XL Risk Consulting

Property Risk Consulting Guidelines

A Publication of AXA XL Risk Consulting

PRC.5.7.1.3

ELECTRIC POWER QUALITY AND RELIABILITY

INTRODUCTION

Business and the economy depend on reliable and clean electric power. Reliable electric power means the electric supply is available and dependable. Clean electric power means the supplied ac current and voltage waveforms are essentially pure sinusoidal waveforms. Typically each cycle repeats at a frequency of 60 Hz in the U.S. and 50 Hz in most other countries. “Computer grade power” is specially conditioned and controlled ultra-clean electric power.

Dirty electric power, by contrast, contains undesirable components that significantly distort the waveform. These components include pulses, off-frequency sinusoidal waves, and other undesirable deviations from the basic desired waveform. These components can repeat at the ac power frequency, or they can cycle at higher or lower frequencies.

Dirty power, steady-state undervoltages (brownouts) and overvoltages can lead to electrical and mechanical equipment damage. Electronic equipment is highly susceptible to all three problems. Machinery can also be affected by these power quality problems. Undervoltage can lead to overheating. Overvoltage can cause high torsional forces. Power and distortion component frequencies can cause mechanical vibration. Vibration effects are amplified when the frequency of the power system or distortion waveform matches the natural resonance of the equipment. Electrical insulation can be overstressed by an abnormal voltage which can lead to overheating and breakdown. Single-phasing (loss of 1 phase of a 3-phase circuit) and phase voltage unbalance cause abnormal currents and can result in severe damage to 3-phase machinery. Power abnormalities and waveform distortions cause control, data processing and diagnostic systems to operate erratically and can lead to business downtime, product rejects and high operating costs.

Outages (power interruptions including blackouts) can also cause serious consequences. Computer data can be lost; a shaft on a large, idle, rotary machine can bow or sag; molten metal can solidify; heating systems can shut down; protection systems can fail; a hospital’s life-support equipment can become inoperative; and a chemical processing plant can experience runaway reactions.

Before electronic loads were common, simple surge arresters, power supply transfer switchgear and voltage regulators assisted most equipment and systems to tolerate common power problems and perform adequately. But electronic loads are increasing and consume more than half the power generation capacity in the U.S. These loads are sensitive to power quality problems. Further, in much of the electronic circuitry in use today, electronic power supplies with switching frequencies as high as 200 kHz have replaced older, linear (sinusoidal) power supplies. Switch-mode power supplies lower power quality. Today, while the miniaturization of modern electronic devices makes reliable, clean power even more crucial, these same electronic devices have become a major contributor to the dirty power problem.

Electric power supply problems are inappropriately considered service quality problems and the sole responsibility of utility companies. However, a user's distribution circuit arrangement, system, and equipment can contaminate the power supply and cause power supply interruptions. Thus, utilities, equipment manufacturers and system designers all share responsibility for power supply conditions.

This guide describes ways to improve power reliability, including emergency power supplies, uninterruptible power systems (UPS) and standby power systems (SPS). It describes devices and equipment used to improve power quality.

POSITION

Test voltage, current, harmonics, waveform distortions, load balance and phase relationships and take appropriate corrective actions if any of the following problems occur anywhere in a facility:

- Circuit breakers periodically trip for no apparent reason.
- Fuses, particularly those in capacitor circuits, periodically blow for no apparent reason.
- The temperature of a conductor, motor or transformer rises unexpectedly or the device "runs hot."
- Electronic equipment experiences recurring nuisance failures.
- The flow of current or its resultant heat is detected in the neutral of a 3-phase circuit.
- Capacitors overheat and fail.
- Interference occurs continually on telephone lines.
- Electronic data is frequently lost.
- The phase-to-phase rms voltages in a 3-phase system serving 3-phase loads differ by more than 1%.
- Meters showing "true-rms" voltage or current identify a different value than averaging-type meters scaled to show rms values.

Derate any power system transformer where necessary to prevent overheating from harmonic distortion; alternately, replace the unit with a transformer rated for use with nonlinear loads. ANSI/IEEE C57.110 and various other guidelines may be applicable.

Provide surge arresters where surges are likely to enter the power or signaling system within a building. As examples, incoming power lines are usually protected at the service entrance; and telephone companies usually install carbon-block gap arresters where phone lines enter a building.

Follow manufacturer's recommendations for surge protection for microprocessor-based equipment, including computers and digital process or programmable logic controllers. Analyze protection for solid-state equipment yearly, as described in PRC.5.2.2.

Provide surge protection for transformers and rotating machinery as described in PRC.5.2.2.

Before high-valued or critical, sensitive electronic equipment is installed consult the manufacturer to identify any power quality requirements. To avoid operational problems, monitor the power supply at the site before equipment installation to evaluate power reliability and quality. An analysis should also be performed:

- Immediately after the installation to detect changes in power quality caused by the equipment.
- Whenever system or equipment changes are likely to affect the quality of power.

Single-phase loads should not be connected to circuits supplying three-phase equipment sensitive to voltage unbalance. A separate circuit should be used.

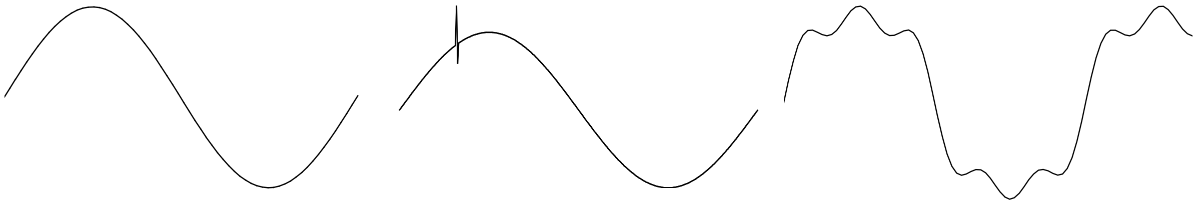
The use of power factor correction capacitors should be avoided in systems having or likely to have harmonics. Or, the installation should be designed to prevent the resonant frequency of the system from amplifying any damaging harmonic waveforms; if the resonant frequency is not so tuned, electrical breakdown of insulation is likely.

Emergency power systems provided for loss control should be reliable. A comprehensive preventive maintenance program should ensure their continued availability. Engine-driven generators should be operated weekly. Full load testing, including testing of transfer switches, should be conducted at least semiannually. Manufacturer's recommendations should be followed.

DISCUSSION

General

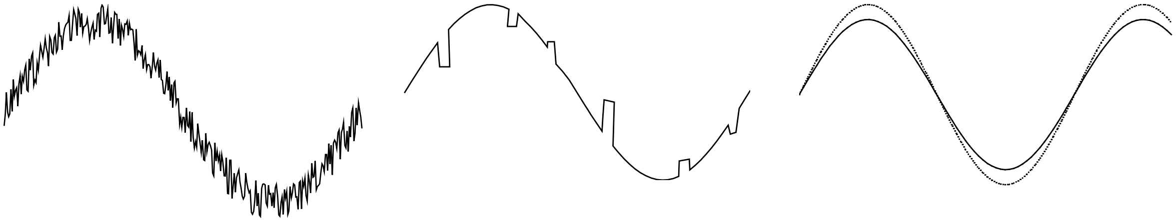
Electric power service problems relate to two basic concerns: power reliability and power quality. Reliability typically means a supply is available to satisfy basic system design parameters and has the appropriate nominal voltage. Typically, power quality applies to distortions of power waveforms and to lesser deviations in voltages. Figure 1 shows power waveforms and typical distortions affecting power quality and reliability.



Clean Power Waveform

Waveform With Transient Spike (Impulses)

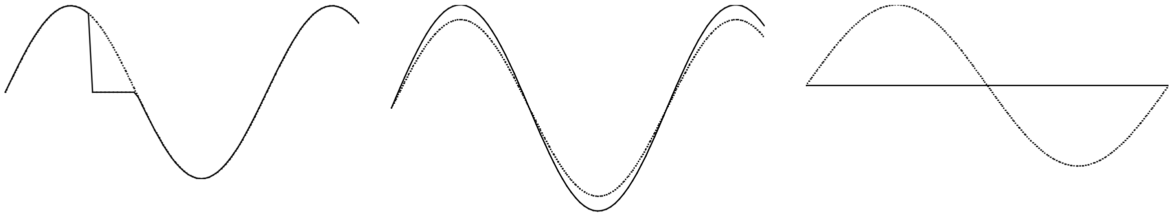
Example Of Low-Order Harmonic Distortion



Waveform With Noise

Line Voltage Notching (High-Order Harmonic Distortion)

Sag



Dropout

Swell

Blackout Or Outage

Figure 1. Waveform Distortions Affecting Power Quality And Reliability.

Power Reliability

Codes and standards such as ANSI C84.1, ANSI/IEEE Std 141, and ANSI/IEEE Std 446 establish voltage profiles for distribution and utilization systems. They set basic power system parameters. Profiles identify required voltages at selected system junctures and allow power quality deviations as long as the shift in value does not exceed specified limits for corresponding specified time intervals.

Voltage deviations with respect to time are the basic consideration when analyzing power reliability. Ideally, if a power supply never experiences significant and lengthy outages, waveform distortions or abnormal voltages, then the power supply is considered 100% reliable. No system can meet this condition. Unanticipated circuit overloads, inadequate voltage regulation or unexpected damage to property can lead to significant and lengthy deviations affecting power reliability.

Generally, when steady-state and diminishing long-term disturbances lasting more than 2.5 seconds prevent a power system from meeting basic system parameters, the abnormality is lengthy and power system reliability is affected. Power outages, e.g., blackouts; low voltage abnormalities, e.g., brownouts; and over-voltages are typical reliability problems. Generally, these are not considered waveform distortions. Reliability problems are typically solved by providing alternate power sources, whereas quality problems are typically solved by reshaping or transforming waveforms.

UPS and SPS can minimize power reliability problems. Other methods include self-contained backup power supplies and dual remote utility connections with automatic switching where the redundant power source is truly independent. No single incident should subject both the primary and redundant supplies to interruption.

Power Quality

The term “dirty power” refers to electric power, voltage or current waveforms containing other than desired components. These voltage and current components contaminate and distort the ideal waveform. They can be caused by:

- Electric switching (digital) devices including switch-mode power supplies.
- Arcing devices including fluorescent lamps and welders.
- Deteriorated wiring, connections or ground currents.
- Weak, overloaded power supplies.
- Saturated (nonlinear) transformers (fluorescent ballasts).
- Various system design problems including transformer saturation from geomagnetically induced currents.

Electrical distortion is typically characterized as noise, harmonics and various other short-term and long-term disturbances. Surge arresters, electromagnetic shields, isolation transformers, constant-voltage regulators, tap-changing regulators, low-impedance power conditioners, proper grounding and electrical maintenance programs can minimize or eliminate some distortions. Typically, power conditioning equipment combines voltage regulation with power system isolation and shielding. UPS systems are generally an excellent way to control power distortions, but their primary purpose is to improve power reliability not to clean poor power quality

Short-term power quality disturbances include dropouts, sags and swells. Dropouts are momentary power losses typically occurring within one electrical cycle. Sags are depletions of power caused when heavy loads are started. Swells are power surges caused by sudden load disconnects. Sags and swells are typically seen as voltage changes lasting 2.5 seconds (150 cycles for a 60 Hz system) or less upon sudden changes in power demand.

Noise

Unpredictable, random, unwanted signals superimposed on data signals or on power waveforms is called noise. In a power system, electrical noise is generally a long series of relatively high-frequency impulses having varying amplitudes and riding on the power waveform. Interference affects data signals; static affects radio signals. Because noise can affect equipment operation, noise makes power and control systems, such as programmable logic controllers, less reliable. In technical terms, noise is electromagnetic interference (EMI) and radio frequency interference (RFI).

Noise voltage occurring between a power or signal line and the system neutral or ground is “common-mode” noise. Noise voltage occurring between power or signalling conductors is normal or “transverse-mode” noise.

Electromagnetic radiation causes noise. These disturbances may be from natural electrical disturbances in the atmosphere, e.g., geomagnetic storms; or the operation of electric or electronic devices, e.g., broadcast transmitters, arcing motors and electric welders. Transmitting a voltage over a power transmission line can produce corona and cause noise. Even “flipping a switch” to turn on room lights can generate electrical noise.

Ground loop noise is caused by current flowing through conductive paths formed by multiple ground connections. The current causes ground-connection points of grounded components to be at different electrical potentials.

Various methods eliminate or reduce noise. These methods include repairing ground connections, isolating grounds (breaking up ground current paths), and installing electromagnetic shields. Sometimes single-phase, shielded, isolation transformers are installed for this purpose.

Powerline noise may also be controlled by installing “low-pass” or “noise” filters. Power waveforms at the desired 60 or 50 Hz frequency can pass through these filters, but higher frequency waveforms, such as transient waveforms in the kHz to MHz frequencies, cannot. The source of noise and the mode of the disturbance determine what is required to control noise.

Harmonics

Electrically, a harmonic is a voltage or current whose waveform cycles at a frequency that is an integer-multiple of the desired or fundamental frequency. Harmonics are caused by the use of variable-speed drives, rectifiers, inductive heaters, personal computers, saturated transformers (fluorescent lighting ballasts), copying machines, solid state switches, fluorescent and high intensity discharge arc lamps and other nonlinear or arcing devices. Harmonics contaminate the sinusoidal power supply waveform. The distorted waveform caused by harmonics is a repeating, nonsinusoidal waveform.

Essentially, any nonsinusoidal, repeating waveform can be reproduced by adding sine waves of different amplitudes and frequencies. Harmonic distortion can thus be measured by separating each undesirable steady-state component from the desired sinusoidal, fundamental-frequency waveform. Each contaminating voltage and current waveform has a distinct frequency that is an integer-multiple of the fundamental frequency.

The sequence or order of a harmonic is set by the integer-multiple of the fundamental frequency. Harmonics are measured for each represented frequency by “tuning” the test instrument to that frequency. Table 1 shows selected harmonics where the fundamental frequency of the system is 60 Hz. Any integer-multiple of “3” (3rd - 6th - 9th - etc.) is a “triplen” harmonic.

Harmonic analyzers are test sets that determine all necessary measurements and calculate waveform distortion. Less expensive instruments reading only voltage for the selected harmonics can be used along with manual calculations to determine the same information.

Total Harmonic Distortion (THD) is the overall level of harmonic distortion of a voltage waveform. The THD of a voltage waveform can be calculated by the formula:

$$V_{thd} = 100 \times \sqrt{\frac{\sum V_h^2}{V_1^2}}$$

where:

$V_{thd} =$ the THD of a voltage waveform (%),

$V_1 =$ the rms voltage of the sinusoidal waveform whose frequency is the fundamental frequency,

and

$V_h =$ the rms voltage for the specified sinusoidal harmonic waveform.

The summation of harmonic voltages starts with the square of the voltage measured for the second harmonic and continues until all significant harmonics have been included. Where there is little harmonic distortion, the rms voltage of the system is essentially equal to V_1.

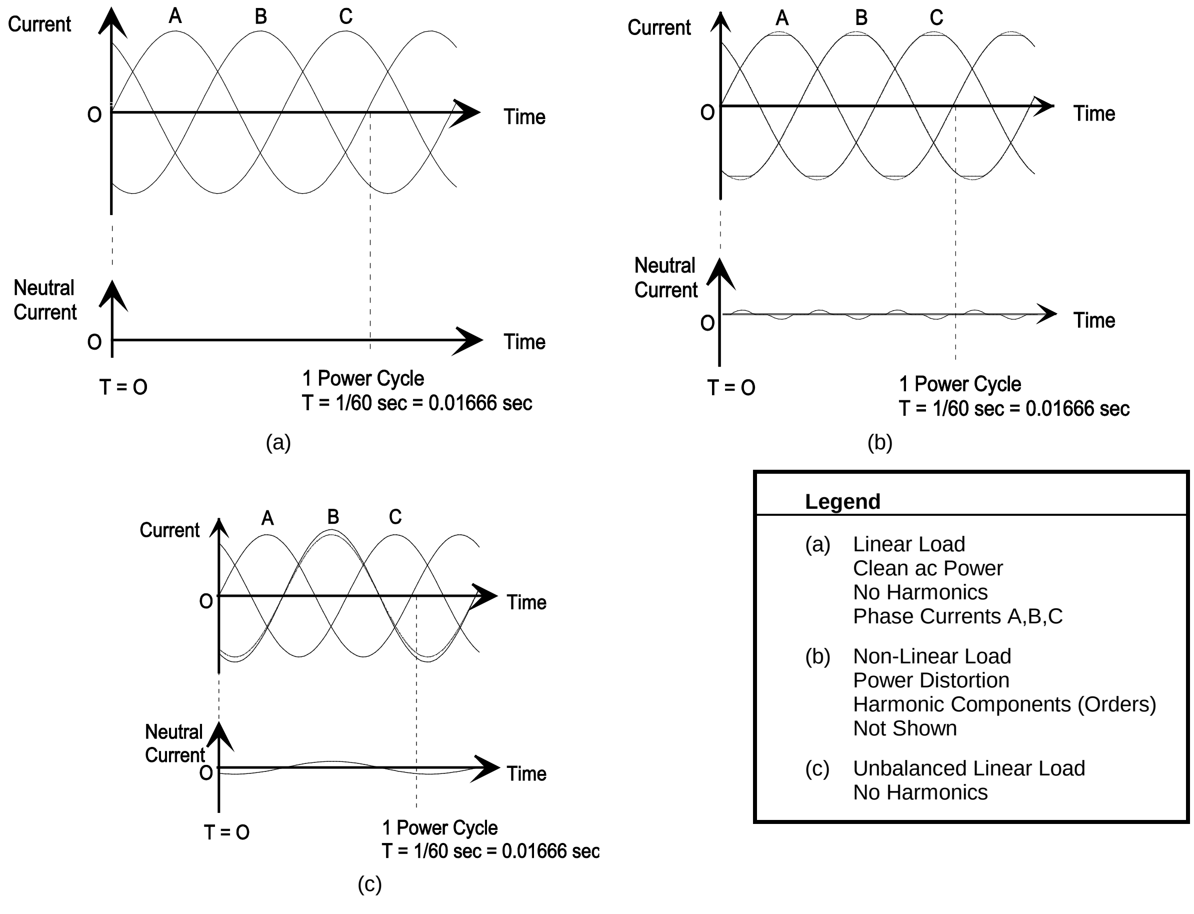
The THD in an industrial power system can easily be 15% or more. Where harmonics cause system problems, corrective measures should be taken.

TABLE 1
Selected Harmonics Of A 60 Hz Waveform

Harmonic (Order)	Frequency (Hz)
2nd	120 (2 × 60)
3rd	180 (3 × 60)
5th	300 (5 × 60)
7th	420 (7 × 60)
11th	660 (11 × 60)

Ideally in a 3-phase, 4-wire circuit, a neutral carries no current. Line currents cancel each other in the neutral as shown in Figure 2(a). But harmonics, like fault currents and unbalanced loading, can cause current to flow in a neutral as shown in Figure 2(b). Even small differences in line voltage can cause unequal phase currents, and cause current to flow in the neutral, as shown in Figure 2(c). Neutral currents can result in overheating. Odd-numbered triplens (3rd - 9th - 15th - etc.) are especially likely to cause this condition, because they are additive in the neutral.

Previously, the National Electrical Code (NEC) sized neutrals for infrequent use. Harmonic currents were not a concern. Today, harmonics are predominant in power systems. Harmonics can produce steady-state neutral currents almost twice as large as the current in any phase. Therefore, many of today's power systems require large-sized neutrals because of harmonics.



(a)

(b)

(c)

Legend

(a) Linear Load
Clean ac Power
No Harmonics
Phase Currents A,B,C

(b) Non-Linear Load
Power Distortion
Harmonic Components (Orders) Not Shown

(c) Unbalanced Linear Load
No Harmonics

Figure 2. Power Waveforms On Y-Connected Loads.

To meet today's needs, specialized equipment is available. Cables can be purchased specifically for use with harmonic loads. Some are manufactured with a single oversized neutral, others with a separate neutral for each phase. Special transformers are available for use with harmonic loads; the “K-Factor” stamped on their nameplates identifies the suitability of these units for use with distorted waveforms.

Typically, to minimize or control problems with equipment and systems, harmonic filters or traps can be used to restrain individual harmonics and maintain the THD below 5%. The harmonic filters or traps are assemblies of capacitors and inductors specially designed to filter the selected harmonic component based on power system requirements. Some original equipment manufacturers are exploring ways to design products to minimize harmonics. Their efforts include making harmonic filters part of their equipment.

Harmonics can also be controlled by “nonelectrical” solutions. As an example, the dc drive for a rubber grinder produced high harmonics in an industrial power system. The solution was to add lubricant to the rubber before the grinding process and to change the blades used in the process. These actions reduced the THD to acceptable levels.

Typically, these generalizations are true:

- Nonsinusoidal waveforms are common in power systems.
- Harmonics will cause problems in systems where the THD is 5% or more.
- Odd number (order) harmonics cause more problems than even order harmonics.
- Lower order harmonics have a higher amplitude and thus cause more problems than higher order harmonics.
- Electronic controls commonly affect power systems by generating harmonic currents and contributing to poor system power factors.
- Facilities using power factor correction capacitors experience greater problems from harmonics.
- Harmonic analyzers are needed to pinpoint the voltages of selected harmonics.
- Standard rms measuring devices will not reliably discern harmonics, although true-rms voltmeters (and ammeters) can better detect harmonic contamination than metering devices based on waveform averaging.
- Oscilloscopes may be needed to analyze line voltage notching caused by commutation gaps.

The combination of inductive devices, e.g., transformers, and capacitors in an electric system establishes a resonant frequency for that system. If the system’s resonant frequency and any harmonic frequency are the same, the magnitude of waveform for that harmonic will increase. The specific harmonic current or voltage could be greatly magnified to more than ten times its original value and result in excessive stress to the system.

Capacitor switching can change the resonant frequency of a system. As capacitors automatically switch on or off line for power factor corrections, the resonant frequency of the system changes. Thus, serious harmonic problems can exist and disappear as capacitors are switched on or off line. Similarly, serious harmonic problems can exist and disappear as harmonic-producing loads are switched on or off line.

For these reasons, power factor correction capacitors are avoided in systems having or likely to have harmonics. Alternately, installations are tuned to prevent the resonant frequencies from amplifying harmonic waveforms.

There are harmonic standards in Europe and the U.S. that tightly restrict equipment-generated harmonics, however, these standards exercise these restrictions in different ways. IEC Standard 555 sets limits for harmonic currents that may be produced by equipment; therefore, manufacturers must design equipment to meet the standard. IEEE Standard 519 recommends limits for harmonic distortion in distribution systems; therefore, U.S. system designers must take actions to control harmonics.

Transients

Transients are surges or changes in steady-state voltage or current that disappear as a new steady-state condition is reached. Typically these rapid electrical changes, usually lasting milliseconds or microseconds, transfer readily between circuits through electromagnetic coupling. A pulse (impulse/spike) usually lasts less than 2 milliseconds and is a short duration transient where the initial and final steady-state conditions of the system are usually the same. The causes of transients include lightning, restoring power following an interruption, routine switching, loose wires, and electrical breakdown and other fault conditions.

Effects of Distortions

Some manufacturers assume their equipment will operate in a system receiving clean power and will never be subjected to voltages deviating more than 5% from normal. Other manufacturers design to real-world conditions so their equipment can withstand diverse electrical disturbances. However, in general, industrial electronic equipment is becoming more complex and more sensitive to electrical disturbances.

Power quality distortions can last for any duration. They can be instantaneous, or steady-state. Their effect on a system depends on the equipment design. For a 0.5 cycle (0.0083 s) “low-voltage” event, a typical computer will withstand a voltage sag to zero volts. The computer will withstand a sag to 87% of rated voltage for a 100 cycle (1.66 s) event. If either sag lasts longer, the computer system will fail. The power quality problem becomes a power reliability problem.

Harmonics and transients expose electrical insulation to abnormal voltage stress. These disturbances can cause power voltage waveforms to peak above the withstand capability of the insulation. Computers, microprocessor-based controllers and other electronic equipment, and windings in motors, transformers and generators, are particularly sensitive to such stress. Computer shutdown, logic errors and electrical breakdown are possible consequences.

Harmonics and low voltage operation of equipment raise the rms operating current and generate heat in a system. Harmonics also induce eddy or circulating currents in systems and equipment and produce undesirable heating. In general, because higher rms, neutral and stray currents raise component temperatures, harmonics and low voltage problems accelerate aging and lead to the shortened service life of equipment. Further, increased operating temperatures weaken insulation to make it more susceptible to breakdown from voltage stress. Finally, increased operating temperatures result in increased power losses and higher operating costs.

Harmonics can cause high frequency vibration in rotating equipment. Vibration results in mechanical stress. Harmonics can increase metering errors which results in higher costs. Harmonics induce stray and circulating currents in shafts, bearings and other metal parts not intended to carry a current. Circulating currents overheat and stress the equipment. This can cause machinery or mechanical breakdown.

Power factor correction capacitors are particularly susceptible to high frequency harmonic waveforms. The capacitors offer a low impedance to the high order harmonics and act as a shunt. High order harmonics flow through the capacitors, overheat them and cause them to fail.

Noise and harmonics affect the performance of equipment where zero-voltage crossings trigger an operation. Instead of two clean zero-voltage crossings occurring per cycle, crossings can occur more frequently because of the additive effects of the positive and negative pulses and harmonics. Timing errors result. Figure 1 graph “Waveform with Noise” demonstrates multiple zero-voltage crossings.

Similarly, noise and harmonics affect the performance of equipment where waveform peak values trigger operations. Additive components can cause a peak at other than the timing point suggested by the fundamental waveform.

Noise, harmonics and transients are damaging to data signals. Signals can be lost or falsely initiated by these disturbances.

Electrical noise is unlikely to damage a power supply or electrical equipment. The net effect on rms values is minimal.

Power Monitoring

To assist diagnosing and correcting the cause of dirty power problems, modern monitoring instruments measure, record and graphically display simultaneous current, voltage and load conditions on each phase of an electric system. Monitoring devices are typically installed at power sources and at sensitive loads, but can be located at other points in a power system.

Conditions are monitored for an extended period, typically 1-4 weeks, to spot trends. Occurrences are analyzed to determine if they correlate to shift changes, to certain times of the day, to the operation of major equipment or to changes in ambient temperatures. Characteristics of the disturbances, particularly amplitude, duration and frequency are studied.

Monitoring equipment can also be permanently installed. Some monitoring systems are programmable to simultaneously analyze process parameters, equipment ambient and power conditions. Some contain alarms to warn when data exceeds set limits and notify personnel at remote locations to take action if needed.

Power Conditioning

The term “power conditioner” has no set meaning. A power conditioner is typically a combination of devices. Power conditioners may do nothing more than filter, or they may purify and regulate a power supply. Some are actually power sources. Some contain programmable parameters and can transmit alarms to personnel at remote locations. Equipment used for power conditioning includes surge suppressors, filters, hybrid devices, voltage regulators, shielded isolation transformers, line reactors and various types of UPS systems including motor-generator (M-G) sets and magnetic synthesizers.

Each type of device can be selected for its desired characteristics. A surge suppressor can be a high-energy crowbar device. A crowbar device provides an essentially short-circuit path to ground once the designed voltage is exceeded. Crowbar devices include carbon-block spark gaps and gas discharge tubes.

Alternately, a surge suppressor can be a faster-acting but lower-energy-dissipating voltage clamping device. Voltage clamping devices include metal-oxide varistors (MOV’s) and other nonlinear resistors. Unlike the crowbar device which shorts out the circuit, the clamping device maintains the system at or near the clamping voltage. The clamping voltage is usually set as the line voltage plus a designated safety factor.

Voltage regulators usually maintain the output voltage within 3% of a set point, while the input voltage can change up to 25%. These units attenuate noise as an incoming waveform when it is transformed. Some types of voltage regulators have high output impedance which reflects load-generated noise back to the load. This can cause other problems. Other types of regulators can overshoot a needed correction when attempting to correct certain ac waveform distortions, and can cause damaging oscillations and unstable voltages. Some designs interrupt power flow when the input voltage drops below a designed threshold. Some units have sensing and control systems designed to be exposed to the input power and are, therefore, susceptible to damage from abnormal power conditions. In spite of such weaknesses, voltage regulators generally transform voltage and control noise adequately. Prices vary greatly, but voltage regulators generally cost slightly less than shielded isolation transformers.

Shielded isolation transformers are usually installed for noise control. They do not regulate voltage but provide a fixed input-to-output voltage ratio, commonly 1:1. They block common-mode noise but do not block noise between current-carrying conductors. Like ferroresonant regulators, isolation transformers can have high impedances and reflect load-generated noise back to the loads. Shielded isolation transformers generally do not reduce low frequency harmonics and resonance problems. Power synthesizers are high-grade nonsinusoidal power sources used in power conditioning and monitoring applications. These complex, multifunction units cost more than most other “pure” power conditioning equipment, but they are sometimes necessary for special applications. They can contain a battery backup to operate regardless of the condition of the ac input. Power synthesizers are a special form of UPS system.

Line reactors are used to control transients and high frequency harmonics. Adjustable speed drives at one facility were found to be tripping out at the same time every day. It was determined that switching at a utility capacitor bank 9 miles (14.5 km) away caused a voltage transient that shut down these drives. When line reactors were installed, the voltage surge was diminished and nuisance trips stopped. The line reactors “filtered” the power supply.

Many power conditioners are “hybrid” devices. A hybrid unit can be made of a combination of various devices to affect specific controls.

A recent entry into the power conditioner market, switched, cryogenic, stored energy systems are used to eliminate short-term power disturbances for large industrial loads. A superconducting circuit maintains distribution system power during dropouts and sags of limited duration.

Emergency Power Systems

An emergency power system is any independent reserve source of electrical energy that can secure personnel safety or loss control of property or business when the principle energy source is lost. UPS and SPS are special types of emergency power systems.

The terms “uninterruptible” and “standby” are not clearly defined by equipment manufacturers. An uninterruptible power supply may actually be momentarily interrupted with some of the UPS equipment available today. Some manufacturers design uninterruptible power supplies capable of only momentary power carry-over or “ridethrough,” usually lasting 4 cycles or less. Some standby equipment requires a high level of maintenance. One manufacturer says its SPS has all the features of an on-line UPS, but without the cost. A review of equipment specifications and manufacturer’s instructions is necessary to evaluate UPS/SPS system capabilities.

An Motor-Gear (M-G) set is a rotary UPS. Electrically, its power supply is separated from its output power. Because there is no electrical connection between the input to the motor and the output of the generator, most of the power quality problems associated with a power supply to an M-G set are effectively isolated from the output power waveform. During short-term power supply outages, rotating motor-generators continue to rotate by their own inertia. This is known as the “flywheel effect.” Continuous clean output power is produced during short term interruptions. Ridethrough capabilities are typically limited to durations lasting less than 10 cycles. The major features of an M-G set are the availability of total electrical isolation, sine wave output and short-term power carry-over. M-G sets are driven by induction, synchronous or dc motors, based on motor availability and power system requirements.

A static UPS typically consists of a rectifier, dc bus with a floating stationary battery, inverter and bypass. The floating, on-line battery automatically becomes the sole power supply when ac power to the rectifier is lost. When ac power is restored, the rectifier again supplies the inverter and recharges the floating battery. The availability of the battery power supply depends on the capacity of the battery and its remaining service life. Batteries in good condition will typically supply UPS power for 10 to 60 minutes, but some systems are designed to provide power for several hours. PRC.5.7.4 guides the maintenance of stationary batteries.

An SPS switches its source of power on when the primary source of power is lost. The time taken for detecting the loss of power, switching on the new power source and finally supplying power is called the transfer time. Thus, a momentary power interruption occurs when an SPS system is used.

An SPS may serve a few emergency lights, a computer system or a complex process. It may contain an electronic power source, or it may be driven by engines or turbines.

Critical systems and systems with high loss potentials generally cannot tolerate long transfer times. These systems may require a UPS rather than an SPS. Typical UPS systems are continuous, “no-break” power supplies.

UPS and SPS systems are not necessarily sinusoidal power sources. Sine wave power is thought to cause fewer problems and is generally preferred for sensitive electronic equipment. For this reason, the output waveform of these supplies must be considered when evaluating their use. The THD of an output waveform can be used as a tool for evaluating a power source.

Emergency power systems can include turbine-generators and diesel, gas and other fuel-engine-driven generators. However, a turbine- or engine-driven generator is normally installed as a backup, auxiliary, or standby power system, rather than as part of a UPS system, because the generator is designed to supply power during infrequent, planned, long-term outages lasting hours or days, rather than during frequent, unexpected, momentary outages due to service quality problems. Engine generators are typically off-line power systems having a transfer or startup time of 10 to 20 seconds or more.

ANSI/IEEE Std 446 provides additional information concerning the application and maintenance of emergency power systems.