Electric Circuits II

Balanced Three Phase Circuits

Lecture # 01

The material to be covered in this lecture is as follows:

- Introduction of three-phase circuit concept
- Balanced Three Phase Voltages.
- Positive Sequence Voltages
- Negative Sequence Voltages

After finishing this lecture, you should be able to:

- Identify the main components of three-phase circuit.
- Understand the role of each main components of three-phase circuit.
- Differentiate between the balanced voltages phases
- Imagine the positive and negative sequence voltages opposite direction.

Introduction of three-phase circuit concept

- The three-phase circuit is the main circuit structure used in power system.
- The electrical power generation is accomplished through three-phase circuit.
- The three phase connection lines transmit power over long distance.
- The energy is distributed and consumed at the load level through three phase and single phase
- Generating, Transmitting, Distributing and consuming electric power is achieved through the three phase circuit
- The basic structure of a three phase system consists of voltage source, transformers, transmission line and connected loads

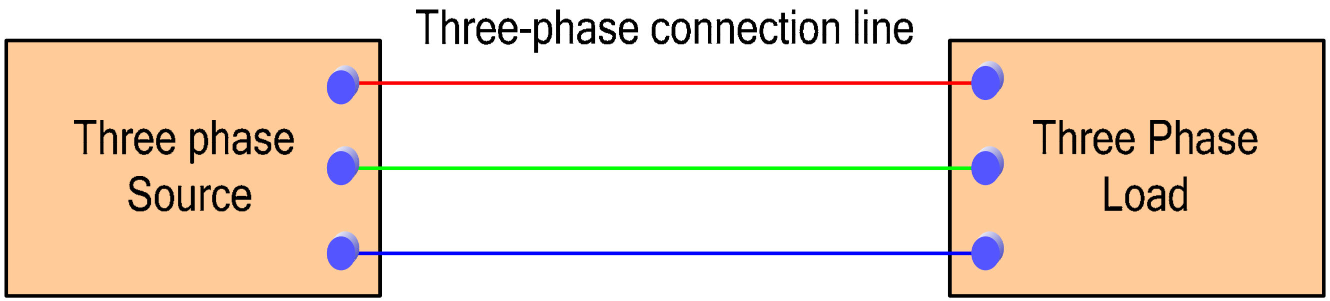

Figure 1.Three phase Circuit Components

Balanced Three Phase Voltages

- Three sinusoidal voltages form a set of balanced voltages when they have the same amplitudes and frequency.
- These voltages are shifted in phase by 120^o with each other.
- The standard practice is to name those phases by a, b and c and use phase a as reference.
- These voltages represent phase a voltage, phase b voltage and phase c voltage.

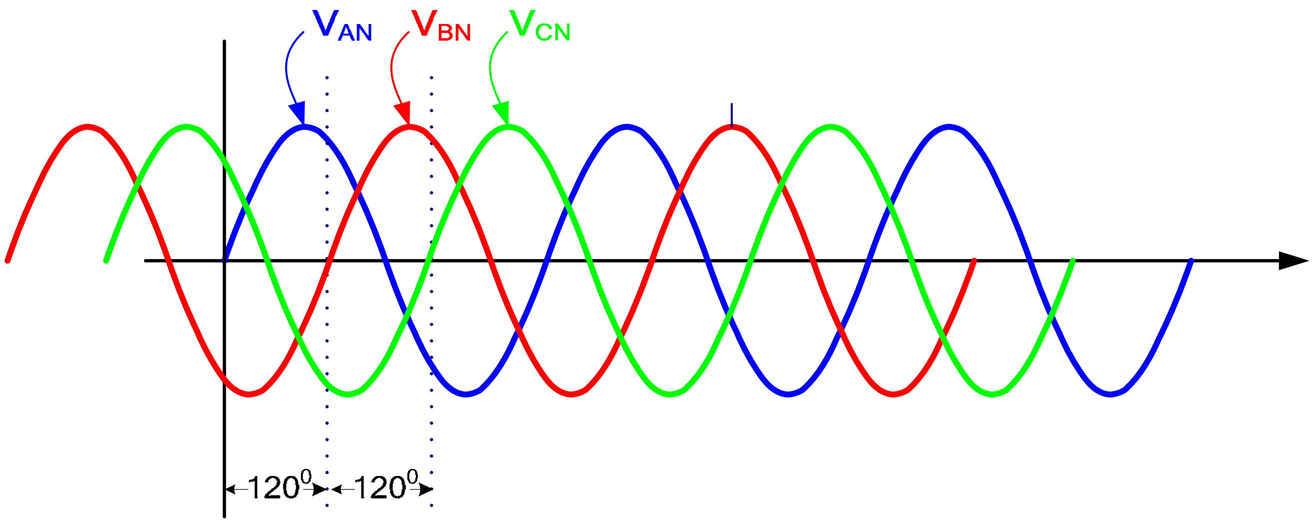

Figure 2. Phase Voltages of Balanced Three Phase source.

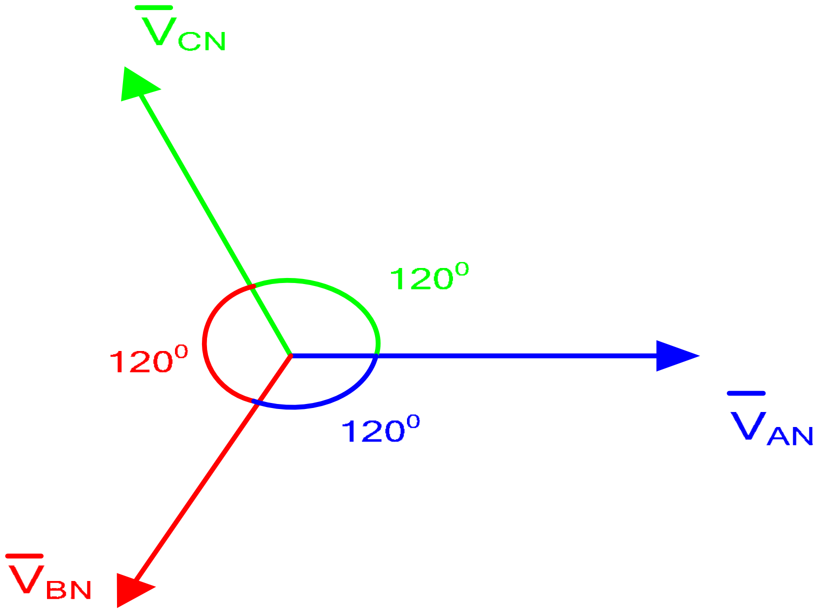

Figure 3. Phasor Diagram for Balanced Three Phase Voltages

Positive Sequence Voltages

- When phase b voltage lags the reference phase a voltage by 120^o and consequently phase c voltage must lead phase a voltage by 120^o.
- The above relation between phases is known as positive sequence or abc.

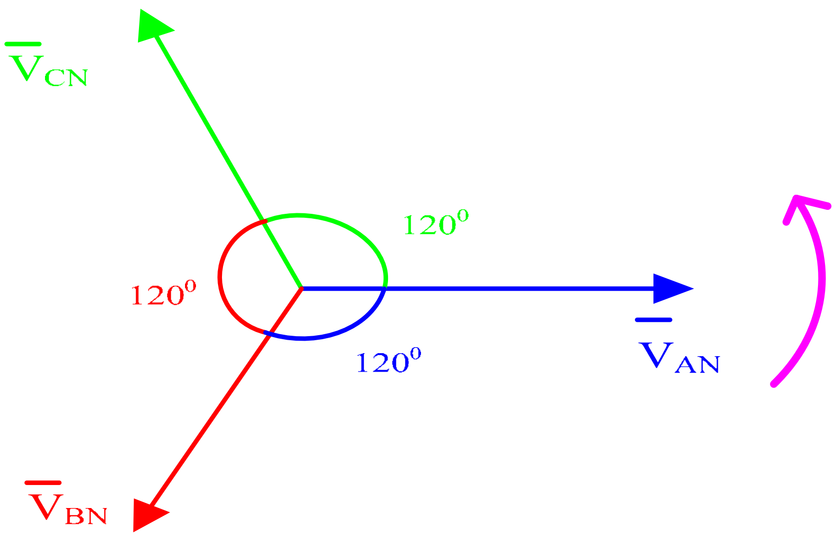

Figure 4. Phasor Diagram of Balanced Three Phase Voltages (abc) sequence

- In phasor notation we represent the set of balanced positive sequence voltage as:

$$V_a = V\angle 0^0$$

$$V_b = V\angle -120^0$$

$$V_c = V\angle +120^0$$

Negative Sequence Voltages

- When phase b voltage leads the reference phase a voltage by 120^o and consequently phase c voltage must lag phase a voltage by 120^o.
- The above relation between phases is known as negative sequence or acb.

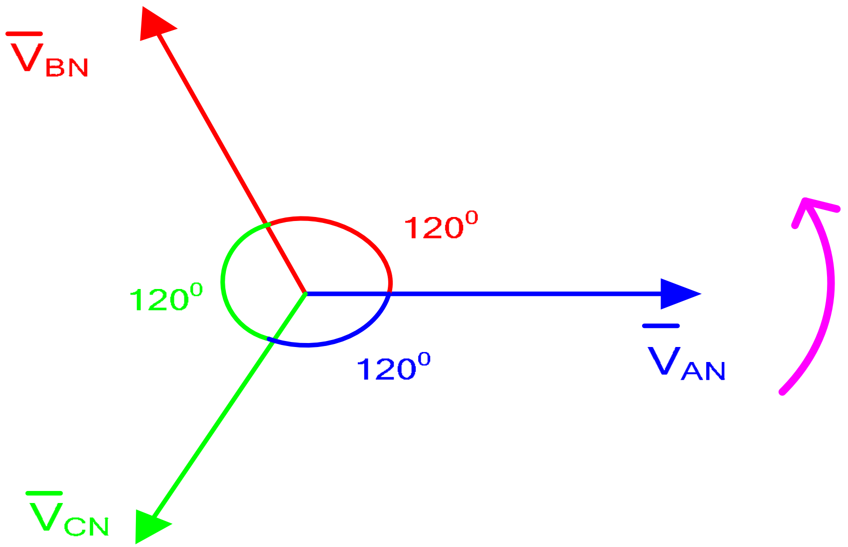

Figure 5. Phasor Diagram of Balanced Three Phase Voltages (acb) sequence

- In phasor notation we represent the set of balanced negaitive sequence voltage as:

$$V_a = V \angle 0^0$$

$$V_b = V \angle +120^0$$

$$V_c = V \angle -120^0$$

- An important Characteristic of a positive or negative sequence set of balanced voltages is that the sum the phasor voltages is equal to zero

$$V_a + V_b + V_c = 0$$

- As a consequence the sum the related instantaneous voltages is equal to zero

$$\upsilon_a + \upsilon_b + \upsilon_c = 0$$

- If the phase sequence is known and one of the voltages of the balanced set is known then the entire set becomes known.

Example:

- Define the phase sequence for this first set voltages

$$\upsilon_a = 208\cos(\omega t + 27^o)V.$$

$$\upsilon_b = 208\cos(\omega t + 147^o)V.$$

$$\upsilon_c = 208\cos(\omega t - 93^o)V.$$

- The relevant phsors are :

$$V_a = 208\angle 27^0 V. \qquad V_b = 208\angle +147^0 V. \qquad V_c = 208\angle -93^0 V.$$

- Therefore the sequence is **acb**

- Define the phase sequence for this second set voltages

$$\upsilon_a = 4160\cos(\omega t - 18^o)V.$$
$$\upsilon_b = 4160\cos(\omega t - 138^o)V.$$
$$\upsilon_c = 4160\cos(\omega t + 102^o)V.$$

- The relevant phsors are :

$$V_a = 4160\angle -18^0 V. \quad V_b = 4160\angle -138^0 V. \quad V_c = 4160\angle +102^0 V.$$

- Therefore the sequence is **abc**

Self Test:

Which options are true for a set of three sinusoidal balanced voltages?

a) Three sinusoidal voltages have the same amplitudes and different frequency.

b) Two sinusoidal voltages are shifted in phase by 120^o from the reference voltage

c) The three voltages are shifted in phase by 120^o with each other

d) In a positive sequence phase b is lagging on phase a by 240^o.

e) In a negative sequence phase b is leading on phase a by 120^o .

answer: c, and e