Power Quality Capacitor Banks: The Under Serviced Electrical Equipment

How often are your capacitor banks serviced? They appear in most electrical setups, but what does it do? How does it impact the building and how often should it be serviced?

Understanding the Layers of Power Quality

Often, “power quality” is the silent player behind several operational inefficiencies. PQ is more than just "dirty power"; it's a multifaceted issue that directly affects your plant's performance. Let us first identify the common culprits of poor power quality to gain a better understanding of the issue at hand.

Transient Surges

Lightning strikes or external disturbances can send a pulse of excess energy into the system. These transient surges, or energy spikes, can be catastrophic for sensitive electrical or electronic equipment, threatening their durability and reliability.

Inrush Current

Hard-starting large electrical loads will lead to very significant inrush currents. A prime example is the HVAC systems that lack soft starters or variable frequency drives (VFDs). Have you noticed lights momentarily dimming when a heating, ventilation, and air conditioning (HVAC) system boots up? That is a symptom of the inrush current at play. This phenomenon results from an abrupt surge of current across the system, leading to a momentary dip in voltage. This voltage dip (and current spike) can disrupt the functioning of electrical equipment.

Power Factor

This subject can be complex but imagine the power factor as comparing the energy required to efficiently operate equipment with the actual energy used by that equipment. If you consume more energy than is necessary, this is inefficient and a waste. The power factor quantifies this efficiency as a percentage.

An 80% power factor means the electrical load uses 20% more energy than needed, while at 100% power factor, the load uses only the energy required for the efficient operation of the equipment. However, this energy comparison involves three distinct energy forms.

Actual power, expressed in kilowatts (kW), is the energy essential to power electrical equipment operation. **Reactive Power** (kVAr) is required by electrical motors to facilitate their rotation and is a power that changes based on a site's inductance or capacitance, causing inefficiencies by requiring additional energy. **Apparent power**, measured in kilo-volt-amperes (kVA), is a value for the system's total energy consumption. The power factor measures the actual power's proportion of total energy use - kW over kVA.

Reactive power in industrial settings usually favors inductance over capacitance because of the presence of multiple electrical pumps and motors. This results in a lagging power factor where current lags voltage after AC power has passed through a motor's electrical coils. Balancing reactive power in both inductive and capacitive loads can achieve equilibrium or Unity (100%). For instance, HVAC systems use inductive motors, causing a lag in reactive power as the voltage and current phases become misaligned. Adding reactive power, in the form of capacitors at the motor, or at the sub-panel servicing the motor, will realign the phases and maximize power efficiency while reducing the number of amps needed to push the power to the motor.

Harmonic Distortion

AC power used in industry is three-phase and has a sinusoidal current waveform. This sine wave should ideally be smooth and consistent. Interference in the fundamental waveform by power electronic circuits, which include AC to DC power conversion components, which have square or stepped waveforms creates harmonic distortion. These harmonics have frequencies higher than the 60Hz or 50Hz frequencies commonly utilized.

Distorted waveforms equal inefficient power consumption and can damage electrical equipment because of the extra current drawn. When current passes through wires or coils, they create heat values already taken into consideration by the equipment and system engineers. Harmonic distortion creates additional current, intensifying the heat in the wires or coils. A rise in temperature boosts resistance, which subsequently increases the current. This repetitive process persists until there is an overheating malfunction. Devices commonly affected include inductive motors and distribution transformers.

> *"In summary, harmonics are distorted electrical waveforms that introduce inefficiencies into your electrical system. They produce wasteful heat and can cause equipment issues including the distortion of data and equipment calibration."*
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> *– Eaton: Harmonic frequencies in electrical systems*
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> *"Harmonics can cause damage to sensitive electronics, interference in communication equipment, and false readings on measurement devices. Harmonics can trip circuit breakers, blow fuses and cause capacitor failures. The effects also include overheating of transformers, cables, motors, generators and capacitors."*
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> *– ABB: Overcome challenges of harmonics*

Addressing Power Quality

While energy efficiency certifications, like the Leadership in Energy and Environmental Design (LEED) Certification, promote green practices, they also emphasize the importance of power quality. The LEED Certification, for instance, demands advanced energy metering capable of detailed tracking and data storage to monitor system-level energy use. This credit motivates those seeking LEED Certification to be wary of their energy consumption and their power quality.

> *9.1.7 LEED™ EA Credit 3: Advanced Energy Metering (Credits: 1–2)*
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> *To support energy management and identify opportunities for additional energy savings by tracking building-level and system-level energy use. This credit applies to Commercial Interiors (1–2 points). Besides whole-building metering, any energy use representing 10% or more of the facility total must also be metered. Also intended to track energy use at the system-level (HVAC) to identify additional energy savings opportunities.*
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> *Advanced energy metering must have the following characteristics. The Advanced Metering credit requires the permanent installation of electricity meters capable of recording 60-min or less consumption (kilowatt-hours) and demand (kilowatts), interval data, remote communications and interface capability to a LAN, building automation system, wireless network or other advanced communication infrastructure. The system must be capable of storing all meter data storage for at least 18 months. The data must be remotely accessible. Besides remote data access, the system must also be capable of reporting hourly, daily, monthly, and annual energy use.*
>
> *– LEED's v4 Practices, Certification, and Accreditation Handbook 2nd Edition*

Although LEED acknowledges the potential dangers of poor power quality, they do not reward the correction of power quality issues. Harmonics, as cited in LEED's v4 Practices, might not always be immediately perceptible. But they can compromise power quality. It is vital to bring in experts to rectify any harmonic distortion that exceeds acceptable levels. As always, adherence to guidelines by bodies like the Institute of Electrical and Electronics Engineers, Inc. (IEEE) is paramount.

It is difficult to perceive small amounts of total harmonic distortion without a meter. Even though your system may experience voltage distortion caused by the increasing penetration of nonlinear loads without serious consequences, and without you being aware that it is occurring, power quality will be compromised, and you will lose efficiency if you do not take steps to address this issue.

If there is excessive harmonic distortion present in your system that is resonating in capacitor banks or degrading motor operation, we highly recommend bringing in a specialized consultant to correct the issue before it costs you money in additional maintenance and/or loss of equipment that requires long replacement lead times.

> *Whatever approach is used to achieve the reduction of harmonics, it must meet the guidelines of the Institute of Electrical and Electronics Engineers, Inc. (IEEE).*
>
> *– LEED's v4 Practices, Certification, and Accreditation Handbook 2nd Edition*

The Strain on the Grid

The US power grid is running out of capacity. As we move towards the electrification of everything, the grid must provide more power. Luckily, we have additional capacity to generate more power to keep pace with existing consumer demand, but demand will grow dramatically over the next decade. The biggest issue facing us today is an antiquated distribution grid that is designed to carry the electrical loads envisioned by utility engineers several decades ago.

The capacity of any system is finite and the cost and timeline to upgrade the transformers and distribution cables in the "last mile" distribution grid to enable them to carry more current is astronomical and will take decades to plan and execute. Consumer demand for more amperage will quickly outstrip the utility's ability to provide it to consumers.

California already has rolling blackouts as utilities find their grid severely constrained.

Utility providers often levy additional charges for poor power factors. We can see this inefficiency tax under various names: power factor correction charges, kVAr charges, and kVA charges. Basic Power has noticed an increase in interest by utility companies to charge for reactive power to recover more of their costs.

Legacy Capacitor Banks

Power Factor Correction is not a new solution for poor power quality, and it is very likely that an industrial facility already contains one or two capacitor banks to avoid the power factor penalties that utility companies started charging their large power customers over 20 years ago. However, these capacitor banks often go unserviced and forgotten for long periods of time. Capacitors have a lifespan of 10 to 15 years if installed under ideal conditions. Harmonics and overheating dramatically shorten the useful life of a capacitor. Consequently, capacitor banks that your facility had installed years ago have already failed to operate properly and your facility may now be experiencing higher current draw.

Every site has a maximum allowable current before the breaker trips. That is the maximum allowable capacity. By reducing the unnecessary current in the system, there will be more capacity for additional equipment to be installed without tripping breakers Although some existing electric panels already incorporate spare breakers in case of site expansion, the reduction in amperage allows for a better wiggle room when expanding the operation without resizing all the wires and breakers or having to upgrade the switchgear.

Passive Harmonic Filters

Capacitor banks with inductors function as passive harmonic distortion filters. Harmonic distortion is additional noise within the electrical system that causes additional heat to build up. This additional heat increases the current draw and further heats the system in a vicious cycle. Sources for harmonics are any electrical device that runs on a battery or contains a DC component like power electronics in Variable Speed Drives, ECM motors, and AC/DC inverters in PV solar systems.

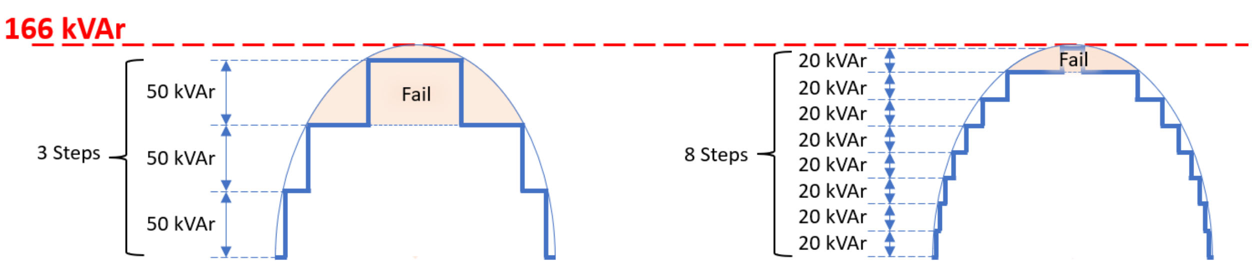
Passive harmonic filters must be pre-tuned to the correct frequency of the harmonic they are designed to absorb, and this requires careful measurement of the power factor and amperage of the load. Once installed these filters need the conditions to remain constant. If the load changes, then the filter may become detuned and no longer filter the right frequency. It is recommended that passive filters are inspected regularly to check the condition of the capacitors and to check that the power factor and current draw have not changed.

Automatic Reactive Power Compensation

Most capacitor banks have a fixed kVAr which is predetermined by an engineer for a particular load, i.e., a single motor. Other banks have an automatic function that allows capacitors to be switched on and off by contactors to address the varying operation of multiple inductive loads. Most of these automatic capacitor banks will have increments of 50 kVAr at each step. Introducing such a massive amount of reactive power instantly will result in voltage transients and a momentary drop in amperage. To tackle this, manufacturers incorporate large inductors to clamp the voltage transient and prevent a momentary drop in current that could affect the operation of sensitive electrical and electronic equipment.

Better Precision

We have overcome the issue of large transients in the VARIVAR by providing 8-12 steps of 20 kVAr. This design eliminates the need for large inductors, given the smaller capacitor switches, and results in a unit half the size and a third of the weight of conventional capacitor banks.



With larger step sizes, the performance of reactive power compensation is limited due to the large increments.

Another concern for this design is that if one step fails, the system will be short by 50 kVAr, which is a large chunk of reactive power missing.

With smaller step sizes, but more steps in the design, we can match the same demand with higher precision.

Suppose one step fails, there will be 7 other steps to provide reactive power.

Additionally, by having smaller steps the VARIVAR can match the load profile better and is more accurate in its compensation, keeping your system closer to Unity. Another advantage to having three times the number of capacitors is that if one fails the effect on performance is minimal.

An Electrician's Role

As we stride towards a more energy-conscious future, the onus is on those who are servicing the site and are capable of evaluating the state of existing capacitor banks. To identify if a capacitor bank is active, there are a few indicators that you can use.

Capacitors banks with obvious signs of bulging or swelling could be due to internal pressure build-up from overheating. To verify any overheating issues, use a thermal imaging device to measure the temperature and ensure that it is below the maximum allowable operating temperature.

Some capacitor banks have LED indicators for active capacitor steps. If the LEDs are off, the capacitors most likely need servicing or replacing.

Look for any signs of leakage around the capacitor as it indicates a breach in the capacitor's casing. This would compromise the integrity and functionality of the capacitors.

Since capacitor banks are often used for power factor correction, measuring the power factor would help identify if the capacitor bank is operational. If the power factor is still too low despite the capacitor bank being active, the site most likely did not install the right amount of reactive power compensation and requires more.

Conclusion

In conclusion, as we stride towards a more energy-conscious future, the onus is on Plant Managers and industries at large to prioritize power quality, not merely as a compliance measure but as an imperative for operational excellence and sustainability. Addressing power quality issues is not just about individual operational efficiency but about fostering a more resilient and sustainable energy ecosystem for all.

Furthermore, power quality implications extend beyond individual facilities. Its impact can reverberate throughout the grid, affecting neighboring operations and even the very sources of our energy distribution. To combat these events, we need to start paying more attention to our equipment, especially the capacitor bank. It is generally installed and forgotten, making it a common under serviced electrical equipment in most sites.