Metric #17: Customer Complaints regarding Power Quality Issues

M.17.1.0 Introduction and Background

This section examines customer complaints regarding Power Quality (PQ). PQ is a simple but subjective term that describes a large number of issues found in any electrical power system. The definition of a PQ incident varies widely, depending on the customer being served. Customers are affected by PQ incidents differently according to their needs. Residential customers tend to be affected more by sustained interruptions, whereas commercial and industrial customers are troubled mostly by sags and momentary interruptions. Avoltage sag, as defined by IEEE Standard 1159-1995, is a decrease in root-mean square (RMS) voltage at the power frequency for durations from 0.5 cycles to 1 minute, reported as the remaining voltage.[1] Momentary interruptions are usually just a few seconds but can last up to a minute whereas sustained interruptions are usually between one and five minutes.

The smart-grid system has the ability to offer several pricing levels for varying grades of PQ, which is expected to give customers more choices. Currently, the standard goal for utilities in relation to power interruptions is 3-4 "nines." Three nines represent 99.9% reliability and correspond to an outage time of 8.76 hours per year while 4 nines (99.99%) are approximately 1 hour of downtime per year. Premium power of 6-9 nines (99.9999% - 99.9999999%) would allow only 31 seconds to .03 seconds of interruption, respectively.

For those customers who are deemed power sensitive, the extra cost of premium power would be a worthwhile investment when compared to the lost revenue from a loss of power. A smart grid will utilize advanced controls to allow for rapid diagnosis and solutions to PQ events as well as decrease the number of PQ disturbances from weather events, switching surges, line faults, and harmonic sources. The grid will also moderate consumer electronic loads by limiting the level of electrical current harmonics a consumer load is allowed to produce.[2]

M.17.2.0 Description of Metric and Measurable Elements

(Metric 17): *the percentage of customer complaints related to power quality issues (excluding outages).*

M.17.3.0 Deployment Trends and Projections

Power-quality incidents in the past have been rather hard to observe and diagnose because of their short interruption period. The increase in power-sensitive and digital loads has forced us to more narrowly define PQ. For example, 10 years ago a voltage sag might be classified as a drop of 40% or more for 60 cycles, but now it may be a drop of 15% for five cycles.[3]

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[1]Institute of Electrical and Electronics Engineers (IEEE). 1995. *Recommended Practice for Monitoring Electric Power Quality.* No. 1159-1995, IEEE, Piscataway, New Jersey.
[2]National Energy Technology Laboratory (NETL). 2007. *A System View of the Modern Grid. Vol 2.* NETL. Accessed October 16, 2008, at:
http://www.netl.doe.gov/moderngrid/docs/ASystemsViewoftheModernGrid_Final_v2_0.pdf
[3]Kueck JD, BJ Kirby, PN Overholt, and LC Markel. 2004. *Measurement Practices for Reliability and Power Quality: A Toolkit of Reliability Measurement Practices.* ORNL/TM-2004/91, Oak Ridge National Laboratory, Oak Ridge, Tennessee. Accessed November 18, 2008 at

Several power-quality studies have been completed in the United States over the past couple of decades. A 1991 paper compares three of these studies. [4] This paper cites studies by IBM (1969-1972 Allen-Segall study) and AT&T (1977-1979 Goldstein-Speranza study). A third and considerably larger study was conducted by National Power Laboratory (NPL) in the early 1990s. The consistent conclusion in all three studies was that disturbances occur and a need for different grades of power is necessary to protect sensitive loads. Comparing the studies and assessing trends, however, is more difficult as each study used different definitions, parameters, and instrumentation. NPL filtered data to compare it to the IBM and then the AT&T surveys in their AC Power Quality Studies paper. The comparison with the IBM study found a decrease in total disturbances per month and a 65% decrease in impulses, but an increase of 150% in outages and an increase of 251% in sag disturbances. The comparison between NPL and AT&T found a 20% decrease in sags, a 151% increase in impulses, an 85% increase in outages, and surges up 300%. Impulse and sag measurements are contradictory, which is likely because of different event definitions and threshold levels used in the IBM and AT&T surveys. Since these studies were completed, the IEEE has established suggestions for power-line settings to allow for more consistent measurement. Settings for 120V loads are shown in Table M.17.1.

Table M.17.1. IEEE Suggested Threshold Settings for 120 V Loads[5]

	Category	Suggested setting	Comments
Conducted phase voltage thresh-olds	Sag	108 V rms	Minus 10% of nominal supply voltage
	Swell	126 V rms	Plus 5% of nominal supply voltage
	Transient	200 V	Approximately twice the nominal phase-to-neutral voltage
	Noise	1.5 V	Approximately 1% of the nominal phase-to-neutral voltage
	Harmonics	5% THD	Voltage distortion level at which loads may be affected
	Frequency	±Hz	—
	Phase imbalance	2%	Voltage imbalance greater than 2% can affect equipment. (Three-phase induction motors should be derated when oper-ated with imbalanced voltages [B11]).
Conducted neutral-to-ground differential voltage thresholds	Swell	3.0 V rms	Typical level of interest for neutral and/or ground problems
	Impulsive transient	20 V peak	Ten to twenty percent of phase-to-neutral voltage
	Noise	1.5 V rms	Typical equipment susceptibility level
Current thresholds	Phase/neutral current	Normal load current on true rms basis	Load current threshold may need to be raised well above normal load current, depending on the desired data and the amount of fluctuation in load current.
	Ground current	0.5 A true rms	Consider Section 250-21 of the NEC [B2] for safety, as well as noise currents, that lead to objectionable voltages, from both safety and data error points of view.
	Harmonics	20% THD (for small customers) to 5% THD (for very large customers)	Measured at service entrance (point of common coupling), and relative to maximum demand load current (refer also to IEEE Std 519-1992 [B13]); harmonic distortion reference values or measurements at a subpanel should be chosen rela-tive to concerns about effects of harmonics on equipment in the circuit that is being monitored such as neutral sizing, transformer loading and capacitors.

http://www.ornl.gov/sci/engineering_science_technology/eere_research_reports/power_systems/reliability_and_power_quality/ornl_tm_2004_91/ornl_tm_2004_91.pdf.

[4]Dorr DS. 1991."AC Power Quality Studies: IBM, AT&T and NPL." *13th International Telecommunications Energy Conference, Kyoto, Japan November 5-8, 1991* pp. 552-559.

[5]Institute of Electrical and Electronics Engineers (IEEE). 1995. *Recommended Practice for Monitoring Electric Power Quality.* No. 1159-1995, IEEE, Piscataway, New Jersey.

A loss of power or a fluctuation in power causes commercial and industrial users to lose valuable time and money each year. Cost estimates of power interruptions and outages vary. A 2002 study prepared by Primen concluded that power quality disturbances alone cost the U.S. economy between $15-24 billion annually.[6] The EPRI in 2001 estimated power interruption and power quality cost at $119 billion per year,[7] and a more recent 2004 study from LBNL estimated the cost at $80 billion per year.[8] It should be noted that the two latter studies also include reliability costs as well as power-quality costs. The cost of a momentary disruption to various users in dollars per kilowatt is shown in Table M.17.2 below.

Table M.17.2. Disruption Cost by Industry[9]

	Cost of Momentary Interruption ($/kW demand)	
Category	**Minimum**	**Maximum**
INDUSTRIAL		
Automobile manufacturing	$5.0	$7.5
Rubber and plastics	$3.0	$4.5
Textile	$2.0	$4.0
Paper	$1.5	$2.5
Printing (newspapers)	$1.0	$2.0
Petrochemical	$3.0	$5.0
Metal fabrication	$2.0	$4.0
Glass	$4.0	$6.0
Mining	$2.0	$4.0
Food processing	$3.0	$5.0
Pharmaceutical	$5.0	$50.0
Electronics	$8.0	$12.0
Semiconductor manufacturing	$20.0	$60.0
COMMERCIAL		
Communications, information processing	$1.0	$10.0
Hospitals, banks, civil services	$2.0	$3.0
Restaurants, bars, hotels	$0.5	$1.0
Commercial shops	$0.1	$0.5

The research team conducted interviews in support of this report with 21 companies collectively serving 0.8-1.2 billion megawatt hours of generation annually and a peak demand of 150,000-175,000 megawatts. The research team asked respondents to estimate the percentage of customer complaints related to PQ issues (excluding outages). The utilities indicated that 3.1 percent of all customer complaints were related to PQ issues. This value represents a weighted average amount.

Recently, PQ has moved from customer-service problem solving to an integral part of the power-system performance process. The design of PQ devices meant to monitor quality has not changed significantly in the past decade. Instead, the hardware, firmware, and software utilized by these systems have advanced dramatically. These changes are driven by market demands, standardization of measurement techniques and communication protocols, specialized large-scale integrated circuits, and

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[6]McNulty S and B Howe. 2002. *Power Quality Problems and Renewable Energy Solutions.* Prepared for the Massachusetts Renewable Energy Trust.

[7]Electric Power Research Institute (EPRI). 2001. *The Cost of Power Disturbance to Industrial and Digital Economy Companies.* Consortium for Electric Infrastructure to Support a Digital Society. EPRI, Palo Alto, California. Accessed October 18, 2008, at http://www.epri-intelligrid.com/intelligrid/docs/Cost_of_Power_Disturbances_to_Industrial_and_Digital_Technology_Companies.pdf.

[8]Hamachi LaCommare K and J Eto. 2004. *Understanding the Cost of Power Interruptions to U.S. Electricity Consumers*. LBNL-55718, Lawrence Berkeley National Laboratory, Berkeley, California. Accessed October 14, 2008, at http://certs.lbl.gov/pdf/55718.pdf.

[9]NETL 2007.

improvements in software methodology. The latest PQ devices use web browsers to allow for remote access of information.

M.17.3.1 Associated Stakeholders

There are a number of stakeholders engaged in PQ issues:

- Electric service retailers working toward providing better PQ to customers.
- End users (residential, commercial and industrial users) needing consistent power quality.
- Regulators interested in enhancing PQ and better serving the customer base.

M.17.3.2 Regional Influences

Regional differences surface for several reasons, such as climate, design of the distribution system, and maintenance levels. The geographical features of an area, the number and type of customers (residential, commercial, or industrial), the economic health of a region, and the fact that utilities have different distribution systems also lead to PQ problems. Therefore, interruption costs for comparable customers in different regions could vary significantly.

Also, PQ is dependent on the number and type of customers in a region. PQ related interruption costs for a similar type of customer will be different depending on the region of the country, what industries predominate in the area, the local demographics, and economic health of the region.

M.17.4.0 Challenges to Deployment

Measuring PQ presents a challenge because of the regional influences of a given area and the inconsistency in definitions and reporting of PQ. Different geographical issues, such as weather, terrain, and demographics, create inconsistencies that make it difficult to compare PQ across regions. The PQ of electrical service is a bit more complex to measure then the reliability since PQ events are harder to observe and diagnose because of their short duration and the fact that definitions and standards are evolving.

M.17.4.1 Technical Challenges

Standards organizations have not created standards for categories of PQ that consumers can choose from according to their needs. Standards for various grades of delivered power could serve as the basis for differentiated PQ pricing. Also, more distinct definitions and better reporting and handling of evolving PQ issues would help clarify the topic, which is still not well understood.

M.17.4.2 Business and Financial Challenges

There are costs associated with implementing advanced PQ devices that some may not be willing to assume. Devices include those used by the utilities to monitor and diagnose problems, and devices used by the end user that depend on the size and type of the critical load. Typically, end-user devices are categorized in three groups: individual operations (controls or individual equipment protection), sensitive sub-facilities (individual circuit protection), and the entire load (at the electric service entrance). PQ

enhancing devices are still too expensive to be widely used. As more cost-effective designs are developed and supply increases in return, prices should come down.

FERC, in a policy statement on matters related to bulk power-system reliability, stated that public utilities may be uncertain about spending significant amounts of money without reassurance they will be able to recover it. The report goes on to note that:

> *"Regulators should clarify that prudent expenditures and investments to maintain or improve bulk power system reliability will be recoverable through rates. The Commission also assures public utilities that they will approve applications to recover prudently incurred costs necessary to ensure bulk electric system reliability, including prudent expenditures for vegetation management, improved grid management and monitoring equipment, operator training, and compliance with NERC reliability standards and Good Utility Practices."*[10]

To provide different grades of power to consumers, a shift in standards must occur. PQ standards have not been well defined in the past and currently only provide a safety net. By implementing standards for the level of PQ customers expect to receive, it would be easier to differentiate between grades of power, thus giving end users more choices. This is particularly important for regulated T&D companies interested in selling premium power competitively while still protecting their customers receiving normal regulated service. Currently, without specific standards for each grade of power, T&D companies could appear to provide low-quality power to increase the sales of higher grade power.[11]

M.17.5.0 Metric Recommendations

Customer sentiment regarding PQ issues is captured by measuring PQ complaints by customers as a percentage of total complaints. What constitutes a PQ complaint, however, is unfortunately open to interpretation. Consideration should be given to constructing a clear definition of what constitutes a PQ complaint. In developing this definition, the research team should work closely with electric-service retailers and subject-matter experts. Further, the number of interviews should be expanded to generate a more precise assessment of this metric. Finally, future reports should also consider reporting the total number of PQ complaints while also noting the total number of complaints reported by the interviewed utilities. Reporting the total number of PQ complaints would enable a better understanding of the magnitude of the issue.

[10] 107 FERC 61,052, Docket No. PL04-5-00. 2004. *Policy Statement on Matters Related to Bulk Power System Reliability*. Issues April 19, 2004, Federal Energy Regulatory Commission, Washington, D.C. Accessed October 14, 2008, at http://www.ferc.gov/whats-new/comm-meet/041404/E-6.pdf.
[11] Kueck et al. 2004.