ELEMENTS OF ELECTRICAL ENGINEERING
Course Code : UE25EE141A/B

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ELEMENTS OF ELECTRICAL ENGINEERING

Overview of Generation, Transmission & Distribution ; Basic Terminology; Average and RMS Values of a sine wave

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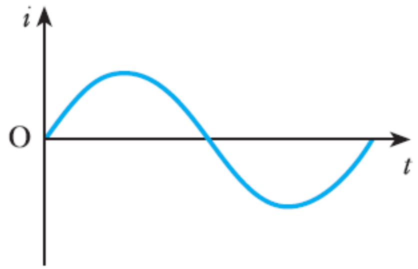
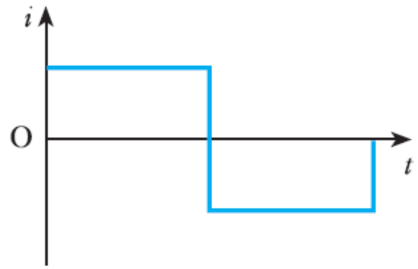
Introduction to Single Phase System

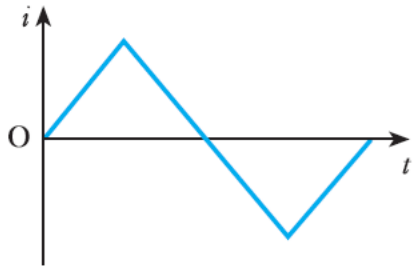
- First Power distribution system was a DC System invented by Edison
- Due to the invention of transformer, AC systems have gained popularity over DC Systems for Power Generation, Transmission and Distribution.
- AC Stands for 'Alternating Current'.
- An AC waveform is a periodic waveform which alternates.



Sinusoidal wave



Square wave



Triangular wave

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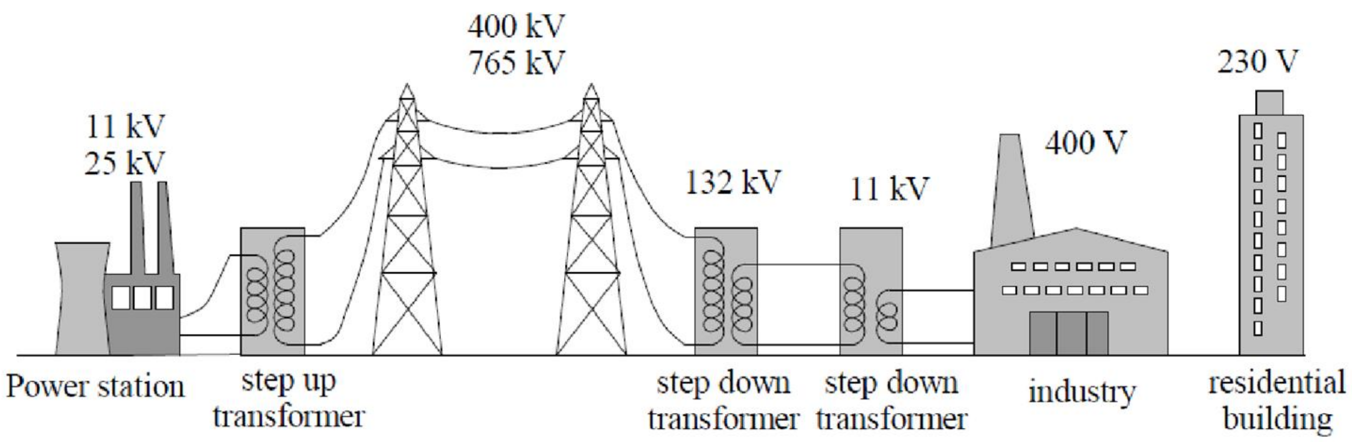
Overview of Power Systems



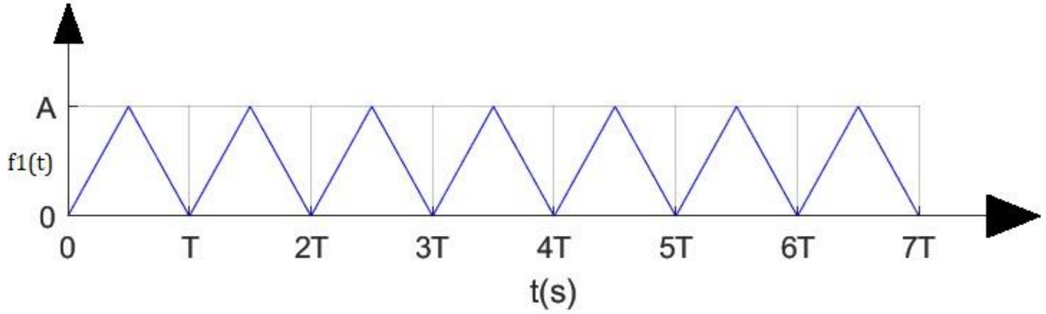
- Power Generation and Power Transmission is done as Three Phase AC Power.
- Power distribution to industries is done as Three Phase AC Power & to domestic consumers is done as Single Phase AC Power.

- **Periodic waveform**:

A periodic waveform is one which repeats itself after certain time interval.

- **Time Period(T)**:

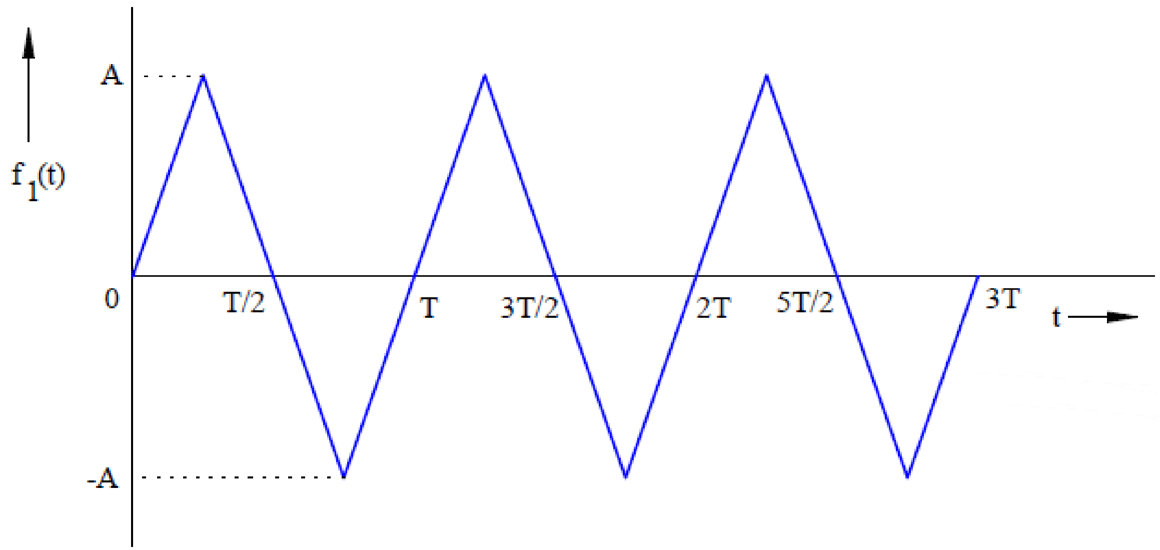
The time taken to complete one cycle of a periodic waveform. It is measured in Seconds.



- **Frequency(f):**

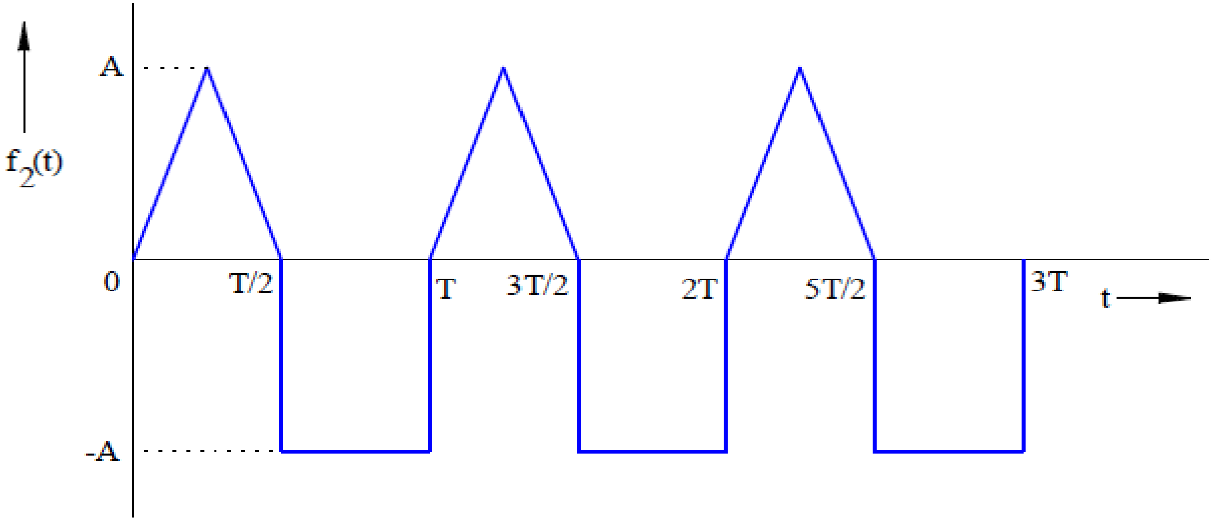
The number of cycles completed in one second of a periodic waveform . It is measured in Hz.

Concept of Pure AC waveform



- A pure AC waveform is one in which positive area is matched by equal negative area.
- Its average value is zero.
- f1(t) is a pure AC waveform

AC waveform with DC Component



- Positive Area is not matched by equal Negative Area

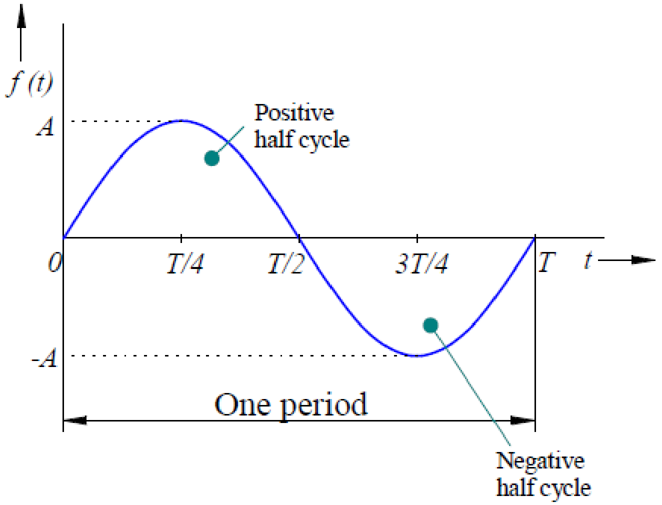
Hence, Average Value is Finite

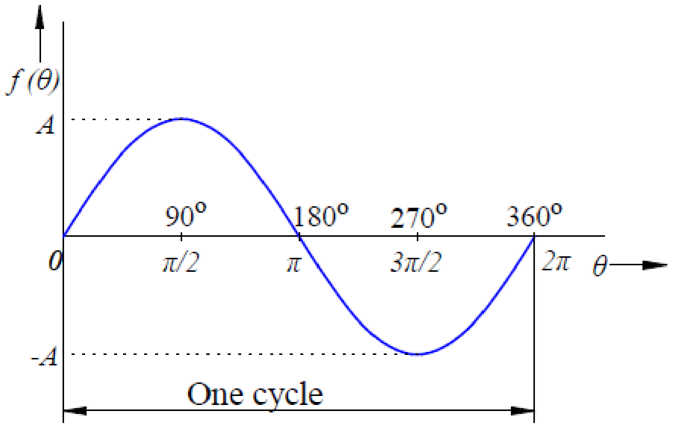
- f2(t) is an AC wave with DC component (Not Pure AC)

Sinusoidal waveform

- Most widely used AC waveform for power generation, transmission & distribution is Sinusoidal Waveform.

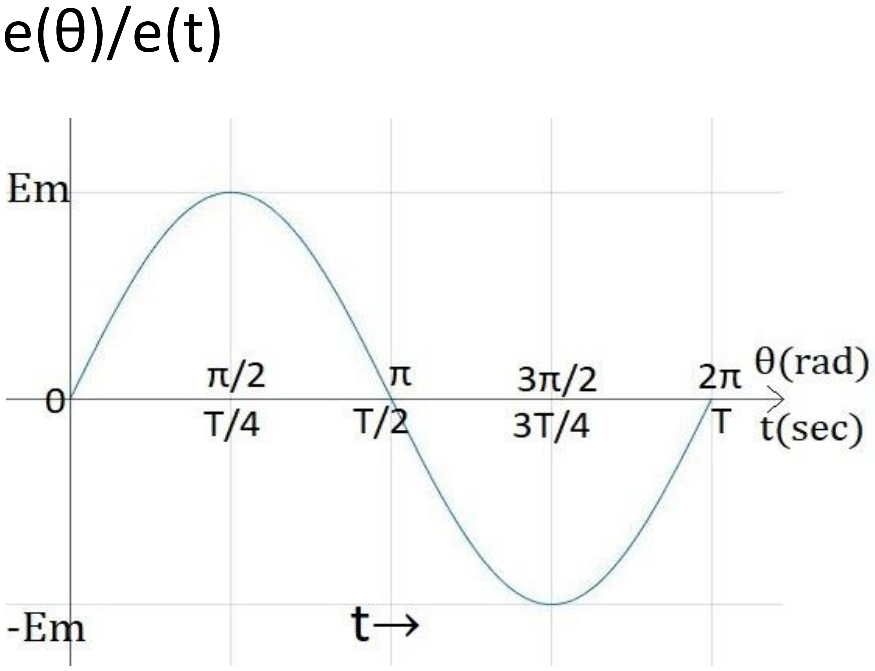
Sinusoidal Waveform:





- It can be expressed as a function of angle or time. Accordingly, one cycle completes in 2π radians or T seconds.

Sinusoidal Waveform – Relation between time and angle



Time (sec)	Angle θ(Rad)
T	2π
T/2	π
1	(2π/T)
t	2π/T*t

Mathematical Representation of a Sinusoidal waveform

- $e(\theta) = E_m \sin(\theta)$

- $e(t) = E_m \sin((2\pi/T)*t) = E_m \sin(\omega t)$

where, $\omega = 2\pi/T = 2\pi f$ is called the angular frequency of the sine wave in rad/s.

- In general, the standard representation of a sinusoidal function is $E_m \sin(\omega t+\phi)$ where ϕ is called the phase angle which can be either positive or negative.

Numerical Example

Question: For a Sinusoidal function of frequency 50 Hz, find

i) Half time period

ii) Angular frequency

Solution:

Time period, $T = 1/f = 1/50 = 0.02s = 20$ ms

i) Half time period $T/2 = 20/2=10$ ms

ii) Angular frequency (ω)

$\omega = 2\pi f = 2\pi(50) = 100\pi = 314.159$ rad/sec

Numerical Example

Question:

The maximum value of a sinusoidal alternating current of frequency 50Hz is 25 A. Write the equation for the instantaneous expression of current,. Determine its value at 3ms and 14 ms.

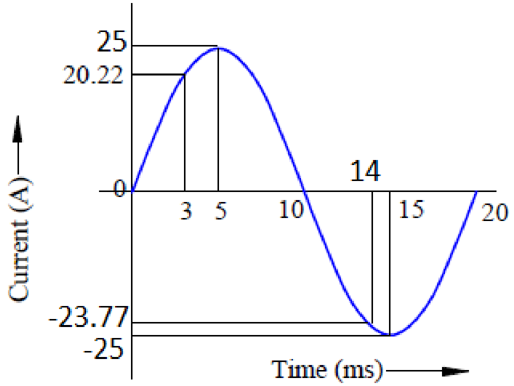
Solution:

$\omega = 2\pi f = 100\pi \text{rad/s}$

$i(t) = 25\sin(100\pi t)$ A

$i(3ms) = 25\sin(100*\pi*0.003) = 20.22A$

Similarly, $i(14ms) = -23.77A$



Note: If radian scale is selected then substitute 'π' symbol in above equation. If degree scale is selected then don't use 'π' symbol, but substitute 180 in place of 'π'.

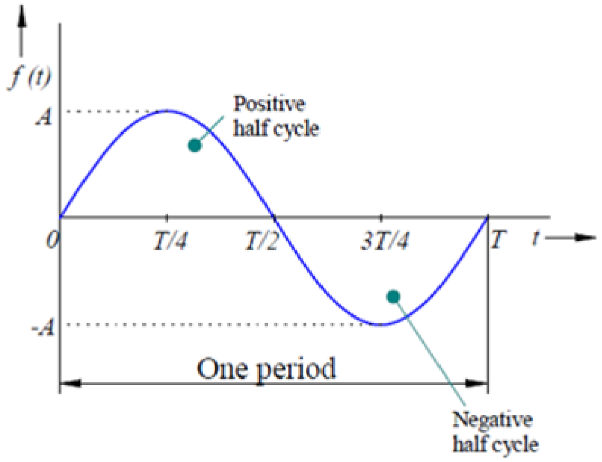
Average value of a Sinusoidal Function

The average value of an AC waveform f(t) is given by

$$F_{avg} = \frac{1}{T}\int_0^T f(t)dt$$

The average value of a sinusoidal function f(t) = Asin(ωt) is

$$F_{avg} = \frac{1}{T}\int_0^T A\sin(\omega t)dt \ = \frac{A}{T}\left(\frac{-\cos(\omega t)}{\omega}\right)_0^T = 0$$



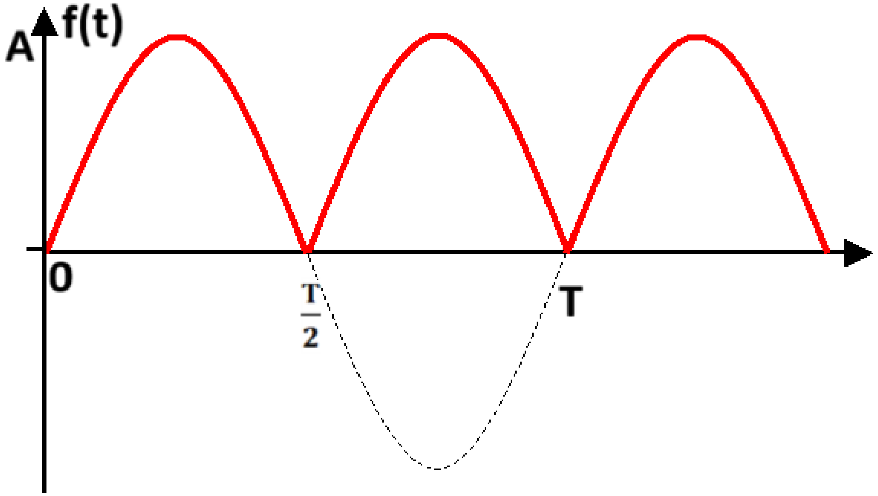
Net Area over one period = 0

Hence, F_{avg} = 0

Average value of a Sinusoidal Function

Since sine wave is a symmetrical wave, average value over one time period is zero. Hence, it is advised to find average value of a rectified sine wave.

A rectified sine wave looks as follows:



Its average value, $$F_{avg} = \frac{1}{(T/2)} \int_0^{T/2} (A \sin \omega t) dt$$

i.e., $$F_{avg} = \frac{2A}{\pi}$$

Effective (or) Root Mean Square (RMS) Value of an AC function

How can we represent an AC waveform effectively by one value?

Consider an AC Voltage v(t) connected across a resistor R for ‘T’ seconds.

Energy consumed by the resistor during this period is

$$E_{AC} = \int_0^T p(t)dt \quad = \int_0^T \frac{[v(t)]^2}{R} dt \qquad \text{------- (1)}$$

Now, excite this resistor using a DC Voltage source of voltage ‘V’ for same time ‘T’ seconds.

Energy consumed by the resistor in this case is

$$E_{DC} = \frac{V^2}{R}.T \qquad \text{------- (2)}$$

Effective (or) Root Mean Square (RMS) Value of an AC function

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That value of DC voltage ‘V’ for which $E_{AC} = E_{DC}$ is said to be the Effective value of the AC voltage v(t).

Hence, $\int_0^T \frac{[v(t)]^2}{R} dt = \frac{V^2}{R}.T$

Therefore, Effective value $V = \sqrt{\frac{1}{T}\int_0^T [v(t)]^2 dt}$

Mathematically the operations involved are

i) Square of the function
ii) Mean (Average) of the function
iii) Square root of the function

Hence, it is also called Root Mean Square (RMS) value.

Effective (or) Root Mean Square (RMS) Value of Sine Wave

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Consider a sinusoidal voltage $v(t)=V_m\sin(\omega t)$

Its RMS value, $V = \sqrt{\frac{1}{T}\int_0^T [V_m \sin\omega t]^2 dt}$

$$= \sqrt{\frac{V_m^{\ 2}}{T}\int_0^T [\sin^2\omega t]dt}$$

$$= \sqrt{\frac{V_m^{\ 2}}{T} * \frac{T}{2}}$$

$$= \frac{V_m}{\sqrt{2}}$$

Finding Power and Energy consumed using RMS value

Major advantage of finding effective (or) RMS value of an AC function is that it makes power calculations easy.

Power consumed in AC circuits, $p(t) = v(t)*i(t)$

Average power consumed, $P = \dfrac{\int_0^T p(t)dt}{T} = \dfrac{\int_0^T \frac{[v(t)]^2}{R}}{T} = \dfrac{\int_0^T \frac{[v(t)]^2}{T}}{R} = \dfrac{V^2}{R}$

Where V = RMS value of voltage.

Similarly, average power consumed is also equal to (I^2*R) where I = RMS current.

Also, Energy consumed in ‘t’ seconds = P*t

i.e., $(I^2R)t$ (or) $\dfrac{V^2}{R}t$

Text Book & References

Text Book:

1. "Basic Electrical Engineering" S.K Bhattacharya, 1st Edition Pearson India Education Services Pvt. Ltd., 2017
2. "Basic Electrical Engineering", D. C. Kulshreshta, 2nd Edition, McGraw-Hill. 2019
3. "Special Electrical Machines" E G Janardanan, PHI Learning Pvt. Ltd., 2014

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1. "Engineering Circuit Analysis" William Hayt, Jack Kemmerly, Jamie Phillips and Steven Durbin, 10th Edition McGraw Hill, 2023

2. "Electrical and Electronic Technology" E. Hughes (Revised by J. Hiley, K. Brown & I.M Smith), 12th Edition, Pearson Education, 2016.

THANK YOU

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