PEP

POWER EFFICIENCY PROJECT

Professor Max Powers' Power Efficiency Project (PEP) is brought to you by the Kansas Corporation Commission and Kansas State University Engineering Extension. Funding provided by a grant from the U.S. Department of Energy.

Power Factor

Although commercial facilities account for an estimated 18%[1] of energy use in the U.S., energy auditors are quick to note many commercial facilities do not analyze their electric bills – the utility provider sends the bills to the facility's accounting department and they simply pay the bill. Even if the facility does look at the electric bill, it frequently looks only at the energy consumption (kWh) and energy demand (KW). An important component frequently overlooked is the **power factor**.

Power factor is a measure of how effectively your facility is using electricity. It is the ratio of the real power used to do work and the apparent power supplied to the circuit. The power factor, which can be found on a utility bill, will be between 0 and 1. A higher power factor benefits both the customer and the electric utility provider. *Note: This is not something that you will see on residential utility bills, but it will be found on the utility bill for a commercial or industrial user such as a grocery store or factory.*

One way to understand power factor is to consider a horse pulling a barge down a canal (see **Figure 1**). It will pull the boat both down the river and toward the shore since the horse is at an angle to the boat. The horse and barge can serve as an example for power factor, or the efficiency of a system. The apparent power or total power is how much the horse and boat move or do work. The reactive power is the unwanted work, in this case how far the boat moves toward the shore. The real power is the desired result, or how far the boat is moved down the river.

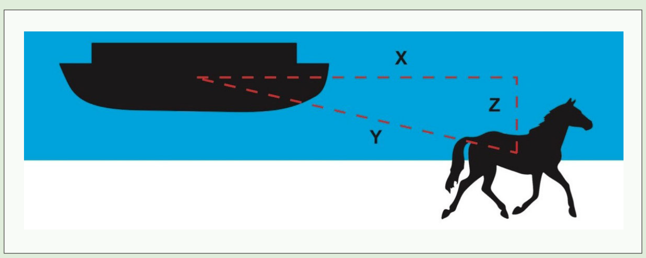

Figure 1:

X represents the real power, Y is the apparent power, and Z is the reactive power.

What is Reactive Power?

When you flip on a switch, voltage and current flow into your equipment in transverse waves. You can think of real power as the positive power generated when the voltage and current are in sync. All the power is used to power your equipment. However, if the waves are not synchronous, some of the power supplied (apparent power) is reactive power, which is not used to power your equipment.

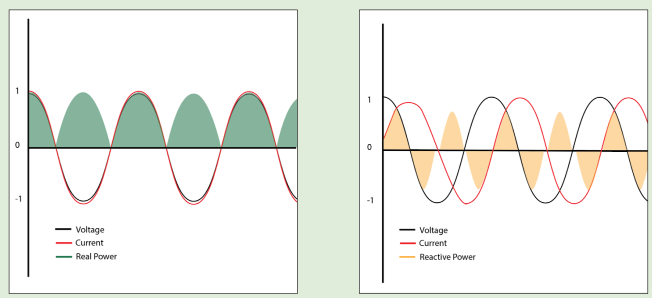

Figure 2:

The left shows the positive, desired power when the voltage and current are synchronized. On the right, non-synchronous waves are shown with reactive power filling in the spaces between.

Reactive power is prevalent with inductive loads (also known as lagging loads, where the current lags behind the voltage), usually from motors. A higher reactive power lowers the power factor, which can cost you money. Induction motors, such as those that are part of refrigeration systems, heating, ventilation, and air conditioning (HVAC) systems, pumps, etc., are the most common cause of a low power factor, because many tend to be in use at similar times and they often run at less than a full load.

The power factor decreases when reactive power increases, as can be seen in the equation below.

$$\textbf{Power Factor} = \frac{\textbf{real power (kW)}}{\textbf{real power (kW) + reactive power (VAR)}}$$

Why does this matter to me?

When you order a soda, you would not want your glass to be completely full of foam. Energy companies agree. Since the electric utility companies provide the apparent power, they prefer that there is little wasted or reactive power. Some utility providers may charge a fee each billing cycle if a company has a power factor of less than 0.90 or 0.95.

How do I increase my power factor?

Industrial motors cause a huge amount of reactive power. To reduce the use of reactive power, a capacitor or a more energy efficient motor can be installed. Capacitors provide the required amount of reactive power instead of pulling it from the electric grid.

Case study

A family-owned grocery store serving a rural community in a small Kansas town is looking to reduce its energy costs. While looking at the utility bill, the grocery store discovered its power factor was 0.6; the utility provider penalizes facilities with a demand factor below 0.95. While no energy savings are associated with an improved power factor, power factor-related and demand-related charges can be decreased.

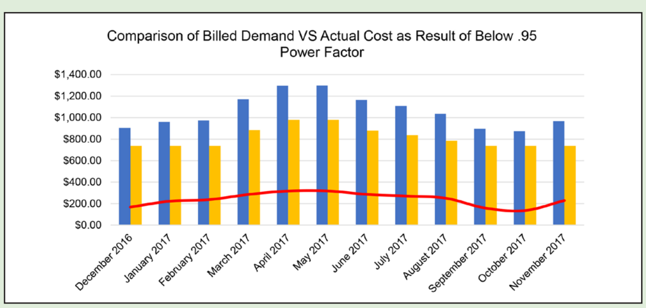

Figure 3:

The grocery store saw a monthly increase in energy costs due to a low power factor.

For the month of January 2017, the grocery store was billed $905.12 for an electric demand of 61.4kW. The actual demand was $737.50 based on 46.4kW actual demand, and a minimum charge of 50kW. Subtracting actual demand from billed demand yields a difference of $167.62, due to the low power factor. By correcting the power factor to 0.95 (the minimum at which no additional charge will be incurred according to the electric provider), the grocery store would see an annual cost savings of almost $3,000 based on historical electricity bills.

Month	Year	Billed Electric Demand (kW)	Actual Electric Demand (kW)	Billed Demand Charge	Actual Demand Charge (based on $14.75/kW)	Actual Demand Charge (minimum of 50kW charged for)	Amount Paid (as result of power factor being under .95)
January	2017	61.364	46.4	$905.12	$684.40	$737.50	$167.62
February	2017	65.082	49.2	$959.96	$725.70	$737.50	$222.46
March	2017	66.08	50	$974.68	$737.50	$737.50	$237.18
April	2017	79.344	60	$1,170.32	$885.00	$885.00	$285.32
May	2017	87.907	66.4	$1,296.63	$979.40	$979.40	$317.23
June	2017	87.953	66.4	$1,297.31	$979.40	$979.40	$317.91
July	2017	78.958	59.6	$1,164.63	$879.10	$879.10	$285.53
August	2017	75.146	56.8	$1,108.40	$837.80	$837.80	$270.60
September	2017	70.139	53.2	$1,034.55	$784.70	$784.70	$249.85
October	2017	60.748	46	$896.03	$678.50	$737.50	$158.53
November	2017	59.221	44.8	$873.51	$660.80	$737.50	$136.01
December	2017	65.527	49.6	$966.52	$731.60	$737.50	$229.02
							$2,877.26

Figure 4:

If the grocery store improves its power factor to 0.95, the billed demand charge would be equal to the actual demand charge, saving the store the monthly amount paid as a result of low power factor.

What to do?

The grocery store can contact a qualified electrician to examine the cause of the low power factor and develop a plan to improve it. Depending on the cause, potential strategies include the following:

- Install capacitors either at the meter or smaller capacitors near motors (this option is likely to be one of the more practical and economic options). Capacitors reduce the reactive power by releasing energy at the same time the inductor is absorbing energy, instead of the inductor drawing the power directly from the grid.
- Install variable frequency drive (VFD) systems on induction motors with low loads or install new motors that will operate near their rated capacity.
- Minimize operation of motors that idle or that are lightly loaded.

References

1. https://www.eia.gov/energyexplained/index.php?page=us_energy_use

For more information on the power factor, contact Kansas State University Engineering Extension at 785-532-4998 or dcarter@ksu.edu.