Hanover Risk Solutions

Power Quality of Commercial and Industrial Power Systems

Power quality is a general term used to describe the quality of several different power-related characteristics. These characteristics are the frequency and amplitude of the voltage, the balance between phases on a three-phase system and the distortion level of the waveform. Which of these characteristics are important and what is considered an acceptable level of power quality will vary from facility to facility.

Most of the older electro-mechanical equipment was robust and could handle minor power quality related issues with little or no effect on operations. But, due to the shift in the type of loads from electro-mechanical to electronic, power quality has become a real concern in all types of businesses. This includes hospitals, universities, commercial buildings and industrial facilities. Poor power quality results in a random mis-operation of equipment; data corruption; loss of process control; and heating of cables, motors and transformers.

Power Source

An ideal power source offers a continuous, smooth sinusoidal voltage, as shown in Figure 1.

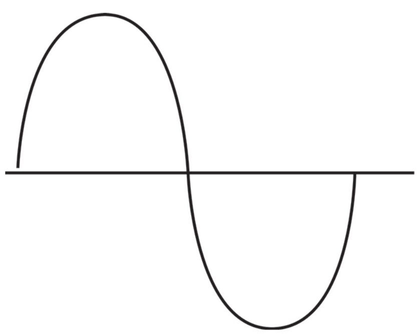

Figure 1

Poor quality power as shown in Figure 2 contains noise, harmonic distortion, voltage sags and swells, interruptions and voltage surge.

Figure 2

Causes of Poor Power Quality

The most obvious source of poor power quality would appear to be weather-related and utility-related disturbances. However, studies have shown that issues such as lightning, other natural phenomena, and utility operations, account for **only a small portion** of all electrical disturbances. A

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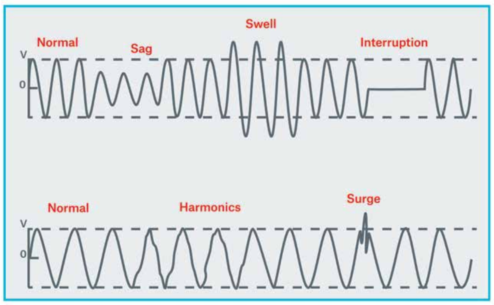
large portion of electrical disturbances are from internal sources or from neighboring businesses that share the same building or are in close proximity. Internal sources can be fax machines, copiers, air conditioners, elevators, and variable frequency drives just to name a few.

Power Quality Issues

Typical power quality issues include: voltage transients (surge), harmonics, voltage sag and swell, voltage imbalance and interruptions.



Courtesy of Advanced Protection Technologies

Voltage Transient (Surge)

Description—A sudden high energy disturbance in line voltage typically lasting less than one cycle (< one second) which causes the normal waveform to be discontinuous.

Cause—Switching type loads

Issue—Data corruption, equipment mis-operation, equipment damage and process interruption.

Harmonic Distortion

Description—Distortion of the current and voltage waveforms caused by the momentary on/off switching of nonlinear loads.

Cause—Elevators, HVAC equipment, rectifiers and welding machines.

Issue—Data corruption, data loss, mis-operation of computer controlled equipment, excessive heat and equipment failure.

Voltage Snag/Swell

Description—A decrease (sag) or increase (swell) in line voltage lasting at least 1/2 cycle (1/120 of a second) to several seconds.

Cause—Utility related events, starting and stopping of large loads.

Issue—If equipment is operated slightly outside the design envelope, random mis-operation and failure may occur. If the equipment is operated significantly outside the design envelope, the equipment will not operate and may fail prematurely. The effects are based on the length, magnitude and timing of the sag or swell.

Voltage Imbalance

Description—Differing voltage levels on each leg of a three-phase system, typically < +/-2% of the average.

Cause—Large loads in a building such as HVAC equipment and elevators are three-phase loads. The small but numerous loads such as copiers, control equipment and computers are single-phase loads. Single-phase loads should be equally distributed among the three phases to prevent imbalance. Imbalance can also be caused by poor connections or blown fuses.

Issue—Depending on the level of imbalance, loads can operate erratically, not operate at all or fail.

Interruptions

Description—A significant or complete loss of voltage. The loss can be momentary or sustained.

Cause—Weather, utility equipment failures, internal faults or internal equipment failures.

Issue—A momentary interruption can damage computers and other electronically controlled equipment or disrupt processes.

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The damage can occur on both the loss and the re-energization of power. Electro-mechanical equipment is generally not affected by these brief outages. Sustained interruptions can last from hours to days. Contingency plans should be developed to address orderly equipment and process shutdown and restarts.

Solutions

Each type of occupancy will have a different sensitivity level to poor power quality and will have different sources of poor power quality. However, common to all businesses is the importance of a well-maintained electrical distribution and grounding system. The importance of these systems cannot be overstated. When addressing potential or actual power quality issues, the power and grounding system should be the first item addressed. This will ensure personnel safety, allow for the proper operation of surge protection devices, minimize the potential for currents on neutral conductors, and provide an adequate reference plane to electronic equipment.

Once the power and grounding system deficiencies have been addressed, the next steps include: power quality walk-throughs, power quality inspections/surveys, and mitigation equipment.

Walk-throughs are a means to understand a facility from a power quality standpoint. In addition to housekeeping and the overall appearance of electrical equipment, items to note during a power quality walk-through include:

- Type of equipment that is installed
- Concentration of computer and electronic equipment
- Presence of welders, power factor correction capacitors, or variable frequency drives
- Heat discoloration of electrical equipment
- Communication and control wiring in close proximity to power wiring
- Condition of the grounding system
- Presence of surge protection installed on power and data lines

The conditions below are considered warning signs for potential power quality issues in a facility. These conditions do not guarantee a problem; however, a facility with these conditions will have an increased likelihood of power quality issues.

- History of power-related issues
- Poorly maintained electrical system
- Failure of surge protection equipment
- Weather and utility disturbances common
- High concentration of electronic equipment
- Infrared surveys which identify current flow (heat) on grounding conductors and/or system neutrals
- Repeating and random equipment mis-operation, failures, tripping of breakers or blown fuses with no identified causes
- Equipment running hot
- Frequent switching to backup power systems
- Lost data or data corruption

Based on the results of the power quality walk-through and the type of processes and equipment at the insured's location, the following recommendations may be appropriate:

- Infrared thermography to locate troubled areas. Not all power quality related issues will cause hot spots but loose connections, harmonics and undervoltage will cause an increase in the operating temperature of equipment.
- A power quality inspection and survey performed by a properly trained and experienced individual. The results of the inspection and survey should be reviewed by a trained and experienced engineer.
- A power quality study if an expansion is planned or a large load is being added. This study should be completed during the design of the expansion or during the specification process of the new piece of equipment.

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Power quality inspections and surveys identify if there is a problem, the types of problems, the extent of the problems, and the potential solutions. Power quality inspections and surveys should only be completed by individuals with the required specific experience and training. In many commercial or light industrial type businesses, only a few loads are sources of power quality issues and only a few loads are susceptible to poor power quality. By identifying these loads during a survey, targeted and therefore less expensive mitigation techniques can be utilized.

A power quality survey is the monitoring and recording of the power supplied to a building or in specific areas of a building. It is important to measure power continuously over an extended period of time such as days or weeks. This will permit all the intermittent events to be captured. Due to the difficulties in identifying power quality related issues, it is highly recommended that only electricians trained and experienced in power quality complete the surveys using the appropriate monitoring equipment. The equipment should be capable of recording very fast events (less than one cycle) and have data storage capabilities. Since it is physically impossible to monitor all points at the same time, selecting the best points to monitor is extremely important. This should be done based on the areas of concern identified during the inspection. The equipment of concern must be energized and operating during the monitoring period. Do not perform a power quality survey during a shutdown.

The review of the data from the survey will determine if a problem exists, identify the type and severity of the problem, and assist in recommending mitigation techniques. The review is performed by qualified and experienced engineers.

Prior to selecting any type of mitigation equipment, the power quality deficiencies responsible for operational issues and failures must be clearly identified. The next step is to estimate the costs of the power quality related issues. This aids in determining an expenditure target for the required mitigation equipment.

A wide variety of power quality correction products is available utilizing a range of technologies and providing a range of protection. Common mitigation techniques include surge protection devices, isolation transformers, voltage regulators, motor generators, standby power supplies, uninterruptible power supplies and harmonic filters. Each technique has advantages and disadvantages and should be applied based on the situation. This list is a good overall representation of the different types of mitigation techniques available but it is not a complete list of all the available techniques.

Surge Protection Devices (SPD)

Function—Diverts surge events to ground.

Description—A device connected between line and ground which has high impedance at normal frequency (50 or 60 Hz) and very low impedance at the high frequencies associated with surge events. Because of this low impedance, the SPD acts as a shunt to ground for surge events. Devices vary in their surge current-handling capability and voltage-limiting capability. Since devices have different voltage and current capabilities, a multi-level approach is required to protect against surge events. The multi-level approach is also known as zones of protection. Each zone experiences a different level of surge event and therefore the SPD should be sized appropriately based on the zone. In general terms, the zones of protection are the service entrance, the load side of the main feeder, and the branch panels.

If a device is connected to a modem or a data line, these lines represent a "backdoor" opportunity for surges to enter and destroy circuit boards. These lines must also be protected by surge protectors.

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Many types of equipment claim to have built in surge protection. But these are often inexpensive varistors, which may or may not provide sufficient protection. They should not be relied upon to protect a piece of equipment.

Isolation Transformers

Function—Attenuates common-mode disturbances on the power supply conductors, provides a local ground reference point and with taps, allows compensation of steady-state voltage drop in feeders.

Description—A transformer with built-in surge protection and special windings with a grounded electrostatic shield between the primary and secondary windings. This grounded shield provides a path to ground which prevents high-frequency noise from reaching the transformer output. Isolation transformers may step-down the voltage (i.e., 480v to 208v) or may provide just one-to-one isolation (208 V in and 208 V out).

Voltage Regulator

Function—Provide a constant steady-state output voltage level for a range of input voltages.

Description—A variety of voltage regulation techniques is utilized. Common techniques include Ferro resonant transformers, electronic tap-switching transformers, and saturable reactor regulators.

Motor Generator

Function—Provides voltage regulation, noise/surge elimination, waveform correction for voltage distortion and electrical isolation between the electrical system and the loads.

Description—Two separate devices, a motor and an alternator (generator), interconnected by a shaft or other mechanical means. Typically the utility is the power supply for the motor which drives the generator to produce clean power.

Standby Power Supply

Function—Inverter and battery backup power system operating as an outage protection system. In normal mode, the inverter is in a standby mode and the load is directly supplied from the input power source. On a loss of input power, the load is switched to the battery supply. There is a momentary break in power when the transfer to and from input power occurs.

Description—Usually comprised of a solid-state inverter, battery, and battery charger.

Uninterruptible Power Supply (UPS)

Function—Maintain uninterrupted supply of regulated voltage for a period of time after a power failure.

Description—A variety of technologies exists. The two common types are rotary and static. A rotary unit consists of a motor generator set with a short ride through capability. A static unit utilizes power electronics and a battery string or other energy storage means as a source of energy during loss of input power. These units are only as good as their batteries. The battery system needs to be sized based on the load and duration of required time and needs to be well maintained.

Other types include combinations of rotary and static units or UPS systems supplemented with engine driven generators for extended outages.

The design of the backup power supply capability should reflect the criticality and size of the loads to be supplied. Redundancy should be in proportion to the level of risk. Each element of the backup power scheme needs to be viewed as a point of failure; if appropriate the design should provide for functional duplication of each.

Harmonic Filters

Function—Acts to reduce the level of harmonic distortion on a power system.

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Description—There are two types: series circuit and parallel circuit. Series inductor/capacitor (LC) circuits have a low impedance to harmonic currents and therefore act as a sink, preventing the harmonics from being fed back to line. Parallel inductor/capacitor (LC) circuits have a high impedance to harmonic currents, and therefore block the flow of harmonic currents.

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The Hanover Insurance Group®

The Hanover Insurance Company
440 Lincoln Street, Worcester, MA 01653

hanover.com
The Agency Place (TAP)—https://tap.hanover.com

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