POWER QUALITY RESEARCH AREA

VISION

EPRI research in the power quality area focuses on presenting a vision for the role that PQ can and should play in enhancing the three principal performance metrics for electric utilities: economic performance for the enterprise, the system performance of the modern grid, and improving customer satisfaction for all users of electric power. This effort has identified a number of key technical foundations for power quality research, including *improving and benchmarking grid PQ performance* and managing the increasing impact of harmonics, flicker, and other PQ phenomena on both transmission and distribution feeders. The research effort also seeks to *manage and extract the maximum value from data resources*, including analysis tools, visualization tools and platforms, and data-integration methods. Understanding and improving *system compatibility between the grid and loads*, including understanding the contribution of new and changing loads on grid performance, are a central focus. Capturing and leveraging EPRI’s extensive power quality expertise is the primary focus of PQ *knowledge development and education activities* through training, customized web content, and accessible and readable documents developed for a broad audience.
IMPROVING AND BENCHMARKING GRID PQ PERFORMANCE

COMPONENTS OF THE FUTURE STATE

Utilities and the public need to understand the true level of quality performance of their transmission and distribution networks, and to identify methods and actions that may improve the quality. New and changing loads require additional benchmarking efforts of current and past grid performance, and it will be necessary to forecast future PQ levels based on changing grid configurations and load mixes.

Today, there is a need to redefine the acceptable levels of power quality for key phenomena—such as harmonic content, voltage sags, flicker, and others—and develop a set of metrics that can be applied at the transmission and distribution levels. Benchmarking power quality will lead to a better understanding of the existing levels of quality provided to consumers and will form the expectations of the levels of quality in the future. In addition, the ability to conduct comprehensive PQ benchmarking has gained feasibility as monitoring systems have become more versatile and cost-effective.

It will be required that we understand today’s level of PQ for a wider variety of phenomena in order to have a basis for comparison as the grid and load characteristics continue to change.

Using PQ technical and informational resources to improve and benchmark grid performance will require:

• Analyzing power quality measurements will be more sophisticated in order to facilitate useful benchmarking of grid PQ as the impacts of the Smart Grid begin to take hold.

• Tools will be developed to estimate future power quality levels based on changing grid configurations and load compositions.

• Methodologies will exist for quantifying and qualifying the impact of PQ and other performance phenomena beyond simplistic counting of events.

• The “harmonics problem” of distribution systems will have a set of clearly defined solutions.

• Creation of a library of Guided Analytics will to facilitate structured and rigorous analysis of a wide range of grid PQ phenomena.

GAPS

There are both technical and implementation gaps between the modernized electricity system characterized above and the current state. Technical and implementation gaps need to be addressed simultaneously.

Technical gaps for achieving improvement and benchmarking of grid PQ performance are:

• A unified framework is needed for benchmarking current PQ performance.

• More sophisticated methods are needed for assessing the impact of PQ phenomena on grid performance, beyond simple counting of events or simple amplitude measurements.

• A unified framework is needed for estimating future PQ levels—and harmonics in particular—for different circuit designs and configurations and for different and changing mixes of loads served.

ACTION PLAN

The EPRI PQ Research Area has begun important initiatives to address these gaps:

• EPRI GridIQ framework: The GridIQ Framework intends to enable rigorous estimation and modeling of the impact of new loads and circuit configuration on grid PQ. This framework will incorporate models for existing as well as emerging and rapidly growing loads (CFLs, PHEV chargers, PV installations, and so on) and combine the models into a system model library.

• EPRI Power Quality Diagnostic System tools: The Power Quality Diagnostic System (PQDS) provided Guided Analytics designed to help engineers and technicians develop solutions for power quality problems and assess the economics, simplifying the calculation required to determine the costs and the expected performance of corrective measures, when compared to a base case.

• Transmission and distribution benchmarking: This benchmarking effort is designed to increase our knowledge of grid performance in a number of important ways, including:

  – Stratification of data to allow finer resolution of performance for different circuits, grid configurations, load served, and so on.
– Addition of transmission-level statistics.
– Addition of multiple phenomena beyond voltage sags, including harmonics and flicker.

A graphical representation of the action plan for this roadmap (also referred to as swimlanes) is attached.

VALUE AND RISK

Electric utilities cannot achieve economic and grid-performance excellence by continuing to pursue the “reactive” approach to power quality—waiting for problems to manifest and solving them retroactively. The emergence of new and changing loads, the impacts of automated grids, and the need to extract greater value from existing infrastructure make a proactive approach to PQ necessary. A proactive approach not only reduces long-run costs but also improves economic performance, grid performance, and customer satisfaction. Enabling better management decisions through trending analysis, estimation of future PQ levels, and recommendations for proactive prevention and mitigation presents a new paradigm for power quality management.
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Improving and Benchmarking Grid PQ Performance</td>
<td>Create and Expand Grid-IQ Circuit Model Library</td>
<td>Create, Expand, and Interface Load Model Libraries</td>
<td>Develop Estimates of Future Harmonics Levels</td>
<td>Customized Circuit/Load PQ Performance Analysis using Grid-IQ</td>
<td>Complete TPQ/DPQIII</td>
<td>Custom On-Demand PQ Benchmarking</td>
<td>Solve the Distribution Harmonics Problem</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Legend**
- EPRI Work
- Other Stakeholders
- Key Milestone
MANAGING AND EXTRACTING MAXIMUM VALUE FROM DATA RESOURCES

COMPONENTS OF THE FUTURE STATE

Power quality data bases have historically been among the largest data repositories maintained by electric utilities. Whereas most of the grid is monitored at 50/60 Hz and RMS levels, power quality has long focused on capturing waveforms, harmonics, and high-frequency signals on power lines.

Extracting useful information from these data streams will not happen on its own. In fact, if history offers any lesson, unless the utility industry recognized and addresses this issue today, we will have huge, but inaccessible, silo’d and awkwardly structured data stores that add cost but little real- or near-time value.

Key elements of extracting the maximum value from PQ data resources include:

• The availability of waveform data will proliferate with the installation of intelligent electronic devices (IEDs) and, eventually, more sophisticated smart meters

• Visualization of grid events will be integrated across different data repositories, including OMS, GIS, maintenance, DFR, and other IED data sources.

• Visualization of data will be distributed and accessible across a wide variety of field-deployable devices.

• Analysis tools for extracting valuable information from waveform data will provide real- or near-time information that will help to improve grid and economic performance.

GAPS

Gaps to achieving these Future States include:

• Integration methodologies and plans for defining the needs for waveform data and sources across increasingly diversified systems.

• Creating infrastructure to allow real- and near-time analysis of waveform data to provide immediate and actionable information.

• Development of versatile platforms to allow visualization of PQ and other grid-performance data for a much broader utility-internal audience.

• Creating interoperability standards for easy interchange of data.

• Creating analysis algorithms not only for PQ phenomena but also for other issues related to grid and equipment performance, such as fault location and the assessment of equipment health.

• Creating a roadmap for enabling useful PQ data from future installations and upgrades of smart meters.

ACTION PLAN

The EPRI Power Quality Research Area has begun important initiatives to address these gaps:

Updated power quality data analysis and visualization: EPRI has developed software tools and analysis algorithms for gathering, visualizing, and extracting information from PQ data, the primary among them being PQView. Featuring data-management tools that can quickly characterize the data, PQView includes statistical analysis and plotting tools that can provide single- or multiple-site power-system analyses. Key to extending this functionality will be updating PQView to become a modern, multi-platform data-visualization and analysis system.

Integrating PQ data streams from Smart Meters and IEDs for power quality applications: While expectations run high that waveform data from smart meters may be of great benefit to the utility industry, early results have not been encouraging. To address this, EPRI will conduct an assessment of the possible and likely usage of smart meter data for PQ applications and define requirements for metering data to serve as a power quality data source.

Development of intelligent PQ data-analysis algorithms: Algorithms will be developed that analyze data from existing data resources and repositories and extract real and actionable information, including fault location, incipient equipment failures, assessment of equipment health and longevity, detection of system impending malfunctions or failure, and correlation of system events with captured data.

Data visualization and deployment platforms: For wider deployment and value of data sources, portable applications—for iPhone, Droid, and similar devices—will be created.

A graphical representation of the action plan for this roadmap (also referred to as swimlanes) is attached.
VALUE AND RISK

A key differentiator among electric utilities is how well they manage data and how well they extract value from existing and emerging data sets. The intelligent acquisition, storage, analysis, and knowledge deployment resulting from increasingly diverse data sets are a fundamental challenge for successful implementation of smart T&D. EPRI’s Power Quality Research Area has been at the forefront of data-based research, identifying new ways to manage and analyze data and bringing real value to electric utilities. Innovative ways of analyzing, displaying, and accessing data are urgently needed.
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Managing and Extracting Maximum Value from PQ Data Resources</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Updated Power Quality Data Analysis and Visualization</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Integrating PQ Data from Smart Meters and IEDs</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Development of Intelligent PQ Data Analysis Algorithms</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Data Visualization and Deployment Platforms</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Legend
- EPRI Work
- Other Stakeholders
- Key Milestone
COMPONENTS OF THE FUTURE STATE

A key focus of power quality is the ability of electric power supplied to the end user to successfully—and consistently—power utility customer loads. This implies a partnership between the utility and the customer—reasonably clean power for the former, and reasonably tolerant loads for the latter.

Both players in this partnership need standards, guidelines, tools, and resources if compatibility is to be achieved at the lowest societal cost.

GAPS:

Key elements of achieving compatibility include:

- Meaningful standards exist for both grid PQ and end use device sensitivity
- Expert tools exist for solving compatibility issues when they occur
- End use device testing identifies issues before process interruptions occur
- The contribution of end use loads to grid PQ levels—and harmonics in particular—is well understood
- The sensitivity of new and changing loads to an increasingly complex grid is well understood

ACTION PLAN

- Active participation of EPRI in meaningful compatibility standards development efforts such as the planned updated SEMI F47 equipment compatibility standard.

- Continued development of the Power Quality Investigator, which enables utility engineers to work with end-use customers to analyze their processes for susceptibility to voltage variations. This needs to include a compilation of background information on various industries, processes, equipment, and components in manufacturing based on experience in facility audits and solving PQ problems.

- Ongoing end-use equipment compatibility and PQ-contribution testing including CFLs, LED, and other lighting technologies; electric vehicle charging; rooftop photovoltaics (PV) and other inverter-based systems; evolving residential electronics; and grid-connected electronic systems such as smart meters and data accumulators.

- Creation of a load-model library of new and changing end-use technologies to enable estimation of future PQ levels for harmonics, flicker, and other PQ phenomena.

- Testing and validation of the performance of new and emerging PQ mitigation technologies and techniques.

- Development of technologies and techniques for improving the resiliency of end use loads.

A graphical representation of the action plan for this roadmap (also referred to as swimlanes) is attached.

VALUE AND RISK

It has been many decades since the electric utility industry has seen such rapid change in both the technology of the grid and the composition/behavior of the load being served. Understanding of both is critical to improved economic performance, grid performance, and customer satisfaction. The EPRI Power Quality Program is assembling and deploying a large, diverse, and growing load-model library for the purposes of understanding and estimating future grid PQ levels so that good management decisions can be made today. More and better PQ analysis tools are needed to enable quick response to utility customer PQ issues.

- System Compatibility Between the Grid and Loads
  - Updated PQ Investigator
  - Compatibility Standards Development
  - Assessment of Equipment Sensitivity
  - Assessment and Modeling of Equipment and DG Contribution to Grid PQ

Legend:
- EPRI Work
- Other Stakeholders
- Key Milestone