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Basic Electrical Engineering (TEE 101)

Lecture 15: Introduction to AC circuits

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Content

This lecture covers:

- **Introduction to AC circuits**
- **Generation of AC**
- **Representation of AC signal**

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Introduction to AC Circuits

The circuits which are powered by an AC source (alternating voltage or current) are termed as AC circuits.

An alternating voltage is any voltage that varies both in magnitude and polarity with respect to time.

Similarly, an alternating current is any current that varies in both magnitude and direction

AC circuits as the name (Alternating Current) implies are simply circuits powered by an Alternating Source, either voltage or current.

Advantages of A.C.

It is economical to generate, transmit and distribute A.C.

It is convenient to convert A.C to D.C

Control of A.C can be carried out without much loss of electrical power

Level of A.C can be increased (step-up) or decreased (step-down) easily by using transformer

Transmission of A.C to long distances is carried out with minimum loss of electrical power

A.C systems can be used in more effective and efficient manner.

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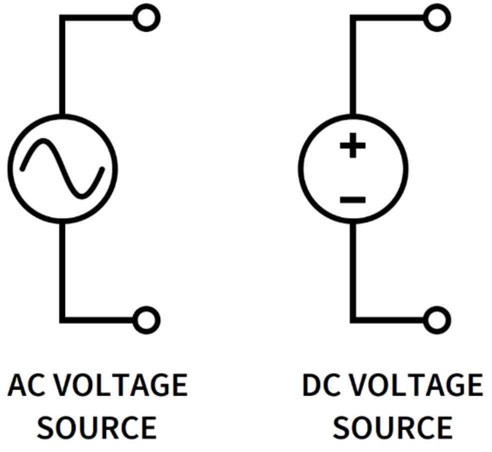
Comparison Between A.C. and D.C.

Comparison Basis	AC	DC
Energy Transmission Capacity	Travels over long distance with minimal Energy loss	Large amount of energy is lost when sent over long distances
Frequency	Usually 50Hz or 60Hz depending on Country	Frequency is Zero
Direction	Reverses direction periodically when flowing through a circuit	It steady constant flow in one direction.
Current	Its Magnitude Vary with time	Constant Magnitude
Source	All forms of AC Generators and Mains	Cells, batteries, Conversion from AC
Waveform	Sinusoidal, Trapezoidal, Triangular and Square	Straight line, sometimes Pulsating.



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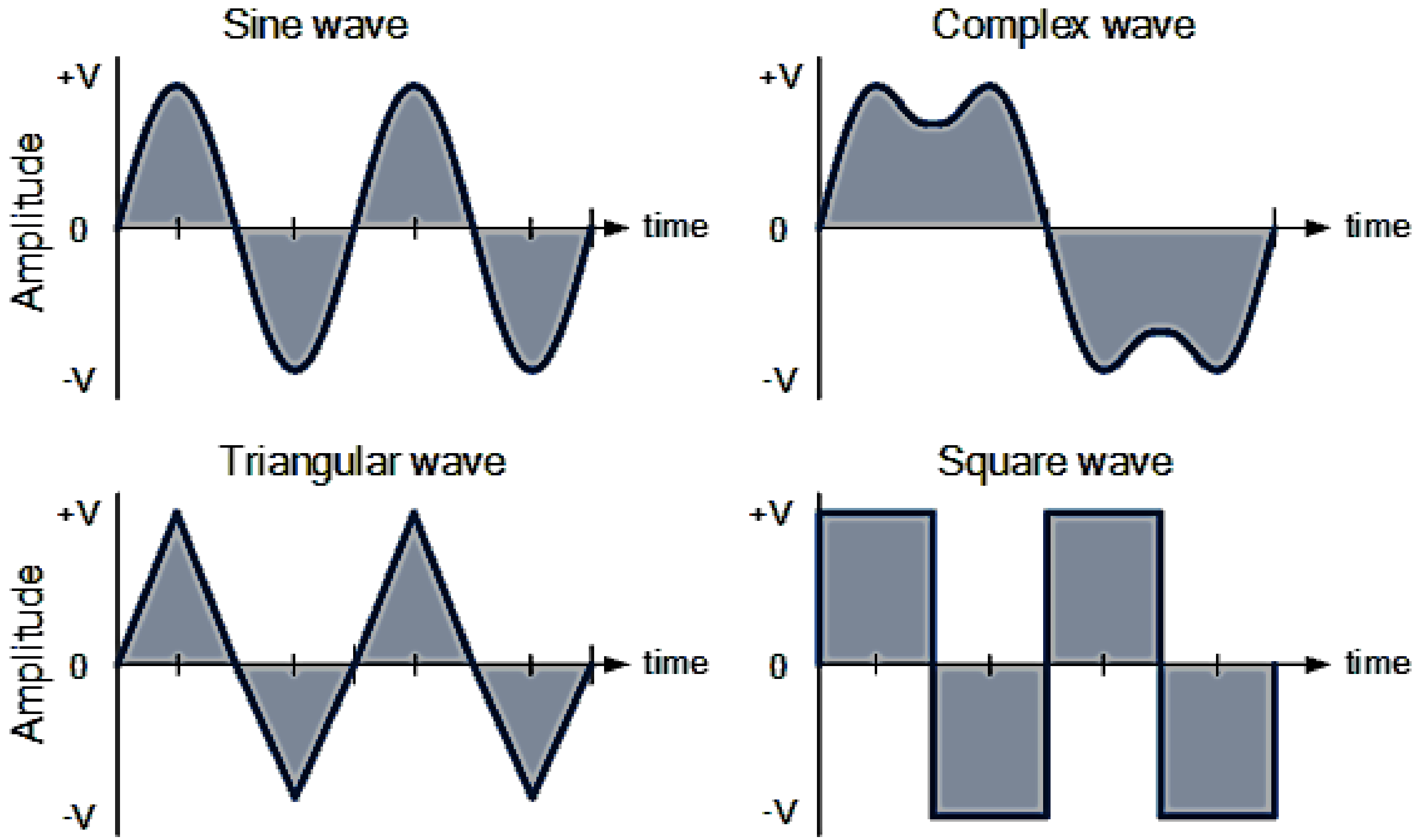
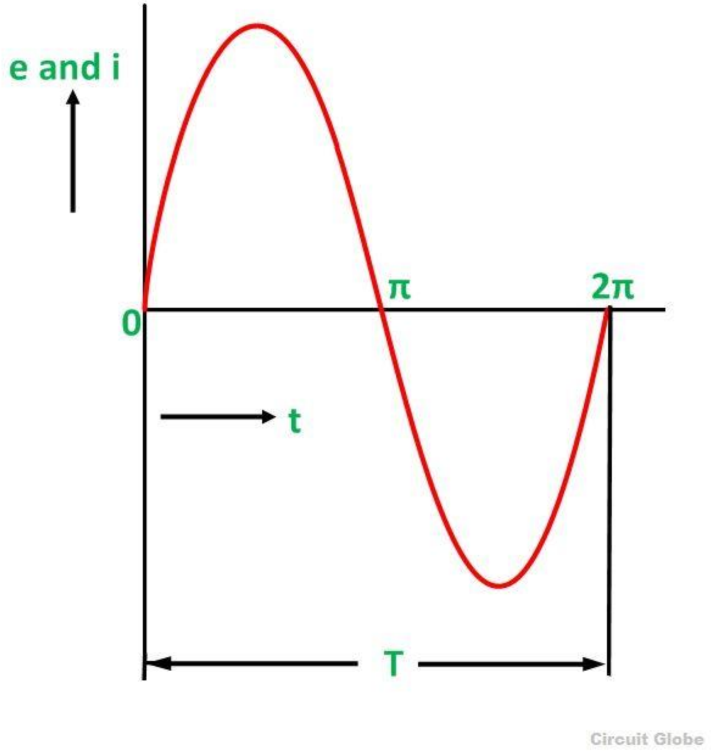
Representation of Alternating Signals

The alternating signal may be represented graphically as shown below:





Generation of Alternating Voltage

The generation of alternating voltage is based on Faraday's Law of Electromagnetic Induction

The alternating voltage is generated in two ways.

By rotating the coil inside the uniform magnetic field at constant speed (figure – a)

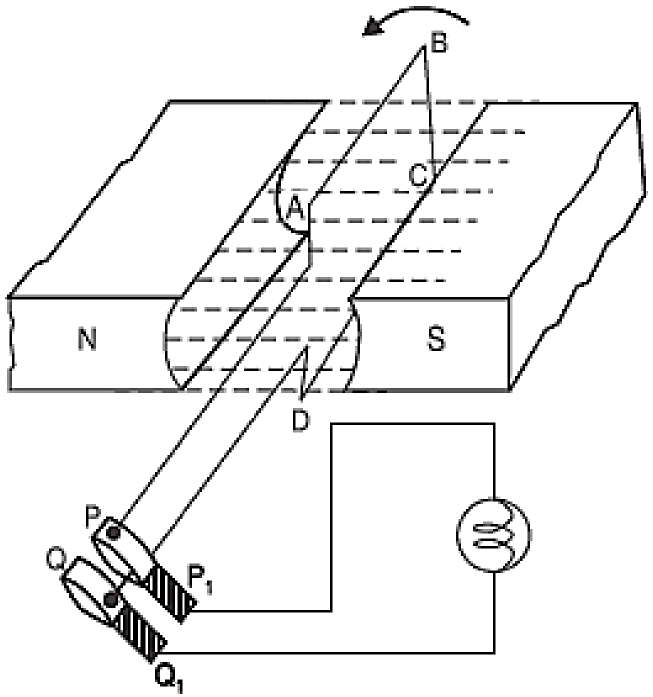
By rotating the magnetic field around the stationary coil at the constant speed (figure – b)

In either case, the generated voltage will be of sinusoidal waveform.

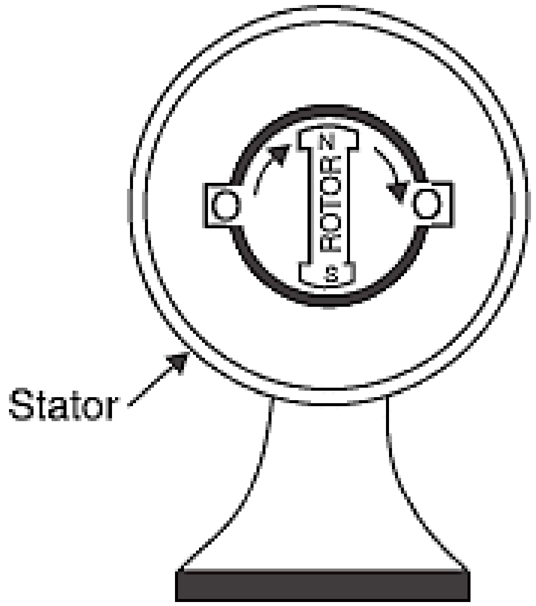
The magnitude of generated voltage will depend upon:

- **The number of turns of coil,**
- **The strength of magnetic field, and**
- **The speed of rotation.**

The first method is used for small a.c. generators while the second method is employed for large a.c. generators.



(figure – a)

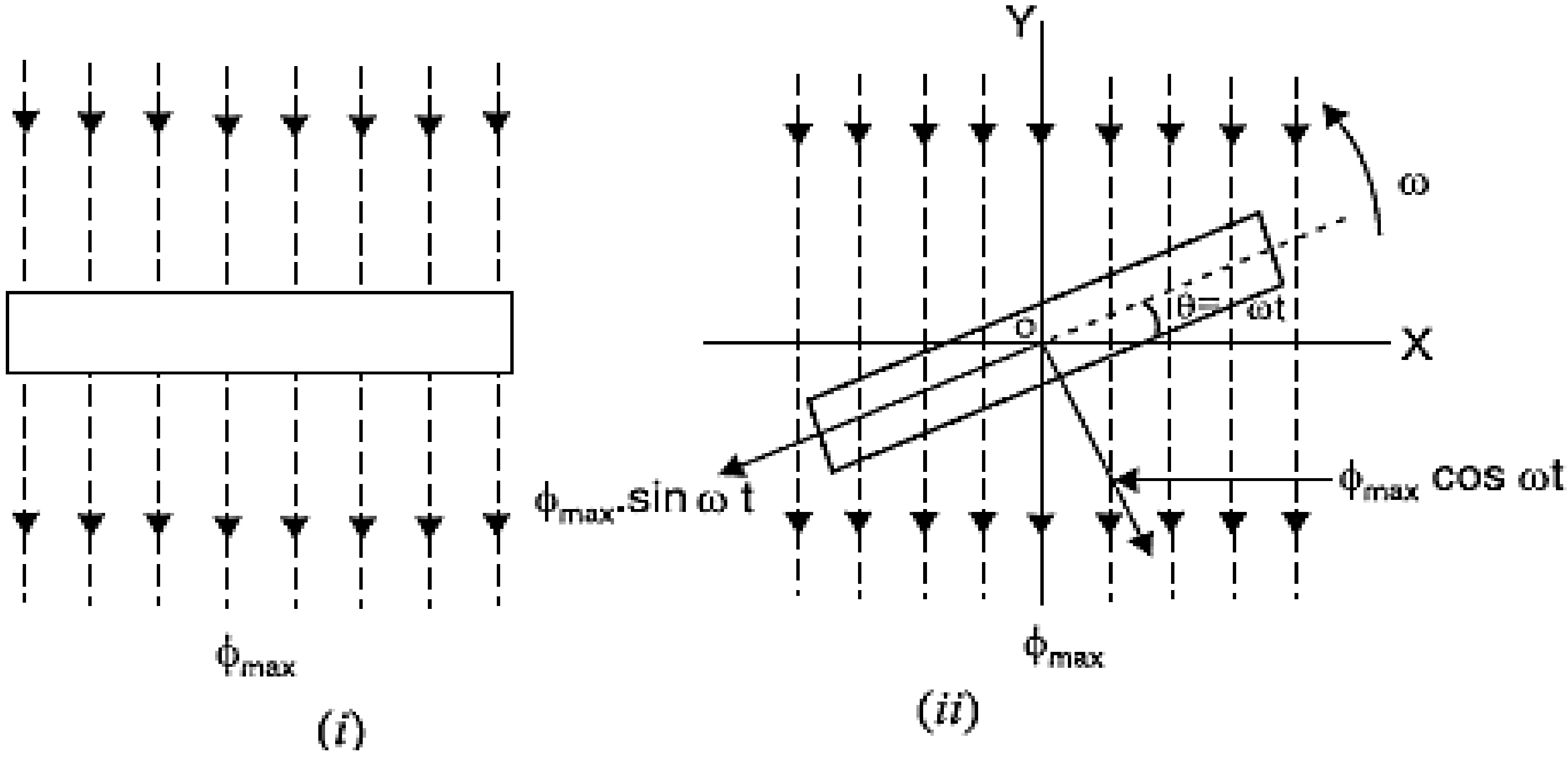


(figure – b)

Equation of Alternating Voltage and Current

Consider a rectangular coil of *n* turns rotating in anticlockwise direction with an angular velocity of ω rad/sec in a uniform magnetic field as shown in Figure below:

The e.m.f. induced in the coil will be sinusoidal. This can be readily established.



Let the time be measured from the instant the plane of the coil coincides with *OX*-axis.

In this position of the coil [See Fig. (*i*)], the flux linking with the coil has its maximum value φ_{max}.

Let the coil turn through an angle θ (= ωt) in anticlockwise direction in *t* seconds and assumes the position shown in Fig. (*ii*).

In this position, the maximum flux φ_{max} acting vertically downward can be resolved into two perpendicular components *viz.* $\varphi_{max}\cos(\omega t)$ and $\varphi_{max}\sin(\omega t)$

Component $\varphi_{max}\ sin(\omega t)$ parallel to the plane of the coil. This component induces "no e.m.f" in the coil.

Component $\varphi_{max}\ cos(\omega t)$ perpendicular to the plane of the coil. This component induces "e.m.f" in the coil.

According to Faraday's laws of electromagnetic induction, the e.m.f. induced in a coil is equal to the rate of change of flux linkages of the coil.

Hence, the e.m.f. v at the considered instant is given by :

$$v = -\frac{d}{dt}\phi(t) \qquad (1)$$

Flux linkages of the coil at the any instant
= No. of turns × Flux linking

$$\phi(t) = N\left(\phi_{\max}\cos(\omega t)\right)$$

Substituting the value of ϕ(t) in equation (1) we get,

$$v = -\frac{d}{dt}\left[N\left(\phi_{\max}\cos(\omega t)\right)\right]$$

Or, $$v = -N\phi_{\max}\left[\frac{d}{dt}\cos(\omega t)\right]$$

Or, $$v = -N\omega\phi_{\max}\left(-\sin(\omega t)\right)$$

Or, $$v = N\omega\phi_{\max}\sin(\omega t)$$

Or, $$v = N\omega\phi_{\max}\sin\theta \qquad (2)$$

At, $sin\theta = 1$, The value of v will be maximum (call it V_m).
Hence, equation (2) can be written as:

$$V_m = N\omega\phi_{\max} \qquad (3)$$

It is clear from equation (4) that e.m.f. induced in the coil is sinusoidal *i.e.*, instantaneous value of e.m.f. varies as the sine function of time angle (θ or ωt).

Equation (2) can be modified as:

$$v = V_m \sin\theta \qquad (4)$$

Thus a coil rotating with a constant angular velocity in a uniform magnetic field produces a sinusoidal alternating e.m.f.

Different Form of Sinusoidal Equation

Generally, the alternating sinusoidal voltage is expressed as:

$$v = V_m \sin \theta \qquad (1)$$

Because, $\theta = \omega t$

The equation (1) can be written as:

$$v = V_m \sin \omega t \qquad (2)$$

Now,

$$\omega = 2\pi f$$

So, $v = V_m \sin 2\pi f t \qquad (3)$

Also, f = 1/T, hence

$$v = Vm \sin \frac{2\pi}{T} t \qquad (4)$$

Similarly, an alternating current can be expressed as:

$$i = I_m \sin \theta \qquad i = I_m \sin(\omega t)$$

$$i = I_m \sin(2\pi f t) \qquad i = I_m \sin \frac{2\pi}{T} t$$

Where,

- ***"ω" is the angular frequency (in rad/sec)***
- ***"f" is the frequency (in Hz)***
- ***"T" is the time period***
- ***"t" is the total time***

Why Sine Waveform?

Although it is possible to produce alternating voltages and currents with an endless variety of waveforms (*e.g.*, square waves, triangular waves, rectangular waves etc), yet the engineers choose to adopt sine waveform.

The following are the technical and economical advantages of producing sinusoidal alternating voltages and currents :

The sine wave can be expressed in a simple mathematical form.

The sine waveform produces the least disturbance in the electrical circuit and is the smoothest and efficient waveform.

The resultant of two or more quantities, varying sinusoidally at the same frequency, is another sinusoidal quantity of the same frequency.

The rate of change of any sinusoidal quantity is also sinusoidal

The mathematical computations, connected with alternating current work, are much simpler with this waveform.

Due to above advantages, electric supply companies all over the world generate sinusoidal alternating voltages and currents.

It may be noted that alternating voltage and current mean sinusoidal alternating voltage and current unless stated otherwise.

Thank You