Topic Refresher: **THE POWER TRIANGLE**

Active, Reactive, and Apparent Power

Power in AC circuits consists of active, reactive, and apparent power. These three quantities are interrelated, and the power triangle is commonly used to describe these relationships.

As shown in Figure 1, the quantities are:

- Active power (P), or "true power" in the figure, given in watts (W)[1]
- Reactive power (Q), given in volt ampere reactive (var) [2]
- Apparent power (S), given in volt ampere (VA)
- Power factor (p.f.), the ratio of active power to apparent power.

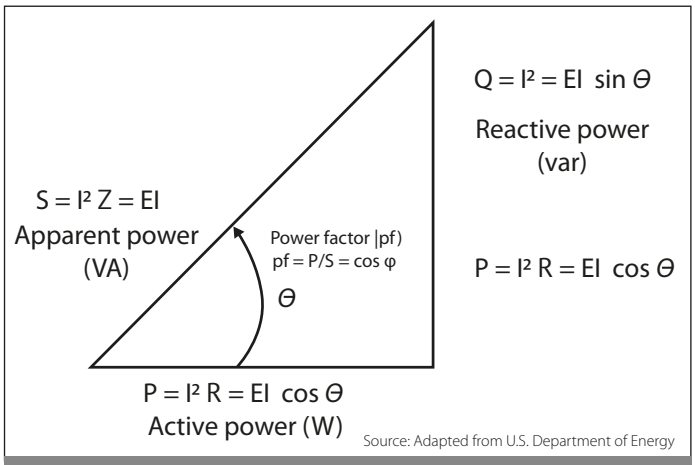

Figure 1. Power triangle

The equations for calculating these values from basic electrical quantities of root mean square voltage (E), resistance (R), reactance (X), impedance (Z), and root mean square current (I) are also shown in Figure 1.

Apparent power is the total power delivered to an AC circuit. The total power might have an active power component that is consumed by resistive loads in the circuit and produces useful work, and the total power might have a reactive power component that is needed to maintain or charge inductive and capacitive fields in the circuit. Both inductive and capacitive loads need reactive power; however, they are opposite in polarity. The reactive component could be inductive, which absorbs positive var; or the reactive component could be capacitive, which absorbs negative var (U.S. Department of Energy 1992).

Inductive Loads

Examples of purely resistive loads are incandescent lightbulbs, toasters, and electric stoves. Inductive loads include all loads with motors, such as hair dryers, fans, blenders, and vacuum cleaners. These types of loads, relative to resistive loads, take longer to develop their magnetic fields

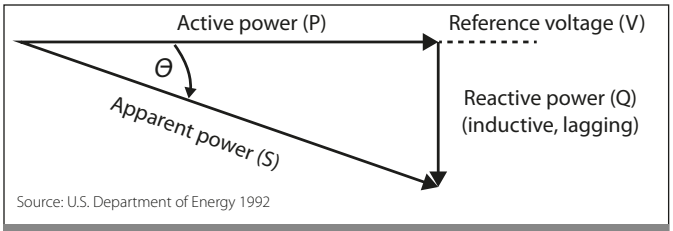

Figure 2. Power triangle with inductive circuit

when voltage is applied, which produces a slight delay in the current. Because of this phenomenon, we can say that for an inductive circuit, current lags the voltage, and the circuit has a lagging power factor (Blume 2007; U.S. Department of Energy 1992). A diagram of the active, reactive, and apparent power components in an inductive circuit is shown graphically in Figure 2.

Capacitive Loads

Examples of capacitive loads include cathode ray TV picture tubes and long extension cords. Recall that a capacitor is a device that takes a bit of time to charge to full power from the charging current. Because of this, we can say that for capacitive loads, current leads the voltage, and the circuit has a leading power factor. A diagram of the active, reactive, and apparent power components in a capacitive circuit is shown graphically in Figure 3.

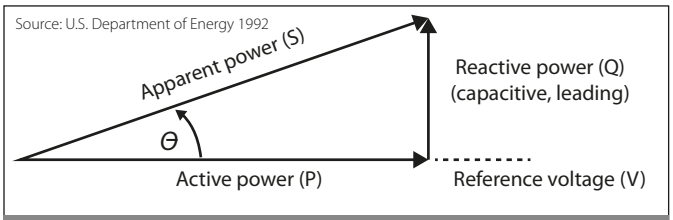

Figure 3. Power triangle with capacitive circuit

Typical distribution circuits contain resistive and inductive loads; therefore, utilities install capacitors to balance the var requirement (Blume 2007).

References

Blume, Steven W. 2007. *Electric Power System Basics: For the Nonelectrical Professional*. IEEE Press Series on Power Engineering. Hoboken, New Jersey: John Wiley & Sons.

U.S. Department of Energy. 1992. *DOE Fundamentals Handbook: Electrical Science, Volume 3 of 4* (DOE-HDBK-1011/3-92). Washington, D.C. https://www.standards.doe.gov/standards-documents/1000/1011-bhdbk-1992-v3.

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[1]In Figure 1, this is shown as true power. It also known as real power.

[2]This document uses the IEEE Std 270-2006 convention for the name and symbol var for reactive power. (For reference, see IEEE Std 270-2006 definitions 3.251 for reactive power and 3.327 for var.)