A New Vision of PQ Research for the Next 10 Years

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***Abstract*—The Electric Power Research Institute has created a detailed vision for power quality research for the next 10 years. The EPRI PQ master plan document defines not only specific needs and objectives of PQ research for the next 10-20 years, but also presents a renewed and vigorous vision for the role that PQ can and should play in enhancing the economic performance of modern electric power suppliers, manufacturers, and other key industry partners.**

Keywords- power quality, planning, vision, collaborative research

I. INTRODUCTION

Some twenty years ago, the Electric Power Research Institute (EPRI) initiated what was then a virtually unheard of field of study – a focused research effort to better define, understand, and improve the quality of electric power supply. This new field of "Power Quality" (PQ) focused initially on defining what PQ was and how to measure it. In the subsequent two decades, research has allowed an evolution and revolution of the PQ field so that it is now widely considered to be an essential core competency for all electric power suppliers. Furthermore, PQ has evolved from being a back-office function to a front-and-center function that is often on the leading edge of utility-customer relations and satisfaction, and a core component of any electric utility's effort to improve overall performance.

The EPRI PQ research program – Program 1 in the institute's technical offering – is a multi-US$ million effort closely supported by over 50 international utilities. In close collaboration with these partners, the institute has developed a PQ research master plan that defines not only specific needs and objectives of PQ research for the next 10-20 years, but also presents a renewed and vigorous vision for the role that PQ can and should play in enhancing the economic performance of modern electric power suppliers, manufacturers, and other key industry partners.

This master plan comprises a number of key components that represent a defined and inspired vision for PQ research, and identify profound opportunities to improve reliability, asset utilization, system planning, compatibility with customer loads, and utility financial performance:

1) Vision and Mission Statements

Central to the master plan is the articulation of both a technical and philosophical vision for why this research effort is needed and how the electric utilities that fund and guide the institute's PQ research intend to conduct it.

2) Success statements

Contained in the first and most fundamental level of the research master plan are 16 success statements that articulate the specific needs and goals for ongoing PQ research and, therefore, for the institute's PQ research effort. These success statements – carefully identified and crafted in close cooperation with utility and industry PQ professionals – represent a positive development in articulating a new vision for PQ research. Collectively, they provide a basis for identifying key needs and opportunities in PQ, and are envisioned to also serve as a means of keeping that research focused on specific, achievable, and economically viable solutions, and charting and quantifying our progress year by year. They represent the "destination" and overall objective for institute-sponsored PQ research.

3) Critical gaps

For each success statement, the master plan process has collectively identified over 100 critical gaps that represent specific needs for enhanced knowledge, capabilities, and

solutions in PQ. The critical gaps are the "stepping stones" needed to realize the success statements. From these critical gaps, the institute – in concert with close advice and support of program funders – has developed, evaluated, and profoundly updated its specific research agenda. Through rigorous prioritization and impact analysis, this process insures that priority is given to those most critical gaps having the highest and most economically significant impact on achieving the vision of the master plan and its incumbent success statements.

4) *EPRI PQ R&D Portfolio*

Beginning with the 2007 research year, the institute's research and development portfolio is a driven by the master plan process, articulating a specific plan for satisfying the critical gaps and, thereby, achieving the success statements and overall vision of the PQ master plan. The Portfolio comprises four project sets and approximately a dozen prioritized, focused, and goal-oriented projects designed to efficiently chart a path to ultimate success while providing extraordinary value to funders each and every funding year.

Working closely with our utility, manufacturing, and other industry partners, the institute seeks to promote the progress of PQ research and increase the focus on using PQ to improvie utility financial and operational performance.

II. Defining a New Mission and Vision for Power Quality

The first step in developing the PQ master plan was to define more appropriate vision and mission statements to guide our research and planning. The goal for these statements was to broaden the reach of ongoing PQ research – to move beyond solving important day-to-day PQ issues, but also to expand to broadly benefit utility and related enterprise.

A. *Vision for the PQ master plan*

The Vision for the PQ research effort is two-part; a philosophical vision, and a technical vision:

1) *Philosophical Vision*

The philosophical vision of the PQ research effort is to develop the practice and understanding of Power Quality into an essential and increasingly valuable tool for optimization of utility business performance at all levels.

2) *Technical Vision*

The technical vision of the PQ research effort is to continuously improve system operations, optimize customer satisfaction, and minimize cost of business through intelligent collection, interpretation, and application of system data.

This vision is intended to be shared not only among our partners but throughout the energy industry and public agencies.

B. *Mission statement for the PQ master plan*

The mission statement for the PQ master plan reflects a strong desire to expand the horizons of PQ research beyond understanding, measuring, and mitigating PQ phenomena, but also to extend that knowledge to produce real financial benefits for utilities and other enterprises.

1) *PQ Research – Mission Statement*

The institute's PQ Portfolio seeks to be the world-wide leader in every aspect of PQ research, knowledge development, and resource deployment, and serves as a vital engine for improved utility performance. The program seeks to engage all facets of the PQ world – from electric utilities to end-use customers, from system understanding to mitigation technologies, from the factory floor to the board room.

III. THE PQ MASTER PLAN PROCESS

The master plan process is illustrated in Figure 1 below. The process begins with first defining what success will look and feel like in the future, and capturing these in the form of success statements, then identifying critical gaps that must be resolved to make the success statement a reality. The institute's PQ research portfolio is derived from these master plan elements which, in turn, drives the actual research and technical transformation conducted and coordinated by the institute. Coming full circle, the results of this research drive the content of future editions of the PQ master plan by driving our vision of how success will look and feel even further down the road.

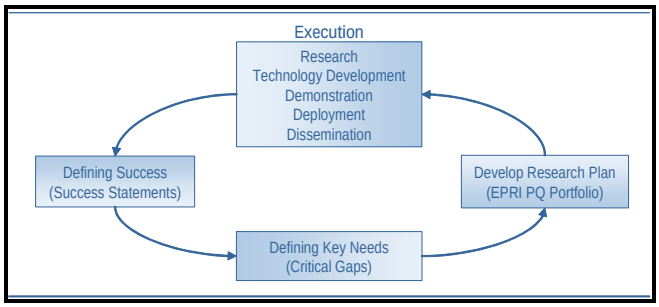

Figure 1. The master plan process

IV. SUCCESS STATEMENTS – INITIAL DRIVER OF THE PQ MASTER PLAN PROCESS

The master plan process begins with creating a vision of what success will look and feel like in the future. By envisioning how we would like the PQ world to be different as a result of our ongoing activities, we then have the power to focus on specific outcomes and obstacles, thereby bringing a renewed and continually revitalized focus to PQ research, while also creating objective metrics by which to measure our progress.

The first draft of the PQ master plan contains 16 success statements, as shown in Figure 2 through 5 below.

A. *Success statements Aligned with EPRI PQ Portfolio Project Set 1A - Improving PQ and Reliability with T&D Design, Maintenance, and Planning*

This institute's PQ project set provides specific guidance and tools to maximize T&D asset utilization and enhance grid power security, quality, reliability, and availability (SQRA) through system design, operations, and maintenance practices and analysis tools. Project set funders will gain specific guidance to enhance T&D power quality and reliability to meet the increasingly diversified requirements of a competitive energy marketplace, including changing regulations and open-access requirements.

The flagship product from the PS1A project set is the Power Quality Diagnostic System (PQDS), a set of tools designed to help engineers and technicians develop solutions for power quality problems. Individual modules perform the major functions required in the diagnostic system, and a Power Quality Case Study Investigation Processor directs the user to modules required for a particular problem or investigation. The Economic Assessment Module (EAM) provides a valuable capability to the power quality engineer in simplifying the calculation process for power quality costs, and determining the expected performance of corrective measures. The module works from a base case model of a utility substation supplying several customers with one or more processes that can be affected by power quality disturbances. Each year, new modules are added to this essential tool.

Success statements aligned with project set PS1A are shown in Figure 2 below.

EPRI PQ Program Master Plan - Success Statements	
Statement Number	**Improving PQ and Reliability with T&D Design, Maintenance, and Planning (PS1A)**
1	In ten years, we know the economic opportunity that exists for improved PQ and reliability and metrics to help achieve an **optimum balance between investment in PQ/reliability and the associated economic benefits**.
2	In ten years, **benchmarking of performance will be a dynamic, ongoing function**, not a project. It will be adaptable to changing metrics, circumstances, etc.
3	In ten years, we have **dynamically-updating system models** based on real time data.
4	In ten years, we will have a **robust 10-year forecast** to help project the composition and characteristics of future loads.

Figure 2. Success statements Mapped to PS1A, Improving PQ and Reliability with T&D Design, Maintenance, and Planning

B. *Success statements Aligned with EPRI PQ Portfolio Project Set 1B - Integrating PQ Monitoring and Intelligent Applications to Maximize System Performance*

This institute's PQ project set provides knowledge-based tools, testing, and measurement technologies necessary to monitor, diagnose, understand, and prevent PQ disturbances throughout the entire electrical power system. PQView is focused on managing power system monitoring information and this program results in the implementation of new advanced applications that increase the value of the monitoring information being collected.

The PS1B project set features the institute's PQView® Software, which stores and analyzes large quantities of PQ-related disturbance and steady-state measurement data. 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 systems analyses. Users can gain access to the same PQ monitoring data through an application known as PQWeb®, a server computer that runs PQView's data management and analysis tasks and allows users to access the results via a web browser such as Internet Explorer or Netscape Navigator. With this software, PQView becomes a multi-platform application, able to work across otherwise incompatible operating systems thereby enabling it to bring PQ data and information to bear on a wide range of power delivery performance issues.

Success statements aligned with project set PS1B are shown in Figure 3 below.

Statement Number	Integrating PQ Monitoring and Intelligent Applications to Maximize System Performance (PS1B)
5	In 10 years, we have **100% compatibility of key electrical system equipment and PQ monitoring and data gathering systems.**
6	In ten years, **all important system devices have integral PQ sensors/monitors.**
7	In ten years, we will be able to **anticipate all preventable and detectable system equipment failures.**
8	In 10 years**,** we will be able to **anticipate all preventable and detectable system faults**
9	In ten years, our monitoring systems will **identify and flag all preventable / intermittent phenomena** and allow location of problems with great accuracy.
10	**faults on a map**, preferably from PQ or other readily-available data sets.
11	In ten years, power quality **data management systems will be automated** as will PQ data mining, reporting, and analysis

Figure 3. Success statements Aligned with EPRI PQ Portfolio Project Set 1C - Achieving Cost-Effective PQ Compatibility between the Electrical System and Loads

C. *Success statements Aligned with EPRI PQ Portfolio Project Set 1C - Achieving Cost-Effective PQ Compatibility between the Electrical System and Loads*

This PQ project set provides advanced PQ disturbance mitigation tools and technology solutions to significantly reduce the number and consequence of electrical disturbances at the transmission, distribution, and end-use level. By integrating key technologies, such as advanced energy storage

technologies with power electronics, this program helps ensure electrical compatibility between the power system and the end-use customer's equipment, enabling PQ to serve as a strategic value creator for the utility industry.

Prominent in the PS1C project set is the Industrial Design Guide (IDG), which seeks to provide a strong technical basis for working with industrial end users in power quality, distribution, and economic development activities. The IDG describes in detail such industrial processes as injection-molded plastics and CNC machining, includes electrical diagrams of the processes and sub-processes, and discusses the economics of process-associated downtime. The descriptions and drawings are interactive, leading the user to important power quality considerations, such as sensitive components, test protocols, solutions, applications, and relevant case studies. This authoritative guide to industrial processes can be used to train new power quality engineers, refresh seasoned representatives, and enhance the credibility of all employees in the presence of end users. The web-based format makes it easy to use and accessible from any location.

Success statements aligned with project set PS1C are shown in Figure 4 below.

Statement Number	Achieving Cost Effective PQ Compatibility between Electrical System and Loads (PS1C)
12	In 10 years, there will be a **universal equipment immunity standard for electronic equipment**, perhaps through IEEE. We will also have a testing standard and certification method.
13	In ten years, we have a **comprehensive equipment design guide that is widely adopted** within the equipment design and manufacturing industry.
14	In ten years, we will thoroughly understand the needs, issues, and **best PQ practices for all PQ-affected customer segments**.
15	In ten years, we will have a **comparable level of understanding of compatibility and PQ issues for DC** as we do for AC.

Figure 4. success statements Mapped to PS1C, Achieving Cost Effective PQ Compatibility between Electrical System and Loads

D. Success statements Aligned with EPRI PQ Portfolio Project Set 1D – PQ Technology Transfer and Knowledge Development

The institute's Power Quality Knowledge project set seeks to provide an array of readable documents covering a wide range of PQ topics, written for both PQ professionals and end-use customer audiences. The program's website contains hundreds of PQ case studies, nearly 300 PQ technical documents, PQ standards references, indexes, conference presentations, and a wealth of other resources.

Success statements aligned with project set PS1D are shown in Figure 5 below.

Statement Number	PQ Technology Transfer and Knowledge Development (PS1D)
16	In ten years, we will have **automated and customizable means to deliver PQ information including newsletters, websites, and custom-packaged material**.

Figure 5. Success statements Mapped to PS1D, PQ Technology Transfer and Knowledge Development

E. Conclusion: critical gaps – Focusing PQ Research

Having developed a clear vision of the institute's PQ research objectives through the success statement process, the next step is to identify what key capabilities must be created or otherwise brought about through either direct research or collaboration with other industry resources. Over 110 critical gaps have been identified in this iteration of the master plan and are currently undergoing refinement.

In addition, a major method of tracking research progress via the master plan will be to periodically assess progress in overcoming the critical gaps. The tables below contain the current critical gaps aligned with the success statement they foster. In addition, the progress toward achieving each gap is approximated.

As illustrated in Figure 6 below, the execution of PQ Research is a five step process:

- Phase 0 – Planning
- Phase 1 – Research and Technology Development
- Phase 2 – Demonstration
- Phase 3 – Deployment
- Phase 4 – Transformation

Each of these phases entails a crucial step toward not only increasing our knowledge of PQ, but in ultimately transforming the PQ world through broad dissemination and adoption of new PQ knowledge and practices.

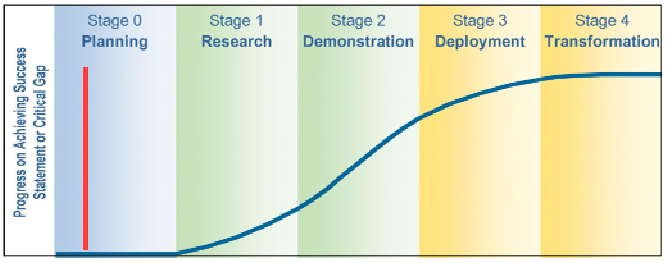

Figure 6. The PQ master plan Critical Gap Process

V. ACKNOLWEDGEMENTS

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CPS Energy
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Dominion Virginia Power
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Great River Energy
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Hoosier Energy Rural Electric Coop., Inc
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