistor.
(iii) Also write equation for current and voltage as a function of time.

Solution:

Step 1: Write the known quantities and point out quantities to be found

$R = 20\Omega$
$V = 36\ Volts$
$f = 60\ Hz$

Step 2: Write the formula and rearrange if necessary

$$I = \frac{V}{R} = \frac{36}{200} = 0.180A$$

Step 3: Power dissipation can be calculate using equation

P = VI = 36 × 0.180 = 6.48 w
We know that ω = 2πf = 2 × 3.14 × 60 = 376.8 Hz
From equations (2) and (3)
$V = V_0 \sin\omega t$
$I = I_0 \sin\omega t$

Step 4: Substituting values of V, I and ω in above equations, we get

V = 36 sin376t
I = 0.180 Sin376t

20.3.1 A.C through capacitors:

When capacitor is connected to a direct current (DC) supply voltage, then capacitor plates gradually accumulate charge until the voltage across the capacitor matches with the source voltage. The capacitor retains this charge as a temporary storage device as long as the applied voltage is sustained. The ability of a capacitor to store charge on its plates is termed capacitance (C)

During the charging process, an electric current flow into the capacitor, causing its plates to acquire an electrostatic charge. This charging current is highest when the capacitor plates are uncharged, decreasing exponentially over time until the capacitor reaches full charge. Once the capacitor is fully charged, it blocks further electron flow onto its plates as they become saturated. Hence it is often said that capacitor blocks direct current after initial transient time.

Now consider a capacitor connected to the AC source as shown in figure 20.9. during the positive half cycle of alternating voltage, the electrons flow from upper capacitor plate to

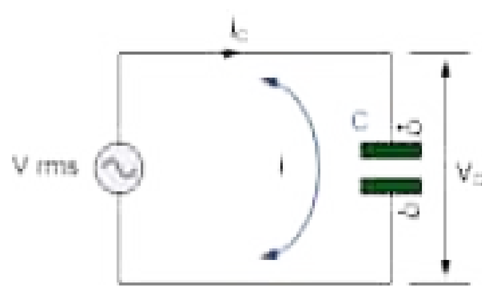


Figure 20.9 capacitor connected to the AC source

the source leaving it as positively charged +Q and source supplies equal number of electrons to the lower plate making it as negatively charged –Q as shown in figure 20.9. During the negative half cycle of alternating voltage, the direction of motion of electrons is also reverted resulting in the capacitor plates becoming charged in the opposite manner and current flows in opposite direction, hence capacitor charges and discharges. In this way the alternating current flows through the capacitor.

If alternating source voltage $V = V_0 sin\omega t$ is applied to the capacitor the charge on any plate of capacitor is given by

$q = CV = CV_0 Sin\omega t$………. (20.6)

From equation (20.6) it is clear that q and V are in phase. Due to the applied current flows through the capacitor as given by

$$I = \frac{\Delta q}{\Delta t} \text{…………… (20.7)}$$

Substitute equation (20.6) in (20.7), we get

$$I = \frac{CV_0 \Delta Sin\omega t}{\Delta t} \quad \text{OR} \quad I = CV_0 \omega Cos\omega t \text{……….. (20.8)}$$

Multiply and divide right side of equation (20.8) by ωc

$$I = \frac{V_0 Sin(\omega t + \frac{\pi}{2})}{1/\omega c}$$

$$I = I_0\, Sin(\omega t + \frac{\pi}{2}) \text{ ……. (20.9)}$$

Equation (20.9) shows that in pure capacitive circuit the current exhibits sinusoidal variation and it leads the voltage by 90 degrees or $\frac{\pi}{2}$ radians or the voltage lags the current by 90 degrees or $\frac{\pi}{2}$ radians as shown in figure 20.10.

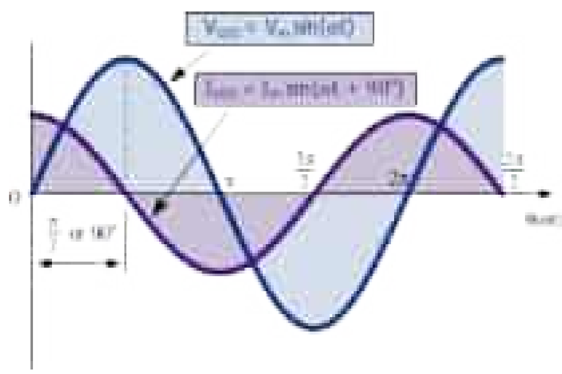


Figure 20.10 Pure capacitive circuit the current varies sinusoidally and leads the voltage by 90 degrees.

The reason is that when a voltage is introduced to an initially uncharged capacitor, the capacitor exhibits low impedance, resulting in the maximum current draw. As the capacitor becomes charged, the current diminishes, causing the voltage across the capacitor to increase. Once the capacitor is fully charged, there is no further current flow, and the voltage attains its maximum level, hence voltage lags the current by 90^0.

20.3.2 Reactance of Capacitor:

In a purely capacitive circuit, capacitive reactance represents the opposition to alternating current flow. Similar to resistance, reactance is measured in Ohms, but it is denoted by the symbol Xc to differentiate it from purely resistive values.

From equations (9), we get

$I = \frac{V_0}{1/\omega c}$……….. (20.10)

Similar to ohms law the term in denominator of equation (20.10) represents the opposition to flow of current; in this case it is called reactance of capacitor.

Hence

$$X_c = \frac{1}{\omega c} \text{.......... (20.11)}$$

Since $\omega = 2\pi f$ so

$$X_c = \frac{1}{2\pi f c}$$

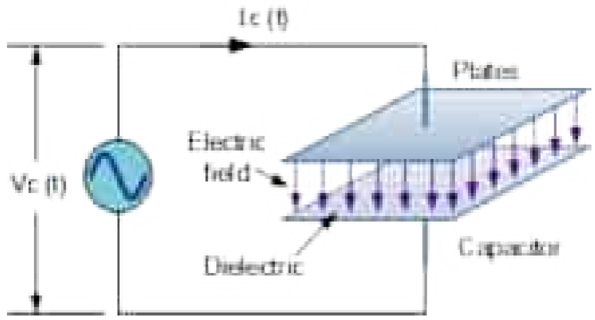


Figure 20.11 Reactance of Capacitor

The capacitive reactance shows an inverse relationship with the frequency of the applied alternating voltage. Consequently, for lower frequencies, the reactance of capacitor increases, while at high frequencies, the reactance decreases.

20.3.3 Phasor diagram of capacitive circuit:

As mentioned in section 20.3 that in an AC circuit, a capacitor experiences a phase shift between the voltage across it and the current flowing through it. The phasor diagram is a graphical tool that illustrates the relationship between voltage and current in a capacitor using vectors, known as phasor. In the phasor diagram shown in Figure 20.12, V represents the voltage across the capacitor, while I denote the current flowing through it. The angle $\emptyset = 90^o$ indicates the phase angle by which the current leads the voltage in a capacitor.

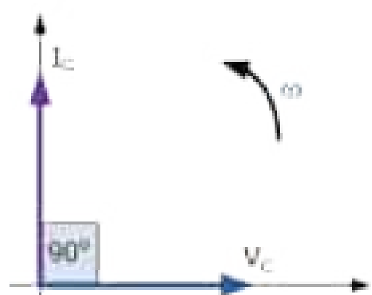


Figure 20.12 Phasor diagram of capacitive circuit

Self-Assessment Questions:

1. Why is the root mean square (RMS) value used to represent AC voltage and current instead of instantaneous peak values?
2. How does the phase angle affect the relationship between voltage and current in AC circuits?

Worked Example 20.3

A 200Ω resistor is connected with AC supply of 36V with frequency 60 Hz. Calculate

(i) Current flowing through the circuit (ii) Power dissipated in the resistor.

(iii) Also write equation for current and voltage as a function of time.

Solution:

Step 1: Write the known quantities and point out quantities to be found

R = 200Ω

V = 36 Volts

f = 60 Hz

Step 2: Write the formula and rearrange if necessary

$$X_c = \frac{1}{2\pi f c}, \quad I_{rms} = \frac{V_{rms}}{X_c}$$

Step 3: Now, calculate the current: =

$X_c = 1/2\pi fc = 1/\ (2\times3.14\times50\times10\times10\ \hat{}\ (-6)) = 3183.1\ \Omega$

$I_{rms} = V_{rms}/X_c = 220/3183.1 = 0.069A$

Step 3: First calculate the maximum current and voltage by using

$I_0 = \sqrt{2}I = 0.097A$

$V_0 = \sqrt{2}\ V = 311.1$

$V = 311.1\ Sin\ (314\ t)$

$I = 0.097\ Sin\ (314\ t + \pi/2)$

20.4 A.C through inductor:

An inductor is a passive electrical component which can be formed by wounding a conducting wire over an insulating object, such as pencil. The primary purpose of an inductor is to oppose changes in current. It resists the flow of alternating current (AC) and stores energy in its magnetic field during the on-time of the AC cycle and releases it during the off-time. Solenoid is an example of inductor.

Consider an inductor in form of solenoid connected with A.C source as shown in figure 20.13.

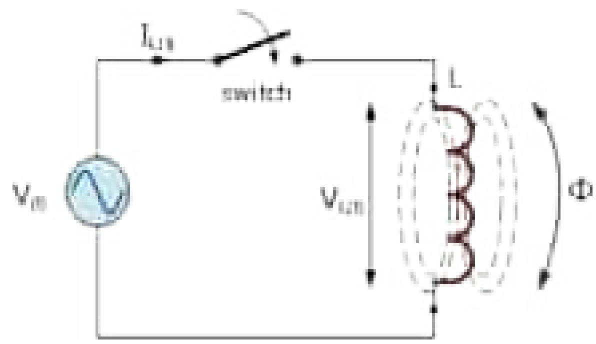


Figure 20. 13 A.C through inductor.

When the switch is closed current start to flow through the inductor, notice that the magnitude and direction of current is changing hence associated magnetic field also varies due to which an induced emf is set up in the inductor so as to oppose the change in accordance with the Lenz law. The magnitude of induced emf is given by

$$\varepsilon = L\frac{\Delta I}{\Delta t}$$

Therefore, to sustain the current, the applied voltage must match the back electromotive force (EMF). Thus, the magnitude of voltage supplied to the coil is expressed as

$V = L\frac{\Delta I}{\Delta t}$............ (20.12)

The alternating voltage produces a sinusoidal current given by

$$I = I_0 Sin\omega t$$

Hence equation (20.12) becomes

$V = L\frac{I_0 \Delta sin\omega t}{\Delta t}$ Or

$$V = \omega L I_0\ Cos\omega t$$

Where $\omega L I_0 = V_0$

$$V = V_0\ Cos\omega t............ (20.13)$$

Using that $Cos\omega t = Sin\ (\omega t + \frac{\pi}{2})$, equation (13) becomes

$V = V_0\ Sin\ (\omega t + \frac{\pi}{2})$........ (20.14)

From equation (20.14) it is clear that in case of inductor connected in A.C circuit the voltage leads the current by $\frac{\pi}{2}$ radians as shown in figure 20.14.

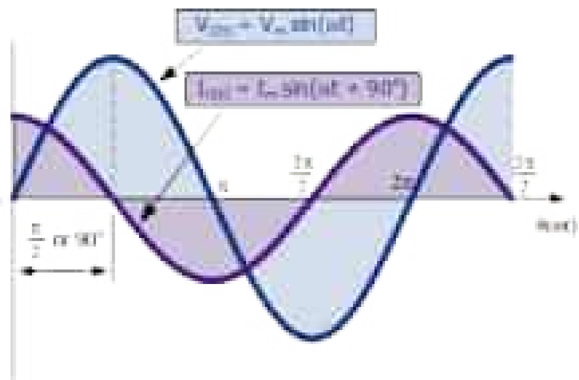


Figure 20.14 Voltage leads current by 90

The reason for voltage leading in an inductive circuit is due to the generation of induced electromotive force (EMF), commonly known as back EMF, when an alternating voltage is applied to the inductor. This back EMF appears instantaneously and induces a counter-current flow, introducing a time delay, typically in the order of milliseconds. As a result, there is a brief time lag for the circuit current to overcome this opposing current and attain its maximum value. That is why the voltage manifests first followed by the appearance of the current after a short interval. Hence the voltage leads the current or the current lags behind the voltage in an inductive AC circuit, draw $I_L$behind $V_L$by a phase angle of 90 degrees as shown by phasor diagram in figure 20.15.

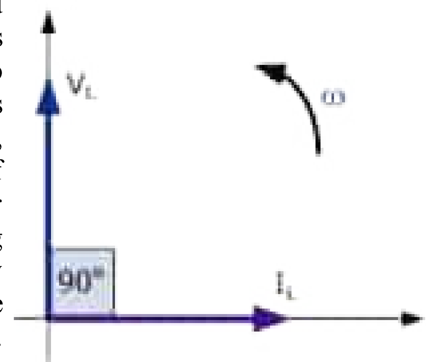


Figure 20.15
Phasor diagram of inductive circuit

Choke coil:

A choke coil, commonly known as choke, is an inductor used in electronic circuits. It is used to block high frequencies above a certain frequency, while allowing the direct current to pass through. It is formed within a core shaped like a donut, around which an insulated coil is wound as shown in figure 20.16. This important electrical component is only used in A.C circuits. Its ability to impede changes in current makes it valuable in applications where a smooth and noise-free DC signal is required. Choke coils find applications in various electronic devices, including power supplies for audio amplifiers, radio frequency (RF) circuits, and other electronic systems where filtering and noise suppression are essential.

Figure 20.16 Chock coil

20.4.1 Inductive Reactance:

The term inductive reactance refers to the opposition that an inductor offers to the flow of alternating current. It is denoted by X_L. It is measured in ohms. The inductive reactance can be calculated by following the method as described in section 20.3.1.

The formula for inductive reactance is given by:

$X_L = \omega L$Or $X_L = 2\pi f L$............ (20.15)

where: X_L is the inductive reactance,

f is the frequency of the AC signal,

L is the inductance of the inductor.

Equation (20.15) shows that inductive reactance is directly proportional to the frequency of the AC signal. As the frequency increases, the inductive reactance also increases.

Worked Example 20.4

Suppose we have an inductor in form of a coil with an inductance of 0.02henries (H) and connected in series with an AC signal having frequency of 50 Hz. Calculate the inductive reactance of coil.

Solution:

Step 1: Write the known quantities and point out quantities to be found

$L = 0.02H$

$f = 50Hz$

$X_L = ?$

Step 2: Write the formula and rearrange if necessary

$$X_L = 2\pi f L$$

Step 3: Substituting the give values in formula, we get

$X_L = 2 \times 3.14 \times 50 \times 0.02$

$X_L = 6.28\ \Omega$

20.5 RLC Circuits:

An RLC circuit is an electrical circuit consisting of a resistor (R), inductor (L), and capacitor (C), connected in series or parallel. RLC circuits are fundamental in electronics for filtering signals, tuning circuits, and resonant applications due to their ability to manipulate frequencies and impedance.

Impedance triangle:

A circuit containing resistor, inductor and capacitor offer opposition to flow of current due to all these circuit elements known as impedance. It is denoted by Z. The impedance triangle is shown in figure 20.17.

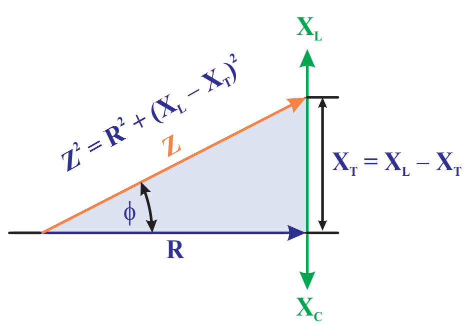


Figure 20.17 impedance triangle

To draw an impedance triangle, represent the resistance (R) as the horizontal side of the triangle.

Represent the inductive reactance (X_L) or capacitive reactance (X_C) as the vertical side of the triangle. The direction (up or down) depends on whether it's inductive or capacitive reactance.

Now the hypotenuse of the triangle represents the impedance (Z). From the right-angle triangle impedance can be calculated by using following relation

$Z = \sqrt{R^2 + X_T^2}$.......... (20.16)

Where Z is impedance, R is resistance in a circuit and $X_T^2$is sum of capacitive and inductive reactance of circuit

20.5.1 AC through RC Series circuits:

Consider a circuit containing resistor and capacitor connected in series with an alternating voltage source as shown in figure 20. 16. Due to series circuit same current will flow through each circuit element. While voltage across resistor will be V_R and V_c across capacitor.

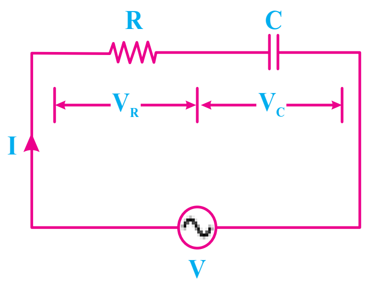


Figure 20.18 RC series circuit

The phasor diagram is drawn taking current as reference direction as shown in figure 20.18. As discussed in section 20.3.3 the voltage lags the current by $\frac{\pi}{2}$ radians in case of capacitor so it is drawn perpendicular to the current phasor in figure 20.19. In RC series circuit the voltage and current are in phase when considering resistor component of circuit.

From the phasor diagram, using pythagoras theorem

$$V = \sqrt{V_R^2 + V_c^2} \ldots\ldots. (20.17)$$

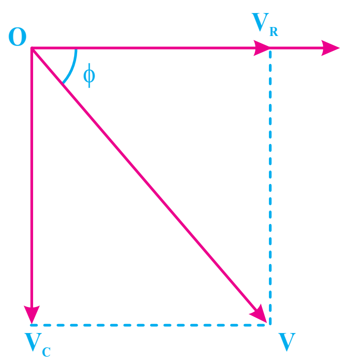


Figure 20.19
Phasor diagram of RC series circuit

Substituting volatage across resistor = IR and across capacitor =IXc in eqaution (16), we get

$$V = I\sqrt{R^2 + X_c^2} \ldots\ldots. (20.18)$$

Comparing eqations (20.16) and (20.18), we find that qauntity $\sqrt{R^2 + X_c^2}$ represents the impedence of RC series circuit. $Z = \sqrt{R^2 + X_c^2}$

Phase angle between current and voltage as shown in figure 20.19 is calculated by

$$tan\emptyset = \frac{V_c}{V_R} = \frac{X_c}{R} \qquad \text{Or} \quad \emptyset = tan^{-1}(\frac{X_c}{R})$$

20.5.2 AC through RL Series circuits:

Next in order to calculate the impedence of RL series circuit, consider a circuit containing indcutor and resistor connected in series with an alteranting voltage as shown in figure 20.20(a). The volatge across resistor and indcuitor in V_R and V_L respectively.

As discussed in section 20.3.6 when an indcutor is connected with alternating voltage then due to generation of back EMF current lag the voltage by 90^0 it is repredented by line perpendciular to the refereence phasor i-e current I as shown in fgiure 20.20(b). Also as discussed in section 20.31 in resisitor the current and voltage are in phase. In phasor diagram it is V_R line.

To calculate the impedance of RL circuit, apply pythagoras theorem on phasor diagram from figure 20.18 (b)

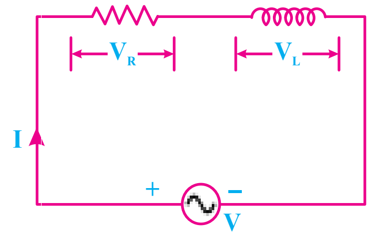


Figure 20.20 (a) Inductor and resistor connected in series

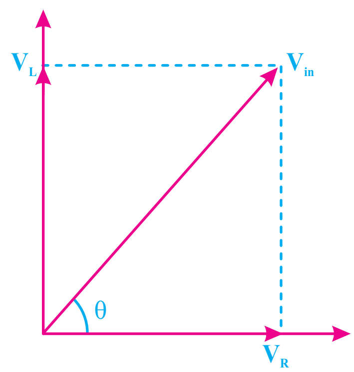


Figure 20.20 (a) Inductor and resistor connected in series

$$V = I\sqrt{R^2 + L_c^2}$$

Where $Z = \sqrt{R^2 + L_c^2}$ represents the impedance of the RL circuit.

Phase angle between current and voltage as shown in figure 20.20(b) is calculated by

$tan\emptyset = \frac{X_L}{R}$ Or $\emptyset = tan^{-1}\left(\frac{X_L}{R}\right)$

Worked Example 20.5

In RC circuit a capacitor of 50μF and resistor of 100 Ω are connected in series with alternating voltage source of 220V and frequency of 50Hz. Find the (a) current in the circuit (b) phase angle between voltage and current.

Solution:

Step 1: Write the known quantities and point out quantities to be found

$C = 50\times10^{-6}F$ $R = 100\ \Omega$, $V = 220Volts$, $f = 50Hz$

Step 2: Write the formula and rearrange if necessary

$$X_c = \frac{1}{2\pi fc} =$$

Step 3: Substituting the give values in formula, we get

$The\ capacitive\ reactance = X_c = \frac{1}{2\pi fc} = \frac{1}{6.28\times50\times50\times10^{-6}} = 636.9H$

$Impedance = Z = \sqrt{R^2 + X_c^2} = \sqrt{100^2 + 636.9^2} = 644.7\Omega$

$Current = I_{rms} = \frac{V_{rms}}{Z} = \frac{220}{636.9} = 345mA$

$Phase\ angle = \emptyset = tan^{-1}\left(\frac{X_c}{R}\right) = tan^{-1}\left(\frac{636.9}{100}\right) = 81.04^0$

20.5.3 RLC Series AC Circuit:

An RLC series circuit consists of a resistor (R), inductor (L), and capacitor (C) connected in series to an AC voltage source as shown in figure 20.21. In such a circuit, the electrical components influence the behavior of the current flowing through the circuit.

Since all three circuit elements are connected in series so same current will flow through them. Hence to analyze the different properties of circuit we draw a phasor diagram of RLC series circuit as shown in figure 20.22.

In section 20.4 and 20.5 the capacitive and reactance were determined as $X_c = \frac{1}{2\pi fc}$ and $X_L = 2\pi fL$. for smaller frequency capacitive reactance is much greater than inductive reactance i-e $X_C > X_L$ causing the circuit to exhibit behavior akin to an RC circuit. For larger frequency inductive reactance dominates over capacitive reactance i-e $X_L > X_C$ and circuit behaves like an RL circuit. Hence the circuit is said to be more inductive than capacitive.

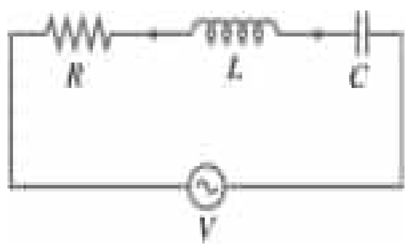


Figure 20.21 RLC Series AC circuit

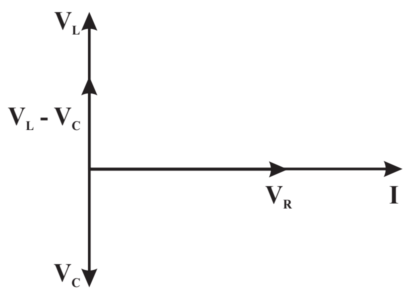


Figure 20.22
Phasor diagram of RLC series circuit

20.5.4 Power in A.C Circuits:

The calculation of power dissipation in a resistor involves the formula $P = VI$. However, this equation is not applicable in circuits where capacitors and inductors are connected to an alternating voltage source. The reason being that in a purely resistive circuit, the current and voltage are in phase. Whereas circuits containing capacitive or inductive elements exhibit a lead or lag of $\frac{\pi}{2}$ radians between the current and voltage, respectively, disrupting the applicability of this relationship. Therefore, in such a cases to determine power dissipation, project V onto the direction of referenece current phasor as shown in figure 20.18 (b). This approach ensures that the applied voltage is in phase with the current. Hence power dissipation in AC circuit is expressed as follows

$$P = VIcos\theta$$

where$cos\theta$ represents power factor.

Worked Example 20.6

A resistor (R) of 10 Ω and an inductor (L) of 0.05 H are connected in series. The AC voltage source has a peak voltage of 100 V and a frequency of 50 Hz.

Find:

1. The impedance of the circuit.
2. The RMS current through the circuit.
3. The average power consumed by the circuit

Solution:

Step 1: Write the known quantities and point out quantities to be found

R=10 Ω

L=0.05 H

V_{peak}= 100V

f= 50 Hz.

Step 1: Impedance of the Circuit (Z):

$X_l = \omega_L = 2\pi f L = 2\pi \times 50 \times 0.05 = 15.7\ \Omega$

$$Z = \sqrt{R^2 + X_L^2} = \sqrt{10^2 + 15.7^2} = \sqrt{100 + 246.49} = \sqrt{346.49} = 18.6\Omega$$

Step 2: RMS Current (I):

$$V_{RMS} = \frac{V_{peak}}{\sqrt{2}} = \frac{100}{\sqrt{2}} = 70.7V$$

$$I_{RMS} = \frac{V_{RMS}}{\sqrt{2}} = \frac{70.7}{18.6} = 3.8A$$

Step 3: Average Power (P):

$$P = V_{RMS} \times I_{RMS} \times \cos\phi$$

$$\text{Where } \cos\phi = \frac{R}{Z} = \frac{10}{18.6} = 0.54$$

$$P = 70.7 \times 3.8 \times 0.54 = 145W$$

Self-Assessment Questions:

1. Compare and contrast the flow of AC through resistors versus capacitors in terms of phase shift.
2. Describe the conditions under which maximum power transfer occurs between a source and a load in an AC circuit.

20.5.5 Resonant Frequency:

For a certain frequency the capacitive and inductive reactance becomes equal, $X_C = X_L$. This frequency is called resonant frequency f_r and circuit is said to be in resonance state. To calculate the resonant frequency, use the fact that

$$X_C = X_L$$

$$\frac{1}{2\pi f c} = 2\pi f L \text{ or } f_r = \frac{1}{2\pi\sqrt{LC}} \ldots\ldots (20.19)$$

From figure 20.23 note that X_C and X_L are in opposite direction. Therefore, at resonant frequency they cancel each effect in circuit. Now opposition to the current flow is solely offered by

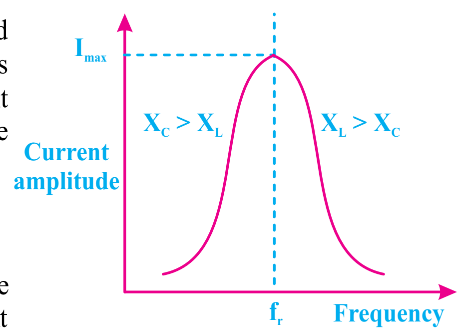


Figure 20.23 the resonant frequency

resistor, resulting in maximum current to flow through the circuit, moreover either side of resonant frequency the current in the circuit decreases, as shown in figure 20.23. RLC series circuit is an important circuit it is used in; Electronic filters, Electromagnetic Interference (EMI) Suppression, Tuned Circuits, etc

20.5.6 Parallel RL Circuit:

In some respects the circuit of figure 20.24 is similar to the purely inductive parallel circuit.

For instance, applied voltage V is still the quantity which is common to both components and is therefore plotted in standard position in the phasor diagram. Also the magnitude of the individual branch currents is determined by the opposition (reactance) of the individual branches. The figure 20.25 shows a composite diagram of waveforms and phasors. Since the phasor diagram shows that the two branch currents are not in phase, it will be necessary to use phasor addition in order to determine the total current.

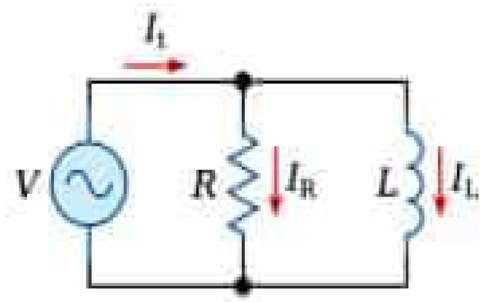


Figure 20.24 Parallel RL Circuit

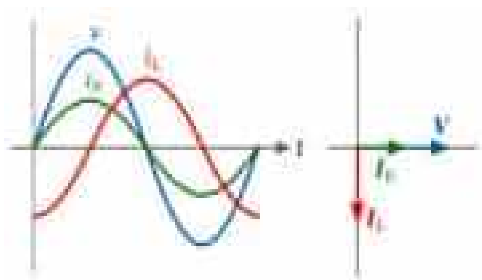


Figure 20.25 Waveforms and phasors

20.5.7 Parallel RC Circuit:

Parallel RC circuits may be resolved in much the same way as are parallel RL circuits. The figure 20.26 illustrates a parallel RC circuit.

The figure 20.27 shows a composite diagram of waveforms and phasors as per circuit conditions. The current phasors IR and IC are out of phase; therefore, phasor addition must be used to determine total current. The solving of an RC circuit follows the method previously applied to LR circuits.

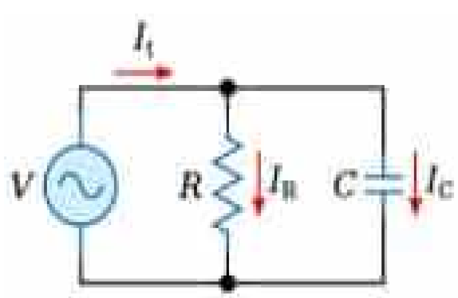


Figure 20.26 Parallel RC Circuit

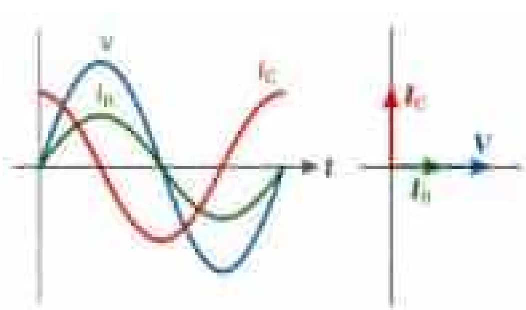


Figure 20.27 Waveforms and phasors

20.5.8 Parallel RLC AC Circuit:

A Parallel RLC AC Circuit is one where the resistor, inductor, and capacitor are connected in parallel to each other and the AC source. In this configuration, the voltage across each component is the same, but the currents through them differ. The parallel arrangement affects the overall impedance and current distribution in the circuit, making it distinct from its series counterpart. In a parallel circuit, the voltage V (RMS) across each of the three elements remains the same. Hence, for convenience, the voltage may be taken as a reference phasor.

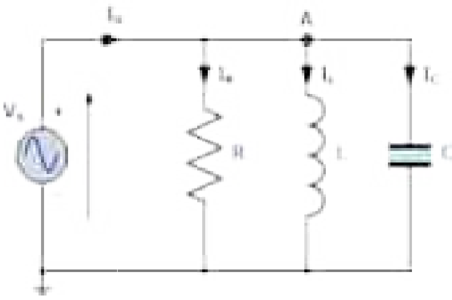


Figure 20.28 Parallel RLC AC Circuit

In the parallel RLC circuit, the supply voltage V_S is common to all three components, while the supply current I_S consists of three parts: the current through the resistor (I_R), the current through the inductor (I_L), and the current through the capacitor (I_C). The current flowing through each branch, and therefore through each component, will differ from one another and from the supply current I_S.

- The total current drawn from the supply is not simply the arithmetic sum of the three individual branch currents but their vector sum.
- Similar to the series RLC circuit, we can solve this circuit using the phasor or vector method. However, in this case, the vector diagram will use the voltage as its reference, with the three current vectors plotted relative to this reference voltage.
- The phasor diagram for an AC RLC parallel circuit is created by combining the individual phasors for each component and adding the currents vectorially.

Since the voltage across the circuit is common to all three circuit elements, we can use it as the reference vector, with the three current vectors drawn relative to this reference at their corresponding angles. The resulting vector current I_S is obtained by first adding the vectors I_L And I_C, and then adding this sum to the vector I_R. The angle between V and I_S.

20.5.9 Phasor Diagram of a Parallel RLC Circuit:

From the phasor diagram of AC RLC parallel circuit given below, we observe that the current vectors form a right triangle, with the hypotenuse represented by I_S, the horizontal axis by I_R, and the vertical axis by $I_L - I_C$. This configuration forms what is known as a Current Triangle. Consequently, we can apply Pythagoras's theorem to this current triangle to mathematically determine the individual magnitudes of the branch currents along the x-axis and y-axis. This will allow us to calculate the total supply current I_S of these components, as illustrated in figure. The circuit's phase angle is give.

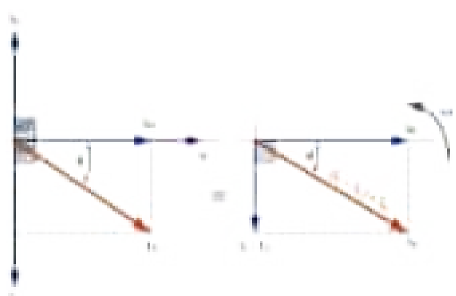


Figure 20.29 Phasor Diagram of a Parallel RLC Circuit

20.5.10 Resonance of Parallel RLC AC Circuit:

A parallel circuit containing a resistance, R, an inductance, L and a capacitance, C will produce a parallel resonance (also called anti-resonance) circuit when the resultant current through the parallel combination is in phase with the supply voltage. At resonance there will be a large circulating current between the inductor and the capacitor due to the energy of the oscillations, then parallel circuits produce current resonance.

A parallel resonant circuit stores the circuit energy in the magnetic field of the inductor and the electric field of the capacitor. This energy is constantly being transferred back and forth between the inductor and the capacitor which results in zero current and energy being drawn from the supply.

In the solution of AC parallel resonance circuits we know that the supply voltage is common for all branches, so this can be taken as our reference vector. Each parallel branch must be treated separately as with series circuits so that the total supply current taken by the parallel circuit is the vector addition of the individual branch currents.

$$I_R = \frac{V}{R}$$

$$I_L = \frac{V}{X_L} = \frac{V}{2\pi fL}$$

$$I_C = \frac{V}{X_C} = V.2\pi fC$$

Therefore, $I_T = \text{vector sum of } (I_R + I_L + I_C)$

$$I_T = \sqrt{{I_R}^2 + (I_L + I_C)^2}$$

At resonance, currents IL and IC are equal and cancelling giving a net reactive current equal to zero. Then at resonance the above equation becomes.

$$I_T = \sqrt{{I_R}^2 + (0)^2} = I_R$$

Therefore, the circuit current at this frequency will be at its minimum value of V/R and the graph of current against frequency for a parallel resonance circuit is shown in figure.

The frequency response curve of a parallel resonance circuit shows that the magnitude of the current is a function of frequency and plotting this onto a graph shows us that the response starts at its maximum value, reaches its minimum value at the resonance frequency when IMIN = IR and then increases again to maximum as f becomes infinite.

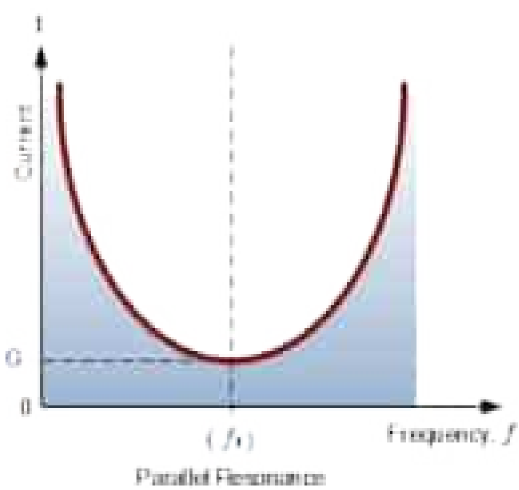


Figure 20.30 The graph of current against the frequency of parallel resonance circuit

The result of this is that the magnitude of the current flowing through the inductor, L and the capacitor, C tank circuit can become many times larger than the supply current, even at resonance but as they are equal and at opposition (180^o out-of-phase) they effectively cancel each other out.

As a parallel resonance circuit only functions on resonant frequency, this type of circuit is also known as an **Rejecter Circuit** because at resonance, the impedance of the circuit is at its maximum thereby suppressing or rejecting the current whose frequency is equal to its resonant frequency. The effect of resonance in a parallel circuit is also called "current resonance".

Self-Assessment Questions:

1. What factors determine the resonant frequency of an LC circuit?
2. How does the quality factor (Q-factor) relate to the sharpness of resonance in a circuit?

Worked Example 20.7

An inductor in for of solenoid have reactance of 500Ω is connected with alternating voltage 220V and frequency of 50 Hz. Calculate the inductive reactance of the solenoid.

Solution:

Step 1: Write the known quantities and point out quantities to be found

V = 220V,

f = 50 Hz,

$X_L = 500\Omega$

Find L =?

Step 2: Write the formula and rearrange if necessary

$$X_L = 2\pi f L$$

Step 3: Substituting the give values in formula, we get

$$L = \frac{X_L}{2\pi f} = \frac{500}{6.28 \times 50} = 1.59 Henry$$

20.5.11 Maximum Power Transfer Theorem:

According to this theorem, maximum power is transferred from a source to a load when the impedance of the source matches with the impedance of the load.

In previous sections we have discussed that impedance is a measure of the opposition a circuit presents to the flow of alternating current (AC). Impedance includes both resistance and reactance, where reactance is the opposition due to capacitance or inductance.

When the impedance of the source matches the impedance of the load, the conditions for maximum power transfer are met. Under these circumstances, the electrical energy is efficiently transferred from the source to the load, resulting in the maximum power transfer.

Mathematically, suppose R_L denotes the resistance of load and R_s is source resistance.

Since $R_L = R_s$ as shown in figure 20.31 so maximum power transfer will occur.

In practical terms, achieving maximum power transfer is often important in designing electronic circuits to optimize efficiency and minimize power loss.

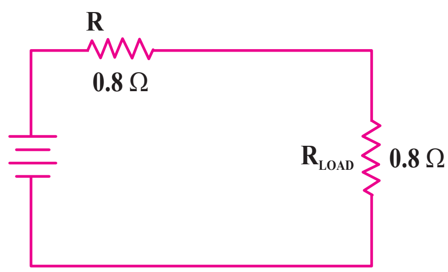


Figure 20.31 maximum power transfer

Worked Example 20.8

For an RLC circuit in parallel with a 5 Ω resistor, a 0.02 H inductor, and a 0.005 F capacitor, calculate the resonant frequency f_r?

Solution:

Step 1: Write the known quantities and point out quantities to be found

$L = 0.02H$

$C = 0.005F$

$f_r = ?$

Step 2: Write the formula and rearrange if necessary

$$f_r = \frac{1}{2\pi\sqrt{LC}}$$

Step 3: Substituting the give values in formula, we get

$$f_r = \frac{1}{2\pi\sqrt{0.02 \times 0.005}}$$

$$f_r = 15.92\ Hz$$

20.6.1 Metal Detectors:

The oscillator circuit is used in metal detectors. Metal detectors used for security checks operate on the principle of electromagnetic induction. A simplified explanation of working of metal detector is described below:

1. **Generating an Electromagnetic Field:**
   The metal detector contains a coil of wire through which an electric current flow, creating a magnetic field around the coil. This coil is often housed in a special arrangement, such as a loop or wand.
2. **Interaction with Metals:**
   When a conductive metal object is brought into the vicinity of the electromagnetic field, it disturbs the field. This disturbance induces a secondary magnetic field in the metal object.

3. **Eddy Currents:**
   The changing magnetic field induces circulating electric currents within the metal object, known as eddy currents. These eddy currents, in turn, generate their own magnetic fields.
4. **Detection of Changes:**
   The metal detector has a receiver coil or coils that are in close proximity to the transmitter coil. The receiver coil(s) detect changes in the magnetic field caused by the presence of the metal.
5. **Alert Mechanism:**
   When the metal detector senses a significant change in the magnetic field, indicating the presence of a metal object, it triggers an alert. This alert can be in the form of an audible sound, a visual signal, or both, depending on the design of the metal detector.

20.6.2 The Electrocardiograph:

The electrocardiograph (ECG) is a medical diagnostic tool used to record the electrical activity of the heart over a period of time.

Principle:

The principle behind the electrocardiograph is based on the electrical signals generated by the heart during each heartbeat.

Working:

The heart is a muscular organ that contracts rhythmically to pump blood throughout the body. This contraction is initiated and coordinated by electrical signals generated within the heart. Electrodes are attached to specific points on the skin of the patient. The standard placement involves attaching electrodes to the limbs and chest. These electrodes are conductive and are used to detect the electrical signals produced by the heart. The electrical signals produced by the heart are picked up by the electrodes. The detected electrical signals are amplified to make them more measurable and are then recorded on a graph or displayed on a monitor. The resulting graph is called an electrocardiogram. The ECG graph represents the electrical activity of the heart over time. It consists of waves and intervals, each of which corresponds to a specific phase of the cardiac cycle. Physicians analyze the ECG to gather information about the heart's rhythm, rate, and various other aspects of its electrical activity. Deviations from the normal ECG pattern can indicate cardiac abnormalities, such as arrhythmias, ischemia, or other heart conditions.

20.6.3 Oscillator Circuit:

An oscillator circuit is an electronic circuit that generates a continuous periodic signal at a specific frequency.

Oscillator circuits produce the carrier wave, which serves as the central frequency around which the information-carrying signal is modulated.

Oscillator circuits are designed to be tunable, allowing broadcasters to set the carrier frequency to a specific value. This turnability is essential for assigning unique frequencies to different radio stations, preventing interference between them. Oscillators are designed to be modulated by an information-carrying signal. In amplitude modulation, the amplitude of the carrier wave is varied according to the audio signal, while in frequency modulation; the frequency of the carrier wave is modulated. This modulation process allows the transmission of audio information. The carrier wave itself does not convey information; it serves as a medium to carry the modulated information signal. The oscillator generates a stable carrier wave, ensuring that the modulated signal can be reliably transmitted over long distances. The carrier wave, when modulated with the audio signal, forms the composite radio wave that propagates through space. This transmitted signal can be received by radio receivers tuned to the carrier frequency.

In summary, the oscillator circuit is the heartbeat of a radio transmitter, generating the carrier wave that facilitates the transmission of modulated information signals. Its stability, tunability, and modulation capabilities are pivotal for effective and interference-free radio broadcasting.

20.6.4 Resonance in Tuning circuit of Radio:

In radio tuning circuits resonance is a important phenomenon that enables the selective reception of a desired radio frequency while rejecting others.

Principle:

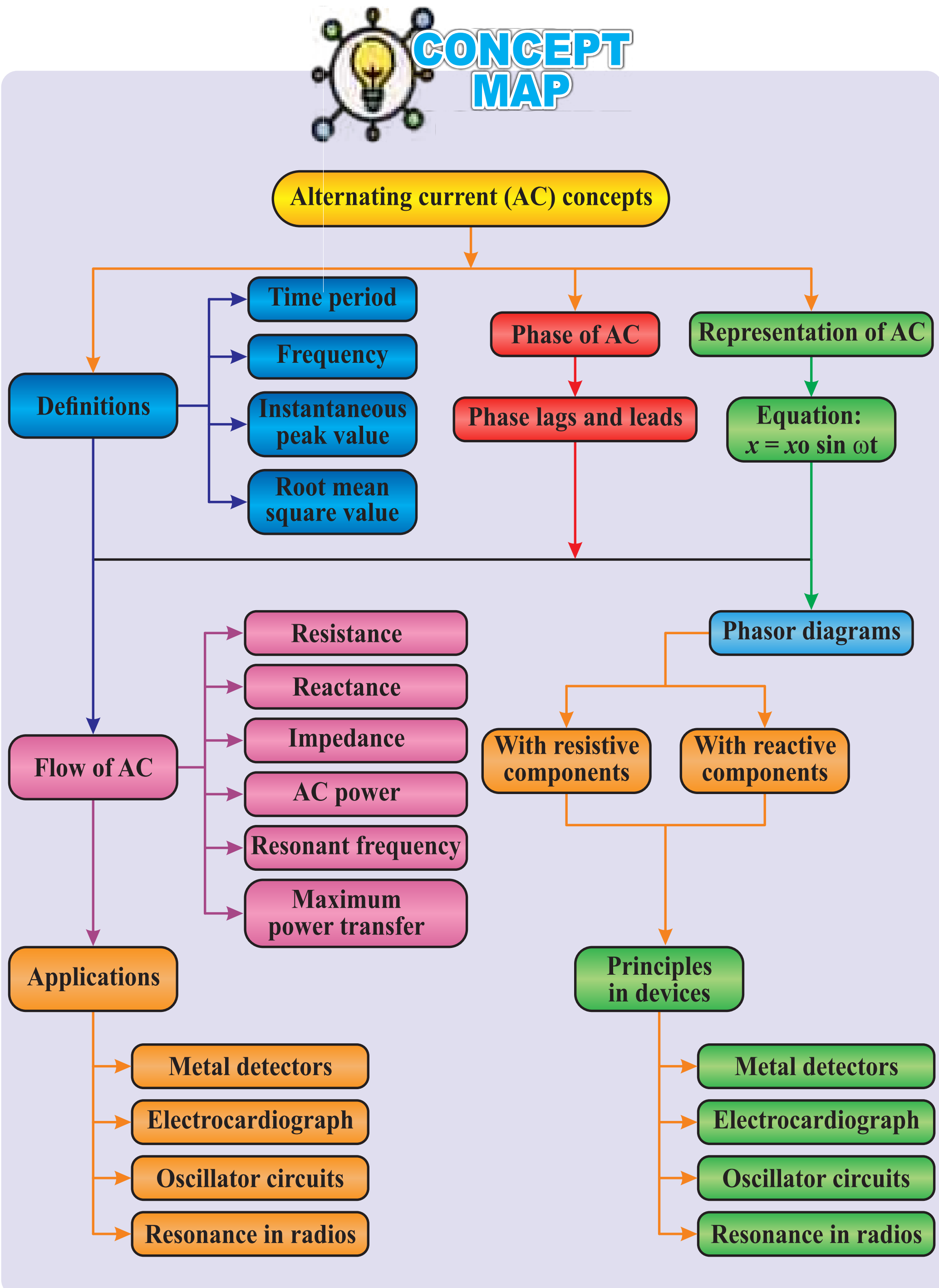
The principle of resonance is crucial in the tuning circuits of radio to enhance the reception of specific radio frequencies. Resonance occurs when the inductive and capacitive reactance in a circuit cancel each other out, resulting in a condition where the circuit efficiently absorbs energy at a particular frequency. Resonance is integral to the functioning of radio tuning circuits. It ensures that radios can selectively receive signals from desired stations with clarity and efficiency, making it possible to enjoy various broadcasted content without interference from other frequencies.

Importance of Broadcasting:

Broadcasting remains a powerful medium with far-reaching impacts on society. It informs, educates, entertains, and connects people, playing a crucial role in cultural preservation, economic development, and social cohesion. Its ability to reach a wide audience makes it an indispensable tool for communication in the modern world.

SUMMARY

- ✓ AC or alternating current refers to the electric charge flow that periodically reverses direction, typically sinusoidal.
- ✓ The frequency of AC current, determines how many times per second the AC current reverses direction.
- ✓ Root Mean Square (RMS equivalent steady DC voltage producing the same power in a resistive load as the AC voltage.
- ✓ Current and Voltage are in phase in a resistive load known as Ohm's Law for AC current as $I = \frac{V_{RMS}}{R}$
- ✓ In pure capacitive circuit the current leads the voltage by 90 degrees or $\frac{\pi}{2}$ radians
- ✓ In inductive circuit the current lags the voltage by 90 degrees or $\frac{\pi}{2}$ radians
- ✓ The combined effect of resistance and reactance in RC or RLC circuit is known as impedance
- ✓ Resonant frequency is the frequency at which an oscillating system naturally vibrates with the greatest amplitude. At resonant frequency the impedance of the system is at its minimum.
- ✓ The RLC series circuit configuration results in high impedance at resonance and a lower overall current compared to the individual component currents.
- ✓ The RLC parallel circuit configuration the components are connected in parallel branches, providing multiple current paths. At resonance, the impedance is at its minimum, allowing a higher overall current flow compared to the series circuit.
- ✓ Maximum power is transferred from a source to a load when the load impedance is equal to the source impedance.
- ✓ ECG is a medical device that records the electrical activity of the heart over time.
- ✓ Oscillator Circuit is an electronic circuit that produces a periodic, oscillating signal, often a sine wave or square wave.
- ✓ Choke Coil is an inductor used to block higher-frequency AC signals while allowing lower-frequency or DC signals to pass.
- ✓ Resonance is the condition in a circuit when the inductive reactance and capacitive reactance are equal in magnitude but opposite in phase, resulting in a maximum voltage or current at a particular frequency.


CONCEPT MAP
Alternating current (AC) concepts
Definitions
Time period
Frequency
Instantaneous peak value
Root mean square value
Phase of AC
Phase lags and leads
Representation of AC
Equation: $x = x_0 \sin \omega t$
Phasor diagrams
With resistive components
With reactive components
Principles in devices
Metal detectors
Electrocardiograph
Oscillator circuits
Resonance in radios
Flow of AC
Resistance
Reactance
Impedance
AC power
Resonant frequency
Maximum power transfer
Applications
Metal detectors
Electrocardiograph
Oscillator circuits
Resonance in radios

EXERCISE

Section (A): Multiple Choice Questions (MCQs)

Choose the correct answer:

1. In alternating current, the flow of electric charge periodically reverses direction. The term for this specific phenomenon is:
   (a) Alternation (b) Oscillation (c) Cycle (d) Resistance
2. The frequency of standard household alternating current in Pakistan is:
   (a) 50 Hz (b) 60 Hz (c) 100 Hz (d) 120 Hz
3. The parameter for measuring the rate of change of alternating current or voltage with respect to time is:
   (a) Amplitude (b) Frequency (c) Phase angle (d) Peak Voltage
4. In AC circuits, what is the phase difference between current and voltage in a purely resistive circuit?
   (a) 0^0 (b) 45^0 (c) 90^0 (d) 180^0
5. A device used to measure the root mean square (RMS) value of an AC voltage or current is:
   (a) Voltmeter (b) Oscilloscope (b) Ammeter (d) AVO meter
6. In an AC circuit. The term "reactance" represent the:
   (a) Ohmic resistance only
   (b) Resistance to DC currents only
   (c) Capacitive and inductive opposition to current flow
   (d) Total impedance, including resistance and phase angle
7. A type of a circuit characterized by equal values of resistance and reactance is:
   (a) Resistive (b) Inductive (c) Capacitive (d) Resonant
8. In an AC sine wave, the peak-to-peak voltage is:
   (a) Double the peak voltage
   (b) The difference between the peak voltage and zero
   (c) The sum of the peak voltage and zero
   (d) The difference between the positive and negative peak voltages
9. What is the power factor of a purely resistive circuit?
   (a) 0 (b) 0.5 (c) 1 (d) -1
10. The purpose of a transformer in an AC power distribution system.
    (a) To convert AC to DC (b) To step up or step down voltage
    (c) To store electrical energy (d) To regulate current flow

Section (B): CRQs (Short Answered Questions):

1. Define RMS voltage and explain its significance in AC circuits.
2. Explain the difference between peak voltage, RMS voltage, and average voltage in AC circuits.
3. Define alternating current (AC) and explain how it differs from direct current (DC).
4. Define reactance in AC circuits and differentiate between capacitive and inductive reactance.

5. Describe the behavior of capacitors and inductors in AC circuits.
6. Explain the phase relationship between voltage and current in capacitive and inductive AC loads.
7. What is resonance in AC circuits? Discuss its conditions and applications.
8. Discuss the role of transformers in AC circuits and explain how they work.
9. Explain the behavior of an RLC series circuit in terms of impedance, resonance, and phase angle.
10. Describe the operation and applications of a transformer in AC circuits.

Section (C): ERQs (Long Answered Questions):

1. Explain the concept of phasor in the context of AC voltage. How are phasors used to represent sinusoidal voltages?
2. Describe the concept of impedance in AC circuits. How does impedance differ from resistance, and what are the units of impedance?
3. How does the reactance of an inductor and a capacitor change with frequency in an AC circuit? Provide an explanation based on the fundamental formulas?
4. Discuss the concept of resonance in RLC circuits. What conditions lead to resonance, and how does it affect the behavior of the circuit?
5. Compare and contrast series and parallel resonance in RLC circuits. What are the key differences between the two resonance configurations?
6. Explain the transient response of an RLC circuit when initially connected to an AC source. What happens to the currents and voltages in the circuit?
7. Why alternating current (AC) is commonly used for long-distance power transmission?
8. Describe the purpose and function of a choke coil in AC circuits.

Section (D): Numerical:

1. A resistor (R) of 20 ohms is connected in series with a capacitor (C) of 10 μF in an AC circuit with a frequency of 50 Hz. Calculate the total impedance? **(3182 ohms)**
2. For an inductor with an inductance (L) of 0.5 H and a frequency of 100 Hz, calculate the inductive reactance? **(314.16 ohms)**
3. In an RL circuit, the resistance (R) is 30 ohms, and the inductance (L) is 0.2 H. Calculate the total impedance at a frequency of 60 Hz? **(81.1ohms)**
4. In an RC circuit, the resistance (R) is 50 ohms, and the capacitance (C) is 20 μF. Calculate the capacitive reactance? **(31.83 ohms)**
5. An AC circuit has a resistance of 40 ohms, an inductive reactance of 30 ohms, and a capacitive reactance of 20 ohms. Draw the impedance triangle and calculate the total impedance? **(41.2ohms)**
6. In a series RL circuit, the resistance (R) is 25 ohms, and the inductance (L) is 0.1 H. Calculate the phase angle and impedance at a frequency of 80 Hz? **(63.8^0, 502 ohms)**
7. In a parallel RC circuit, the resistance (R) is 60 ohms, and the capacitance (C) is 30 μF. Calculate the total current flowing through the circuit at a frequency of 120 Hz? **(60 V)**
8. In an RLC circuit, the resistance (R) is 50 ohms, the inductance (L) is 0.1 H, and the capacitance (C) is 50 μF. Calculate the resonance frequency? **(70.7Hz)**