

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

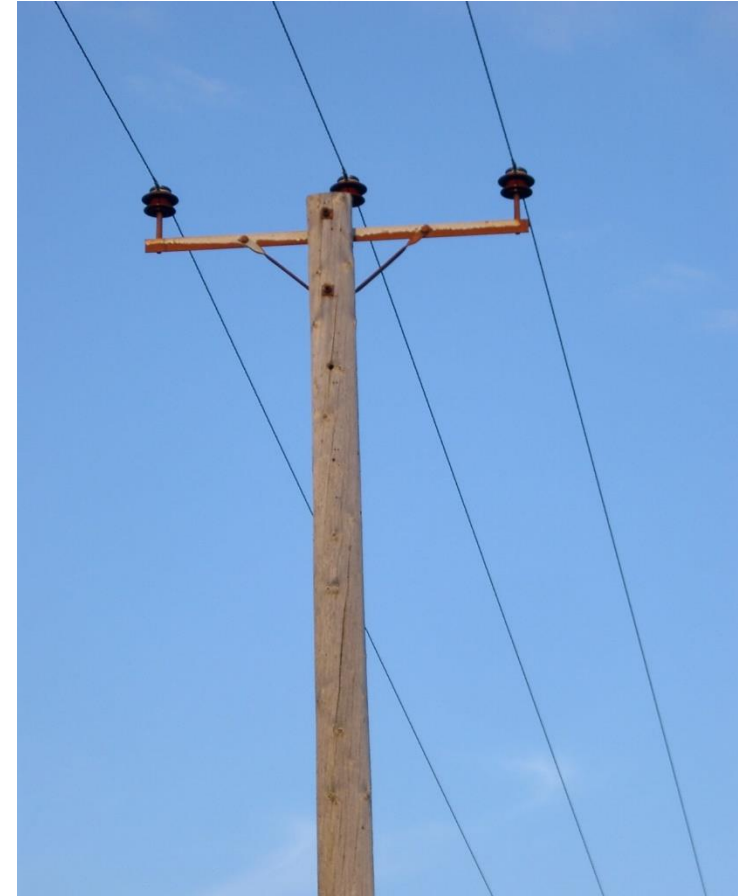
- **Why Polyphase System?**
- **What is a Polyphase Source?**
- **Balanced Three-phase System.**
- **Wye (Y) and Delta (Δ) Connected Source and Load.**
- **Analysis of a balanced Three-phase System**
- **Power Measurement in a Three-phase System**

Three-phase Transmission Lines over IIT Guwahati Campus





3-phase Transmission line



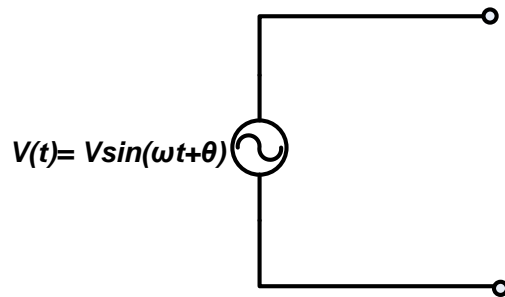
3-phase distribution line

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 1990s .
- 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 $v = V \angle \theta$ 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

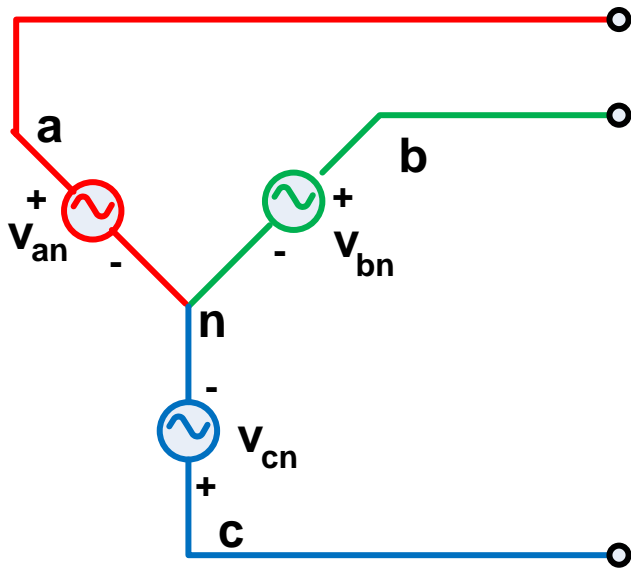


A single-phase source is characterized by three features:

- 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°

Mathematically the three phase voltages can be represented as

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

$$v_{an} = V_P \sin \omega t \text{ with an equivalent phasor } V_P \angle 0^\circ$$

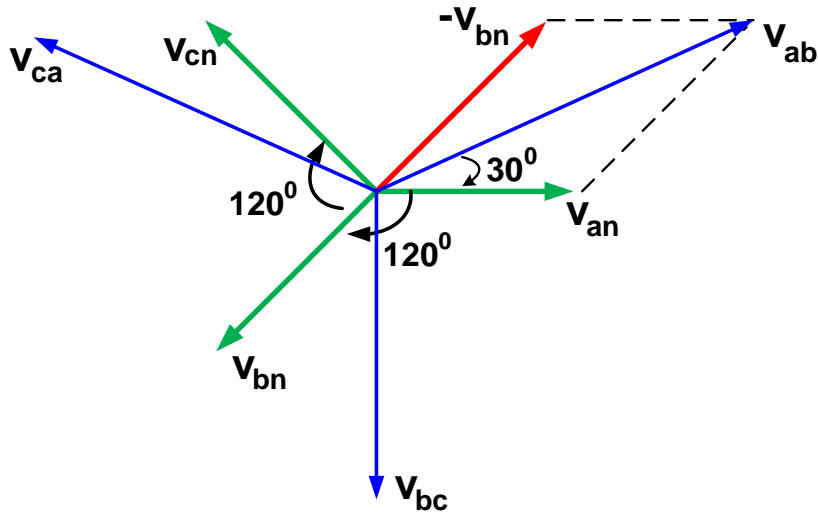
$$v_{bn} = V_P \sin (\omega t - 120^\circ), \text{ with an equivalent phasor } V_P \angle -120^\circ$$

$$v_{cn} = V_P \sin (\omega t - 240^\circ), \text{ with an equivalent phasor } V_P \angle -240^\circ$$

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

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.

$$\begin{aligned}
 v_{ab} &= v_{an} - v_{bn} = V_P \angle 0^\circ - V_P \angle -120^\circ \\
 &= V_P \sin \omega t - V_P \sin (\omega t - 120^\circ) \\
 &= V_P [\sin \omega t - (\sin \omega t \cos 120^\circ - \cos \omega t \sin 120^\circ)] \\
 &= V_P \left[\sin \omega t - \left(\sin \omega t \left(-\frac{1}{2} \right) - \cos \omega t \frac{\sqrt{3}}{2} \right) \right] \\
 &= \sqrt{3} V_P \left[\frac{\sqrt{3}}{2} \sin \omega t + \frac{1}{2} \cos \omega t \right] \\
 &= \sqrt{3} V_P [\cos 30^\circ \sin \omega t + \sin 30^\circ \cos \omega t] \\
 &= \sqrt{3} V_P \sin(\omega t + 30^\circ)
 \end{aligned}$$

Balanced Three-Phase Source

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

$$v_{ab} = \sqrt{3} V_P \sin(\omega t + 30^\circ), \Leftrightarrow V_P \angle 30^\circ$$

$$v_{bc} = \sqrt{3} V_P \sin(\omega t - 90^\circ), \Leftrightarrow V_P \angle -90^\circ$$

$$v_{ca} = \sqrt{3} V_P \sin(\omega t - 210^\circ), \Leftrightarrow V_P \angle -210^\circ$$

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

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