Introduction to Three Phase System

Single Phase System

A single phase ac power system consists of a generator connected through a pair of wires (a transmission line) to a load. Figure 1(a) depicts a single phase two-wire system, where *Vp* is the magnitude of the source voltage and φ is the phase. What is more common in practice is a single-phase three-wire system, shown in Fig. 1(b). It contains two identical sources (equal magnitude and the same phase) which are connected to two loads by two outer wires and the neutral. For example, the normal household system is a single-phase three-wire system because the terminal voltages have the same magnitude and the same phase. Such a system allows the connection of both 120-V and 240-V appliances.

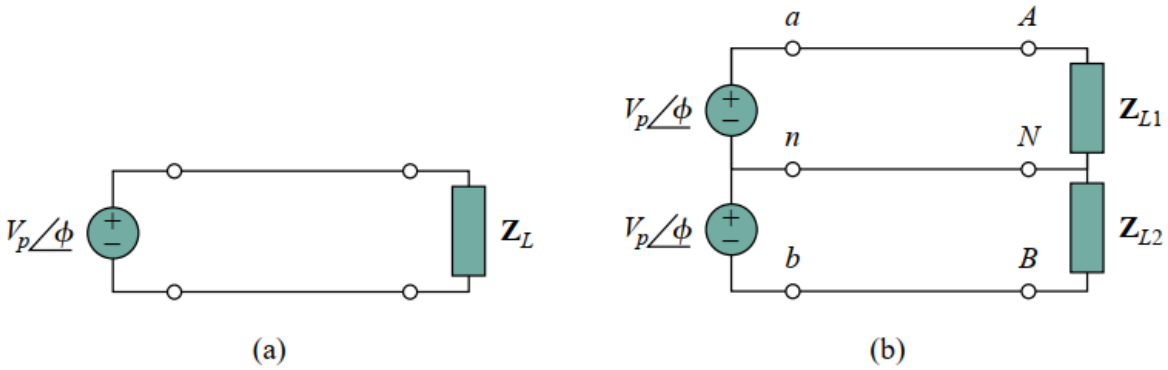

Fig. 1. Single-phase systems: (a) two-wire type, (b) three-wire type

Q. What is single phase system? Mention the characteristics of single phase system.

Poly Phase System

Circuits or systems in which the ac sources operate at the same frequency but different phases are known as poly-phase. Figure 12.2 shows a two-phase three-wire system, and Fig. 12.3 shows a three-phase four wire system. As distinct from a single-phase system, a two-phase system is produced by a generator consisting of two coils placed perpendicular to each other so that the voltage generated by one lags the other by 90◦. By the same token, a three-phase system is produced by a generator consisting of three sources having the same amplitude and frequency but

out of phase with each other by 120◦. Since the three-phase system is by far the most prevalent and most economical poly-phase system, discussion in this chapter is mainly on three-phase systems.

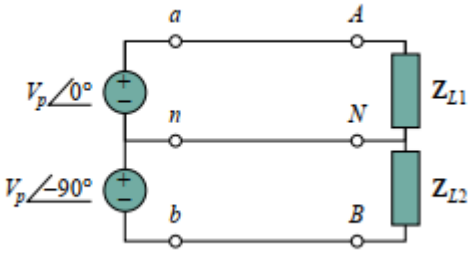

Fig. 2(a) Two phase three wire system

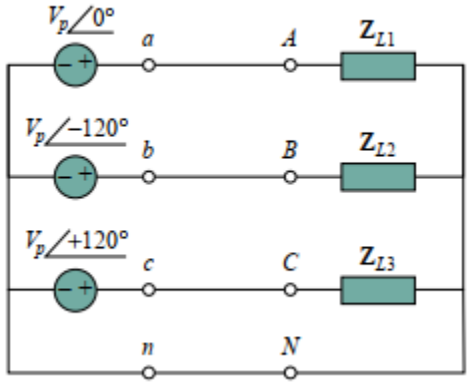

Fig. 2(b) Three phase four wire system

Q. What is two phase system? Mention the characteristics of two phase system.

Q. What is three phase system? Mention the characteristics of three phase system.

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Advantages of Three-Phase System

- First, nearly all electric power is generated and distributed in three-phase, at the operating frequency of 60 Hz (or ω = 377 rad/s) in the United States or 50 Hz (or ω = 314 rad/s) in some other parts of the world. When one phase or two-phase inputs are required, they are taken from the three phase system rather than generated independently.
- Second, the instantaneous power in a three-phase system can be constant (not pulsating). This results in uniform power transmission and less vibration of three-phase machines.
- Third, for the same amount of power, the three-phase system is more economical than the single-phase amount of wire required for a three-phase system is less than that required for an equivalent single-phase system.

What are the advantages of three-phase system?

Voltage Generation Process of Three-phase voltage

Three-phase voltages are often produced with a three-phase ac generator (or alternator) whose cross-sectional view is shown in Fig. 3(a). The generator basically consists of a rotating magnet (called the *rotor*) surrounded by a stationary winding (called the *stator*). Three separate windings or coils with terminals *a-a*, *b-b*, and *c-c* are physically placed 120◦ apart around the stator. Terminals *a* and *a*, for example, stand for one of the ends of coils going into and the other end

coming out of the page. As the rotor rotates, its magnetic field "cuts" the flux from the three coils and induces voltages in the coils. Because the coils are placed 120◦ apart, the induced voltages in the coils are equal in magnitude but out of phase by 120◦ (Fig. 3(b)). 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.

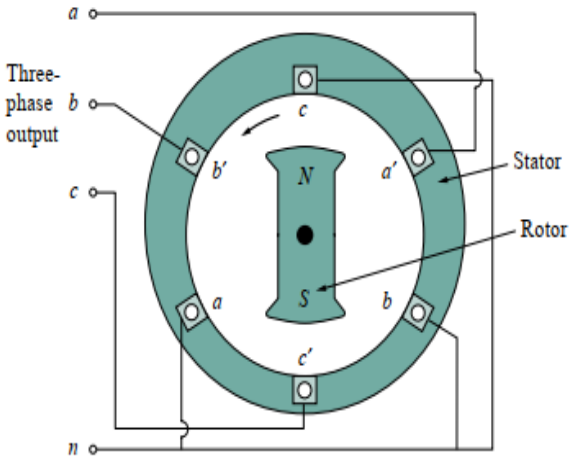

Fig. 3(a) Three phase alternator

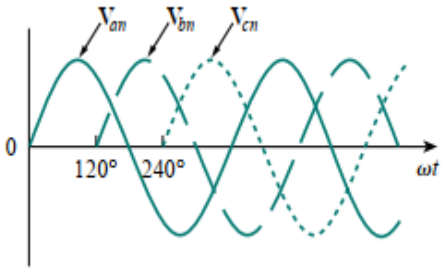

Fig. 3(a) Three phase voltage

Balance Three phase Voltage and Load

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 scarce.) A three-phase system is equivalent to three single-phase circuits. The voltage sources can be either wye-connected as shown in Fig. 4 (a) or delta-connected as in Fig. 4 (b). Let us consider the wye-connected voltages in Fig. 4 (a) for now. The voltages **V***an*, **V***bn*, and **V***cn* are respectively between lines *a*, *b*, and *c*, and the neutral line *n*. These voltages are called *phase voltages*. If the voltage sources have the same amplitude and frequency ω and are out of phase with each other by 120◦, the voltages are said to be *balanced*. This implies that

$$\mathbf{V}_{an} + \mathbf{V}_{bn} + \mathbf{V}_{cn} = 0$$
$$|\mathbf{V}_{an}| = |\mathbf{V}_{bn}| = |\mathbf{V}_{cn}|$$

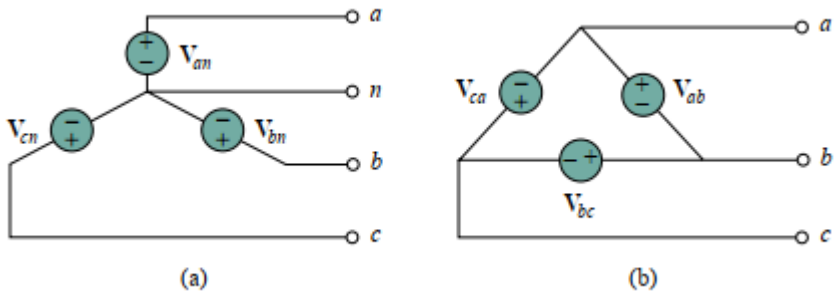

Fig. 4. Three Phase Voltage (a) Y-connection (b) Delta Connection

Balanced phase voltages are equal in magnitude and are out of phase with each other by 120◦.

A balanced load is one in which the phase impedances are equal in magnitude and in phase

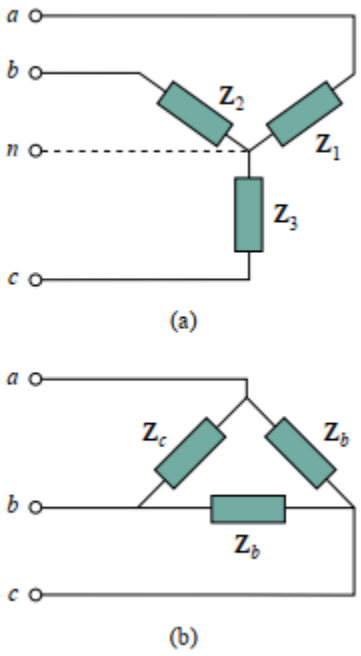

Fig. 5. Balance Load

Phase Sequence Calculation

The phase sequence may also be regarded as the order in which the phase voltages reach their peak (or maximum) values with respect to time.

Two types of phase sequence are found in three phase system.

- Positive Sequence
- Negative Sequence

Since the three-phase voltages are 120◦ out of phase with each other, there are two possible combinations. One possibility is shown in Fig. 6 (a) and expressed mathematically as

$$Van = Vp \angle 0^\circ$$

$$Vbn = Vp \angle -120^\circ$$

$$Vcn = Vp \angle -240^\circ = Vp \angle +120^\circ$$

where Vp is the effective or rms value. This is known as the abc sequence or positive sequence. In this phase sequence, Van leads Vbn, which in turn leads Vcn. This sequence is produced when the rotor in Fig. 6(a) rotates counterclockwise. The other possibility is shown in Fig. 12.7(b) and is given by

$$Van = Vp \angle 0^\circ$$

$$Vcn = Vp \angle -120^\circ$$

$$Vbn = Vp \angle -240^\circ = Vp \angle +120^\circ$$

This is called the acb sequence or negative sequence. For this phase sequence, Van leads Vcn, which in turn leads Vbn.

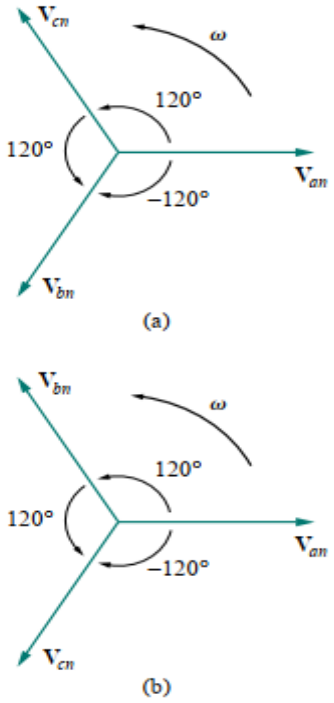

Fig. 6 (a) positive sequence (b) Negative sequence.

Possible Configuration

There are four possible combinations of three phase systems.

- Y-Y connection (i.e., Y-connected source with a Y-connected load).
- Y-Δ connection.
- Δ-Δ connection.
- Δ-Y connection.

In subsequent sections, we will consider each of these possible configurations. It is appropriate to mention here that a balanced delta-connected load is more common than a balanced wye-connected load. This is due to the ease with which loads may be added or removed from each phase of a delta-connected load. This is very difficult with a wye-connected load because the neutral may not be accessible. On the other hand, delta connected sources are not common in practice because of the circulating current that will result in the delta-mesh if the three-phase voltages are slightly unbalanced.

What are the problem of delta-wye system?

Practice Problems:

Determine the phase sequence of the set of voltages

$$v_{an} = 200\cos(\omega t + 10°)$$

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

Practice Problems:

Given that $\mathbf{V}_{bn} = 110\angle 30°$, find $\mathbf{V}_{an}$ and $\mathbf{V}_{cn}$, assuming a positive (abc) sequence.

Answer: $110\angle 150°$, $110\angle -90°$.

OBE based Question:

Suppose you are Mr. X, assistant engineer of PGCB, who has worked on a three-phase system. During your experiment, you have used the phase voltage of 110<0˚v, 110<-120˚ v, and 110<120˚v of a generator. If you will use the phase voltage of 110<-30˚v, 110<90˚v, and 110<210˚v, the phase sequence will be different-Justify this.

30 minutes for group study