Capacitors

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In terms of electrical savings, capacitors reduce line losses and power factor penalty. Generally, electricity utility suppliers install revenue meters capable of recording kilowatt demand, kilowatt-hours (kWh) and kilovolt-amp reactive hours (kVARh) on customers' electric lines that exceed pre-established peak demand levels.

Electrical power in Alternating Current (AC) has three components: real power ($P = I^2R$), reactive power ($Q = I^2X$), and apparent power ($S = I^2Z$). Inductive loads, such as transformers, electric motors, and high intensity discharge lighting, cause low power factor. Power factor (PF) is the ratio of real power to apparent power, and represents how much real power electric equipment utilizes.

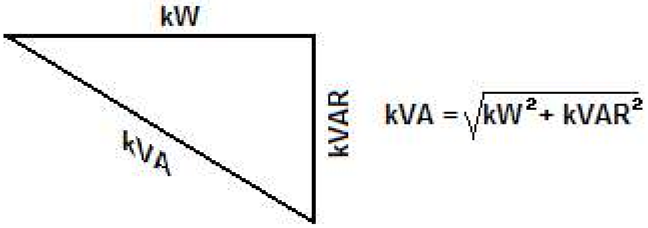
Power Factor = W (real Power)/VA (Apparent Power)

Electrotek Concepts, a leading power systems engineering consultant, cautions that power factor should not be confused with energy efficiency or conservation. They note that improving the efficiency of electrical equipment reduces energy consumption, but may not improve power factor.

Inductive loads require the electrical current to produce a magnetic field, which produces the desired work. The total or apparent power required by an inductive device is the addition of real power, measured in Watts (W), and reactive power, which is the nonworking power resulting from the magnetizing current measured in Volt-Amps reactive (VAR).

Apparent Power (VA) = Real Power (W) + Reactive Power (VAR)

The "power triangle," below, illustrate the relationship between apparent, real, and reactive powers:



Reactive power required by inductive loads increases apparent power, measured in Volt-Amps (VA), which causes the power factor to decrease. Low power factor causes power losses in the electric distribution system, which causes voltage drops. Low voltage can cause overheating and premature failure of motors and other inductive devices; some utilities charge a penalty for low power factor.

Low power factor require a higher current draw, which leads to larger cables in the electrical distribution system. Higher currents lead to higher copper losses in cables and transformers.

A reduction in kVARs reduces apparent power and increases power factor. Reducing kVARs, however, does not reduce kW. Therefore, if the customer is not incurring a utility penalty, savings, if any, will be insignificant.

Small and fractional horsepower motors have low power factors in the range of 50 to 60%, see graph below. Likewise, idling and lightly loaded motors, as well as equipment that operate above its rated voltage adversely affect power factor.

High Efficiency Motors

High efficiency motors when operated near their rated capacity realize the benefits of high efficiency design. Therefore, as low efficiency motors fail, they should be replaced with high efficiency motors. High efficiency motors meet the Energy Policy Act (EPAct) of 1992 and have lower losses than old standard motors, and NEMA Premium motors have lower losses than the high efficiency motors.

Capacitors

Capacitors store energy in an electric field, produced by electric charges on the capacity plates. Capacities connected from line to neutral provide reactive power to an AC circuit. When the capacity provides reactive power, it mitigates or eliminates the need for the system to provide it. The maximum energy that can be store in a given capacitor is limited by the maximum electric field that the dielectric can withstand before it breaks down.

Strategically placed capacitors, in parallel with the load, can reduce the magnitude of reactive power of the system, between the loads and the metering point. Thus, capacitors reduce total current used by the load. Ghosh (2003) indicates that capacitors draw the leading current and partially, or completely, neutralize the lagging reactive component of the current.

Pacific Gas and Electric Company (PG&E) recommends that customers contemplating power factor reduction must understand existing and future harmonic content of the loads in the premise, because failure to do so will result in a potential catastrophic failure of the capacitor.

Adding capacitors to the power system introduces the possibility of resonance. If the reactance of inductive and capacitive parts of a circuit is equal, energy will oscillate between the inductance and capacitance, producing high voltages that could increase the capability of the system's insulation (PG&E, 2004); more VARS than needed should not be introduced in the system.

Correcting for line losses by adding capacitors should only be implemented after consultation with an experienced electrical engineer and if, within a six-year period, the marginal benefit exceeds the marginal cost of installing the capacitor. According to Ghosh (2003), the life of a capacitor is limited to about 8 to 10 years.

The two economic drivers that that would cause a customer to consider installing power factor correction capacitors are: (1) additional load cannot be added to the existing customer electrical distribution system and (2) to avoid or reduce utility penalty for low power factor (PG&E, 2004).

PG&E (2007) notes that capacitors should be as near the load as possible or near the end of feeders to:

1. Reduce total current in circuits between the load and the metering point.
2. Raise voltage near the loads, rendering improved motor performance.
3. Capacitor kVAR reduction as the load drops off.

Capacitors can reduce utility penalty incurred for poor power factor. Power factor adjustment only applies to customers that have high kW demand. Capacitors also can reduce line losses. However, line losses are general small.

PG&E (2004) indicates that facilities that have more than more than 15% non-linear load, such as adjustable speed drives, should perform a harmonic study prior to installing capacitors. Accordingly, shunt capacitors can change the system response to injected harmonic currents. They also noted that transient over-voltages are of concern when capacitor switching is involved.

References

Ghosh, S. (2003). Fundamentals of electrical and electronic engineering. New Delhi, India: Prentice Hall.
Economics of Power Factor Correction in Large Facilities, > 400kW, April 2004. Retrieved January 1, 2008 from http://www.pge.com/docs/pdfs/biz/power_quality/power_quality_notes/economics.pdf.