

Guide to Power Quality



Why Power Quality is an Issue

Rolling brownouts, voltage sags, spikes, electrical noise and harmonic distortion... If you haven't experienced any of these power problems yet, you will. In today's market, you can't take the power from your local utility for granted. The growing use of microprocessors in appliances, office equipment and process controls has made us all aware of the power quality demands from equipment and the unpredictability of its supply.

Equipment and machinery can be damaged or even fail when subjected to power anomalies. One or two seconds of outage or a surge can bring your business down for hours or days. No matter where you are, spikes, surges, brownouts and other power problems are potential problems.

With the U.S. utility deregulation, many people now realize that power is not an unlimited resource. Part of the problem utilities face is that they cannot produce enough power to supply growing needs, and it can take years to build additional power plants.

While utility power can be unpredictable, what happens inside your building can be worse. About



80% of power quality problems are caused inside a facility, from inadequate wiring or incorrect grounding, to large loads sharing the same circuits. These problems can be compounded by starting, running and stopping large machinery and other business-critical systems. If your building is more than 15 years old, it probably wasn't designed to meet the demands of today's high power equipment. The systems supporting your organization's key functions may be overloading the wiring and causing power problems and failures that can harm valuable equipment.

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Understanding Power Problems

You can protect your business by investing in the right power

quality equipment. But how do you know which solution is right for you?

Many power quality problems are easily identified once a good description on the problems is obtained. Unfortunately, the tensions caused by power problems often result in vague or overly dramatic descriptions of the problem. When power problems happen, try to note the exact time of the occurrence, its effect on electrical equipment, and any recently installed equipment that could have introduced problems to the system.

A power quality audit can help determine the causes of your problems and provide a well-designed plan to correct them. The power quality audit checks your facility's wiring and grounding to ensure that it is adequate for your applications and up to code. The auditor will check the quality of the AC voltage itself, and consider the impact of the utility's power system. The findings will be included in a report outlining problems found during the audit and recommended solutions

Many businesses and organizations rely on computer systems and other electrical equipment to carry out mission-critical functions, but they aren't safeguarding against the dangers of an unreliable power supply. This guide will give you a clear understanding of the causes and effects of specific power problems and of the most effective solutions.

Common Power Problems

Here are some of the most common power supply problems and their likely effect on sensitive equipment:

A **power surge** takes place when the voltage is 110% or more above normal. The most common cause is heavy electrical equipment being turned off. Under these conditions, computer systems and other high tech equipment can experience flickering lights, equipment shutoff, errors or memory loss.

High-voltage spikes occur when there is a sudden, rapid voltage peak of up to 6,000 volts. These spikes are usually the result of nearby lightning strikes, but there can be other causes as well. The effects on vulnerable electronic systems can include loss of data and burned circuit boards.

Switching transients take place when there is an extremely rapid voltage peak of up to 20,000 volts with a duration of 10 microseconds to 100 microseconds. Switching transients take place in such a short duration that they often do not show up on normal electrical test equipment. They are commonly caused by machinery starting and stopping, arcing faults and static discharge. In addition, switching disturbances initiated by utilities to correct line problems may happen several times a day. Effects can include data errors, memory loss and component stress that can lead to break down.

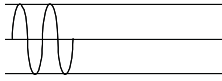
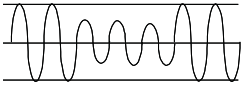
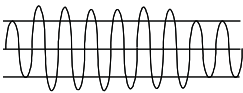
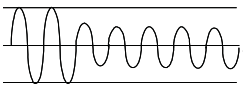
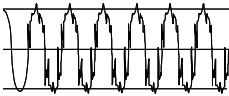
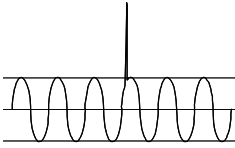
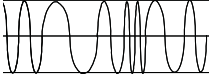
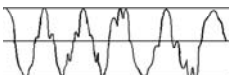
A **frequency variation** involves a change in frequency from the normally stable utility frequency of 50 or 60 Hz, depending on your geographic location. This may be caused by erratic operation of emergency generators or unstable frequency power sources. For sensitive equipment, the results can be data loss, program failure, equipment lock-up or complete shut down.

Power sags involve voltages that are 80-85% of normal for a short period of time. Possible causes are heavy equipment being turned on, large electrical motors being started, and the switching of power mains (internal or utility). A power sag can have effects similar to those of a power surge, such as flickering lights, equipment shutoff, memory loss and data errors.

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Power Quality Problems

Problem	Sine Wave	Definition	Cause	Effect
Blackouts		A zero-voltage condition lasting for more than two cycles.	<ul style="list-style-type: none"> Acts of nature Tripped circuit board Power distribution failure Communications breakdown 	<ul style="list-style-type: none"> File corruption Hardware damage Programming loss Costly system reboot Equipment shutoff Downtime
Power Sags		Voltage below 120 volts	<ul style="list-style-type: none"> Heavy equipment being turned on Starting large electrical motors Switching power mains Overloaded circuits 	<ul style="list-style-type: none"> Equipment shutoff Overheating Equipment damage Hardware failure Data loss
Power Surge		Voltage above 120 volts	<ul style="list-style-type: none"> Heavy equipment being turned off Utility malfunctions Utility grid problems 	<ul style="list-style-type: none"> Equipment shutoff Flickering lights Memory loss Data errors
Brownout		A steady state of low voltage	<ul style="list-style-type: none"> Planned by utility company Heavy equipment being turned on Starting large motors Switching power mains Overloaded circuits 	<ul style="list-style-type: none"> Shortened equipment life-span Data loss and corruption
Electrical Line Noise		Radio Frequency Interference (RFI), electromagnetic interference (EMI), and other frequency causes	<ul style="list-style-type: none"> Electrical motors Broadcast transmissions Microwave radiation Distant electrical storms Relays Motor control devices 	<ul style="list-style-type: none"> Equipment damage Equipment shutoff Data loss Storage loss System lockup
High Voltage Spikes/ Switching Transients		Rapid voltage peak up to 6,000 volts, with a duration of nanoseconds to 1/2 cycle	<ul style="list-style-type: none"> Lightning strikes Switching operations Arcing faults Static discharge Equipment shutoff 	<ul style="list-style-type: none"> Equipment damage Equipment shutoff Disk crash Circuit board damage Data error
Frequency Variation		A change in frequency of more than 3 Hz	<ul style="list-style-type: none"> Erratic operation of generators Unstable frequency power sources 	<ul style="list-style-type: none"> Data corruption Equipment shutoff Disk crash
Harmonic Distortion		Distortion of the normal waveform, generally transmitted by nonlinear loads	<ul style="list-style-type: none"> Switched mode power supplies Variable speed motors and drives Copiers and fax machines 	<ul style="list-style-type: none"> Overheating Equipment damage Communication error

Electrical line noise is defined as Radio Frequency Interference (**RFI**) and Electromagnetic Interference (**EMI**) and causes unwanted effects in the circuits of computer systems. Sources of the problems include motors, relays, motor control devices, broadcast transmissions, microwave radiation, and distant electrical storms. RFI, EMI and other frequency problems can cause equipment to lock-up, and data error or loss.

A **brownout** is a steady lower voltage state. An example of a brownout happens during peak electrical

demand in the summer, when utilities can't always meet the requirements and must lower the voltage to limit maximum power. When this happens, systems can experience glitches, data loss and equipment failure.

A power failure or **blackout** is a zero-voltage condition that lasts for more than two cycles. It may be caused by tripping a circuit breaker, power distribution failure or utility power failure. A blackout can cause data loss or corruption and equipment damage.



The Solutions

Protecting your power quality is a big business right now. There are many choices of equipment and manufacturers. How do you know which is right for you?



The most expensive solution is not always the right solution for the problem. Both correct identification of the power problems and your company's needs should be addressed to ensure an accurate assessment.

Here also, is where the use of a qualified power quality auditor can prove to be invaluable. The auditor will not only identify power quality issues within your company, but will also help you assess your specific power needs. The auditor can then put together a recommendation that meets your needs without unnecessary expense.

There are five basic categories of solutions to some of these power problems, each having different capabilities, strengths and weaknesses. Below is an explanation of these categories and their effectiveness against specific power problems.

Surge Suppressors

Transient Voltage Surge Suppression (TVSS) provides protection against transient surges, which can happen so quickly that they do not register on normal electrical testing equipment.

Surge suppressors or surge protectors are the most basic form of power protection. A surge suppressor is often used to shield important, but less critical or highly sensitive equipment. It is also used as a complement to more comprehensive power protection solutions. They are passive electronic devices that protect against transient high-level voltages.

Transients are often the cause of "unexplained" equipment problems, computer lockup, data loss, and other "gremlins" inside a facility. Transient voltage surge suppressors can be incorporated into voltage regulators, power conditioners, and UPS for added protection.

Depending on the components involved, surge suppressors offer limited protection against power surges. In the case of frequent high voltage spikes, a high quality surge suppressor is a good choice. When large equipment like AC motors are turned on and off, they create large, fast voltage changes (switching transients). However, low frequency surges (slow changes at 400 Hz or less) can be too great for a surge suppressor attempting to clamp that surge.

Voltage Regulators

A voltage regulator maintains the input voltage to the facility or system to within a narrow range. Regulators provide excellent protection against sags, brownouts, surges and spikes, and moderate noise attenuation, but do not protect against blackouts. There are five types of voltage regulators: Ferroresonant, Tap Switching Transformer, Limited Range Variable Transformer, Buck-Boost, and Hybrids.

Ferroresonant Regulators

Ferroresonant constant voltage regulators use a capacitor in series with a transformer coil, and tend to be high impedance devices that are sensitive to load changes, and therefore, do not handle high inrush loads well. They can interact with switch mode power supplies to produce transients and electrical noise on the output. Their resonant circuits make them particularly sensitive to frequency changes. Applied carefully, ferroresonant regulators can provide $\pm 2\%$ – $\pm 5\%$ output regulation, load isolation, and noise attenuation.

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Common Power Problems and Solutions

Problem	Surge Suppressor	Voltage Regulators	Standby UPS	Line-Interactive UPS	On-Line UPS	Power Conditioner	Generator
Blackout	No	No	Yes	Yes	Yes	No	Yes
Brownout	No	Yes	No	No	Yes	Yes	No
Power Sag	No	Yes	No	No	Yes	Yes	No
Power Surge	Yes	Yes	No	Yes	Yes	Yes	No
Line Noise	No	Some	No	No	Some	Yes	No
Spikes/Transients	Some	Yes	No	Some	Yes	Yes	No
Frequency Variation	No	Yes	No	No	No	Yes	No
Harmonic Distortion	No	No	No	No	No	Yes	No

Tap Switching Transformer Regulator

Regulators based on tap-switching transformers monitor output voltage and use solid-state switching circuits for changing the transformer taps. Typically, these units provide from $\pm 3\%$ to $\pm 5\%$ output regulation. These regulators are extremely fast, but their fast response can sometimes cause problems with switch mode power supplies, and can produce harmonics and radio frequency interference.

Limited Range Variable Transformer Regulator

Limited range variable transformer regulators use variable transformers to directly control the output voltage of the regulator. This places the transformer's brush assembly directly in the power path of the regulator, which could cause premature regulator failure. Limited range regulators provide excellent regulation, from $\pm 1\%$ to $\pm 3\%$.

Buck-Boost Regulators

The buck-boost regulator consists of three basic components: a motorized variable transformer, a buck-boost transformer, and a controller. These regulators are very reliable and provide from $\pm 1\%$ to $\pm 3\%$ voltage regulation. The controller monitors the output voltage and then uses the feedback signals to determine drive commands for the transformers.

Hybrid Regulators

Ideally, a voltage regulator will combine two or more of these technologies in order to maximize the regulator's stability and output regulation.

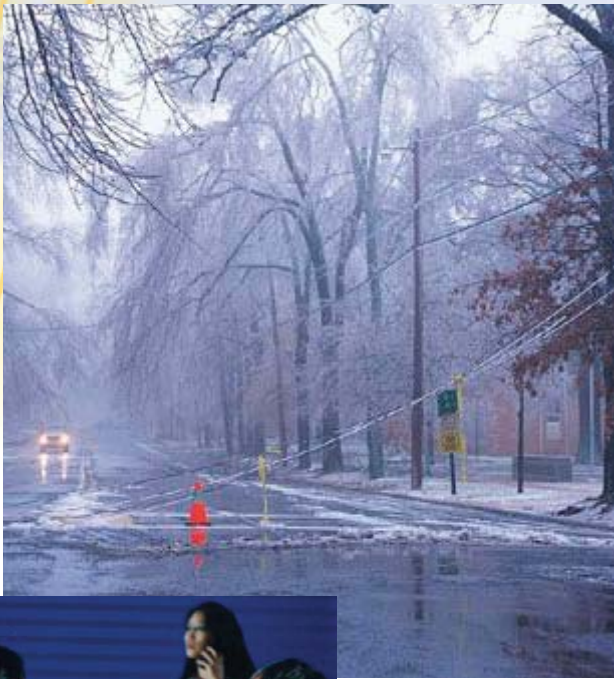
Called hybrid regulators, these units bring voltage regulation up to a power conditioning level, providing comprehensive power conditioning features, such as harmonic suppression.

Power Conditioners

There is no official definition of what constitutes a power conditioner. Often, a transient voltage surge suppressor (TVSS) is called a power conditioner because it filters (suppresses) the transient surges that can wreak havoc on equipment. Some call TVSS the original power conditioner.

Basically, a power conditioner should address and correct voltage anomalies, while also providing protection against line noise, harmonics, RFI and EMI, and frequency variations.

Power conditioners can vary in size and capability, so it is best to get a thorough definition of the power problems a particular unit addresses. Some power conditioners are built specifically for certain applications. For example, there are power conditioners built for the computer and telecommunications industries that are small enough to be mounted on a standard 19" or 23" computer rack.



Uninterruptible Power Supplies

There are three basic types of UPS: Standby (or Offline), Line Interactive, and Double Conversion (or Online)

Standby (Offline)

This type of UPS consists of a basic battery/power conversion circuit and a switch that senses irregularities in the electric utility. The equipment to be protected is usually directly connected to the primary power source, and power protection is available only when line voltage dips to the point of creating an outage. Some off-line UPS include surge protection circuits to increase the level of protection they offer.

In the case of power surges, a standby UPS passes the voltage surge to the protected system until it hits a predetermined level, usually around 115% of the input voltage. At the surge limit value, the unit then goes to battery. Although they do not provide complete power

isolation, they provide reasonably good protection against spikes and switching transients. *However, they do not protect against sags, line noise, frequency variation or brownouts unless the battery is delivering power to the protected system.*

If the UPS is forced to go to battery frequently, it can drain the battery, making it unavailable during blackouts. Since standby UPS provide only partial protection against many common power problems, they are most often used to shield a single user or less critical or sensitive equipment.

Line Interactive

Line interactive UPS are hybrid devices that offer a higher level of performance by adding better voltage regulation and filtering features to the standby UPS design.

Like standby models, line interactive UPS protect against power surges by passing the surge voltage to the equipment until it hits a predetermined voltage, at which point the unit goes to battery. They provide moderate protection against high voltage spikes and switching transients, although, again, not with complete isolation.

With power sags, line interactive UPS may use a tapped transformer to provide the voltage levels needed to maintain output voltage. Essentially, the unit switches to battery to adjust the tap location at set intervals to maintain the output voltage as the input voltage falls. It will eventually go to battery full-time once the input voltage reaches a pre-selected level. This system offers adequate protection as long as the power sags aren't continuously changing, which may reduce battery time. If it is frequently going to battery, you run the risk of not having the batteries fully charged for use during a power outage.

For electrical line noise and frequency variation, line interactive UPS work only when the inverter is operating and the battery is the power source, which may drain the battery during prolonged unstable conditions that typically occur during generator operation.

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Ferroresonant UPS, another hybrid technology, keeps the inverter in standby mode similar to line interactive and standby UPS. The protected system, however, is powered from the utility through the ferroresonant transformer. The transformer provides voltage regulation and power conditioning for disturbances such as electrical line noise. The ferroresonant transformer also maintains a reserve of energy that is usually sufficient to power most small equipment or PCs briefly when a total outage occurs. This keeps the equipment supplied with power within most input requirements until the inverter is switched on.

However, ferroresonant UPS are not very effective against unstable frequency variations or sudden current changes. In general, ferroresonant UPS work best with most non-computer or non-critical technology, or with linear loads such as motors, heaters and lights.

Double Conversion (Online)

Double Conversion UPS, often called “Online” provide the highest level of power protection and are an ideal choice for shielding your organization’s most important computing and equipment installations. This technology uses the combination of a double conversion (AC to DC/DC to AC) power circuit and an inverter, which continuously powers the load to provide both conditioned electrical power and outage protection. Online UPS offer complete protection and isolation from all types of power problems – power surges, high-voltage spikes, switching transients, power sags, electrical line noise, frequency variation, brownouts and blackouts. In addition, they provide digital-quality power not possible with offline systems. For these reasons, they typically are used for mission critical applications that demand high productivity and system availability. Double Conversion UPS can be the most cost-effective way to ensure comprehensive power protection.

Generators

Generators are machines that convert mechanical energy into electrical energy. They are usually used as a backup power source for a facility’s critical systems such as elevators and emergency lighting in case of blackout. However, they do not offer protection against utility power problems such as overvoltages and frequency fluctuations, and although most can be equipped with automatic switching mechanisms, the electrical supply is interrupted before switching is completed, so it cannot protect against the damage that blackouts can cause to expensive equipment and machinery.

If you use a generator to backup to a UPS during extended blackouts, the U.S. Department of Commerce suggests that it be rated at about 2 1/2 times higher than the UPS it is backing up.

Power Factor and Harmonic Correction

Power factor is a term commonly used when considering the efficiency of an electrical power distribution system. Most commercial and industrial alternating current (AC) loads are inductive, due to the nature of the types of devices connected on the electrical system. Such equipment can produce poor, or a low, power factor. The power factor capacitor function is to provide kilovar to a system at the point where connected, providing improved power factor. Requirements of the user (commercial, industrial, utility etc.), will vary widely. Small fixed motor load capacitors through automatically switched capacitors are commonly provided.

Harmonics are currents and voltages that have multiplied within an electrical system. Commonplace linear loads continue to become more non-linear due to electronic and digital type devices. Because of this, the traditional sine wave shape has changed, reflecting these many current and voltage distortions. To mitigate harmonics, various passive equipment is available which typically will minimize one or two harmonic orders. Active harmonic filters, a power electronic solution, will cancel multiple harmonic orders, generally to the 51st order.

Summary

Power quality problems can vary across a broad spectrum. They can cause anything from minor inconvenience to expensive equipment shutoff and breakdown. The most important thing to remember is that every time an electrical device is subjected to power problems, it suffers some level of damage.

There are a number of specialized solutions available to correct power problems. A power quality audit is highly recommended, especially if your company does not have the expertise in house to track down the root of the trouble. An audit will help you identify the source(s) of your problems, and recommend the most efficient solution.

About Staco Energy Products Company

Since 1937, customers worldwide have been relying on Staco Energy Products Company to deliver voltage control and power quality solutions tailored to their needs.

As a leading power quality resource, we offer our customers world-class support; from our thorough applications assessment, to our ability to design and deliver a solution that is tailored to the specific needs of our customers; through delivery and commissioning.

Our professional, factory trained service team is in place to ensure that our customers' revenues are protected, and their investment provides them with many years of trouble free operation.

Staco develops total power solutions for OEM and end user applications.

Represented locally by:

We offer a wide array of power quality products, including:

- **Uninterruptible Power Supplies**
- **Power Conditioners**
- **Voltage Regulators**
- **Power Factor Correction and Harmonic Mitigation**
- **Active Harmonic Filters**
- **Variable Transformers**
- **Custom Engineered Test Sets**



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