# A Guide to Power Quality Problems and Solutions

The selection of any Process Control & Automation or Signaling protection device can be based on the following circuit parameters:

Businesses are heavily reliant on the "solid-state" electronic components that are part of today's office equipment and manufacturing systems - from security alarms, process controllers, computing equipment, communications switchboards to even fax machines.

While the power authority attempts to provide a constant voltage power supply free from corruption, local or unforeseen circumstances such as neighboring industries, storms or accidents can intervene to cause power-quality irregularities that can cripple operations.

Most modern electronic equipment systems are much less tolerant to transient voltages than the robust circuits developed over twenty years ago.

Power surges may be caused by a variety of factors. Lightning is blamed for many such disturbances and indeed is a prime culprit. However, by far the largest number of disturbances in urban and office environments are caused by power switching transients. Switching of inductive loads such as motors, air conditioning plants, domestic appliances and even the office photocopier can cause transient spikes of many thousands of volts.

## Power Quality Problems

### Under-voltage

An under-voltage is distinguished by the power supply voltage being less than the "nominal" voltage for a period of time. Although there is no standard definition of limits and duration, it is commonly accepted that under-voltages are those that occur for a few cycles of the supply voltage up to a few seconds in duration.

These variations may be caused by the power supply authority or by adjacent industries operating heavy loads such as large motors, welders, electric furnaces, etc. Variation typically occur where the power supply is heavily loaded or the reticulation feeders are long. Depending upon the type of electrical equipment, the duration and amplitude of the under-voltage, some equipment may fail to operate as intended under these conditions.

*An extended duration under-voltage may also be referred to as a "brownout". A short duration under-voltage may also be referred to as a "sag" or "dip".*

### Temporary over-voltage (TOV)

An over-voltage is where the power supply voltage increases above "nominal" voltage for a period of time. Although there is no standard definition, it is commonly accepted that over-voltages are those that occur for a few cycles of the supply voltage up to periods of a few seconds in duration.

A short term over-voltage generally has little effect, but an extended duration or abnormally high magnitude can cause equipment to overheat and fail.

*A short duration over-voltage may also be referred to as a "swell" or "surge". The term temporary over-voltage (TOV) is often used to define a short term condition due to 'normal' equipment operation, while Abnormal over-voltage refers to a large over-voltage typically due to some fault condition.*

### Transients

A transient voltage is a large impressed voltage with a very short duration (microseconds). Voltages may be in the magnitude of several thousands of volts, and due to the short duration, frequency components are significantly higher than the nominal frequency.

Although these events are of a very short duration, the high peak voltage is often sufficient to breakdown sensitive electronic components. The usual result is that the equipment stops operating with a blown fuse. Unfortunately the fuse, being a thermal device, probably blew some time after the transient had already passed through to damaged susceptible semiconductor components.

Lightning is blamed for many such transients and indeed is a prime culprit. However, by far the largest number of transients in urban and office environments are caused by power switching transients. Switching of inductive loads such as motors, air conditioning plants, domestic appliances and even the office photocopier can cause transient spikes of many thousands of volts. It is estimated 85% of all power quality problems are due to transient voltages, most of these being produced within ones own facility.

Studies of typical transient voltage levels have been carried out, and the results of one such study forms the basis of the American National Standard C62.41, *IEEE Guide for Surge Voltages in Low-Voltage AC Power Circuits.* The survey found that voltage transient up to 6.5kV could occur on equipment circuits.

*A transient voltage may also be referred to as "spike", "glitch" or "voltage impulse".*

### Power outages

A power outage is distinguished by a complete absence of voltage supply. This event may be caused by power distribution system equipment failure or an accident such as someone cutting a cable. A power outage may also be caused by the operation of an upstream over current protective device removing power from a circuit where an overload or other fault is detected. The duration of a power outage may be from a few tenths of a second to several hours.

*The term "dropout" is used to define a momentary power outage of less than one cycle.*

### Dropouts

A dropout is a momentary power outage where a portion of one power cycle is missing. These events are commonly caused by loose connections within the power system.

Equipment is affected dependant upon its ability to "ride through" the voltage dropout.

*The term "notch" may also used to describe this event, however, more accurately "notching" is a repetitive event such as caused by the commutation of current from one phase to another.*

### Frequency variations

Frequency variation is the deviation of the supply voltage frequency from its nominal value (60Hz in USA). As the system frequency is set by the speed of rotation of its generators, changes of more than 1% are rare. Small changes do occur as large blocks of load or generator capacity are added or removed from the network.

Frequency variations are more common in supplies fed from small generator systems.

Most equipment is generally not affected by frequency variations

### Noise

Noise is generally defined as the presence of unwanted higher frequency electrical signals that do not fall into the other power quality classifications given here.

Noise is often created by electronic switching devices, such as solid state rectifiers and switching power supplies.

Noise can cause miss-operations of some sensitive equipment, hum on telephone circuits and distortion on VDUs.

### Harmonic distortion

Harmonic distortion is caused by the operation of equipment that draws non-linear current (e.g. solid state rectifiers and switching power supplies) and is evident by the power waveshape being distorted from its normal sine waveshape. Each cycle of the supply is similarly affected for the duration of operation of the non-linear load.

## Power Quality Solutions:

### Surge Protection Devices (SPDs)

Surge Protection Devices use non-linear voltage limiting (or switching) components to clamp transient voltages to a safe level. SPDs are the most cost-effective power quality improvement device as:

1) Transient voltages account for approximately 85% of all power quality problems
2) SPDs are typically the cheapest form of protective device to purchase/install.

Some SPDs may include a filter also giving rudimentary protection against noise.

These devices may also be referred to as Transient Voltage Surge Suppressors (TVSS), Surge Arresters and Surge Arresters.

| | SPDs | Filters | Line Conditioners | Isolation transformers | UPS (Standby) | UPS (Online) |
|---|---|---|---|---|---|---|

| | | | | | | |
|---|---|---|---|---|---|---|
| **Under-voltages** | | | ✓ | | *(4)* | ✓(5) |
| **Over-voltages** | | | ✓ | | *(4)* | ✓ |
| **Transients** | ✓ | (1) | (1) | ✓ | *(1)* | ✓ |
| **Outages** | | | | | ✓ | ✓(4) |
| **Dropouts** | | | (2) | | *(1)* | ✓ |
| **Frequency** | | | | | | ✓ |
| **Noise** | (1) | ✓ | (1) | ✓ | *(1)* | *(1)* |
| **Harmonics** | | (1) | | ✓(3) | | |

Notes (1) Higher quality/performance units may additionally provide this protection
(2) Ferro resonant type units provide protection from this
(3) Protection may be provided depending upon transformer connection and harmonic problem
(4) Protection provided only for duration of battery capacity
(5) For severe under-voltages, protection may only be provided for duration of battery capacity

## Filters

Filters are available as standalone devices or often as part of some SPDs. Standalone filters are typically industrial devices designed to attenuate the higher frequency noise (EMI/RFI), while SPD filters (“plug strips”) generally provide less attenuation (especially at higher frequencies) and hence are less effective.

For the protection of industrial equipment, products such as the CRITEC Transient Discriminating Filter range are available. These “filters” are Series LC designed to reduce the rapid rate-of-voltage-rise of the pre-clamped waveform. These filters are designed for maximum effectiveness in the 5-50kHz bandwidth, and the RFI/EMI filtering provided is of secondary benefit.

CRITEC Technical Note TNCR006 provides further information.

Harmonic filters, also known as wavetraps, are special types of filter used on motor speed control circuits where harmonic voltage and current distortion are often encountered. These large specialist devices limit the harmonic problems affecting other equipment and increase efficiency while reducing the heating of the motor. EMI/RFI filters offer little value in these applications.

## Line Conditioners

*Line conditioners* solve the problem of inconsistent power supply voltage by providing a voltage regulating function. There are many types of line conditioners available, but essentially they can be divided into two main categories, the ferro resonant type which employs magnetic principles and the electronic tap changing type.

Ferro resonant line conditioners ensure a constant output voltage for a wide range of input voltage, particularly at light load. They are generally operated in a well under rated condition and store enough energy in their magnetics to ride through outages of up to one cycle. (For switch mode power supply loads, this is not too important because they can ride through a complete power failure for up to one cycle.) Because of the magnetics involved, ferro resonant line conditioners are large, heavy and generally inefficient.

Electronic line conditioners on the other hand are lightweight, highly efficient and have a good overload response. They employ thyristors or other solid state devices to switch taps on an auto transformer thereby boosting or reducing the incoming voltage to regulate the output to within a tight tolerance, generally better than 5%. They do not have the energy storage capabilities of the ferro resonant types.

Most line conditioners will include EMI/RFI filtering, while some also provide rudimentary surge protection. It is always recommended to supplement this protection with a specialist SPD unit.

## Isolation Transformers

Isolation Transformers are the solution where electrical isolation is required such as sites with electrically noisy grounds. Some isolation transformers also provide attenuation to higher frequency noise, thus there is an overlap in the protection provided by Isolation Transformers and SPDs. The noise attenuation ability of some isolation transformers may also provide protection against very small transient voltages.

The smaller and lighter SPD provides superior protection against differential mode transients and adequate protection for an estimated 85 to 90% of industries noise problems. Due to overall performance, size, weight and cost, the SPD is the first choice for most installers for protection of sensitive electronic industrial equipment such as PLCs.

If isolation is required, the isolation transformer is the solution, and an SPD is strongly recommended to be included to enhance protection.

CRITEC Technical Note TNCR016 provides further information.

## UPSs

The term UPS or uninterruptible power supply is often used loosely to embrace the spectrum of products designed to provide battery backup support when the utility power fails. Although all UPSs employ battery back-up to supply AC power via an inverter during power failure, three main types are available:

**1) Short Break or Standby**

These low cost designs are normally used for protection of a single computer. During normal operation, the power supply is fed from the AC supply through a small internal filter to the protected equipment. If a power outage or under-voltage is detected, an automatic switch operates transferring the UPS output circuit to the internal inverter. This operates until utility power returns or batteries are exhausted.

The transfer time of short break UPS is typically 4ms, quick enough that switch mode power supplies do not detect the short interruption of power. As the inverter only needs to operate for the duration of the battery charge, it can be made much smaller and cheaper.

In the case of under or over-voltages, if these exceed a nominal margin the UPS must switch to battery power. Therefore, this design of UPS is not suited to sites with poor power supply regulation. Because the AC supply is connected directly to the load under normal conditions, it is essential to make sure that a good SPD and filter are incorporated.

**2) True on line**

In this design, the UPS inverter is continuously operating and supplying the connected load. The AC supply is used to recharge the batteries. As the output is supplied from the inverter, any failure, under or over-voltage, to the UPS input has no effect on the output. In effect, a true on-line UPS re-synthesizes the voltage supply thereby creating a level of isolation between what happens on the input and what is produced at the output.

**3) Hybrid**

In efforts to lower cost, many of today's designs use advanced technology such as circuits that combine the rectifier and inverter function of the true-on-line design blurring the traditional definitions. In some designs, although no output switching device or transfer time is evident while normal AC supply is available, the inverter is actually in a standby mode.