Electrical Sciences (EE-101)

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Lecture Plan

Polyphase Systems / Circuits

★ **Balanced Three-phase Systems (Star (Y) & Delta (Δ))**

★ **Three-phase Power Measurement**

Magnetic Circuits

★ **Electro-magnetism**

★ **Mutual Inductance and Coupling**

Frequency Response

★ **Resonance**

★ **Filters**

Text Book: Engineering Circuit Analysis *by Hayt, Kemmerly and Durbin, McGraw Hill, 7th Ed.*
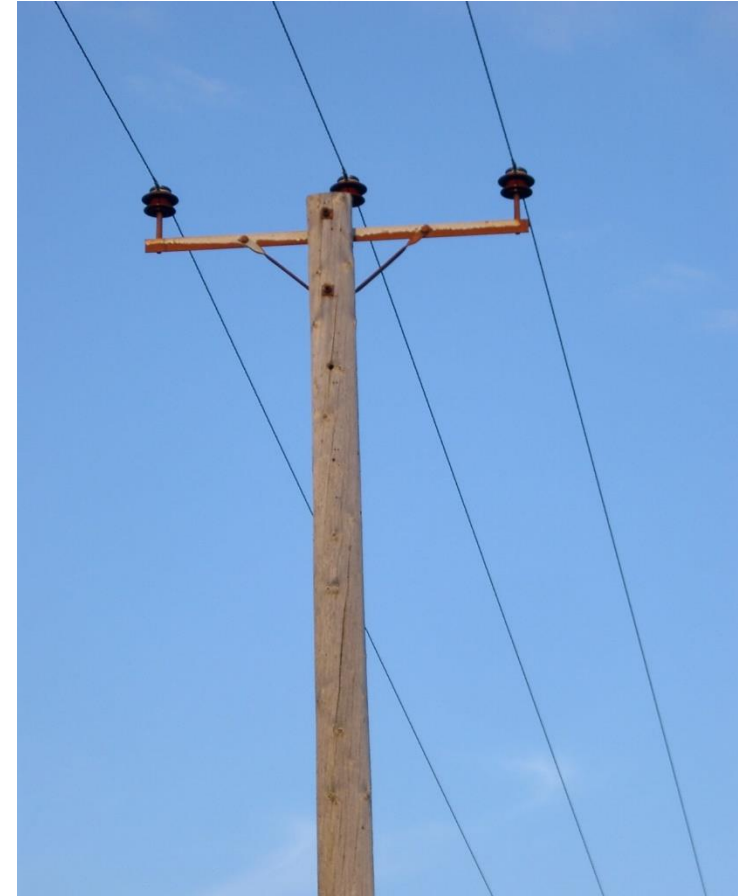
Polyphase Systems / Circuits

- **Why Polyphase System?**

- **What is a Polyphase Source?**

- **Balanced Three-phase System.**

- **Wye (Y) and Delta (Δ) Connected Source and Load.**

- **Analysis of a balanced Three-phase System**

- **Power Measurement in a Three-phase System**

Three-phase Transmission Lines over IIT Guwahati Campus

3-phase Transmission line

3-phase distribution line

Polyphase Systems

- A C systems came into existence in the late 1880s because of the generation , transmission and consumption limitation of DC power .
- During the first use of AC, one basic problem remained: single phase motors are not able to start by themselves. This led to the invention of poly phase system in the early 1890s .
- Consequently some advantages of 3-phase system over 1-phase system came out to be:
  - 3-phase generators, motors and transformers are simpler, cheaper and more efficient
  - 3-phase transmission lines deliver more power for a given cost or for a given weight of conductor
  - Voltage regulation of a 3-phase system is inherently better

Single-phase Source

A single-phase source is denoted by $v(t) = V \sin(\omega t + \theta)$ as a function of time or as $\boldsymbol{v} = V \angle \theta$ in phasor form. The amplitude can be maximum or rms value. For a sinusoid function the maximum and the rms quantities are related through a multiplying factor of $\sqrt{2}$. A single-phase source is shown as
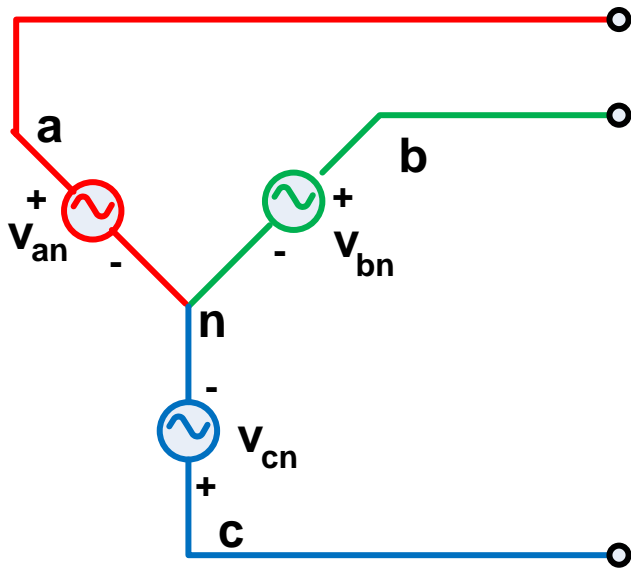
V(t)= Vsin(ωt+θ)
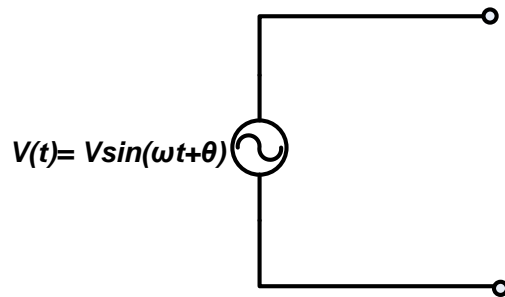
A single-phase source is characterized by three features:

- Amplitude, V (it can be a rms or peak value)
- Frequency, ω
- Phase, θ

Balanced Three-Phase Source

A Star (Y) connected balanced three-phase source consists of three single-phase sources

Various features of this three-phase source are:

- n is the neutral which is the common node for the three source voltages

- Quantities of three phases (of a 3-phase system) are represented by using subscripts '*a*', '*b*' and '*c*' or 'R', 'Y', 'B'. They are called phase-*a*, phase-*b* and phase-*c* or phase-*R*, phase-*Y* and phase-*B*

- v_{an}, v_{bn} and v_{cn} are the three-phase voltages

Balanced Three-Phase Source

For a balanced three-phase source

- The three phase voltages have equal magnitude
- All the sources operate at the same frequency
- Sum of the three phase voltages is equal to zero
- The three phase voltages differ from each other by a phase angle of 120^0

Mathematically the three phase voltages can be represented as

$|v_{an}| = |v_{bn}| = |v_{cn}|$

$v_{an} = V_P \sin \omega t$ with an equivalent phasor $V_P \underline{/0^0}$

$v_{bn} = V_P \sin (\omega t - 120^0)$, with an equivalent phasor $V_P \underline{/-120^0}$
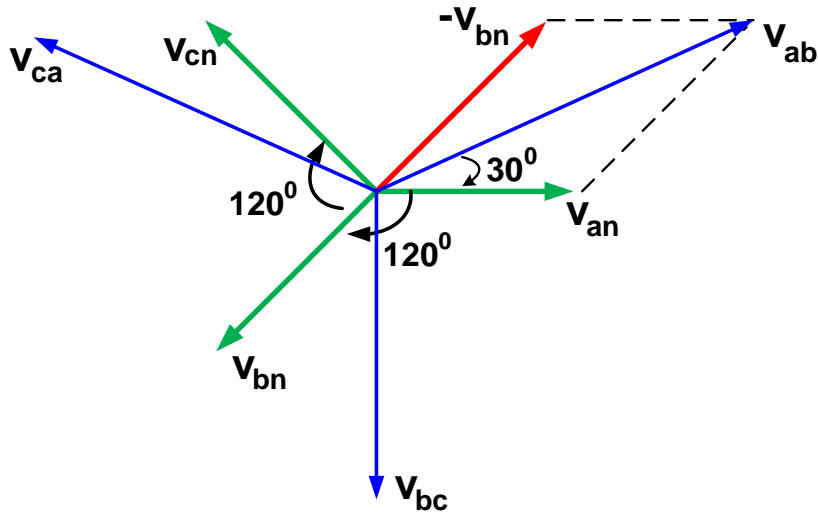
$v_{cn} = V_P \sin (\omega t - 240^0)$, with an equivalent phasor $V_P \underline{/-240^0}$

This is called positive phase sequence. In this course, we will follow this phase sequence.

$v_{an} + v_{bn} + v_{cn} = 0$

Balanced Three-Phase Source

Graphically the three-phase voltages (phasors) can be seen as

v_{ab}, v_{bc} and v_{ca} are called line voltages which are the voltage difference between two corresponding phase voltages.

$$v_{ab} = v_{an} - v_{bn} = V_P \angle 0^0 - V_P \angle -120^0$$

$$= V_P \sin \omega t - V_P \sin (\omega t - 120^0)$$

$$= V_P[\sin \omega t - (\sin \omega t \cos 120^0 - \cos \omega t \sin 120^0)]$$

$$= V_P \left[\sin \omega t - (\sin \omega t \left(-\frac{1}{2}\right) - \cos \omega t \frac{\sqrt{3}}{2}) \right]$$

$$= \sqrt{3} \, V_P \left[\frac{\sqrt{3}}{2} \sin \omega t + \frac{1}{2} \cos \omega t) \right]$$

$$= \sqrt{3} \, V_P [\cos 30^0 \sin \omega t + sin 30^0 \cos \omega t)]$$

$$= \sqrt{3} \, V_P \sin(\omega t + 30^0)$$

Balanced Three-Phase Source

Line voltage $v_{ab} = \sqrt{3}\, V_P \sin(\omega t + 30^0)$ leads the phase voltage v_{an} by an angle of 30^0 and its magnitude is $\sqrt{3}$ times the magnitude of the phase voltage V_P. The three line voltages are

$$v_{ab} = \sqrt{3}\, V_P \sin(\omega t + 30^0), \Leftrightarrow V_L \underline{/30^0}$$

$$v_{bc} = \sqrt{3}\, V_P \sin(\omega t - 90^0), \Leftrightarrow V_L \underline{/-90^0}$$

$$v_{ca} = \sqrt{3}\, V_P \sin(\omega t - 210^0), \Leftrightarrow V_L \underline{/-210^0}$$

$$|v_{ab}| = |v_{bc}| = |v_{ca}|$$

$$v_{ab} + v_{bc} + v_{ca} = 0$$