EnergyIdeas
Clearinghouse

Energy Efficiency
FACTSHEET

Reducing Power Factor Cost

Low power factor is expensive and inefficient. Many utility companies charge large commercial and industrial customers an additional fee when power factor is less than about 0.95. Low power factor also reduces an electrical system's distribution capacity by increasing current flow and causing voltage drops. This factsheet describes power factor and explains how you can improve your power factor in order to reduce electric bills and enhance your electrical system's capacity.

Why Improve Your Power Factor?

Some of the benefits of improving your power factor are:

- Your utility bill will be smaller. Low power factor requires an increase in the electric utility's transmission and distribution capacity in order to handle the reactive power component caused by inductive loads. Utilities usually charge large customers with power factors less than about 0.95 an additional fee. You can avoid this additional fee by increasing your power factor.
- Your internal electrical system's capacity will increase. Uncorrected power factor will cause increased losses in your electrical distribution system and limit capacity for expansion.
- Voltage drop at the point of use will be reduced (i.e. improved). Voltages below equipment rating will cause reduced efficiency, increased current, and reduced starting torque in motors. Under-voltage reduces the load motors can carry without overheating or stalling. Under-voltage also reduces output from lighting and resistance heating equipment.

What is Power Factor?

AC power is transmitted with the least losses if the current is undistorted and exactly synchronized with the voltage. Light bulbs and resistance heaters draw current exactly synchronized and proportional to voltage, but most other loads tend to draw current with a time lag (i.e. phase shift) or to distort it (i.e. introduce harmonics). It takes more current to deliver a fixed amount of power when the current is phase shifted or distorted. The ratio of the actual power transmitted ("real power") to the apparent power that could have been transmitted if the same current were in phase and undistorted is known as the power factor. It is always less than or equal to 1.

$$\text{Power Factor} = \frac{\text{Real Power}}{\text{Apparent Power}}$$

Before the growth in electronic loads, such as computers and adjustable speed motor drives, distortion was only a minor problem. Instruments and analysis techniques for evaluating power factor were devised only to consider the phase shift component of power factor. Phase shift is measured in degrees, but it is equivalent to time (where 360 degrees equals the time required for one full AC cycle). Today this component of power factor is called the displacement power factor (DPF) to distinguish it from the true power factor (TPF) that accounts for distortion as well as phase shift.

Utilities that impose low power factor penalties tend to meter and bill only on DPF. Ignoring the effects of harmonic distortion leads to some fairly simple mathematical relationships illustrated by the power triangle in Figure 1.

Real power = 100 kW

Phase angle = 45.6°

Reactive power = 102 kVAR

Apparent power = 143 kVA

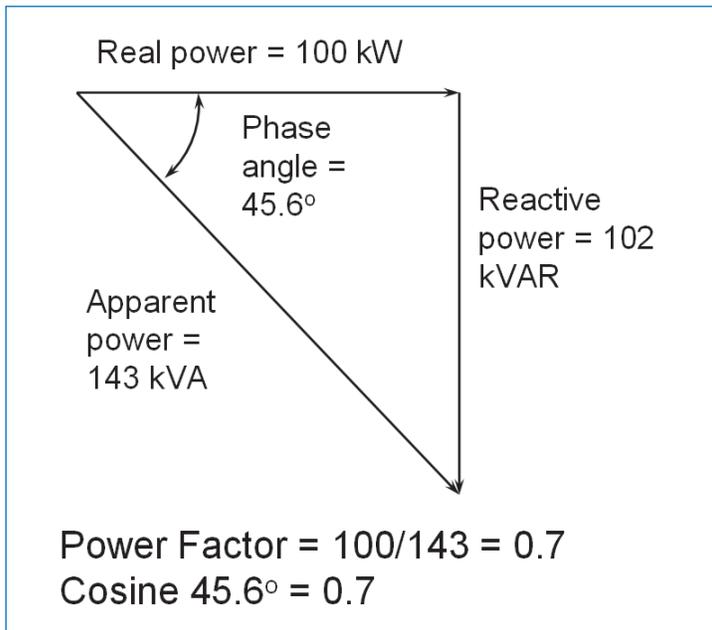Power Factor = 100/143 = 0.7
Cosine 45.6° = 0.7

Figure 1. Power Triangle

If you measure current with an ammeter and voltage with a voltmeter, you can multiply them to get apparent power. The real power equals the apparent power multiplied by the cosine of the phase angle difference between voltage and current. DPF is exactly equal to the cosine of the phase angle difference. A third power term is reactive power. The physical meaning of reactive power can be better understood by considering the example plot of voltage and current for a motor using 200 kW and 0.7 power factor (see Figure 2).

The power cycles at twice line frequency, averaging +200 kW over a full cycle. At each instant the voltage multiplied by the current equals instantaneous power. Even when both current and voltage are negative, the power is positive because a minus times a minus is a plus.

However, phase lag causes voltage to sometimes be positive when current is negative and vice versa. In these instants, power is negative and the motor is actually a generator feeding power back into the system. One can think of apparent power as the total power exchange between the motor and power line, the real power as the net power flow to the motor, and the reactive power as the component of apparent power that is exchanged back and forth between the line and the motor.
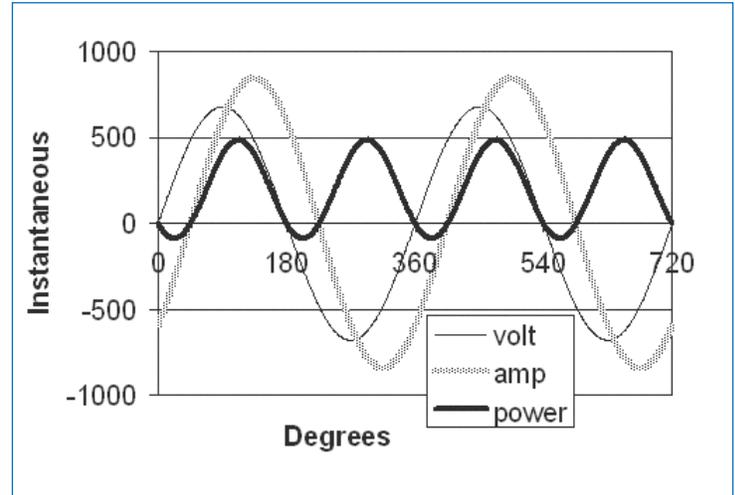

Figure 2. 0.7 Power Factor at 200kW

Cause of Low Power Factor

Low power factor is caused mainly by induction motors, but also by inductive loads (such as transformers and magnetic lighting ballasts). Unlike resistive loads that create work entirely by consuming watts or kilowatts, inductive loads require some current to create a magnetic field, and the magnetic field facilitates the desired work. The total or apparent power required by an inductive device is a composite of the following:

◆ Real power (measured in kilowatts, kW)
◆ Reactive power associated with components that alter-
  nately store energy and release it back to the line during
  each AC cycle (measured in kilovars, kVAR)

Reactive power required by inductive loads increases the amount of apparent power (measured in kilovolt amps, kVA) in your distribution system. The increase in reactive and apparent power is reflected by the increase of the angle between the two, causing the power factor to decrease.

Correcting Your Power Factor

Some strategies for correcting your power factor are:

◆ Install capacitors in your AC circuit to decrease the magnitude of reactive power. Capacitors draw leading reactive power. That means their current is 180 degrees out of phase with inductive loads, so they are storing energy when inductive loads are releasing it back to the line and vice versa.

As shown in Figure 3, reactive power (measured in kVARs) caused by inductance always acts at a 180-degree angle to reactive power from capacitors.
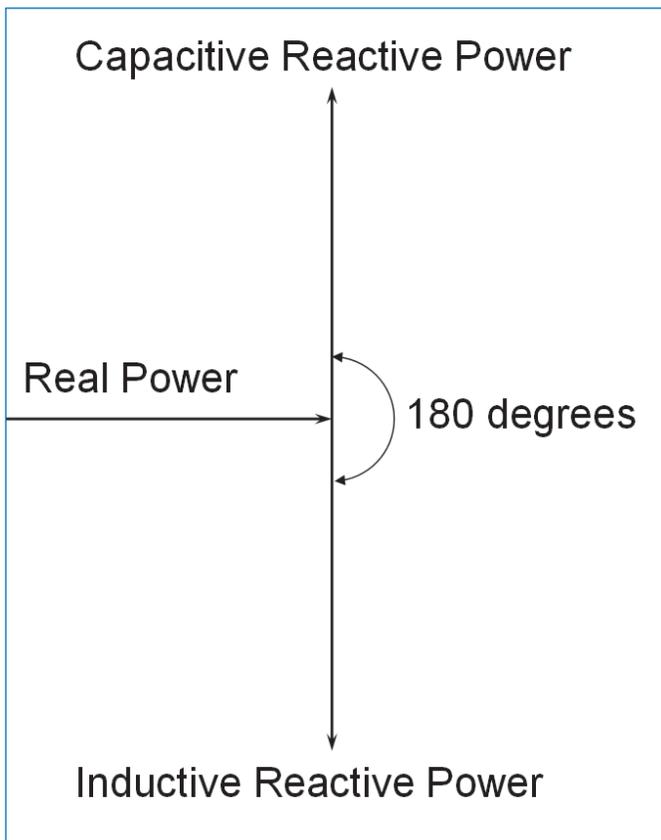
Figure 3. Capacitive Reactance/Inductive Reactance

The presence of both inductive and capacitive reactance in the same circuit results in the continuous alternating transfer of energy between the capacitor and the inductive load, thereby reducing the current flow from the line. In a sense, energy is caught and reflected back by the capacitor instead of having to flow all the way back and forth from the power generator.

In Figure 4 the power triangle shows an initial 0.70 power factor for a 100 kW (real power) inductive load. The reactive power required by the load is 102 kVAR. By installing a 69-kVAR capacitor, the apparent power necessary is reduced from 143 to 105 kVA, resulting in a 27 percent reduction in current. Power factor is improved to 0.95.
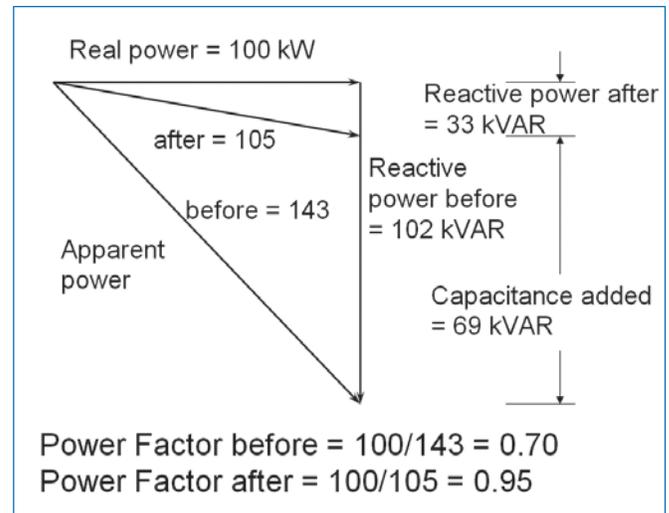

Power Factor before = 100/143 = 0.70
Power Factor after = 100/105 = 0.95

Figure 4. Effect of Power Factor Correction

◆ Replace over-sized motors with NEMA Premium™ efficiency motors of the right horsepower. Any motor's power factor is dramatically worse when it is loaded significantly below the full nameplate horsepower rating.
◆ Shut down idling motors. When totally unloaded, even uncoupled, a motor still draws over half its full-load reactive power.
◆ Avoid operation of equipment above its rated voltage. Over-voltage increases reactive power.

Capacitor suppliers and engineering firms can provide the assistance you may need to determine the optimum power factor correction and to correctly locate and install capacitors in your electrical distribution system.

 Be mindful that if harmonic distortion is significant in your power system, DPF analysis techniques will understate your true reactive power and overstate your true power factor. DPF analysis may accurately reflect the power factor metered and billed by your utility, but it will understate your in-plant distribution system losses. Moreover harmonic distortion can cause a variety of other system problems including harmful resonance currents in capacitors you have installed to control DPF. If you suspect significant harmonic distortion, you must address harmonic problems in conjunction with displacement power factor.

Businesses and industries in the Pacific Northwest can get additional technical information on controlling power factor from the EnergyIdeas Clearinghouse. See the end of this factsheet for contact information.

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