University of Diyala

College of Engineering

Department of Power and Electrical Machines Engineering

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Second Year – Bachelor (BSc) – EPE 203

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EPE 203 Electric Circuits Analysis I

Lecture 1

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Lecture 1

Balanced three-phase voltages and phase sequence.

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Three-phase voltages are often produced with a three-phase AC generator whose cross-sectional view is shown in **Figure 1**, below.

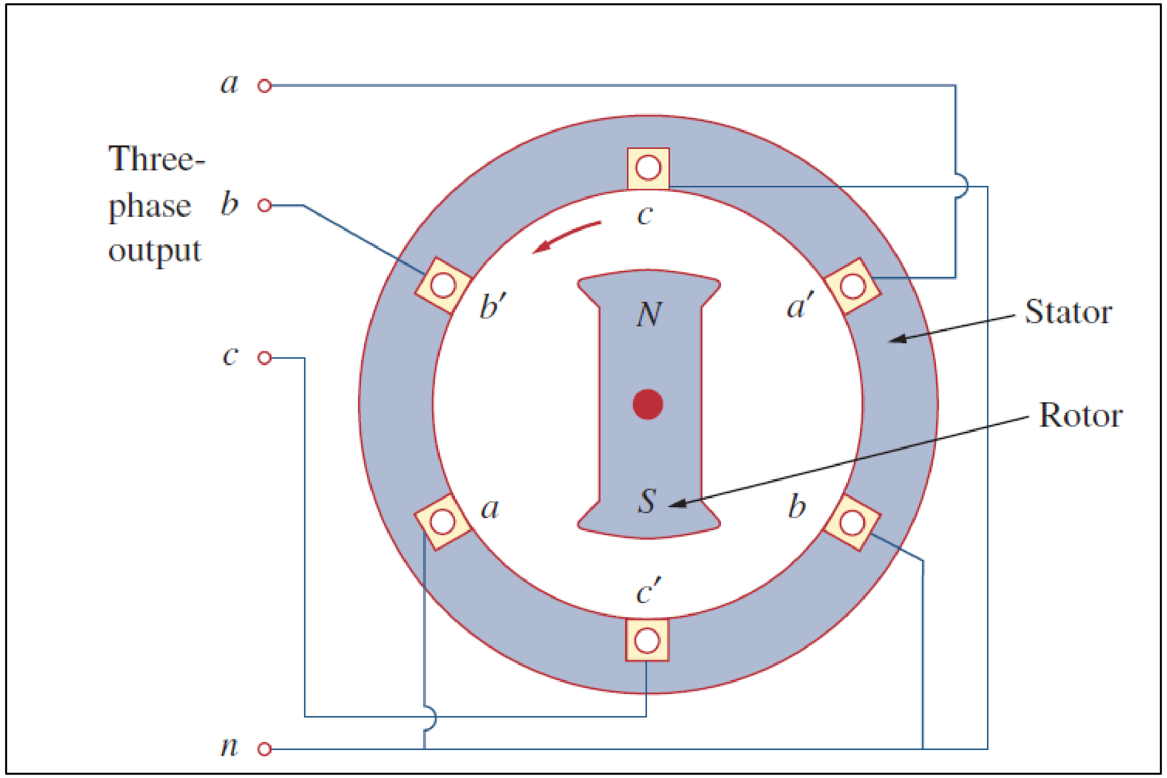


Figure 1: A three-phase generator.

The generator essentially consists of a rotating magnet (rotor) encompassed by a stationary winding (stator). Three separate windings or coils with terminals $a - \acute{a}$, $b - \acute{b}$, $c - \acute{c}$ are placed with 120° apart around the stator.

Terminals a & $\acute{a}$ for example, stand for one of the ends of coils going into and the other end coming out of the page. When the rotor part rotates, its magnetic field "cuts" the **flux** from the three coils and induces **voltages** in the coils.

As long as the coils are placed apart 120°, the induced voltages in the coils are equal in magnitude but out of phase by 120° as shown in **Figure 2**, below.

Since each coil can be regarded as a single-phase generator by itself, the three-phase generator can supply power to both single-phase and three-phase loads.

A typical three-phase system consists of three voltage sources connected to loads by three or four wires (or transmission lines). (**Three-phase current sources are very rare.**) A three-phase system is equivalent to three single-phase circuits.

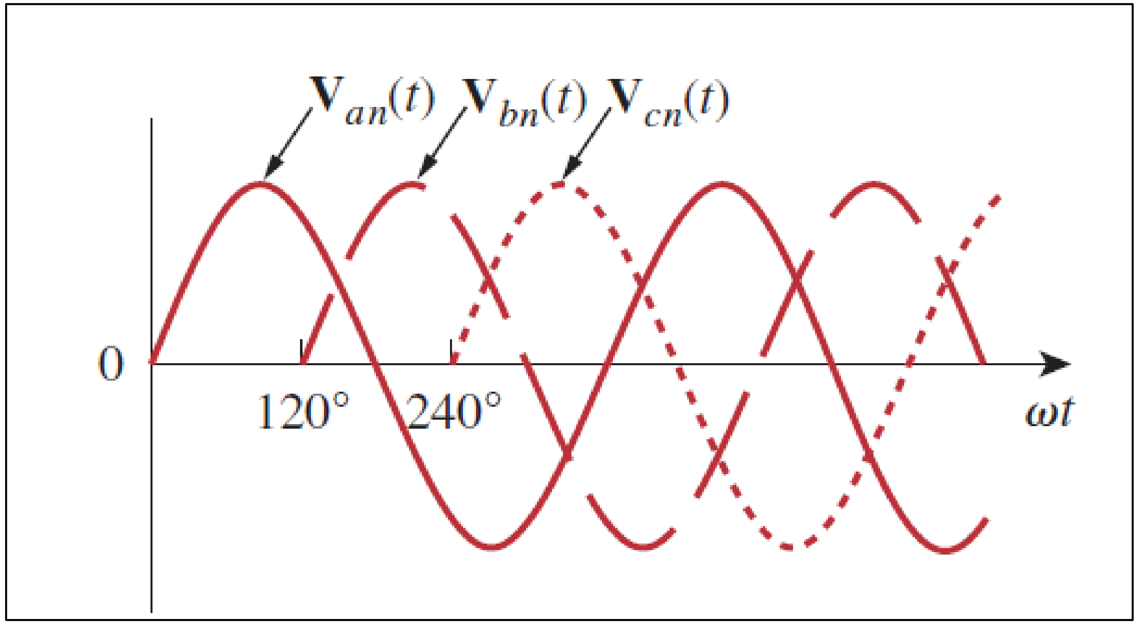


Figure 2: The generated voltages are 120° apart from each other.

The three-phase voltage sources can be either wye-connected (Y) as shown in **Figure 3(a)** or delta-connected (Δ) as in **Figure 3(b)** below.

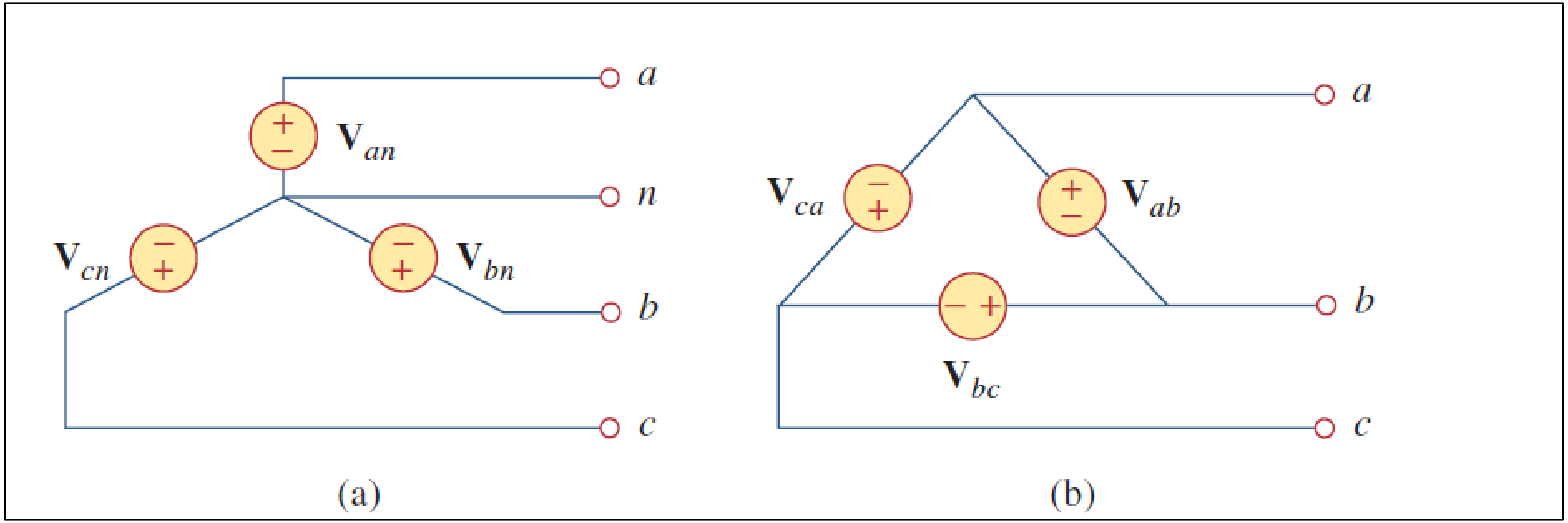


Figure 3: Three-phase voltage sources: (a) Y-connected source, (b) Δ–connected source.

- **Phase voltages:** V_{an}, V_{bn}, V_{cn} — between each phase (a, b, c) and neutral n
- **Line voltages:** V_{ab}, V_{bc}, V_{ca} — between two phase lines only

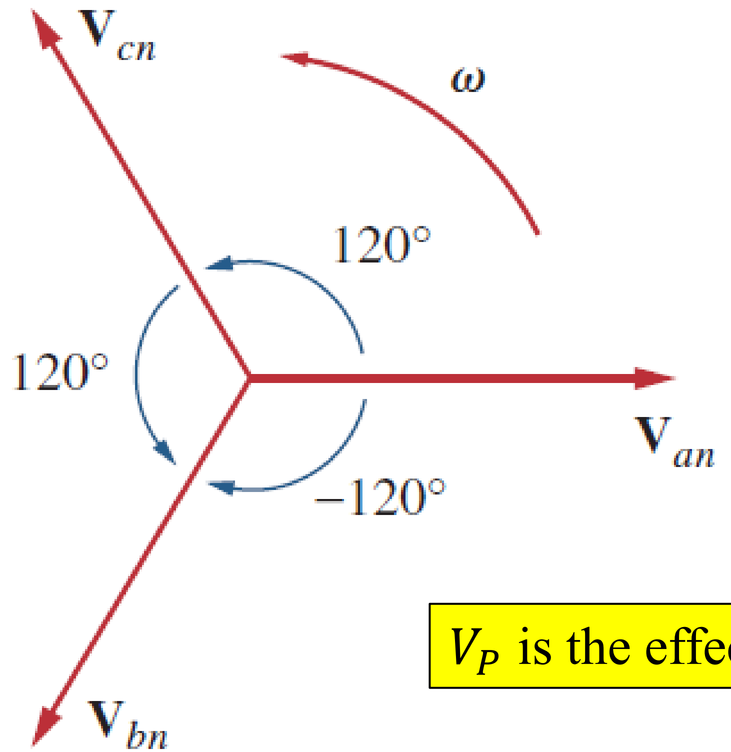
The phase sequence is the time order in which the voltages pass through their respective maximum values.

Connection	Voltage	Current	Relation & Phase Shift
Star (Y)	Phase voltage $V_{ph} = V_{LN}$ (line-to-neutral)	Line current $I_{line} = I_{ph}$	Line voltage $V_{line} = \sqrt{3}V_{ph}$, leads phase voltage by 30°
	Line voltage $V_{line} = V_{AB}, V_{BC}, V_{CA}$		$V_{line} = \sqrt{3}V_{ph}\angle 30^\circ$
Delta (Δ)	Phase voltage $V_{ph} = V_{AB}, V_{BC}, V_{CA}$	Line current $I_{line} = \sqrt{3}I_{ph}$	Line voltage = Phase voltage $V_{line} = V_{ph}$
		Phase current I_{ph} (through winding)	Line current leads phase current by 30°

Diagram (a):

- V_{an} is on the horizontal axis (reference phase).
- V_{bn} lags V_{an} by 120°, and V_{cn} leads V_{an} by 120° (or equivalently, lags by -120°).
- This corresponds to a **phase sequence of** $a \to b \to c$, also called **positive phase sequence**.
- Positive phase sequence means that the voltages reach their peaks in order: **a, then b, then c**.

$$\mathbf{V}_{an} = V_p\angle 0°$$
$$\mathbf{V}_{bn} = V_p\angle -120°$$
$$\mathbf{V}_{cn} = V_p\angle -240° = V_p\angle +120°$$



(a)

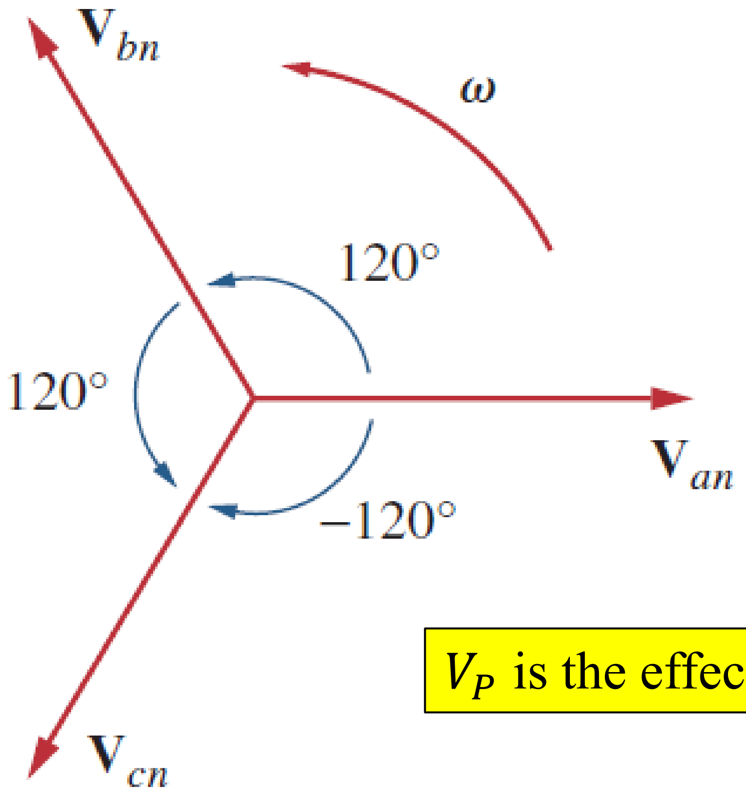
Phase sequence: abc
(Positive sequence)

V_P is the effective or rms value of the phase voltages.

Diagram (b):

- V_{an} is still the reference.
- V_{bn} now **leads** V_{an} by 120°, and V_{cn} **lags** V_{an} by 120°.
- This is a **negative phase sequence** ($a \to c \to b$), meaning the order of the phase peaks is reversed.
- Negative phase sequence can happen if there's a wiring swap or fault in the system.

$$\mathbf{V}_{an} = V_p\angle 0^\circ$$
$$\mathbf{V}_{cn} = V_p\angle -120^\circ$$
$$\mathbf{V}_{bn} = V_p\angle -240^\circ = V_p\angle +120^\circ$$



(b)

Phase sequence: acb
(Negative sequence)

V_P is the effective or rms value of the phase voltages.

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From the previous explanation of **phase sequence** in its two types (+ve & -ve). Is the following equation correct or not?

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

Determine the phase sequence of the set of voltages

$$v_{an} = 200\cos(\omega t + 10^\circ)$$

$$v_{bn} = 200\cos(\omega t - 230^\circ), \qquad v_{cn} = 200\cos(\omega t - 110^\circ)$$

Solution:

The voltages can be expressed in phasor form as

$$\mathbf{V}_{an} = 200\underline{/10^\circ}\ \text{V}, \qquad \mathbf{V}_{bn} = 200\underline{/-230^\circ}\ \text{V}, \qquad \mathbf{V}_{cn} = 200\underline{/-110^\circ}\ \text{V}$$

We notice that $\mathbf{V}_{an}$ leads $\mathbf{V}_{cn}$ by 120° and $\mathbf{V}_{cn}$ in turn leads $\mathbf{V}_{bn}$ by 120°. Hence, we have an *acb* sequence.

Homework

Given that $V_{cn} = 120\angle 45^{\circ}$ V, Find V_{an} and V_{bn}, assuming (abc) sequence.

Given that $V_{an} = 220\angle 60^{\circ}$ V, Find V_{bn} and V_{cn}, assuming (acb) sequence.