The Poweer Sheet

Consultant Web Page

POWER FACTOR CORRECTION

INTRODUCTION

Power factor often is an inexpensive, as well as overlooked way to reduce electrical costs. Proper system analysis and identification of the points in the electrical distribution system where power factor can be corrected are needed before applying capacitors. First, an understanding of power factor and electric utility rates are needed.

WHAT IS POWER FACTOR?

Power factor is a measure of how effectively electrical power is used. Power factor is the ratio of "real power" and "apparent power". 1.0 is the highest attainable power factor. Figure 1, at the right, is a graphical representation of power factor.

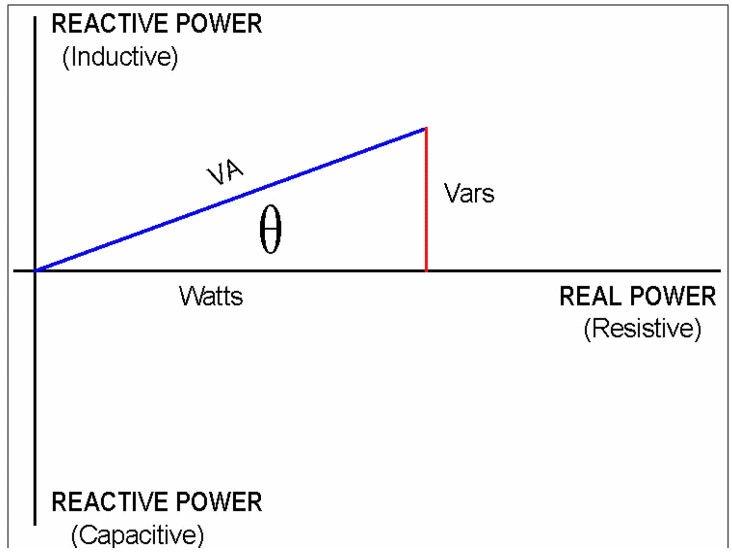

FIGURE 1 - Graphical Representation Power Factor

In Figure 1 to the right,

- **Θ = Angle between Current and Voltage**
- **COS Θ = Power Factor**

The "VOLT-AMPERES" or VA as shown in figure 1, is the apparent power while "WATTS" is the power actually doing work. Work, in this context, is considered converting electrical power to useable energy such as turning a motor shaft, powering lights, or powering electric heat. In other words, power factor is the ratio of current drawn which does real work verse the total current drawn from the electric utility.

Electric utilities charge based on the VA consumed by a facility, not the WATTS consumed. The utility must generate electric power based on the total ***apparent power*** (or VA) needed by the system. In addition, the transmission lines must be sized to carry the apparent power. Therefore, electric utilities must build power plants and transmission lines to account for power factor. Obviously this is an added capitol cost for the utility to account for power factor. Hence, the reason electric utilities often add a substantial charge to facilities with a low power factor. The low power factor adds cost to the electric utility and this cost is passed on to the end user in the form of surcharges.

REAL POWER

So what is "real power"? Real Power is the electrical power that performs actual work. For example, the work performed by an electric motor turning the motor shaft is real work. The heat an electric heater gives off is real work.

Figure 2 on page 2 shows the vector diagram of a resistive circuit. As the figure demonstrates, a purely resistive circuit has a power factor of 1 because the apparent and real power are the same. The most efficient use of electrical power occurs when the power factor is 1.

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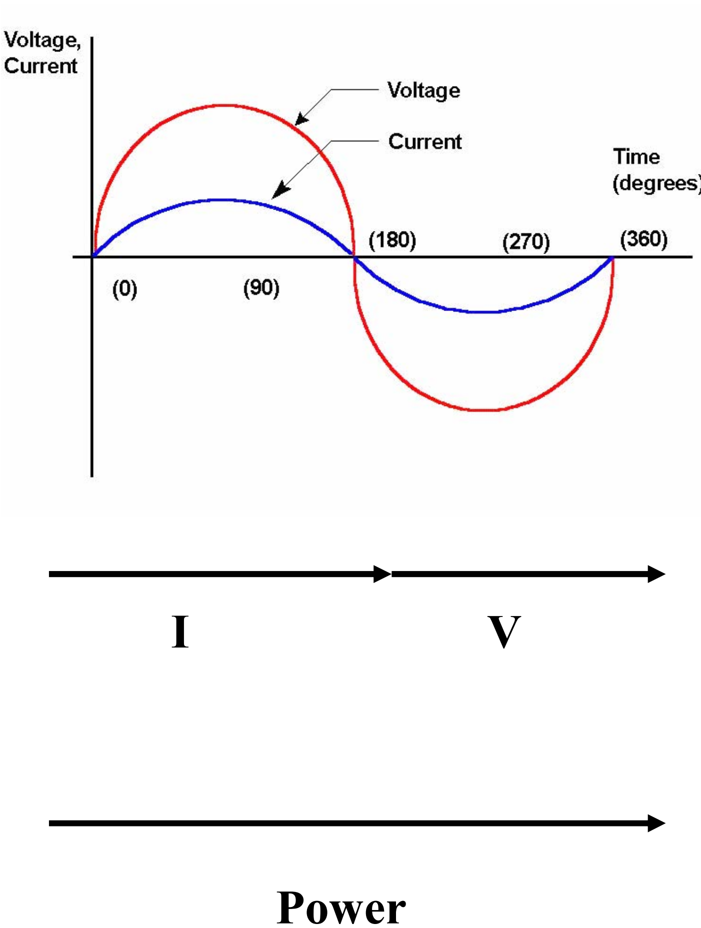

FIGURE 2 - Resistive Circuit Power Diagram

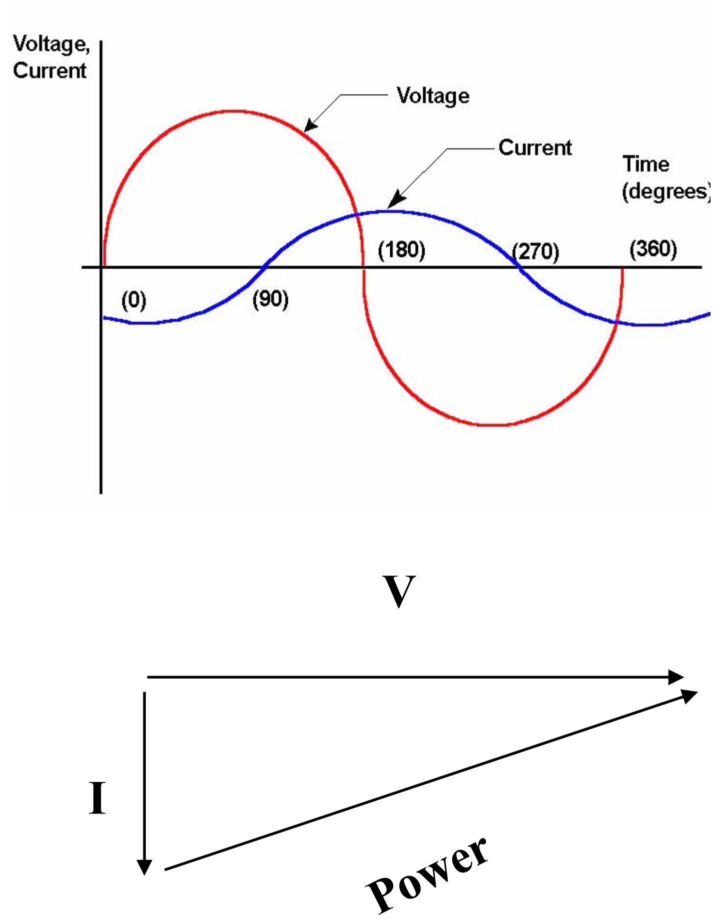

FIGURE 3 - Inductive Circuit Diagram

APPARENT POWER

To understand what apparent power is, one must understand inductive loads. Inductive loads are electrically powered devices that that need a magnetic field to produce work. The energy needed to sustain this magnetic field is the component of the apparent power which performs no real work.

For example, an electric motor uses stored electrical energy (***inductance***) to created a magnetic field in the motor stator. This electro-magnetic field is need to turn the motor shaft. Although the electro-magnetic field in the stator performs no work turning the shaft, the energy is needed for operation of the motor.

Other devices needing inductive or electro-magnetic fields for operation are florescent lighting ballasts, motors, and induction furnaces.

Figure 3 is a vector diagram of an inductive load. For these loads, current lags behind voltage by 90º. Because power is voltage times current, current that lags behind voltage produces less power that a resistive circuit where voltage and current peak at the same time. As figure 2 shows a resistive circuit where the voltage and current are in-step, meaning the current and the voltage are at the same phase angle and is the most efficient use of power. The power factor is 1 because the apparent power and the real power are doing the same work.

In contrast, Figure 4 represents capacitive circuits where voltage lags ***behind*** the current by 90º. Remember, this is opposite of inductive circuits where current lags behind voltage by 90º. Unlike inductive loads, few electrical field devices are capacitive. Therefore, an electrical distribution

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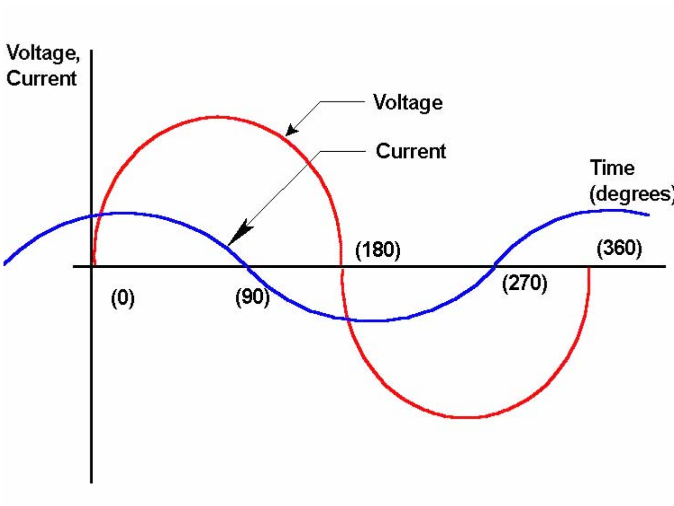

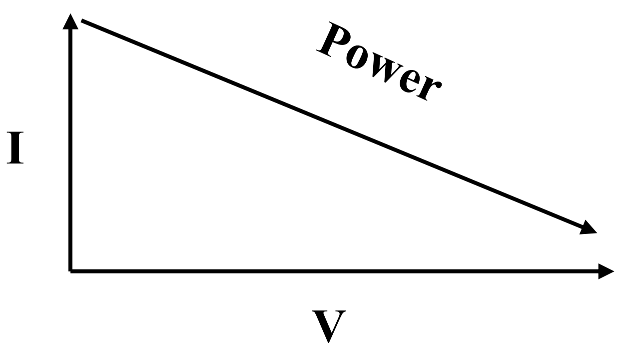

FIGURE 4 - Capacitive Circuit

systems will lean inductive. Only in those inductive loads will current of that load lag voltage by 90º. Because not every load is inductive, the total of resistive and inductive loads of the entire system will cause the current to lag voltage typically less that 90º. The closer the phase angle between the current and voltage, the more efficient the power is used and the power factor approaches 1.

POWER FACTOR CORRECTION

The idea behind power factor correction capacitors is to decrease the amount by which current lags behind voltage, making the real power more closely match apparent power. Because capacitive loads pull the current in the opposite direction of inductive loads, the addition of power factor correction capacitors on inductive loads will decrease the amount that current lags behind voltage.

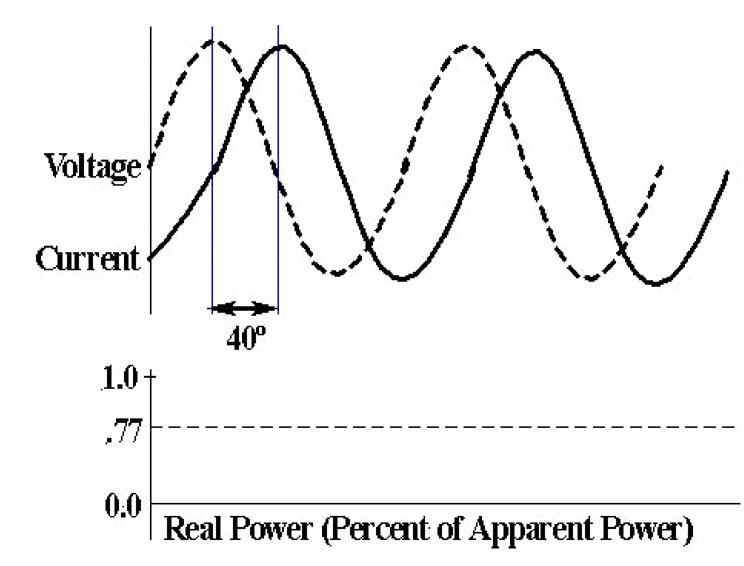

FIGURE 5 - Current and Voltage before Power Factor Correction

Figure 5 shows an inductive system load that causes the current to lag behind voltage by 40º. As seen, the points where the current and voltage peak are far apart. Because power is voltage times current, the figure show that power is not maximized because of the this separation. This 40º lagging current is a power factor of .77.

Figure 6 is after the application of power factor correction capacitors. As seen, the gap between current and voltage is closed from 40º to 20º. This decrease in lagging angle

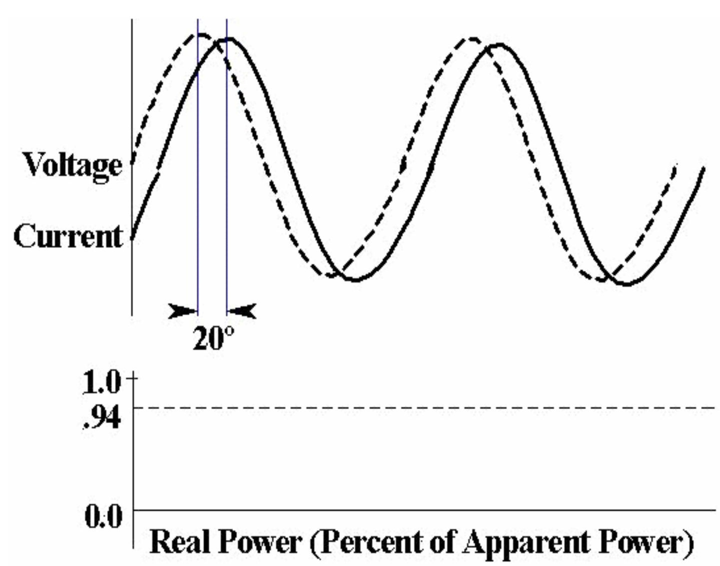

FIGURE 6 - Current and Voltage after Power Factor Correction

continued from page 3

pulls the sine wave peaks of the current and voltage closer together. Again when voltage and current are multiplied at each point, the power is greater than in Figure 5, where the separation is 40º. This 20º lagging current is a power factor of .94. This is a 20% increase in efficiency of power usage and is real dollar savings.

LOW VOLTAGE POWER FACTOR CORRCTION QUICK SELECTOR

EXISTING POWER FACTOR	DESIRED CORRECTED POWER FACTOR					
	100%	**95%**	**90%**	**85%**	**80%**	**75%**
50%	**1.732**	**1.403**	**1.247**	**1.112**	**.982**	**.850**
55%	**1.518**	**1.189**	**1.033**	**.898**	**.768**	**.636**
60%	**1.333**	**1.004**	**.848**	**.713**	**.583**	**.451**
65%	**1.168**	**.839**	**.683**	**.548**	**.418**	**.286**
70%	**1.020**	**.691**	**.535**	**.400**	**.270**	**.138**
75%	**.882**	**.553**	**.397**	**.262**	**.132**	
80%	**.750**	**.421**	**.265**	**.130**		
85%	**.620**	**.291**	**.135**			
90%	**.485**	**.156**				
95%	**.329**					

The above table is used to size power factor capacitors.

The left column is the existing power factor and the remaining columns are the desired power factor. Find the corresponding multiplication factor in the table. Use the below formula to determine the required capacitors.

kVA of capacitors required = factor from table x kW load

EXAMPLE

Load = 500kW
Existing Power Factor = 70%
Desired Power Factor = 85%

kVA of capacitors required = factor from table x kW load
= .400 x 500kW
= 200 kVA of capacitors