

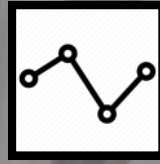


POWER QUALITY

AND YOUR BUSINESS

A SUMMARY OF THE POWER QUALITY REPORT PUBLISHED BY
THE CENTRE FOR ENERGY ADVANCEMENT THROUGH TECHNOLOGICAL INNOVATION

HYDRO ONE NETWORKS INC | SEPTEMBER 2014



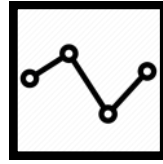
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Background

This report was published with the purpose of introducing topics that are covered in the Centre for Energy Advancement Through Technological Innovation's (CEATI's) full report, entitled "Power Quality Reference Guide for Customers and Utility Representatives (Project No. T134700-5164) . Any views published in this report represent the views of Hydro One Networks Inc. only and is no way intended to be interpreted as the views of the Centre for Energy Advancement through Technological Innovation (CEATI) or any other organization. For more information on Power Quality and Reliability, and for the full version of the CEATI Power Quality Reference Guide, please visit <http://www.HydroOne.com>.



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What is PQ?

Definition and Background

Power Quality (PQ) is important because many customers' electronic devices and appliances are designed to operate at a specific voltage and frequency. In North America, these devices are generally designed to operate at standard voltages (120V, 240V, and 480V) and frequency (60 Hz). Deviations in these quantities may cause equipment to malfunction or get damaged

Power Quality is defined as "Any power problem manifested in voltage, current, or frequency deviations that result in failure or misoperation of utility or end user equipment."

Many PQ issues arise from the incompatibility between the power delivered by the utility at the Point of Common Coupling (PCC) and the customer's energy-using equipment. Common PQ issues include transients, voltage sags and swells, harmonics voltage variations and momentary power supply outages.

Common Power Quality Problems include:

- Natural Phenomena (e.g. inclement weather)
- Normal utility operations (e.g. automatic protection system operations to clear faults)
- Neighboring customers' equipment (e.g. welding equipment adjacent to an office building)
- The customer's own equipment and facilities (e.g. large motor starting, electric arc furnaces, sensitive electronic equipment)

Symptoms

Common equipment symptoms of power quality issues include:

- Equipment damage
- Equipment trips
- Blinking digital displays
- Data or information loss/software glitches
- Loss of instructional programming and controller timing
- Abnormal number of service calls on sensitive equipment
- Disk drive problems
- Computers re-booting

How does PQ impact my business?

Hydro One direct connect industrial customers are supplied from 230kV, 115kV, 44kV, 27.6kV and 13.8kV networks. Power quality issues at the customer's PCC will propagate down to the customer's plant.

PQ events can have a high cost impact per event depending upon the individual plant and process.

Potential impact on operations:

- Stopped or slow production
- Lost production or sales
- Reduced product quality
- Scrap/restart

The relative importance of a particular category of power quality phenomena for a specific customer will depend on the type of electrical equipment installed in the facility. The nature of interactions between customer equipment and the power quality phenomena – equipment damage, equipment/process trip, compromised product quality etc. – and the frequency at which it occurs (or could be expected to occur) are also critical factors in the evaluation process, once the cause has been identified.

What can I do about PQ?

Equipment

Include PQ withstand capability in equipment procurement considerations. This means keeping problem equipment out of the facility, or at least identifying ahead of time the power conditioning requirements.

Customer equipment sensitivity is the primary factor that determines if a power quality variation will disrupt a load or process. Some loads may be sensitive to just the magnitude of the event, while other loads may be sensitive to both the magnitude and duration of the event.

The wide range of equipment sensitivities underlines the importance of working with the manufacturer to ensure that the equipment can work in the environment where it will be used, and to develop specifications based on realistic power system conditions

Equipment categories: Important equipment categories to consider and the power quality disturbance that may affect them include:

- **Adjustable speed drives** – harmonic distortion, transient voltages
- **Electronic controls, programmable logic controllers** – voltage sags
- **Switch-mode power supplies** – harmonic current generation, neutral current
- **Fluorescent lighting** – harmonic generation
- **Power factor correction capacitor banks** – harmonic resonance, switching transients
- **Motors and motor contactors** – voltage imbalance, harmonic heating, voltage sags
- **Electronic equipment** – high frequency transients

Equipment Susceptibility Curves

The following guidelines exist for identified manufacturing sectors, but they do not (and cannot) represent general power delivery standards for electric utilities:

Computer Business Equipment Manufacturers Association (CBEMA):

Describes the tolerance of mainframe computer

equipment to the magnitude and duration of voltage variations on the power system.

Information Technology Industry Council (ITIC):

ITIC is a successor organization to the Computer and Business Equipment Manufacturers' Association (CBEMA). ITIC has recommended a newer capability curve for single-phase data processing equipment operating at 120V.

The Semiconductors Equipment and Materials International (SEMI):

SEMI has developed a PQ need curve that provides a voltage vs. time characteristic that their equipment is expected to ride-through during voltage variation events.

It is important to work with manufactures to ensure that the equipment can work with in the environment where it will be used, and to develop specifications based on realistic power system conditions.

Analyzing PQ Problems & Monitoring

Monitoring is often used to characterize power quality problems at various locations on power systems. Factors to consider when selecting an instrument include:

- Number of measurement channels
- Temperature specifications of the instrument
- Input voltage range and power requirements
- Ability to measure three phase voltages
- Data sample rate
- Ability to measure currents
- Housing of the instrument
- Ease of use
- Communication capability
- Documentation and analysis software

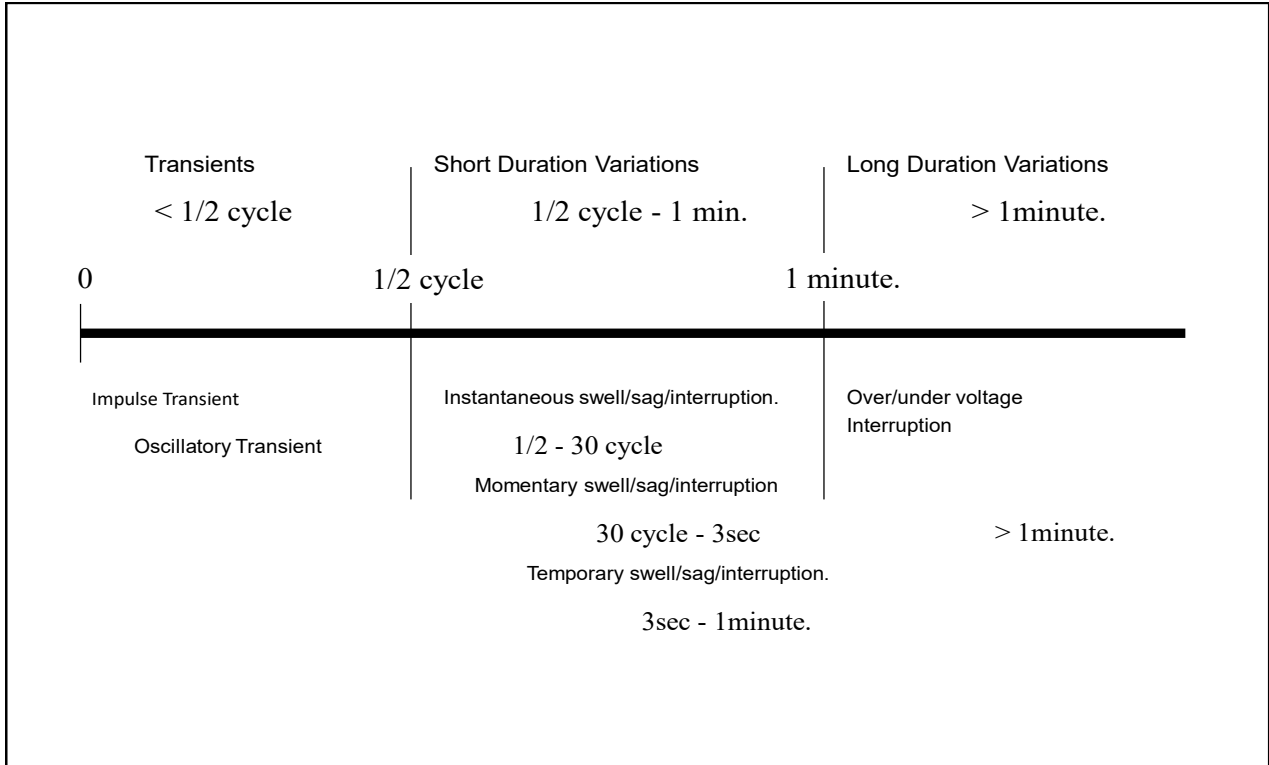
Who should I contact in Hydro One?

If you experience a PQ issue, contact your "NMO Contact" as listed in your Connection Agreement. For general inquires, contact your Hydro One Account Executive.

Power Quality Phenomena & Possible Customer Solutions



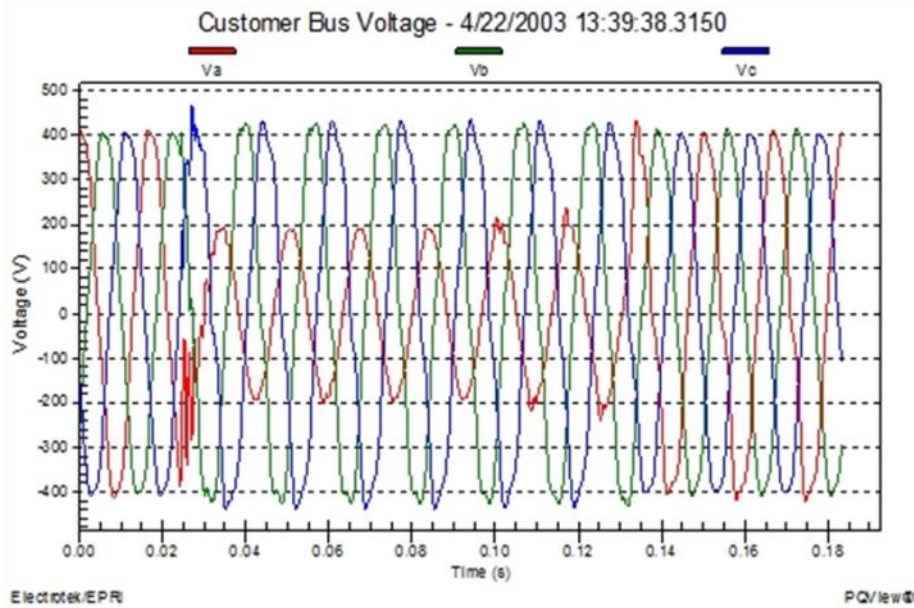
Categorization of Disturbances



Voltage Variations

DISTURBANCE	POSSIBLE CAUSES	POSSIBLE IMPACT	POSSIBLE SOLUTIONS	COMMENTS
<p>Sag (picture/diagram)</p> <p>- Short duration decrease in the RMS voltage magnitude from the nominal voltage</p>	<p>- Usually caused by a fault on the power system or due to a large motor starting</p>	<p>- Depends on the voltage magnitude during the disturbance, the duration of the disturbance, and the sensitivity of the equipment</p> <p>- Can cause misoperation or shutdown of sensitive equipment</p>	<p>Ferroresonant transformers, coil-lock devices, magnetic synthesizers, batteries, large capacitors, and a number of power-electronic based power conditioners can be used for protection against voltage sag events</p>	<p>Impossible to completely eliminate because utilities can only take limited actions to minimize the frequency of faults' occurrences</p> <p>If the equipment is not critical in nature or does not cause major disruptions in manufacturing or jeopardize facility and personnel safety, voltage sag protection may not be justified</p>

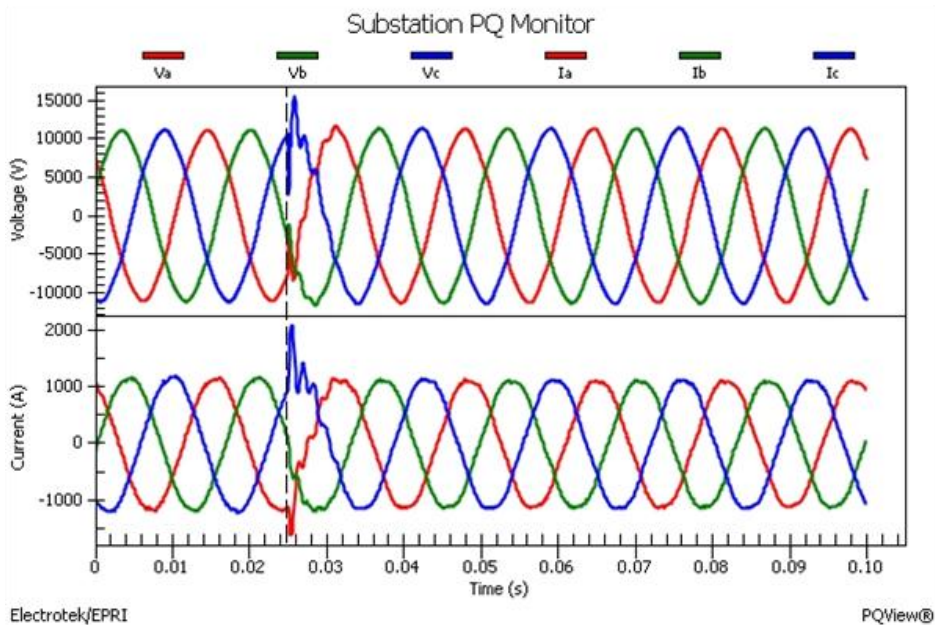
Figure 1: Example of a measured customer secondary voltage sag event



Transients

DISTURBANCE	POSSIBLE CAUSES	POSSIBLE IMPACT	POSSIBLE SOLUTIONS	COMMENTS
High-frequency impulsive transients	- Equipment switching operations or lightning strikes to electric facilities	- Equipment misoperation and failure	- A wide range of off-the-shelf and inexpensive transient voltage surge suppressor (TVSS) products can be applied	
Low frequency oscillatory transients	- Switching (energizing) of utility shunt capacitor banks	- Nuisance tripping of power-electronic equipment, especially common types of adjustable-speed drives	- Tuned harmonic filter for shunt compensation - Series choke or reactor/isolation transformer	- Usually of modest magnitude but contain substantial energy so their electrical effects can be felt quite far from the point of origin

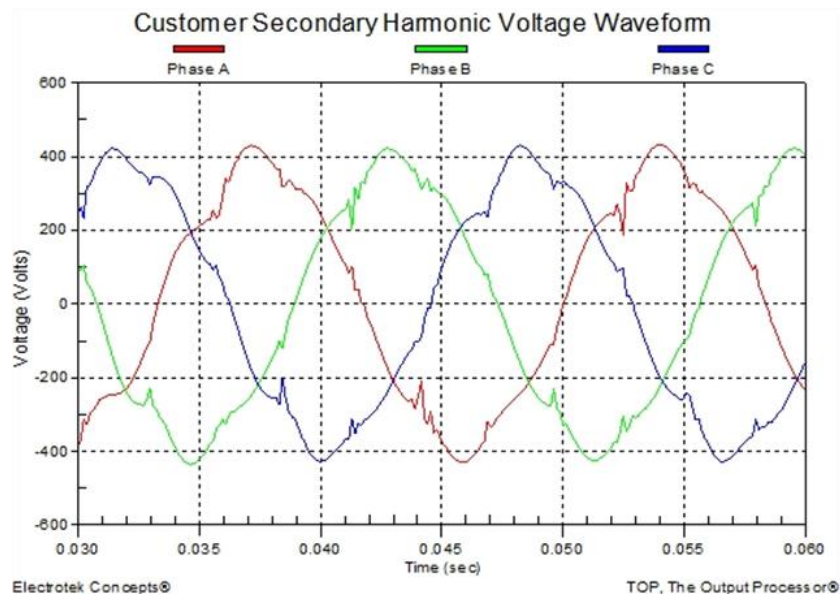
Figure 2: Example of a substation capacitor bank energization transient

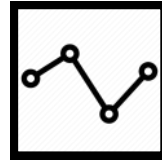


Waveform Distortions

DISTURBANCE	POSSIBLE CAUSES	POSSIBLE IMPACT	POSSIBLE SOLUTIONS	COMMENTS
<p>Harmonics</p> <ul style="list-style-type: none"> - Sinusoidal voltages or currents with frequencies that are integer multiples of the fundamental frequency of the supply system - Harmonic distortion is a steady-state voltage or current that originates in the nonlinear characteristics of devices connected to the system and are often characterized using RMS trends over longer periods of time 	<ul style="list-style-type: none"> - Harmonic producing loads: adjustable speed drives, electronic ballasts for fluorescent lighting, electric arc furnaces, computers distributed throughout commercial and industrial facilities, and other power-electronic technologies 	<ul style="list-style-type: none"> - Misoperation of equipment - Failure of capacitor banks - Mysterious tripping of circuit breakers - Overheating of transformers 	<ul style="list-style-type: none"> - Reduce harmonic currents produced by loads - Add filters to control the flow of harmonic current - Modify the frequency response of the system to reduce voltage distortion levels 	<ul style="list-style-type: none"> - The basic philosophy is that the customer is responsible for limiting the amount of harmonic currents injected into the overall power system, and the utility is responsible for avoiding conditions on the power system that could create unacceptable voltage distortion levels

Figure 3: Example of a measured customer secondary harmonic voltage





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For more information

Visit <http://www.HydroOne.com> for more information on Power Quality and Reliability and for the full CEATI Reference Guide. For general questions contact LargeAccounts@HydroOne.com.