Power Quality

Power Protection Products, Inc.
Power Quality Book
by Dan Maxcy  I  2017 Update

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THE POWER QUALITY "BIG 8"

Sags: IEEE-1100

Swell: IEEE-1100

Over-voltages: IEEE-1100

Undervoltages:

Harmonics: IEEE-519

Noise: IEEE-1100

Transients:

Grounding: IEEE-142

**Sag:** A sudden decrease in voltage that lasts less than a minute.

**Swell:** A sudden increase in voltage that lasts less than a minute.

**Overvoltage:** A voltage greater than that at which a device or circuit is designed to operate lasting longer than one minute.

**Undervoltage:** A voltage which is below the optimum, operational, or rated value of a component, circuit, device, piece of equipment, machine, or system. They last longer than one minute. Such a voltage may produce a distortion, a malfunction, or failure. In computers and similar devices, undervoltages can lead to data losses.

**Harmonics:** Currents that occur on the electric power system as a result of non-linear electric loads at frequencies other than 60 Hertz. Harmonic frequencies on the power system are a frequent cause of power quality problems.

**Transient:** A temporary excess of voltage and/or current in an electrical system lasting less than .016 seconds.

**Noise:** Any electromagnetic disturbance that interrupts, obstructs, or otherwise degrades or limits the effective performance of electronics and electrical equipment.

**Grounding:** Providing a conductor that directs excess electric current to the Earth to dissipate the buildup of hazardous voltages that would otherwise result in damaging electrical shock to people, property or equipment.
When we speak of Power Quality there are many terms used to describe problems with power in our facilities. Common ways to describe these power problems are spikes, surges, glitches, blackouts, brownouts, etc. Quite often these terms are associated with specific problems with equipment or systems. Examples are equipment damage, data problems or loss, equipment malfunction or complete system failure. The problem with using the above terms comes when trying to determine exactly what the power problem is and precisely the cause for the equipment or system failure. In this document we are going to review these terms and solutions. We will start by discussing the terms.

The Power Quality industry has come a long way with identifying power quality problems. The first hurdle needed to overcome was defining exactly what power quality problems occur and how to define them. The IEEE is the most often used source for electrical standards when dealing with power quality. The IEEE stands for “The Institute of Electrical and Electronics Engineers”. The IEEE is a society of electrical and electronic engineers from across the country. Members of this society meet on regular bases to discuss and develop standards that represent a consensus on the subject of Power Quality.

The recommendations of the IEEE come from people in the industry who actually manage and design facilities. Their expertise is widely recognized as “THE INDUSTRY STANDARD”. The IEEE standard 1100 (also know as the Emerald Book) is the best source for defining power quality problems. It also discusses problems with equipment and systems and it offers solutions to these problems. Other IEEE standards define and discuss in depth other power quality problems. Let's look at some of them...

Our first goal is to define power quality problems. We start with what we call the Power Quality “Big Eight”. When trying to determine a particular power quality problem it is helpful for us to use the SAME language. Therefore, the IEEE uses specific terminology to define power quality problems. They are the following: Over voltages, Under voltages, Sags, Swells, Transients, Noise, Harmonics, and Grounding. These are called the “Big Eight”. Notice the terms spikes, surges, glitches, blackouts, brownouts etc. are not mentioned. The reason for this is simple. Spikes, surges, etc. are general terms that could mean many things to many people. IEEE wanted to be exact in their definitions so we could be exact in our solutions to power quality problems.
The IEEE defines a Sag as the following:

IEEE-1100,2.2.67:

An rms reduction in the ac voltage, at the power frequency, for durations from a half cycle to one minute.

This tells us if voltage goes below a certain standard for more than a half cycle (which equals 8 thousandths of a second) to 1 minute, it is called a sag. The following is an example of a voltage sag:

![Voltage Sag Graph](image1)

The low voltage starts at 65 Milliseconds (thousandths) of a second. And ends at 135 Milliseconds (thousandths).

135 minus 65 equals 70 Milliseconds, therefore this meets the definition of a sag.

The IEEE defines a Swell as the following:

IEEE 1100,2.2.78:

An increase in rms voltage or current at the power frequency for durations from (a half cycle) to 1 minute.

This tells us if voltage goes above a certain standard for more than a half cycle (which equals 8 thousandths of a second) to 1 minute it is called a swell.

![Voltage Swell Graph](image2)
The IEEE defines an Over Voltage as the following:

IEEE-1100,2.2.56:

…an RMS increase in the ac voltage, at the power frequency, for a period of time greater than 1 minute.

This tells us if voltage goes above a certain standard for more than 1 minute it is called an over voltage. The following is an example of an over voltage:

The over voltage starts at 8 minutes and ends at 13 minutes, thus lasting 5 minutes which meets the definition of an over voltage.
The IEEE defines an Under Voltage as the following:

IEEE-1100,2.2.56:

...an RMS decrease in the ac voltage, at the power frequency, for a period of time greater than 1 minute.

This tells us if voltage goes below a certain standard for more than 1 minute it is called an under voltage. The previous example also shows an under voltage.

The IEEE defines a Transient as the following:

IEEE-1100- 2.2.83:

A sub cycle disturbance in the ac waveform that is evidenced by a sharp, brief discontinuity of the waveform. May be of either polarity and may be additive to, or subtractive from, the nominal waveform.

This tells us if voltage goes above or below a certain standard for less than one cycle (which equals 16 thousandths of a second) it is called a transient. The following is an example of a transient.

Transients can be either positive (above the sine wave) or negative (below the sine wave) and according to IEEE have values to over 20,000 volts.

IEEE also tells us **few solid-state devices can tolerate much more than twice their normal rating**. This means voltages more than 240 volts on a 120 volt system cause damage to most modern electronic equipment.
The IEEE defines Noise as the following:

IEEE 1100, 2.2.49:

Unwanted electrical signals that produce undesirable effects in the circuits of the control-systems in which they occur.

We call this specification the “catch all” specification meaning that if it’s not an over-voltage, under-voltage, sag, swell, or transient, it must be noise. The following is an example of a sine wave with no problems and then one with noise. The distortion of the bottom sine wave does not meet the IEEE criteria for an over-voltage, under-voltage, sag, swell, or transient, but it still causes problems with electrical and electronic equipment.

You might wonder why IEEE defines noise. The reason is that noise can and does cause problems. The equipment that commonly solves over-voltage, under-voltage, sag, swell, or transient problems may NOT necessarily solve noise problems. There is specific equipment to address noise.
A Harmonic is defined as the following:

A harmonic is the term used for current flow on your facilities power system at frequencies other than 60Hertz.

These harmonic currents cause many problems in our facilities. The IEEE has very precise standards and numbers to calculate if your facility has a high enough harmonic content to cause damage to your facility and its equipment. Some of the most common problems are:

- Electrical and Electronic damage.
- Control System errors due to Electrical noise caused by harmonics.
- Blown Fuses for no APPARENT reason.
- Nuisance tripping of Circuit Breakers.
- Energy Inefficiency

The following waveform captures illustrate a system without harmonics and one with harmonics. The second waveform speaks for itself when illustrating the damaging effects to a facilities power system when high harmonics are present.
What Exactly is Power Quality?

No Harmonics:

With Harmonics:
Grounding:

Most people in our industry believe the code book says electrical ground system must be installed so that its resistance to earth is less than 25 ohms.

**THIS IS NOT TRUE.**

You might want to look at NEC 250.53, it actually states:

“A single... electrode shall be supplemented by an additional electrode... If a single... electrode has a resistance to earth of 25 ohms or less the supplemental electrode shall not be required”

This could bring about a situation in which one electrode (ground rod) could measure 200 ohms resistance to ground and the installation of another might only bring the total down to 100 ohms. Therefore, a condition could arise where a facility may have a ground resistance higher than 25 ohms and still be in compliance with the National Electrical Code.

**IEEE 142, 4.1.2 states:**

“Ground resistance should be 1 ohm for substations and 2-5 ohms for commercial and industrial services.”

The lower the ground resistance the better.

A facility with high ground resistance is more susceptible to power quality problems than one with a low ground resistance. A high ground resistance can help induce large voltages into your electrical system causing electrical and electronic failure.

If your facility ground resistance has not been measured within the last 90 days IT SHOULD BE.
The Power Quality Correction Pyramid

POWER QUALITY PYRAMID

Custom Solution

Uninterruptible Power Supply System

Power Conditioning

Harmonic Cancellation

Grounding and Surge Protection Devices
An Introduction to P3 & PQU

Power Protection Products, Inc. (P3)

P3 is the industry’s trusted and respected advisor for critical power, cooling and energy solutions.

P3 represents some of the leading industry brands and strives to provide the top performing products. We stay on top of industry advances and have designed and built a variety of data center infrastructures, IT expansion projects, and industrial power upgrades.

We believe in providing a stable and secure electrical environment to meet customers’ needs. For more information about our power, cooling, and data center related products & services give us a call or visit our website.

Power Quality University

Providing an educational environment for hands-on training, testing, & evaluation of today’s power quality solutions & equipment.

P3 is "showing you how" with our Power Quality University (PQU) free seminar series. PQU brings real world knowledge into the classrooms. The instructors who teach at PQU are highly qualified professionals and are all experts in the field. Upon completion of a PQU program, students can obtain Continuing Education Credits (CEU's). PQU is just one more way that Power Protection Products, Inc. is supporting the electrical and data center communities in a positive way.

Learn more at PQU! www.powerqualityuniversity.com

For more information about our products, service plans and support services contact us at:

877-393-1223

Or visit our website:

www.p3-inc.com