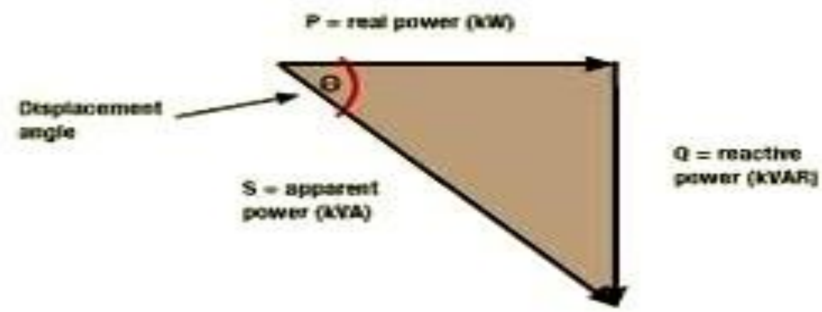
CHAPTER - 4

Power Factor Improvement

Economics of power factor improvement:

Real power is considered the work-producing power measured in watts (W) or kilowatts (kW). For example, real power produces the mechanical output of a motor.
Reactive power is not used to do work, but is needed to operate equipment and is measured in volt-amperes-reactive (VAR) or kilovar (kVAR). Many industrial loads are inductive such as motors, transformers, fluorescent lighting ballasts, power electronics, and induction furnaces.
The current drawn by an inductive load consists of two components: magnetizing current and power producing current. The magnetizing current is required to sustain the electromagnetic field in a device and creates reactive power. An inductive load draws current that lags the voltage, in that the current follows the voltage wave form. The amount of lag is the electrical displacement (or phase) angle between the voltage and current.



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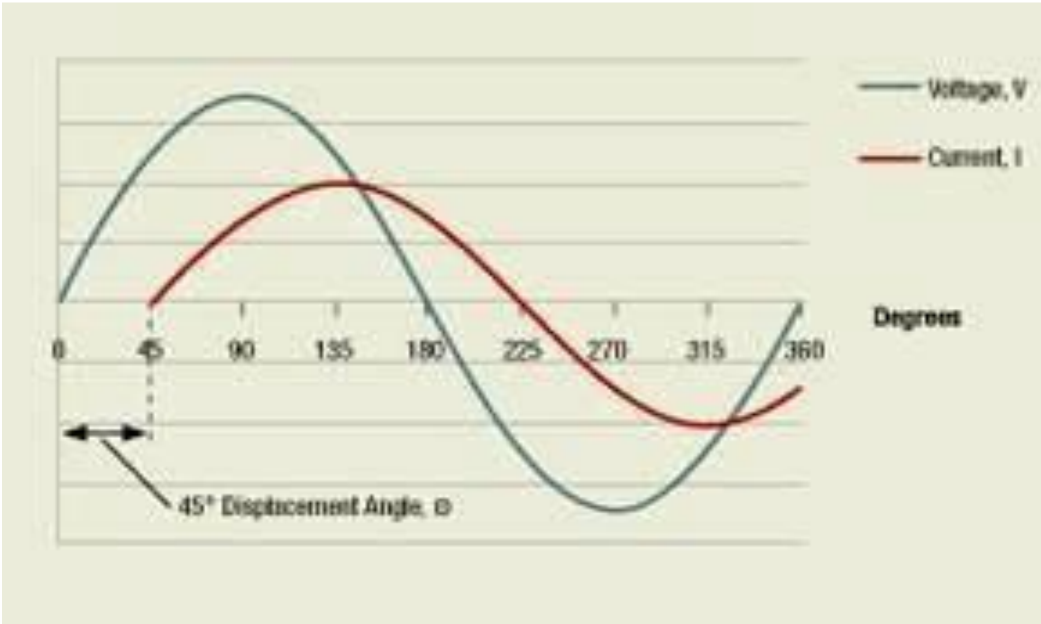
(or phase) angle between the voltage and current. n the absence of harmonics, apparent power (also known as demand power) is comprised of (vectorial sum) both real and reactive power and is measured in units of volt-amps (VA) or kilovolt-amps (kVA).

Power factor (PF) is the ratio of the real power to apparent power and represents how much real power electrical equipment uses. It is a measure of how effectively electrical power is being used. Power factor is also equal to the cosine of the phase angle between the voltage and current



Electrical loads demand more power than they consume. Induction motors convert at most 80% to 90% of the delivered power into useful work or electrical losses. The remaining power is used to establish an electromagnetic field in the motor. The field is alternately expanding and collapsing (once each cycle), so the power drawn into the field in one instant is returned to the electric supply system in the next instant. Therefore, the average power drawn by the field is zero, and reactive power does not register on a kilowatt-hour meter. The magnetizing current creates reactive power. Although it does no useful work, it circulates between the generator and the load and places a heavier drain on the power source as well as the transmission and distribution system.

As a means of compensation for the burden of supplying extra current, many utilities establish a power factor penalty in their rate schedule. A minimum power factor, usually 0.85 to 0.95, is established. When a customer's power factor drops below the minimum value, the utility collects a low power factor revenue premium on the customer's bill. Another way some utilities collect a low power factor premium is to charge for kVA (apparent power) rather than kW (real power).
With a diverse range of billing rate structures imposed by electrical utilities especially for large users, it is imperative to fully understand the billing method employed.

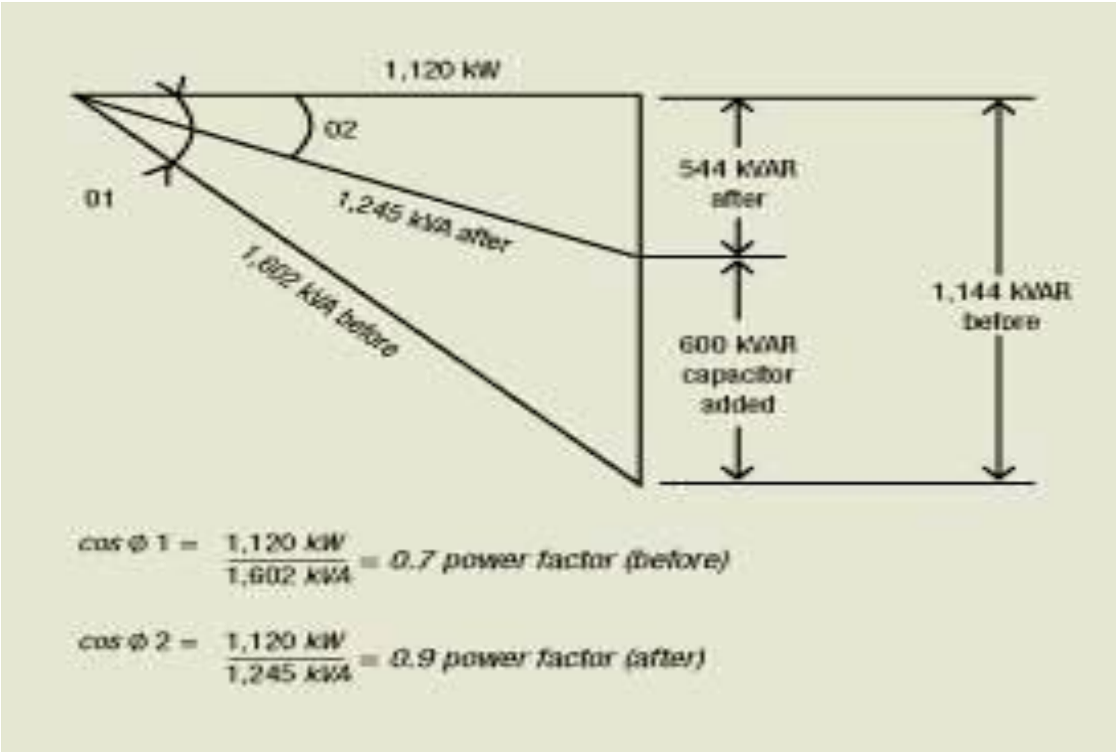
Improving power factor:

Adding capacitors is generally the most economical way to improve a facility's power factor.

While the current through an inductive load lags the voltage, current to a capacitor leads the voltage. Thus, capacitors serve as a leading reactive current generator to counter the lagging reactive current in a system.

The expression "release of capacity" means that as power factor of the system is improved, the total current flow will be reduced. This permits additional loads to be added and served by the existing system. In the event that equipment, such as transformers, cables, and generators, may be thermally overloaded, improving power factor may be the most economical way to reduce current and eliminate the overload condition.

Primarily, the cost-effectiveness of power factor correction depends on a utility's power factor penalties. It is crucial to understand the utility's rate structure to determine the return on investment to improve power factor.



Maintaining a high power factor in a facility will yield direct savings. In addition to reducing power factor penalties imposed by some utilities, there may be other economic factors that, when considered in whole, may lead to the addition of power factor correction capacitors that provide a justifiable return on investment. Other savings, such as decreased distribution losses, improved voltage reduction, and increased facility current carrying capacity, are less obvious. Though real, often these reductions yield little in cost savings and are relatively small in comparison to the savings to be gained from reducing power factor penalties.

Harmonic current considerations:

This article intentionally assumes that a facility does not have significant harmonic currents present. However, some caution must be taken when applying capacitors in a circuit where harmonics are present (true power factor).

Although capacitors themselves do not generate harmonics, problems arise when capacitors for power factor correction improvement are applied to circuits with nonlinear loads that interject harmonic currents. Those capacitors may lower the resonant frequency of that circuit enough to create a resonant condition. Resonance is a special condition in which the inductive reactance is equal to the capacitive reactance. As resonance is approached, the magnitude of harmonic current in the system and capacitor becomes much larger than the harmonic current generated by the nonlinear load. The current may be high enough to blow capacitor fuses, create other “nuisance” problems, or develop into a catastrophic event. A solution to this problem is to detune the circuit by changing the point where the capacitors are connected to the circuit, changing the amount of applied capacitance, or installing passive filter reactors to a capacitor bank, which obviously increases its cost. Use of an active harmonic filter may be another solution.

Capacitor bank considerations and associated costs:

The selection of the type of capacitor banks and their location has an impact on the cost of capacitor banks. More difficult than determining the total capacitance required is deciding where the capacitance should be located. There are several factors to consider, including:

Should one large capacitor bank be used, or is it better to add small capacitors at individual loads?

Should fixed or automatically switched capacitors be employed?

In general, since capacitors act as a kVAR generator, the most efficient place to install them is directly at an inductive load for which the power factor is being improved.

Fixed capacitor location schemes include:

This will generally improve losses, although it is not an optimal solution.Distributing the capacitors using the motor sizes and the NEMA tables as a guide. This solution does not reflect the need for more released capacity, if this is a goal. Capacitors sized for small loads are often proportionally much more expensive than larger fixed capacitors, primarily because of installation costs.

Capacitor switching options include:

Switching a few of the capacitors with larger motors is an option. The capacitors may be physically installed either directly connected to the motor or through a contactor on the motor control center that is tied in with the motor control. If the motors are large enough to use capacitors of the same size as were being considered for the fixed capacitor scheme, little additional cost is incurred for installing them on the motors. Where the economy is lost is when the capacitors are placed on several small motors. There is relatively little difference in installation costs for large and small 480-V units.

The second switching option is to consider an automatic power factor controller installed in the capacitor bank. This will switch large capacitor banks in small steps (25 through 50 is common) to follow the load. Automatic power factor capacitor banks should be installed at the motor control center rather than on the main bus, if optimal distribution loss is a goal. The economics of purchasing, installing, protecting, and controlling single large automatically switched capacitor banks can tilt the decision toward a main bus location, especially if the primary goal is to avoid power factor penalties.

Reactors can be added to fixed or automatic power factor capacitor banks to prevent the risk of the harmful effects of harmonics (detuned filters).

Power quality:

Transients:

- ✓ Impulsive Transients
- ✓ Oscillatory Transients

Short Duration Variation:

- ✓ Voltage Sags or Dips
- ✓ Voltage Swells
- ✓ Interruptions
- ✓ Voltage Magn

itude
Step
Long
Durat
ion
Varia
tion:

- ✓ Undervoltages
- ✓ Overvoltages
- ✓ Interruptions

What is power quality?

Power quality is simply the interaction of electrical power with electrical equipment. If electrical equipment operates correctly and reliably without being damaged or stressed, we would say that the electrical power is of good quality. On the other hand, if the electrical equipment malfunctions, is unreliable, or is damaged during normal usage, we would suspect that the power quality is poor.

As a general statement, any deviation from normal of a voltage source (either DC or AC) can be classified as a power quality issue. Power quality issues can be very high-speed events such as voltage impulses / transients, high frequency noise, waveshape faults, voltage swells and sags and total power loss. Each type of electrical equipment will be affected differently by power quality issues. By analyzing the electrical power and evaluating the equipment or load, we can determine if a power quality problem exists. See Power Quality events for a more detailed description of power quality problems.

We can verify the power quality by installing a special type of high-speed recording test equipment to monitor the electrical power. This type of test equipment will provide information used in evaluating if the electrical power is of sufficient quality to reliably operate the equipment. The process is similar to a doctor using a heart monitor to record the electrical signals for your heart. Monitoring will provide us with valuable data; however the data needs to be interpreted and applied to the type of equipment being powered. Let’s look at two examples of interpreting data for a USA location (other countries use different voltages but the same principal applies).

Power Quality Events:

Power quality problems have many names and descriptions. Surges, spikes, transients, blackouts, noise, are some common descriptions given, but what do they mean? This section delves into
defining power quality issues and terminology.

Power quality issues can be divided into short duration, long duration, and continuous categories.

The

computer industry has developed a qualification standard to categorize power quality events.

The most common standard is the CBEMA curve (Computer Business Equipment Manufacturing Association).

What can cause power quality problems?

Typical problems include grounding and bonding problems, code violations and internally generated power disturbances.

Other internal issues include powering different equipment from the same power source. Lets take an example of a laser printer and a personal computer. Most of us would not think twice about plugging the laser printer into the same power strip that runs the PC. We are more concerned about the software and communication compatibility than the power capability; however, some laser printers can generate neutral-ground voltage swells and line-neutral voltage sags every minute or so. The long term effect to the PC may be power supply failure. We have to be careful in how technology is installed and wired.

Most common Power Quality problems:

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A decrease of the normal voltage level between 10 and 90% of the nominal rms voltage at the power frequency, for durations of 0,5 cycle to 1 minute.

Causes:

Faults on the transmission or distribution network (most of the times on parallel feeders). Faults
in consumer‟ s installation. Connection of heavy loads and start-up of large motors.

Consequences:

Malfunction of information technology equipment, namely microprocessor-based control systems (PCs, PLCs, ASDs, etc) that may lead to a process stoppage. Tripping of contactors and electromechanical relays. Disconnection and loss of efficiency in electric rotating machines.