ONTARIO ENERGY BOARD

GUIDE TO ADDRESSING DISTRIBUTION POWER QUALITY ISSUES

MARCH 28, 2024

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1 INTRODUCTION

This *Guide to Addressing Electricity Distribution Power Quality Issues* (Guide) provides an overview of power quality issues, including their identification, investigation, and mitigation strategies applicable to customer facilities before and after their connection to the electrical distribution system (below 50kV). Specifically, this Guide is intended to assist both customers and distributors in collaboratively managing power quality, providing a uniform practice for distributors to address power quality issues throughout Ontario.

This Guide does not cover issues related to farm stray voltage or reliability of the supply of electricity.

2 POWER QUALITY ISSUES OVERVIEW

Ensuring optimal power quality at the connection point is vital to prevent undesirable electrical disturbances and protect sensitive equipment. Section 4.1.1 of the Distribution System Code (DSC) provides that a distributor shall follow good utility practice in managing the power quality of the distributor’s distribution system and define in its Conditions of Service the quality of service standards to which the distribution system is designed and operated. The DSC has other provisions related to addressing power quality issues which are identified throughout this Guide. A distributor’s connection agreement may also provide specific details about power quality and service at a customer connection point. Customers are advised to consult their distributors about the power quality at their connection points before acquiring and installing sensitive equipment.

Power quality refers to the characteristics of the electrical power supplied to electrical systems, and its compatibility with the characteristics of the electrical systems that use it. It includes various aspects of the electricity supply, including voltage, frequency, and waveform. Adequate power quality is necessary for the safe, reliable, and efficient functioning of electronic equipment. Identifying the sources of power quality issues can be complex due to their ability to spread across the distribution network and among customers.

In addition, the sensitivity of equipment to power quality fluctuations varies widely. Thus, the equipment a customer chooses significantly influences how power quality issues affect industrial and commercial operations. Additionally, devices installed by customers can introduce power quality disturbances, impacting not only their operations but also those of others on the same distribution system.

Power disruptions are classified into sustained interruptions (lasting more than one minute) and momentary interruptions (lasting one minute or less), with the latter sometimes mistaken for power quality issues. This Guide, however, focuses exclusively on power quality and not on power interruptions.

A compilation of different power quality disturbance types, as well as reference documents for in-depth exploration and understanding can be found in Appendices 1 and 2 to the Guide.

3 POWER QUALITY ISSUE INVESTIGATION

Investigating power quality issues presents a challenge due to the complex and interconnected nature of electrical systems. Issues may originate from the transmission system, the distribution system or within a customer's own premises. Even when the distributor's operational conditions are met and compliance with industry standards and best practices (as outlined in Appendix 2) are achieved at the point of connection, a customer's facility may still experience power quality issues. Furthermore, the diverse load sensitivities and resilience requirements of customers contribute to the intricacies of investigating and resolving such issues. The following steps detail the essential elements and anticipated results of the investigation process.

Step 1: Customer Assessment

As the initial step after power quality issues have occurred, the customer should assess their equipment and site to confirm if the power quality issue originates within their premises, behind the meter. It is highly recommended to engage a certified electrical technician or a power quality consultant for this task. The technician or consultant should conduct a thorough evaluation of the electrical system, including common trouble areas such as grounding, wiring integrity, and compatibility of connected equipment. A report detailing the findings should be prepared. This report serves as a supporting document for further investigation and resolution efforts.

Step 2: Customer Files an Inquiry

Upon confirming that the issue does not stem from within the premises, the customer should file an inquiry with their distributor. This inquiry should provide a description of the observed symptoms, dates and times of their occurrence, and any significant findings from the initial assessment, including data logs, if available, and the assessment report. The comprehensive information helps in facilitating a streamlined diagnostic approach by the distributor and avoiding duplicative efforts.

Step 3: Distributor Responds to the Inquiry

Section 7.3.1 of the DSC provides that when a customer or a representative of a customer requests an appointment with a distributor, the distributor shall schedule the appointment to take place within 5 business days of the day on which all applicable service conditions are satisfied or on such later date as may be agreed upon by the customer and distributor.

Following the inquiry, the distributor should promptly acknowledge receipt and may begin the diagnostic process through a phone call, email, or virtual meeting. Section 4.1.3 of the DSC requires the distributor to respond to and take reasonable steps to investigate all consumer power quality complaints and report to the consumer on the results of the investigation.

Additional information might be requested to facilitate the initial investigation. The distributor should maintain a detailed record of all communications, which includes the customer's concern, any initial findings, and the steps planned for further investigation. If the issue cannot be addressed remotely and is outside the normal system operation, a site visit by the distributor's technical staff will be arranged. Customers should be informed of the investigative procedures, possible timelines, and any potential costs involved if the investigation points to customer-side issues.

Step 4: Distributor Site Visit

During the site visit, the distributor's technical staff will conduct a comprehensive inspection of the distributor's electrical infrastructure at the location experiencing the power quality issue. The staff will inspect for loose connections, signs of equipment defects, or overheating and evaluate the integration of customer equipment with the distribution system. This assessment may go beyond visual observation and include diagnostic tests to detect any abnormalities in voltage, current, and grounding systems. Temporary remedies may be implemented by the distributor's staff to mitigate immediate concerns.

Step 5: Distributor Installs Monitoring Device

If the initial site visit does not reveal the cause of the power quality issue, the installation of advanced monitoring equipment, such as power quality analyzers, may be necessary. These devices are designed to capture detailed information about electrical parameters over time, allowing for a granular analysis of the power quality issue. The monitoring may require the strategic placement of devices across different locations within the distribution system to accurately identify the source of the disturbance. This step is iterative and may extend over a period, depending on the complexity of the issue at hand. The distributor should maintain continuous communication with the customer regarding the status of the monitoring, expected durations, and preliminary findings, which is essential for maintaining transparency and managing expectations.

A list of power quality monitoring and analysis tools is provided in Appendix 3 of this Guide.

Step 6: Distributor Post-investigation Report & Documentation

The final step involves the consolidation and documentation of the investigation's findings. The distributor should prepare a report detailing the identified issues, the

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methodologies employed during the investigation, key findings, technical analyses, and any corrective actions undertaken or recommended. This report should be communicated to the customer promptly, ensuring they are fully informed of the outcomes and any further steps required to resolve the issue. Retaining the collected data and documentation for a minimum of five years is crucial for reference in future investigations or for comparative analysis over time.

4 POWER QUALITY ISSUE RESOLUTION

The resolution of power quality issues is a collaborative effort involving the customer, the distributor, and potentially other customers if they contribute to the disruption. The approach to resolution depends on the source of the issue, as identified through the investigation process above. The resolution process is categorized based on the origin of the problem:

- issues stemming from the customer’s site;
- issues arising from the distribution system; and
- disruptions caused by other customers.

The subsequent sections provide the resolution strategies and responsibilities for each scenario.

Customer-site Issues

When the investigation concludes that the power quality issue originates from the customer’s premises without impacting other customers or the broader distribution system, the primary responsibility for resolution lies with the affected customer. In such cases, the customer is encouraged to deploy appropriate corrective measures at their own expense. Potential solutions may include upgrading equipment, reconfiguring existing system, or incorporating power quality enhancement devices to mitigate the issue.

Section 4.1.4 of the DSC provides that, if the source of a power quality problem is caused by the consumer making the complaint, the distributor may seek reimbursement for the time and cost spent to investigate the complaint. The OEB expects distributors to ensure that these costs are reasonable and relate directly to addressing the identified power quality issue.

Distribution System Issues

When the investigation identifies that the power quality issue arises from the distributor's distribution system and falls outside the bounds of normal operational parameters (excluding disruptions caused by electrical faults or environmental factors), it is distributor’s responsibility to address and resolve the issue in a timely manner.

In cases of voltage fluctuations, the distributor is required by Section 4.1.2 of the DSC to maintain a voltage variance standard in accordance with the standards of the Canadian Standards Association CAN3-C235. The distributor shall practice reasonable diligence in maintaining voltage levels, but is not responsible for variations in voltage from external forces, such as operating contingencies, exceptionally high loads and low voltage supply from the transmitter or host distributor.

Regarding harmonic distortions, Section 4.1.5 of the DSC requires that the distributor must take appropriate actions to control harmonic distortions found to be detrimental to consumers connected to the distribution system. If the distributor is unable to correct a problem without adversely impacting other distribution system consumers, a distributor may choose not to make the corrections. In deciding which actions to take, a distributor should use appropriate industry standards and good utility practice as guidelines.

In every situation, it is crucial for the distributor to communicate clearly and openly about its resolution strategies, or any potential constraints to the customer affected by the power quality issue. Should the distributor find itself unable to mitigate the problem, the customer may need to explore alternative options, such as the use of behind-the-meter technologies, to address the issue on their end.

Disruptions Caused by Other Customers

If the power quality issue is traced back to another customer, the distributor is obligated to undertake proactive measures to rectify the situation. This process involves sending a written notification to the customer causing the disruption, which outlines the nature of the issue, references the applicable technical standards, and establishes a reasonable deadline for its resolution, taking into account the severity of the problem. The notification should explicitly state that the financial responsibility for addressing the issue rests with the customer causing the disruption.

In accordance with Sections 4.1.6 and 4.1.7 of the DSC, a distributor shall require a customer that owns equipment connected to the distribution system to take reasonable steps to ensure that the operation or failure of that equipment does not cause a distribution system outage or disturbance. The distributor may require that any customer condition that adversely affects the distribution system be corrected immediately by the customer at the customer’s cost.

Should the customer at fault fail to remedy the situation within the timeframe allotted by the distributor, the distributor may need to intervene directly in its distribution system to mitigate the disruption pursuant to its obligations under the DSC including, without limitation, the requirement of section 4.1.1 that it follow good utility practice in managing the power quality of its system. This may include disconnecting the customer pursuant to section 4.1.8 of the DSC.

Furthermore, section 4.2.6 of the DSC provides that the distributor, in establishing its disconnection policy as specified in its Conditions of Service, consistent with sections 30 and 31 of the *Electricity Act, 1998*, may consider as reasons for disconnection (among others set out in the section) an adverse effect on the reliability and safety of the distribution system; a material decrease in the efficiency of the distributor's distribution system; and a materially adverse effect on the quality of distribution services received by an existing connection.

Throughout these processes, maintaining open lines of communication, providing timely updates, and ensuring a clear delineation of responsibilities are essential for the effective and efficient resolution of power quality issues. This collaborative approach helps protect the power system's integrity and ensures the satisfaction of all stakeholders involved.

5 POWER QUALITY ISSUE PREVENTION AND MITIGATION

When establishing a reliable and compliant electrical connection, both customers and distributors must make careful considerations to ensure adherence to technical requirements and standards for maintaining appropriate power quality levels. The following paragraphs outline key considerations for both parties.

Distributor Considerations

Distributors can offer customers information on the local distribution system's configuration, voltage levels, operational and protection schemes, operating conditions specified in the DSC and their Conditions of Service document.

Customer Considerations

Equipment Selection and Specification

- Select equipment resilient to the expected power quality environment, considering local system conditions and the level of acceptable sag tolerance.
- Design facilities or specify equipment to comply with technical requirements like voltage sag tolerances, harmonic distortion limits, and voltage regulation, guided by industry standards listed in Appendix 2.

Mitigation Tools and Technologies

Develop and implement tools and technologies to mitigate any power quality issues related to the customer's load, using simulation software for new facilities and load analysis tools for existing ones. Customer-installed mitigation equipment may include:

- Power factor correction systems to reduce reactive power penalties that may be applicable depending on the customer's rate plan with the distributor.

- Harmonic filtering equipment to lower harmonics created by power electronic loads.
- Surge protection devices to reduce transient voltage events, such as lightning strikes, that can damage equipment and disrupt power quality.

Electromagnetic Compatibility (EMC)

Follow EMC best practices to minimize the potential for electrical interference between equipment and prevent interference with the distribution system or other equipment.

Grounding and Earthing

Ensure proper grounding and earthing practices to minimize risks associated with voltage transients, electrical noise, and electrical shock hazards.

Training

Have trained personnel to ensure proper operation and maintenance of equipment to mitigate power quality issues that may arise during or after connection to the distribution system.

6 POWER QUALITY MONITORING AND ANALYSIS TOOLS

Power quality monitoring and analysis can help to identify existing issues as well as changes in electrical network conditions. Performing power quality analysis entails a strategic blend of methodologies and technological tools for comprehensive data acquisition, measurement, and subsequent analysis. The selection of these tools is influenced by several factors including the intricacy of the power quality issue at hand, the granularity of analysis required, and the financial resources allocated for this purpose. Appendix 3 provides a list of tools and equipment commonly used for power quality analysis. Adequately trained personnel are crucial for the effective and safe use of power quality monitoring and analysis tools.

7 ORGANIZATIONS AND STANDARDS APPLICABLE TO POWER QUALITY IN ONTARIO

This section identifies a range of organizations and standards pivotal to understanding and managing power quality, including methodologies for measuring power quality and assessing related issues.

- **Canadian Standards Association (CSA)** has certification and testing requirements and standards related to power quality for manufacturers and importers.
- **Independent Electricity System Operator's (IESO)** Energy-efficiency programs may have compliance obligations related to power quality. Efficient operations often align with improved power quality.
- **Industry-specific Power Quality Standards**: various industry organizations have developed standards that specifically address power quality issues. Although compliance is often voluntary, adherence to these standards is crucial for preventing power quality issues. These standards are listed in Appendix 2, offering a valuable resource for stakeholders aiming to understand and mitigate power quality issues.
- **Institute of Electrical and Electronics Engineers (IEEE)** has published various power quality standards, recommended practices and guides related to power quality as shown in the appendices and are widely used in North America. Compliance with IEEE standards is often considered a best practice, and in many cases, distributors and industrial facilities adhere to these standards voluntarily.
- **International Electrotechnical Commission (IEC)** has power quality related standards, certification and testing requirements for electrical equipment. Appendix 2 contains a listing of relevant IEC documents. Many IEC standards have reciprocal CSA standards.

APPENDIX 1 – Power Quality Disturbance Types

Power Quality Disturbance	Nature of Disturbance	Symptoms/Effects	Typical Sources
Sag/swell	A momentary, less than a minute, change in voltage magnitude: • Sag: a reduction in voltage ranging from 10 to 90% of nominal. • Swell: an increase in voltage above 110% of nominal	• Data loss, errors • Process disruptions • Equipment malfunctions	• Short circuits (faults) • Rapid changes in large loads e.g. large motor starting
Transient (surge)	A sudden, brief, and temporary deviation from the nominal voltage level, typically lasting for a few microseconds to milliseconds.	• Damage to electronic equipment • Data loss or corruption	• Lightning strikes • Switching operations
Flicker	Rapid and repetitive variations in light output.	• Visual discomfort	• Large dynamic load cycling
Harmonic distortion	The modification of the normal sinusoidal voltage waveform. Created when devices draw	• Equipment overheating • Increased energy losses • Increased noise; buzzing or	• Power electronic devices • Saturated magnetic devices

Power Quality Disturbance	Nature of Disturbance	Symptoms/Effects	Typical Sources
	current in short bursts rather than a continuous flow.	humming sounds from transformers and motors	
Voltage imbalance	Unequal phase voltages	• Vibration and stress in machines.	• Unequal loading between phases • Transformer tap settings
Noise, Electromagn-etic Interference (EMI)	Unwanted electrical signals that interfere with the normal operation of electronic devices.	• Equipment malfunctions • Data errors and loss • Distorted audio and video reception	• Unshielded wiring • Emissions from power electronic devices
Under / overvoltage	A sustained deviation from the normal voltage level lasting more than one minute.	• Reduced device performance • Equipment damage or malfunction • Device overheating	• Overloaded circuits • Transformer tap settings • Oversized capacitor banks
Voltage notching	Brief, recurring dips in voltage typically lasting microseconds caused by phase-controlled (SCR based) rectifiers.	• Timing circuit issues and malfunction of devices sensitive to multiple voltage zero crossings.	• Phase controlled (SCR) rectifiers, e.g. large DC motor speed control in steel rolling mills.

APPENDIX 2 – Reference Documents

Reference	Title	Description & applicable disturbance types
IEEE 1250	IEEE Guide for Identifying and Improving Voltage Quality in Power Systems	• Power Quality (PQ) Background and directory to other standards
IEEE 1159	IEEE Recommended Practice for Monitoring Electric Power Quality	• PQ phenomena definition and monitoring • Transient (surge) • Sag/swell • Under/overvoltage
IEEE 1453	IEEE Standard for Measurement and Limits of Voltage Fluctuations and Associated Light Flicker on AC Power Systems	• Flicker: definition, measurements, studies and guidance on limits
IEEE 519	IEEE Standard for Harmonic Control in Electric Power Systems	• Harmonic: definition, measurements, guidance on limits Voltage notching
IEEE 1668	IEEE Recommended Practice for Voltage Sag and Short Interruption Ride-Through Testing for End-Use Electrical Equipment Rated Less than 1000 V	• PQ primer. Technical specification for equipment guidance. Non-industry specific. Under/overvoltage
IEEE Std 100	IEEE Standard Dictionary of Electrical and Electronics Terms	• Glossary
IEEE Std 493	IEEE Recommended Practice for the Design of Reliable Industrial and Commercial Power Systems	• Guidance on momentary outages
IEEE 142	IEEE Recommended Practice for Grounding of Industrial and Commercial Power Systems	
IEEE Std 1100	IEEE Recommended Practice for Powering and Grounding Electronic Equipment	• Describes power correction devices and their application

IEEE Std 1547	IEEE Standard for Interconnecting Distributed Resources with Electric Power Systems	• Distributed Energy Resource (DER) power quality considerations
UL1449	Surge Protective Devices (SPD)	• Transient (surge)
SEMI F47 and F42	Voltage Sag Immunity & Test Method for Semiconductor Processing Equipment Voltage Sag Immunity	• Equipment and test specification for semiconductor manufacturing
NEMA MG 1	Motors and Generators	• Power quality assessment for electrical machines and their interaction with power systems
CAN/CSA-CEI/IEC 61000	Electromagnetic compatibility (EMC)	• EMC emission and immunity limits. Noise. Harmonic distortion. Voltage imbalance.
IEEE 1531	Guide for Application and Specification of Harmonic Filters.	
ITIC Curve	Information Technology Industry Council Curve	• Outlines voltage conditions where IT equipment is expected to operate properly
CSA-C235	Preferred Voltage Levels for AC systems up to 50 000V	• Steady-state voltage operating ranges

APPENDIX 3 – Monitoring and Analysis Tools

- **Power quality analyzers** measure and record steady-state parameters such as voltage, current, power, harmonics and flicker. Advanced models can record transient events and waveforms.
- **Digital Multimeters (DMMs)** are versatile instruments that can measure voltage, current, resistance, and other electrical parameters for basic load analysis.
- **Current clamps (or ammeters)** allow non-intrusive measurements of current in circuits. They can be used in conjunction with DMMs or power quality analyzers.
- **Oscilloscopes** are essential for visualizing waveforms, particularly when dealing with complex load behavior.
- **Data loggers** can record sampled steady-state measurements over an extended period, making them useful for profiling load behavior and identifying patterns in load variations.
- **Power factor meters** measure how effectively electrical power is used.
- **Harmonic analyzers** provide a detailed harmonic analysis, especially in industrial settings where harmonics can be a significant concern.
- **Energy monitoring systems** integrate multiple sensors and meters to monitor and record various electrical parameters over time, providing a comprehensive view of load characteristics.
- **Energy management software tools** can help in data analysis, visualization, and reporting. They can take data from various monitoring devices and create meaningful reports for load analysis.
- **Infrared thermometers and imaging cameras** are useful for identifying hotspots and overheating in electrical equipment, which can be indicative of load problems.
- **Load banks** are used to apply an artificial load to a system to test its performance under various conditions. They are especially useful for load testing and compliance checks in critical applications.
- **Simulation software** can model load behavior and predict how different loads will impact the electrical system for predictive load analysis.
- **Datalogging sensors** can monitor environmental conditions, equipment temperature, and other variables that may affect load performance.
- **Voltage recorders** record voltage waveforms over time and are useful for diagnosing voltage disturbances and variations.