What Exactly is Power Quality?

Power Protection Products, Inc.

Power Quality White Paper
by Dan Maxcy  I  2013 Update

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

877-393-1223  I  www.p3-inc.com
WHAT EXACTLY IS POWER QUALITY?

By Dan Maxcy

Revised 2013

The Power Quality "Big 8"

- **Sags:** IEEE-1100
- **Swell:** IEEE-1100
- **Over-voltages:** IEEE-1100
- **Under-voltages:** IEEE-1100
- **Harmonics:** IEEE-519
- **Noise:** IEEE-1100
- **Transients:** IEEE-C62.41/1100
- **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.

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

**Harmonics:** Electric voltages and currents that appear on the electric power system as a result of non-linear electric loads. Harmonic frequencies in the power grid are a frequent cause of power quality problems.

**Transient:** A temporary excess of voltage and/or current in an electrical circuit which has been disturbed.

**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 & equipment.
When we speak of Power Quality I hear many terms to describe problems with power in our facilities. I have heard power problems called spikes, surges, glitches, blackouts, brownouts etc. Quite often these terms are associated with specific problems with equipment or systems. For example, 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 exactly the cause for the equipment or system failure. In this book 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 in the past years 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 Electronic 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.

Our first goal is to define power quality problems. We start with what I 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 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 a (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](image)

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.
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:

![Graph showing voltage over time with over voltage and under voltage indicated](image)

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.
What Exactly is Power Quality?

The IEEE defines an Transient as the following:

IEEE-1100-1999, 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.

I call this specification the catch all spec. What I mean is...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, 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:

We have yet to discuss Grounding. In short, most people in our industry believe the code book says electrical ground rods must be installed so that their resistance to earth is less than 25 ohms.

**THIS IS NOT TRUE.**

You might want to look at NEC 250-56, it actually states:

“A single electrode...that does not have a resistance to ground of 25 ohms or less shall be augmented by one additional electrode...”

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 60 days IT SHOULD BE.**
In conclusion:

We have defined what the “Big Eight” is when talking about Power Quality. We have not covered (in this article) what to do about it if your facility has any of the “Big Eight”. That is the purpose of our company. We work every day with these issues and have a great track record with solving power quality problems. Please contact Power Protection Products, Inc. if you want more information on Power Quality issues.
An Introduction to P3 & PQU

Power Protection Products, Inc. (P3)

P3 specializes in representing only the best products and services that enhance power quality. By specializing in power quality, we can provide our customers with in-depth analysis, service and solutions that will meet the needs of our customers and end users. P3 works closely with your local market suppliers and vendors in order to provide you with convenient purchasing options, sales channels and follow-up service. We act as an extension of your current vendor base and work closely with your local market leaders in the power quality and electrical equipment area. In today's world of sensitive electronic equipment, power protection is no longer an option; it's a necessity.

Power Protection Products, Inc. provides the highest quality products and services available today that will protect and maintain your power supply as well as reduce your downtime, equipment failure and maintenance costs.

Learn more at PQU!
www.powerqualityuniversity.com

Power Protection Products, Inc. is "showing you how" with Power Quality University (PQU). Power Quality University brings real world electrical knowledge into the classrooms. Students are taught the importance of power quality and the many factors which go into ensuring and providing good power quality. 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 affecting the electrical community in a positive way.