

Power Quality For The Digital Age

POWER FACTOR IN THE DIGITAL AGE

AN ENVIRONMENTAL POTENTIALS WHITE PAPER

Introduction

One method to measure the efficiency of the electrical distribution system is power factor. Power factor is defined as the ratio of active power supplied to the load versus apparent power supplied to the facility. Power factor is expressed with a number between 0 and 1. A power factor of 1, also called unity, means that 100 percent of the power supplied to the facility is used for actual work. A power factor of zero means that none of the power being supplied to the facility is being used for actual work. In reality, power factor is never 1 or 0 but somewhere in between.

Utility companies may assess financial penalties for facilities that have a bad power factor. There are several power quality products that facility managers will install in order to increase the facility's power factor. The most popular are power factor correction capacitors.

Basics Of Electrical Power

There are three types of electrical power available in the facility.

- 1) Active power(kW), does the actual work, such as heating the coil and rotating the motor.
- 2) Reactive power (kVAR), energizes the magnetic field but does no actual work.
- 3) Apparent power(kVA), is the sum of active and reactive power.

In simple terms, power required to energize a pure resistive load such as an incandescent light bulb is active power. The power required to sustain the magnetic field in a transformer or motor is a reactive power. Even though the work done by magnetic field in the transformer is not visible, it is required for basic operation.

Active power is consumed by resistive loads while reactive power is consumed by inductive and/or capacitive loads.



Power Factor Correction Capacitors

The most popular method of improving power factor is installing power factor correction capacitors. Power factor correction capacitors work on the principle of increasing the reactive power from a capacitive load in the system to offset the reactive power from inductive loads.

Both inductive and capacitive loads store energy. The way inductive loads store energy causes the current to lag the voltage. The way capacitive loads store energy causes current to lead the voltage. This time lag between the voltage and current raises an important issue here: counterbalancing power factor.

Counterbalancing power factor is the process through which the power factor lag due to inductive load can be balanced by using a power factor lead source such as capacitor. Likewise, power factor lead due to capacitive loads can be balanced with inductive loads. This means a capacitive load can be used to decrease the reactive power generated by inductive thereby improving the power factor. This is the basic operating principle of power factor correction capacitors.

Technically, a power factor correction capacitor is a box of capacitors which is installed in the facility to increase the power factor by pumping capacitive reactance to the electrical system.

Figure 1: Power factor correction capacitors concept of operation

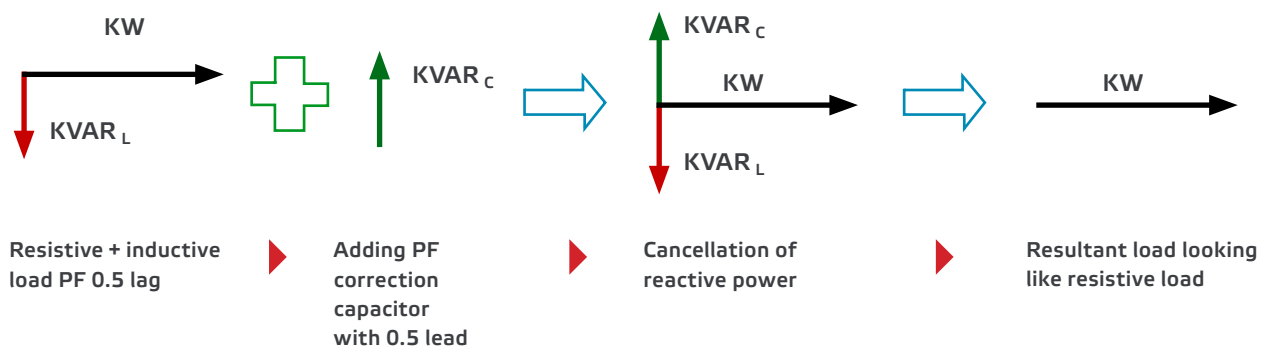
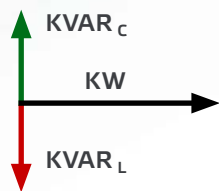


Figure 1 demonstrates the operating principle of a power factor correction capacitor. The first image shows an inductive load decreasing the power factor by 0.5. The next image shows an increase in reactive power from a capacitive load, the power factor corrective capacitor, by 0.5. This offsets the reactive power from the inductive load and improves the power factor. In these conditions power factor correction capacitors are very useful.

Now examine an electrical load with resistance, inductance and capacitance can be represented as:



←
Figure 2: Resistive + inductive + capacitive (real world load)

Figure 2 represents the presence of resistive, inductive and capacitive loads in the system. This is an accurate representation of the real world load. It is impossible to have pure resistive loads in any electrical system because wire connects all the electrical loads in the facility and wire has inductance. Transformers and motors are typical examples of inductive loads. Likewise, every facility will have capacitive loads. Nonlinear loads such as electronic ballasts, VFD's and computers are examples of capacitive loads.



PF Correction Capacitors in the Digital World

Power Factor correction will not improve the power factor of electronic loads such as switched mode power supplies which are found in personal computers and other electronic devices that use rectifiers and switching transistors to regulate voltage. Prior to the invention of sophisticated digital technology, loads were either purely resistive or purely inductive. Under these conditions a power factor correction capacitor would significantly improve the power factor. Capacitive reactance pumped by the PF correction capacitor decreases the inductive reactance and reduces the wasted energy and increases the power factor to close to 1.

But today, we live in digital world; everything is computerized and programmable. All digital, electronic and computerized loads are capacitive. Installing a power factor correction capacitor at these load centers would actually degrade the power factor. The following diagram demonstrates how a PF capacitor degrades the power factor when installed at a digital load.

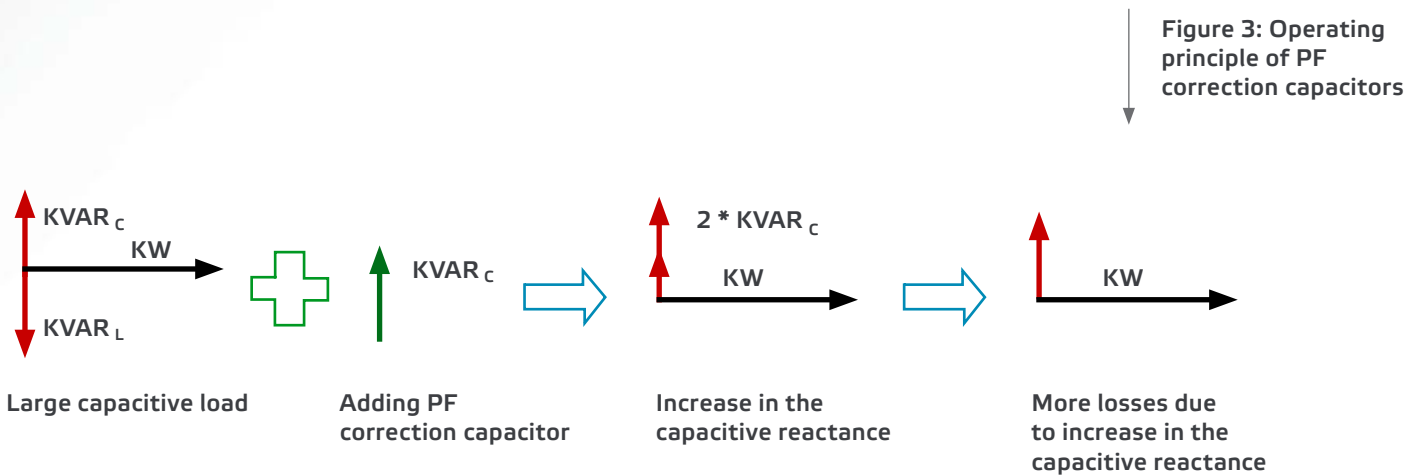


Figure 3 demonstrates a power factor corrective capacitor at a digital load center. Since digital loads are capacitive, this means power factor leads the voltage. The power factor corrective capacitor adds additional capacitance into the electrical system. This increases the capacitive reactance and electrical losses and degrades the power factor. This means that power factor correction capacitors should only be applied at the main panel.



Protection and Power Factor Correction Capacitors:

In the event of transients or high frequency noise in the electrical system, capacitor becomes the least path of resistance. Since $X_C = \frac{1}{2\pi fC}$ for higher frequencies X_C becomes smaller meaning lower resistance. This means the electrical noise is diverted to the PF correction capacitors, which do not have a protection component and therefore are easily damaged.

Prolonged exposure of a PF correction capacitor to high frequency noise or voltage transients will completely degrade the dielectric material of the capacitor, decreasing the resistance of the PF correction capacitor to zero. This will cause a short circuit leading to a fuse trip and/or damage to other loads in the system.

Voltage transients in the electrical system will deteriorate the capacitance value of the PF correction capacitor by equation $C = \frac{Q}{V}$. From this equation as the voltage increases due to transients, C decreases.

When C decreases, the permittivity (ϵ), which is the ability to permit the electrical charge in the material, will decrease by equation $C = \frac{\epsilon A}{d}$. A decrease in the permittivity will cause a breakdown in the dielectric material causing holes on the plates of the capacitor. This will also create arc over the plates causing flashover.

So, when capacitors in the PF correction capacitor are subject to voltage transients, the dielectric material in capacitor will breakdown causing a fire hazard. This means PF correction capacitors are not protected against transients or surges.



The EP Solution

Besides counterbalancing the reactive power by increasing capacitive reactance, there is one more solution: reducing the inductive reactance. Environmental Potentials' patented waveform correction technology safely and efficiently reduces inductive reactance. EP's patented circuit distributes the inductive reactance with its inductors and slowly dissipates it with resistors. By doing so, EP's filters reduce the inductive reactance from the system and minimize wasted energy. Figure 5 demonstrates this principle.

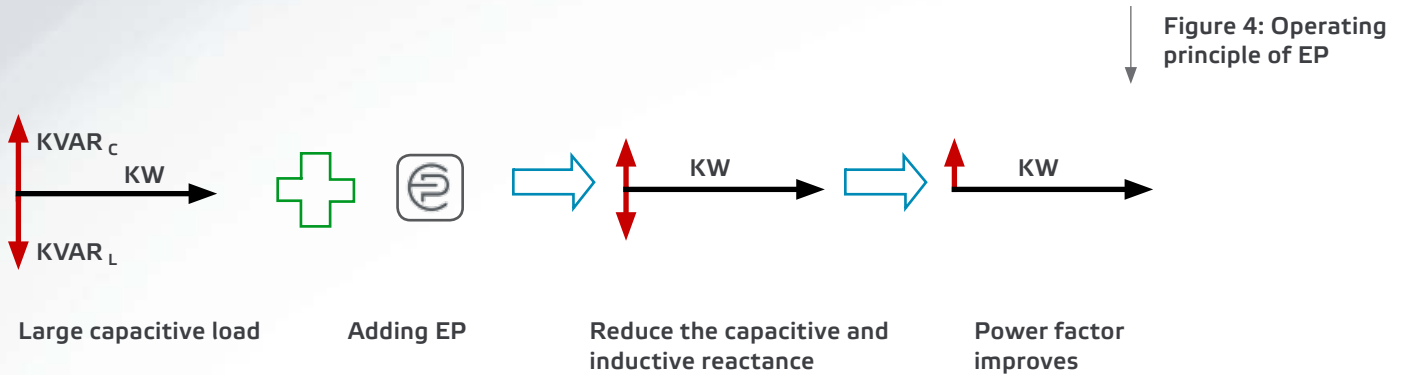


Figure 4 demonstrates the operating principle of EP waveform correction technology. The first image demonstrates the inductive and capacitive reactance in the system due to inductive and capacitive loads. The bypass circuit on Environmental Potentials' filters will divert all the additional reactance in the electrical system contributed by both inductive and capacitive to its resistive circuit. This resistive circuit is an isolated circuit which dissipates the reactance energy in the form of heat. Since it's isolated, no part of reactance is fed back to the electrical system. This ensures that the harmful reactance energy cannot enter into the electrical system.

EP works for both inductive and capacitive reactance. This means it can be installed applied at inductive loads (motor) and nonlinear loads (VFD). This improves the power factor and power quality.

Likewise, Environmental Potentials' waveform correctors also have a built in protection circuit that protects equipment in the facility and EP's patented circuit.



Conclusion

Power factor is the ratio of active power supplied to the load versus apparent power supplied to the facility. Power factor is represented by a number between 0 and 1. The closer to 1 the better the power factor and vice versa. Good power factor has a low amount of reactive power and a high amount of active power. Conversely, poor power factor has a high amount of reactive power and a low amount of active power. Utility companies may impose financial penalties on facilities with poor power factor.

The most popular method to improve power factor is to install power factor correction capacitors. This is an attempt to offset inductive reactance by increasing the capacitive reactance. Installing a power factor corrective capacitor at the main panel will improve the power factor.

However, digital equipment is capacitive. This means that digital equipment is already increasing the capacitive reactance into the system. Applying a power factor corrective capacitor at load centers will increase reactive power and further degrade the power factor.

Environmental Potentials' patented waveform correction technology removes both inductive and capacitive reactance from the system thereby improving the power factor. EP filters have a built in protective circuit which protects the unit and facility from harmful high frequency noise generated by the voltage transients.





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