Power Factor—

Ratio of True to Apparent Power

Ian Woofenden

Derivation: From Latin posse, *to be able, and Latin* factor, *maker, doer.*

Electrons, or "charges," are the energy carriers in an electrical circuit. Charges are part of the material of the conductor, the copper or aluminum wire. They go in one direction around a direct current (DC) circuit. They go back and forth in an alternating current (AC) circuit. Charges don't leave the circuit, and they aren't used up.

In AC circuits, the direction of charge flow reverses many times a second. The voltage (electrical pressure) and amperage (rate of charge flow) go from zero to maximum in one direction ("positive"), back to zero, to the maximum in the other direction ("negative"), and then back to zero. We call this a "cycle, " and in the United States, AC is 60 cycles per second (Hertz or Hz for short).

When the voltage and amperage peak and then go to zero at the same time as each other, we say that they are "in phase." (See diagram below left.) This is what happens in circuits that have only resistance. But many AC circuits also have a couple of other electrical properties—inductance and capacitance. These push the voltage and amperage out of phase with each other, so that they peak at different times. We call these circuits "reactive," because some of the energy is bounced back at the source in a delayed reaction, due to the characteristics of inductors and capacitors. Reactive loads include motors, fluorescent light ballasts, and many electronic devices.

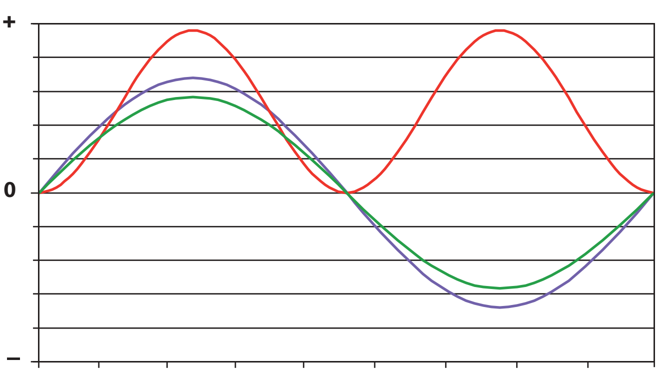
Power, the rate of energy flow, can be calculated by multiplying voltage and amperage (electrical pressure and charge flow rate). So theoretically, if your source voltage is 120 and your amperage is 10, you are generating energy at the rate of 1,200 watts. (We'll ignore the intricacies of rms, techies.)

In a reactive circuit, it's not that simple, because the voltage and amperage are not in phase. The second diagram (below right) shows a circuit where the voltage and amperage are not in phase—they peak at different times, and the power actually goes negative for a portion of the cycle (shaded area). With the same voltage and amperage out of the generator, the actual power available to the load will be less in this circuit.

The generating source has to produce the full amperage in either case. But less power is available to the load when voltage and amperage are out of phase. Some of the charges are just moving energy back and forth unnecessarily, and this creates an illusion of power, known as "reactive power."

We call the product of volts times amps in a reactive circuit "apparent power" (also called "volt-amps", and abbreviated "VA"). We call the power that is usable to the load "true power" (watts, abbreviated "W"). The ratio of

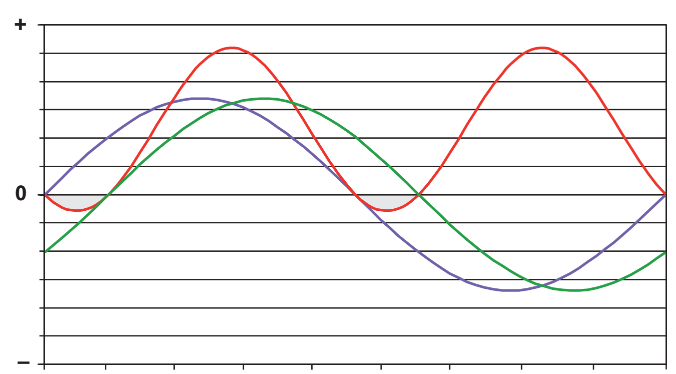
Resistive Load (PF = 1.0, V & A In Phase)



Time

Voltage Power Amperage

Reactive Load (PF = 0.8, V & A Out of Phase)



Time

Voltage Power Amperage

apparent power to true power is called "power factor" (PF). A power factor of 1 is ideal. It is when the apparent and true power are the same.

$$W \div VA = PF$$

If we take the same 120 volts and 10 amps from the example above, but the load in the circuit has a power factor of 0.8, the power available to the load will actually be only 960 watts.

The excess energy in reactive circuits is not lost. It just "sloshes" around in the circuit, bouncing back to the source. But since losses in a circuit are tied directly to the charge flow rate (amperage), raising the amperage in a given size of wire means that the losses will increase. So a circuit with bad (low) power factor will need larger wires to keep the losses at the same level as a circuit with good (high) power factor.

On the physics side of things, I like to picture charges bouncing back and forth in a reactive circuit. They don't do the work they could because the driving force (voltage) is out of synch with the charge flow. "Watts" measures the energy flow from the generating source to the load. "Volt-amps" measures the theoretical maximum energy flow, including the illusory reactive energy that is bounced back to the generating source.

The practical lessons are that high power factor devices are always going to be easier on your generating sources—they will increase efficiency in your systems. And wire sizing must take into account the full apparent power that the load needs, even though some of it is recycled by the circuit.

My thanks to Hugh Piggott for going above and beyond the call in helping me with the technical end of this column. He says, "I have seen it compared to a glass of beer. The amount of beer in the glass is the apparent power. The liquid is real power. The froth is reactive power." Me? I don't drink the stuff, so I wouldn't know…

Access

Ian Woofenden, PO Box 1001, Anacortes, WA 98221 • ian.woofenden@homepower.com