



## Power Quality University



We are glad you are here, its almost time to “*Learn about General Power Quality*”.

While you are waiting, subscribe to our Podcast channel, The Power Grid





**Providing an educational environment for training, testing, and evaluation of today's power quality and data center solutions and equipment.**

P3 leads Customer Education through Power Quality University ( PQU )

- Highly Qualified, Expert Instructors
- Practical, Relevant Topics
- Continuing Education Credits (CEU's)

### Upcoming Events

Power Factor Correction - Friday, July 10 – 9 AM – 11 AM CDT

Surge Protection Devices Thursday, July 23 – 12 PM – 1 PM CDT

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## General Power Quality



*Presented by*



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### Agenda

Introductions to P3  
Speakers & Hosts

**Speaker: Brian Branigan**  
**Host: Amy Strong**  
**Karah Butac**

### Program

- Power Quality Related Definitions
- Industry & Utility Standards
- Effects on a Facility
- How to Maintain Proper Power Quality

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



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## DATA CENTERS

Providing industry knowledge, product expertise, & technological innovation over a broad portfolio of products and services to our customers across a wide range of industries and applications.

To achieve zero downtime, scale the data center to meet ever changing requirements, and reduce energy costs, you need the most reliable and efficient power and cooling infrastructure available.

**Modular & Scalable Data Center Equipment**  
Systems that grow and change with your modern Data Center.

**Traditional Data Center Equipment**  
Systems built around existing older equipment.

We can provide both  
Modular / Scalable and Traditional  
Data Center Equipment



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**INDUSTRIAL POWER SOLUTIONS**

Power Quality Specialists with expertise in your Power Quality needs.

Industrial Power Quality doesn't just happen. It takes technical expertise, investment in products and facility coordination to achieve the desired levels of Power Quality. With experience in both new construction and retrofit installations, P3 can help you select and install the correct products.

We provide Industrial Power Quality Solutions

Custom Solutions  
Uninterruptible Power Supply System  
Power Conditioning  
Harmonic Cancellation  
Grounding and Surge Protection Devices

Surge Protection Devices  
Harmonic Mitigating Transformers  
Power Factor Correcting Capacitors

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**Power Quality Monitoring**

System analysis and evaluation of power quality issues to provide solution recommendations for the best possible performance from your existing power system.

The ability to quickly identify and remedy power quality problems will lengthen the life of electrical equipment and improve power system availability.

Our engineering technicians will help you understand your unique facility power system.

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Service plans and support services that provide maintenance, parts, & service necessary to ensure the best possible performance from your existing power system.

We offer customized, flexible, full-service packages that offer hassle-free system maintenance to improve uptime at predictable cost which include technical support, preventive maintenance, quick on-site response, and remote monitoring.

- Service Plans
- Energy Management Services
- Power & Cooling Analysis
- Data Center Assessments
- Project Management
- Battery Replacement

We provide top quality maintenance service & support

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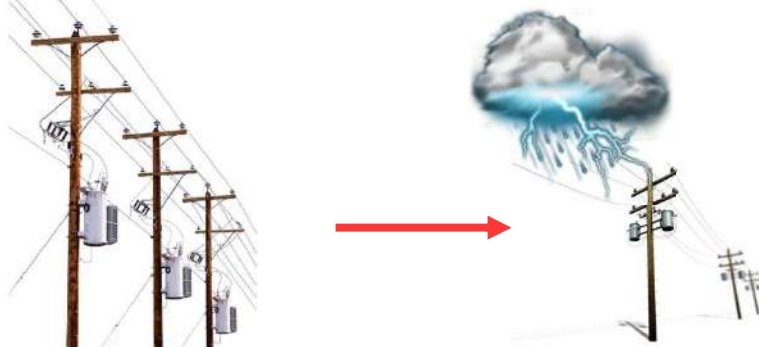
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## Power Quality

THE POWER GRID



**GOOD POWER**

**BAD POWER**

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## Power Quality

THE POWER GRID

### What is good Power?

- IEEE is the most often quoted “Source” for definitions of Power
- IEEE stands for “Institute of Electrical and Electronic Engineers”
- IEEE defines Good Power as:  
***Clean, pure power exhibits constant voltage and frequency, perfect sinusoidal waveshapes, and is free of harmonics, noise, and transients.***

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### What is Bad Power?

IEEE defines Bad Power as:

***Power that includes voltage variations, voltage swells, voltage sags, over-voltages and under-voltages, harmonics, transients, traveling waves, and power failures.***

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## The Power Quality BIG 8



- Over-voltages
- Under-voltages
- Sags
- Swells
- Harmonics
- Noise
- Transients
- Grounding

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# Voltage Sag

**IEEE-1100-2.2.67:**

**A... reduction in the ac voltage, at the power frequency, for durations from a 0.5 cycle to 1 Min.**

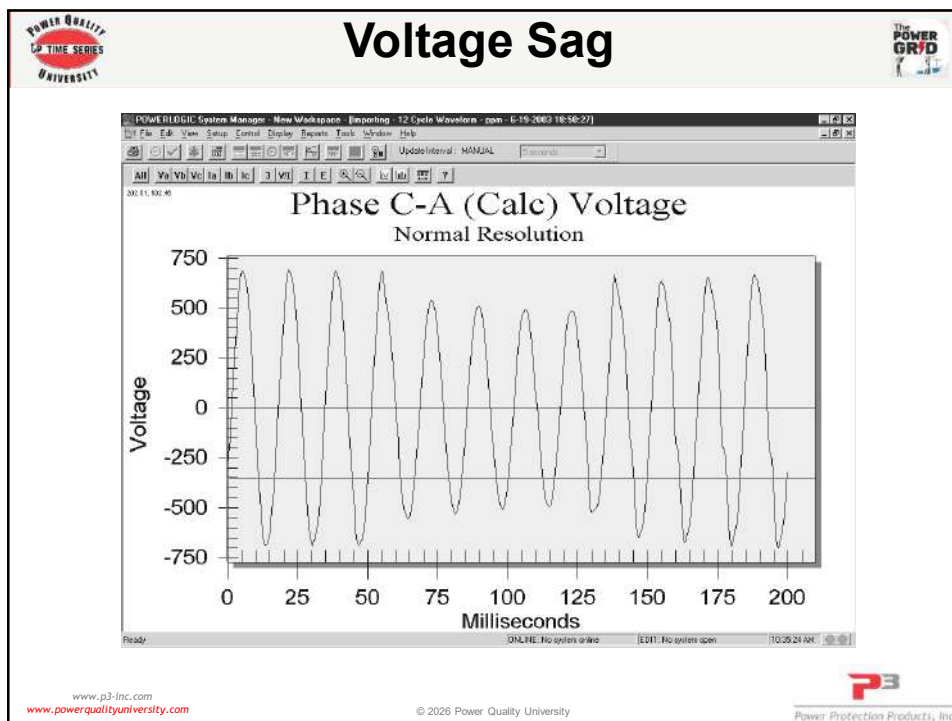
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# Voltage Swell

**IEEE 1100-2.2.78:**

**An increase in... voltage or current at the power frequency for durations from 0.5 cycle to 1.0 min.**

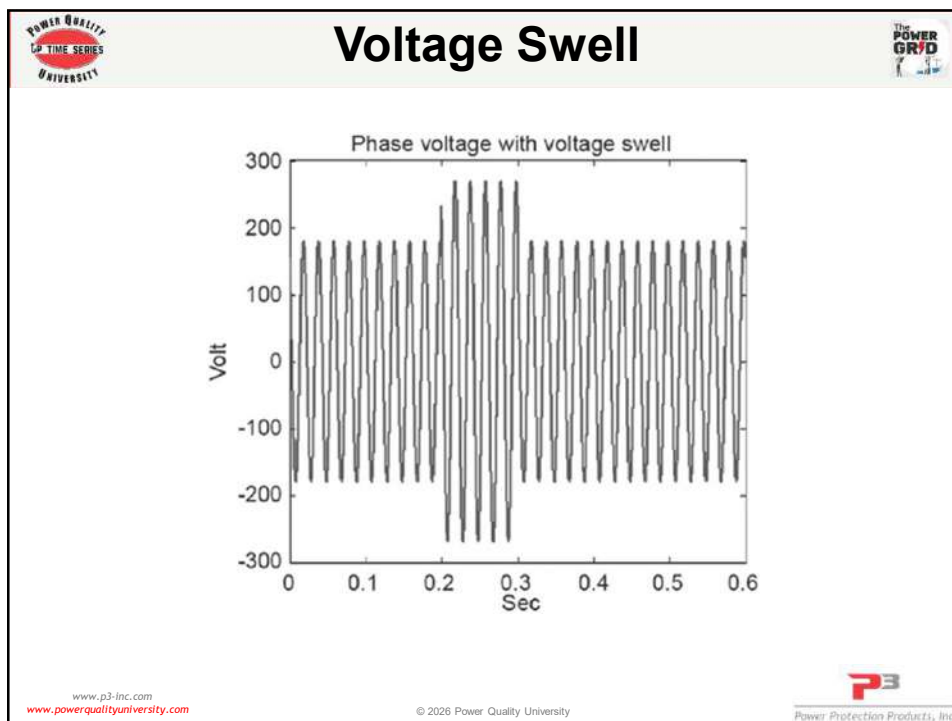
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## Over-voltages



**IEEE-1100-2.2.56:**

**Increase in the ac voltage, at the power frequency,  
for a period of time greater than 1 min.**

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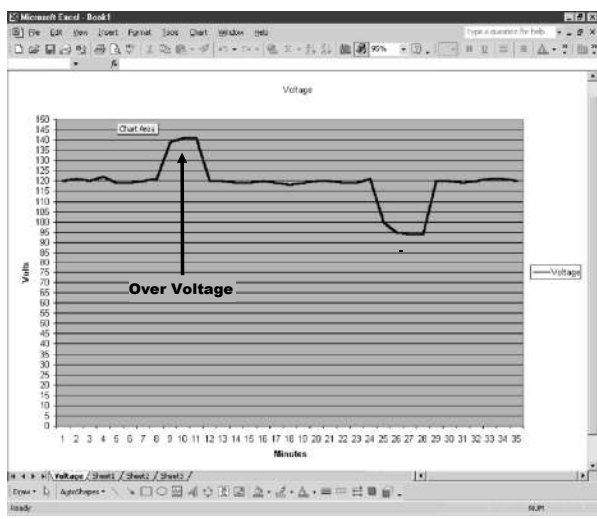
  
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## Over-voltages





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## Under-voltages



**IEEE 1100-2.2.56:**

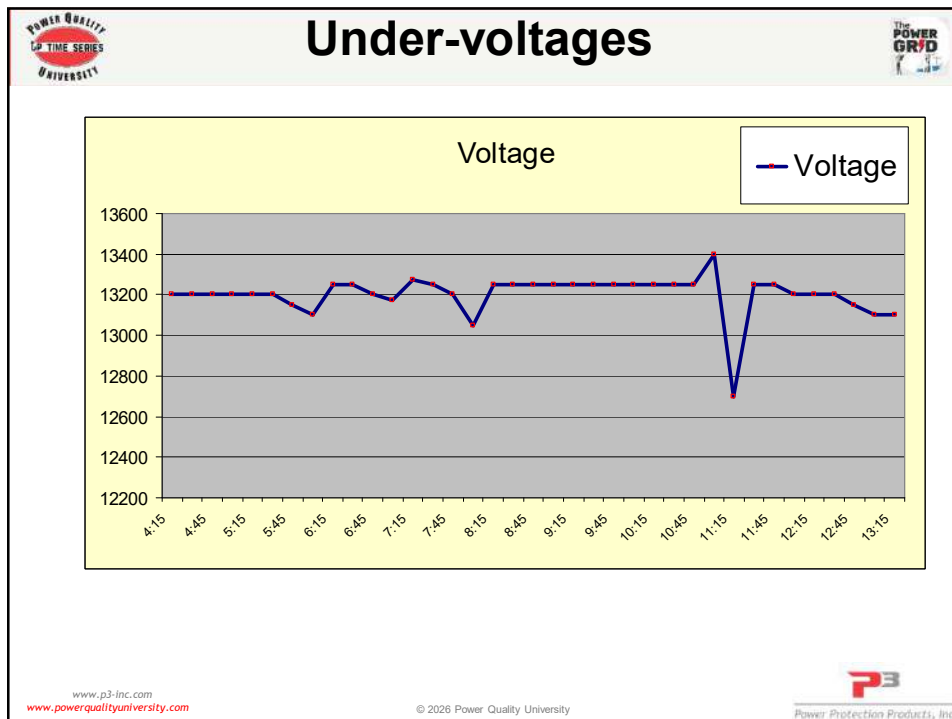
**Decrease in the ac voltage, at the power frequency, for a period of time greater than 1 min.**

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## Utility Standards



**Utility standards are defined by the various *State Utility Boards*. Most require the utility must adhere to this standard:**

- 1. Voltage limits as stated by IEEE/ANSI C84.1**

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## Utility Standards



### IEEE/ANSI C84.1

| Standard Voltage | Voltage Range A   | Voltage Range B   |
|------------------|-------------------|-------------------|
| 120              | 114-126           | 110-127           |
| 120/240          | 114/228-126/252   | 110/220-127/254   |
| 208Y/120         | 197Y/114-218Y/126 | 191Y/110-220Y/127 |
| 480Y/277         | 456Y/263-504Y/291 | 440Y/254-508Y/293 |
| 13200Y           | 12870Y-13860Y     | 12504Y-13970Y     |

---

***“Electrical supply systems shall be so designed and operated that most service voltages will be within the limits for range A”***

***“When...Range B... voltages occur, corrective measures shall be undertaken within a reasonable time to improve voltages to meet Range A requirements.”***

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## Transient



**IEEE-1100-2.2.83:**

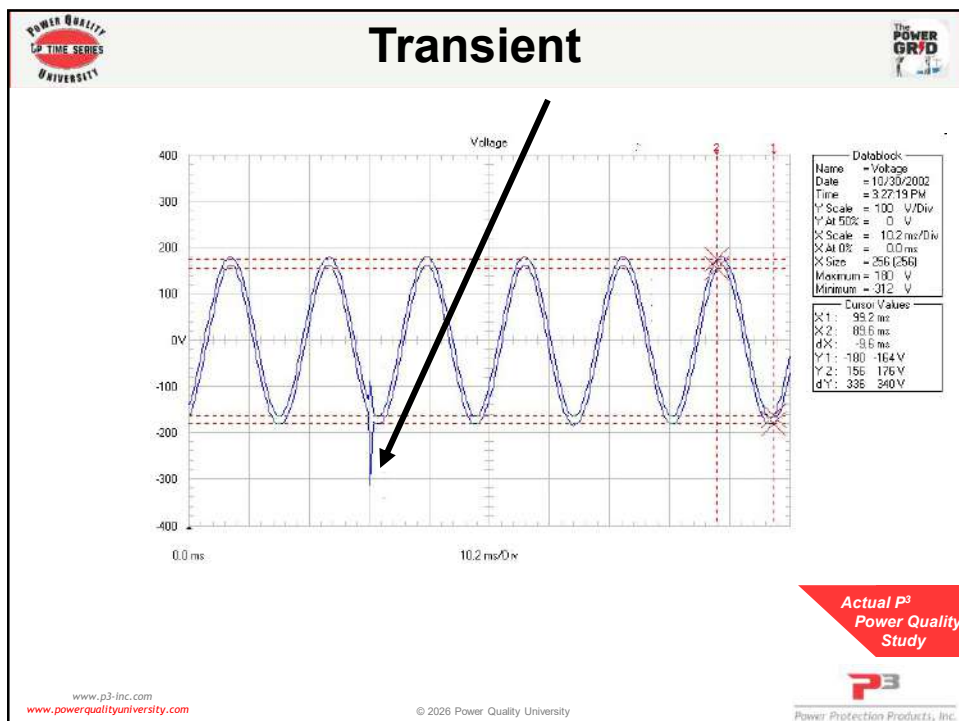
**A sub-cycle disturbance in the ac waveform that is evidenced by a sharp, brief discontinuity of the waveform. May be of either polarity and may be additive to, or subtractive from, the nominal waveform.**

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## Noise

**IEEE 1100-2.2.49:**

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

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## Noise, Waveform Capture



Standard 120V Utility Line

Noise from GSC Model 708 paper shredder

Noise

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## Harmonics



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

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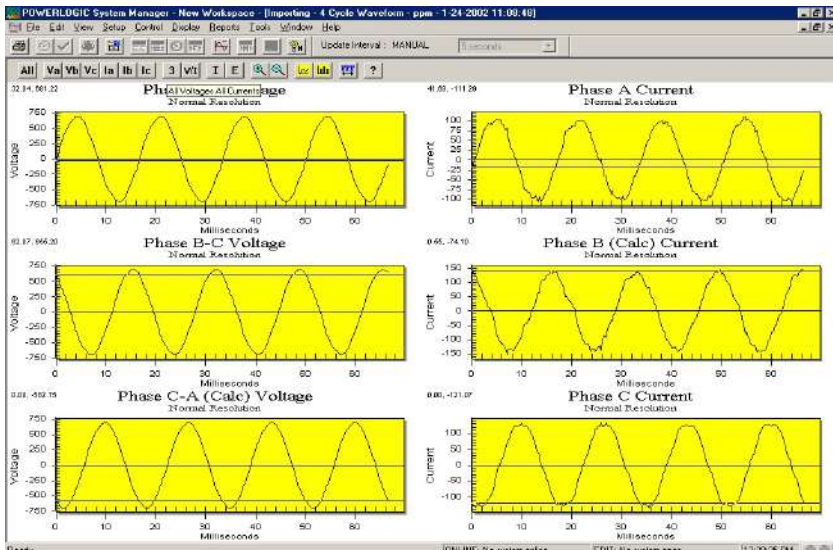
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## Harmonics



### Low Harmonic Waveform



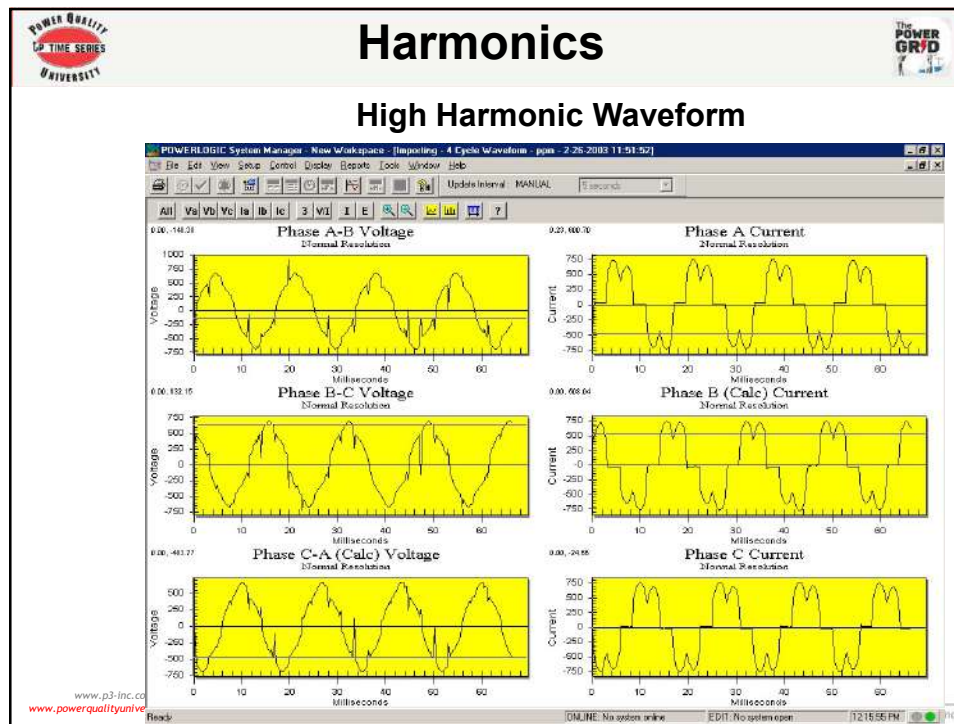
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**Harmonic Problems**

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

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## Harmonic Frequencies



### Typical Harmonic frequencies that cause problems:

$$3 \times 60 = 180\text{HZ}$$
$$5 \times 60 = 300\text{HZ}$$
$$7 \times 60 = 420\text{HZ}$$
$$11 \times 60 = 660\text{HZ}$$
$$13 \times 60 = 780\text{HZ}$$

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## Grounding for Power Quality



**NEC 250.53 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”.**

**Is this good enough?**

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## Earth Reference

**IEEE 142-4.1.2 Recommended Acceptable Values**

- The most elaborate grounding system may not perform satisfactorily unless the connection of the system to earth is adequate for the particular installation.
- With reference to power quality, the earth connection is one of the most important parts of the whole grounding system.
- The connection to earth of the electrode system... should be... 1-5 ohms for commercial and industrial services.

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## Earth Reference After Installation

**IEEE 142-4.4.1 Need for Measurement**  
Many indeterminate factors exist in any formula for the calculation of the resistance to earth. Total reliance should not be placed on the calculated results. For example, the soil resistivity varies inversely with the soil temperature and directly with the moisture content and may vary with the depth. The only certain way to determine the resistance is to measure it after the system has been completed.

**IEEE 142-4.4.3 Periodic Testing**  
Tests should be made periodically after the original installation and test so that it can be determined whether the resistance is remaining constant or is increasing. If later tests show that the resistance is increasing to an undesirable value, steps should be taken to reduce the resistance...

**Don't bury it and forget it!**

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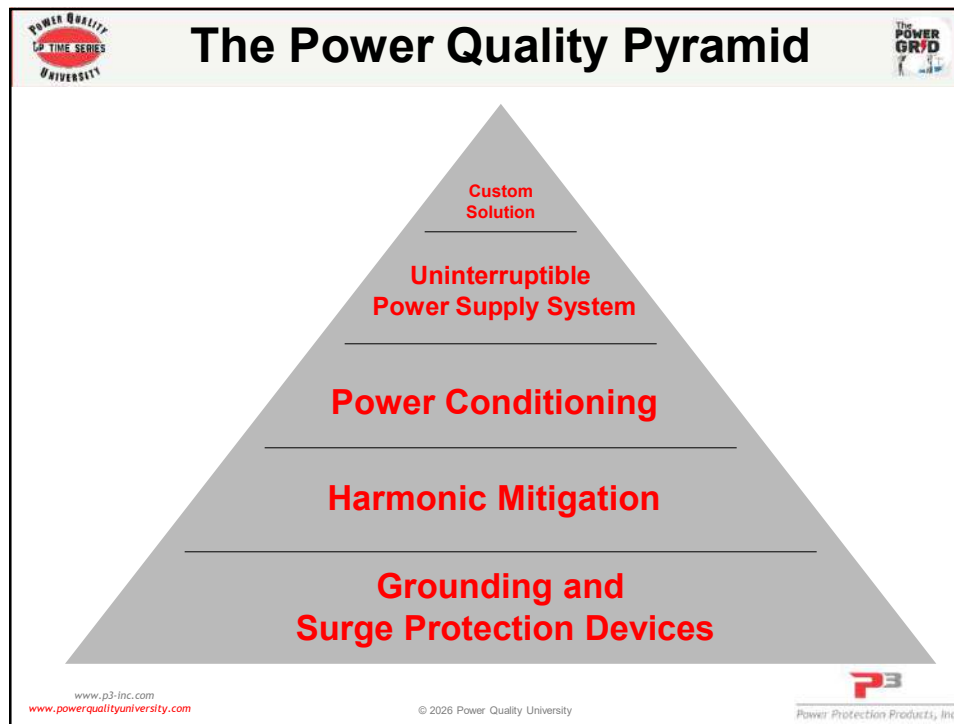
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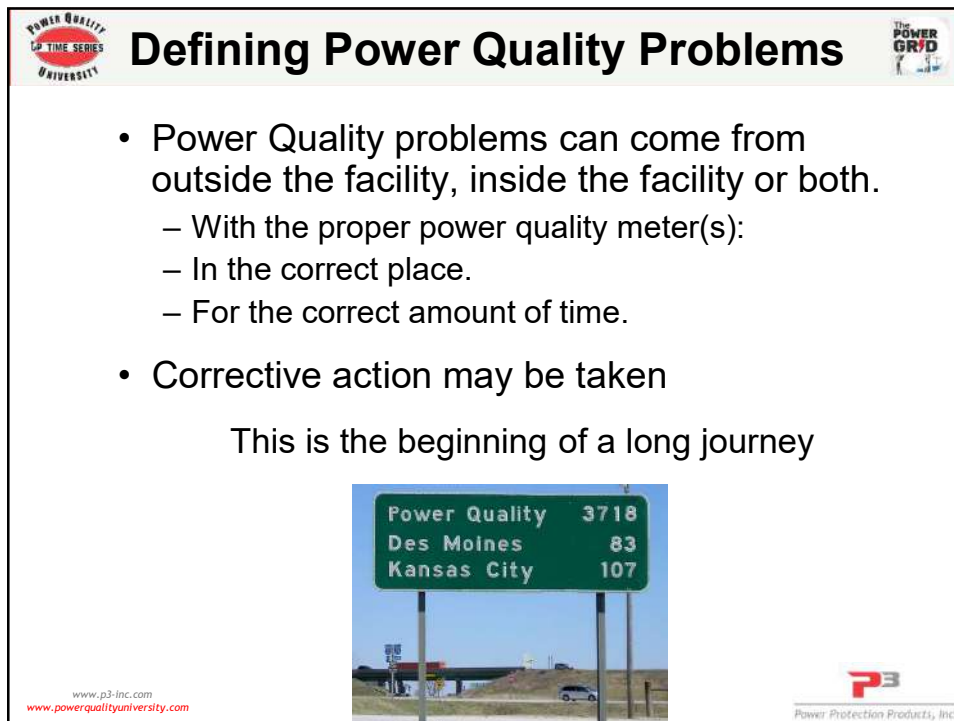
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**Defining Power Quality Problems**

- Power Quality problems can come from outside the facility, inside the facility or both.
  - With the proper power quality meter(s):
  - In the correct place.
  - For the correct amount of time.
- Corrective action may be taken

This is the beginning of a long journey



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## Defining the problems





Using a “Good” Power Quality Analyzer in the right place will help you in this process.

- Up to date equipment
- Current Software
- Correct CT Sizing
- Trained User

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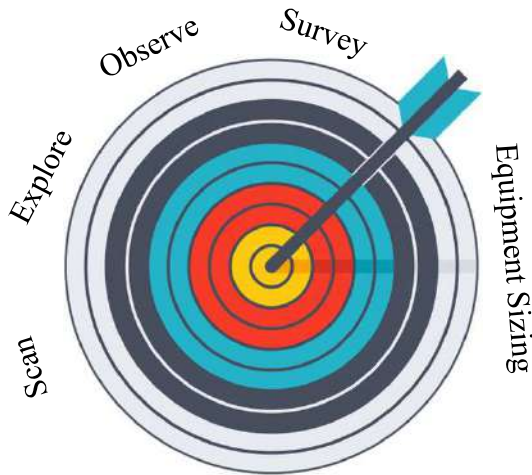
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## Determining Your Target





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## Determining Your Target



Determining your target and what you are looking for is the most important first step in the monitoring process. This will impact the power quality meter placement, set up and duration.

- Right meter
- Right information
- Right location

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## The Right Equipment

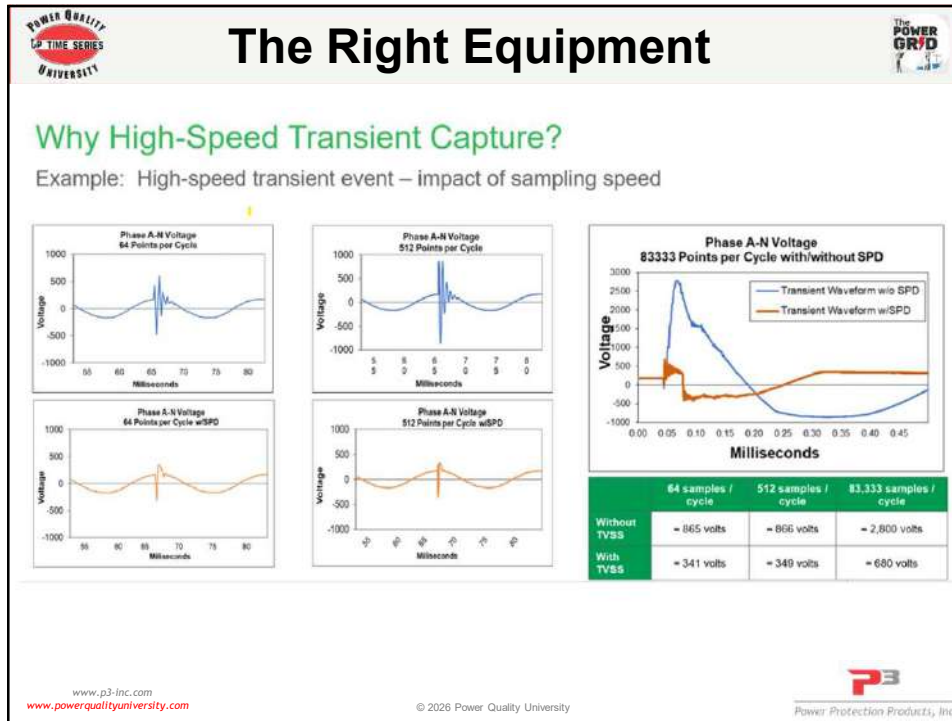


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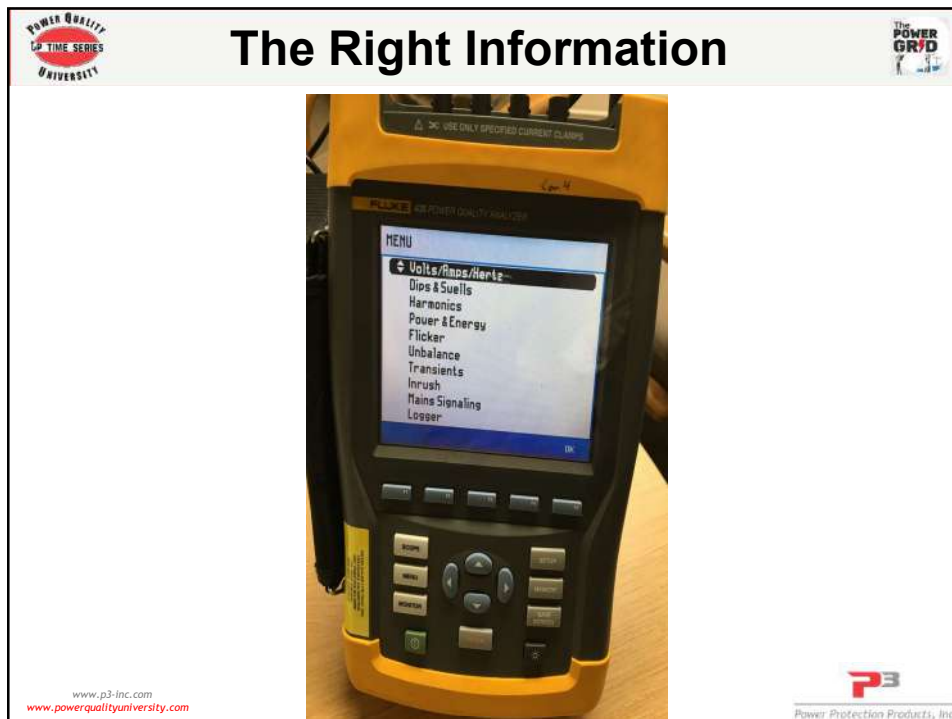
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## The Right Meter Location



### Meter Placement is Critical



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## The Right Location



### Large Facility with Multiple Main Services




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## Meter Set Up is Important



Placement of CTs?

Program Set Up

Equipment Safety



External Power Source

Software Updates

Meter Placement

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## Setting up the Meter





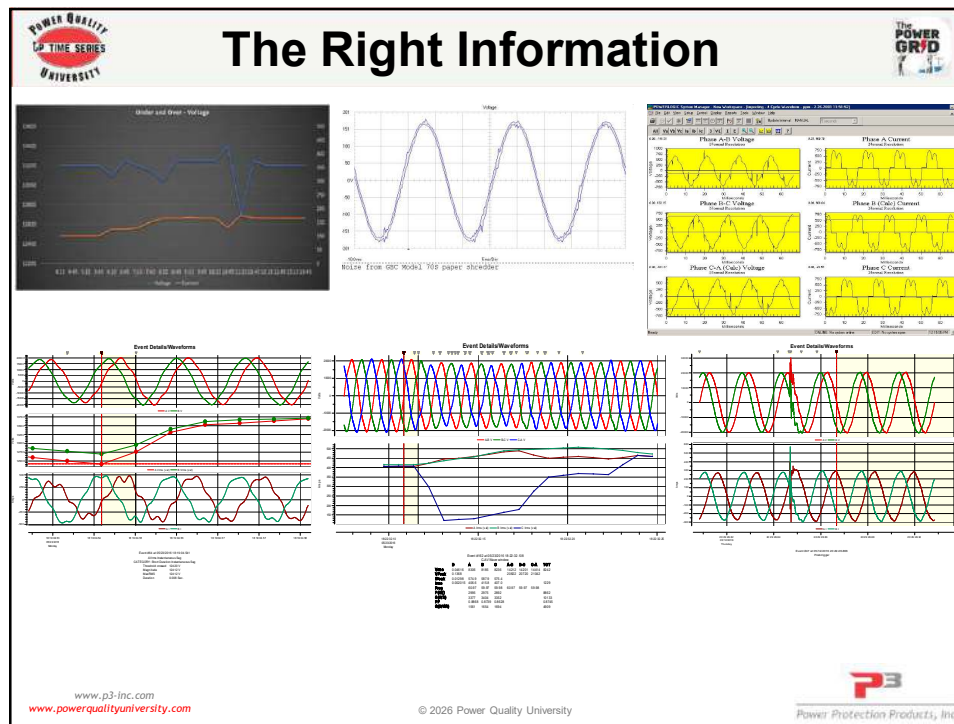


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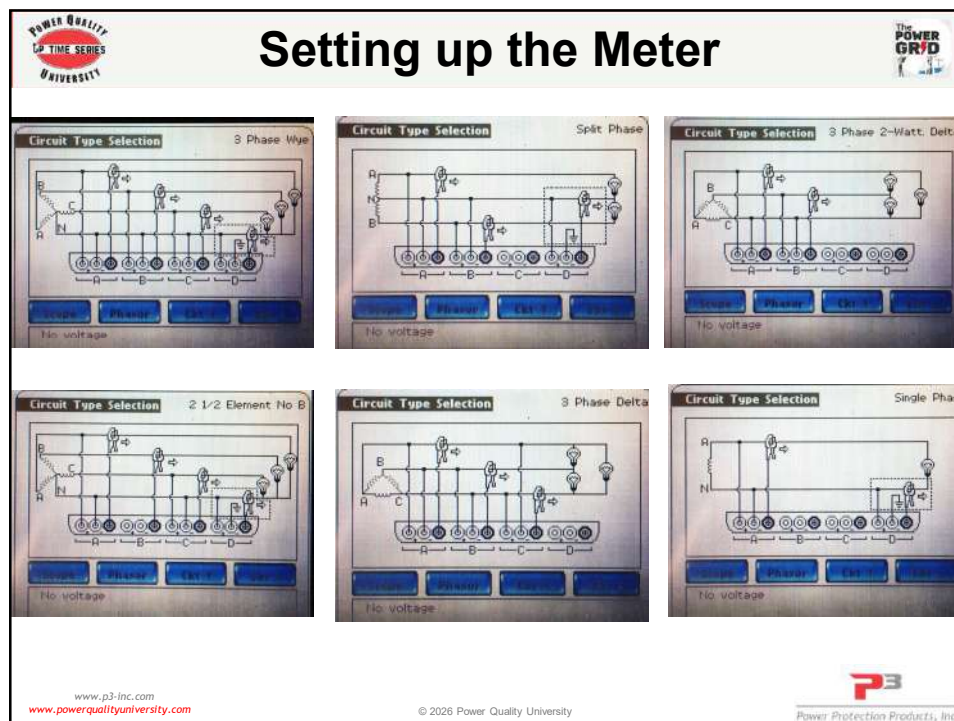
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## Setting up the Meter






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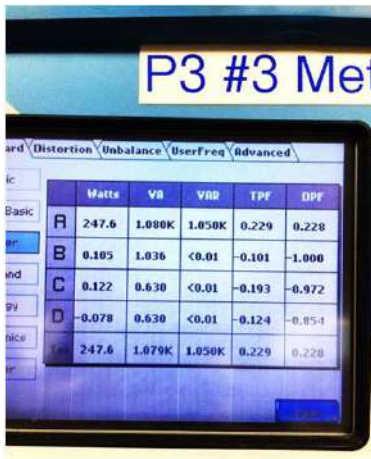
  
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## Meter Verification





### Importance of Data Verification

Once the meter is set up and in place, it is important to verify that the data is being collected at the proper rate and in the proper form, adjustments may be required based on the electrical system.

Issues:

- Is the meter working?
- Are the meter readings accurate?
- Does the meter data “make sense”?
- Is the meter memory filling up?

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## Meter Installation & Removal



When metering, its important to have a systematic approach to the meter installation and removal: confirm data, download and check files, review time frames and results prior to safely setting up and then removing the meter.



- 8-5? – after hours? – Weekends – Holidays?
- Who is qualified?
- NFPA 70E procedures must be followed.
- Safety meetings must be held.
- Don't just hook it up and then later rip it out. It can lead to erroneous information.

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## Interpreting the Data



Reports can come in many forms and levels of detail:

**Requirements:**

- Updated Software,
- Knowledgeable expert using the program
- Licenses up to date
- Current computer system



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## Presenting the Results



Executive Summary

Presentation of Findings

Detail of the data

Recommendations



### Power Quality Summary

| Location | Voltage | Current | V Harmonics | C Harmonics | Power Factor | Sag / Swells |
|----------|---------|---------|-------------|-------------|--------------|--------------|
| BPS1     | ✓       | ✓       | ✓           | ✓           | ✗            | ⚠            |
| FPS1A    | ✓       | ✓       | ✓           | ✓           | ⚠            | ⚠            |
| FPS1B    | ✓       | ✓       | ✗           | ✗           | ✓            | ⚠            |
| FPS2A    | ✓       | ✓       | ⚠           | ✗           | ✗            | ✗            |
| FPS2B    | ✓       | ✓       | ⚠           | ⚠           | ✗            | ✗            |
| FPS3A    | ✓       | ✓       | ✗           | ✗           | ✗            | ✗            |
| TPS2A    | ✓       | ✓       | ✓           | ✓           | ✗            | ⚠            |
| TPS2B    | ✓       | ✓       | ⚠           | ✓           | ✗            | ✗            |
| TPS3     | ✓       | ✓       | ✓           | ✓           | ✗            | ⚠            |
| MD       | ✓       | ✓       | ✓           | ✓           | ✓            | ✗            |

**Legend**

- ✓ Good
- ✗ Bad
- ⚠ Caution
- ⚡ Large
- ⚖ Unbalanced

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