Note that this equation indicates that the instantaneous power is always constant in time rather than pulsating, as in the single-phase case. Therefore, power delivery from a three-phase voltage source is very smooth, which is another important reason power is generated in three-phase form.

11.2

Three-Phase Connections

By far the most important polyphase voltage source is the balanced three-phase source. This source, as illustrated by **Fig. 11.9**, has the following properties. The phase voltages—that is, the voltage from each line a, b, and c to the neutral n—are given by

$$\begin{aligned}
\mathbf{V}_{an} &= V_p\underline{/0°} \\
\mathbf{V}_{bn} &= V_p\underline{/-120°} \\
\mathbf{V}_{cn} &= V_p\underline{/+120°}
\end{aligned} \qquad\qquad \textbf{11.11}$$

The phasor diagram for these voltages is shown in **Fig. 11.10**. The phase sequence of this set is said to be *abc* (called positive phase sequence), meaning that $\mathbf{V}_{bn}$ *lags* $\mathbf{V}_{an}$ by 120°.

We will standardize our notation so that we always label the voltages $\mathbf{V}_{an}$, $\mathbf{V}_{bn}$, and $\mathbf{V}_{cn}$ and observe them in the order *abc*. Furthermore, we will normally assume with no loss of generality that $\underline{/\mathbf{V}_{an}} = 0°$.

An important property of the balanced voltage set is that

$$\mathbf{V}_{an} + \mathbf{V}_{bn} + \mathbf{V}_{cn} = 0 \qquad\qquad \textbf{11.12}$$

This property can easily be seen by resolving the voltage phasors into components along the real and imaginary axes. It can also be demonstrated via Eq. (11.9).

From the standpoint of the user who connects a load to the balanced three-phase voltage source, it is not important how the voltages are generated. It is important to note, however, that if the load currents generated by connecting a load to the power source shown in Fig. 11.9 are also *balanced*, there are two possible equivalent configurations for the load. The equivalent load can be considered as being connected in either a *wye* (Y) or a *delta* (Δ) configuration. The balanced wye configuration is shown in **Fig. 11.11a** and equivalently in **Fig. 11.11b**. The delta configuration is shown in **Fig. 11.12a** and equivalently in **Fig. 11.12b**. Note that in the case of the delta connection, there is no neutral line. The actual function of the neutral line in the wye connection will be examined, and it will be shown that in a balanced system the neutral line carries no current and, for purposes of analysis, may be omitted.

The wye and delta connections each have their advantages. In the wye case, we have access to two voltages, the line-to-line and line-to-neutral, and it provides a convenient place to connect to ground for system protection. That is, it limits the magnitude of surge voltages. In the delta case, this configuration stays in balance better when serving unbalanced loads, and it is capable of trapping the third harmonic.

Figure 11.9

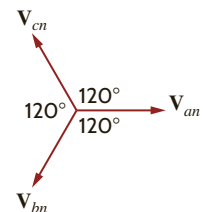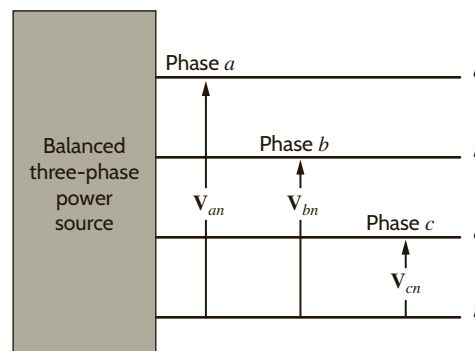Balanced three-phase voltage source.

Figure 11.10

Phasor diagram for a balanced three-phase voltage source.