Distribution Systems - Program 180

Program Overview

Program Description

The traditional distribution system philosophy has been to maintain acceptable electrical conditions at the lowest possible cost for all customers. Today, system operators also need to improve the efficiency and reliability of the distribution system, accommodate a high penetration of distributed energy resources, and maximize utilization of existing distribution assets without compromising safety and established operating constraints. Significant changes to the distribution design and operating practices—often referred to as “grid modernization”—are needed to accommodate these new requirements. At the same time, utilities will continue to grapple with the ongoing challenges of an aging infrastructure, increasing customer expectations, increased competition for resources, and an aging workforce.

Given these challenges, electricity distribution companies are under pressure to improve reliability and system performance, build the necessary infrastructure to integrate distributed energy resources, and deal with changing load characteristics, while maintaining efficiency and safety, usually under severe budget constraints. New technologies will be critical to enabling grid operators to meet these goals. New technologies will be critical to future modern grid operation. The modern grid must integrate widespread distributed energy resources as part of the normal operation of the system. In addition, tools and technologies, such as distribution management systems, automation systems, protection systems, and planning tools must be designed to facilitate modern grid operation.

EPRI's Distribution Systems program has been structured to provide utilities with research and application knowledge to support both management of the grid today and the transition to a modern grid. The program includes research that will support smart grid implementation and will provide tools for planning, design, maintenance, operation, and analysis of the distribution system. Members of the program have access to a portfolio of projects that cover the range of distribution issues, as well as the opportunity to collaborate with other members and EPRI technical experts to share ideas and solutions, improve knowledge transfer, and ultimately improve operational performance.

In close collaboration with its members, EPRI has published a 10-year, forward-looking *Distribution Research Area Strategic Plan* (1022335) to articulate its research objectives. This strategic plan is a living document and is under continual refinement by the funding members so that the research being conducted by EPRI is aligned and prioritized with the real needs of the industry. This document is publicly available.

Research Value

With the knowledge acquired through this research program, members will have access to information that can help them do the following:

- Plan and operate a smart distribution system.
- Improve diagnostics, inspection and assessment methods, tools, and techniques.
- Optimize component procurement specifications and equipment application guidelines to improve investment decisions.
- Enhance the location and prediction of system fault locations as part of an overall distribution management system.
- Identify and apply new approaches and strategies for managing underground distribution systems.
- Support the implementation of advanced distribution control functions for reliability improvement, voltage control, and integration of distributed resources—the smart grid.
- Plan for efficiency improvements and new technologies with existing planning models and approaches.

- Assess the economics and benefits of new smart grid applications and advanced technologies.
- Integrate advanced metering and other distributed sensor technologies with planning and operational models and systems.
- Understand industry leading practices in the management and operation of distribution systems.

Approach

The EPRI approach for providing value in the Distribution Systems program involves multiple strategies:

1. **Basic research**. Research into new technologies, practices, and tools provide the foundation for ongoing advancements in the industry. This research includes new technologies, such as nano dielectric cables and solid-state transformers, as well as the foundation for new tools for simulating and analyzing the performance of the distribution system.
2. **Testing**. The work conducted in EPRI laboratories and in cooperation with other industry centers of excellence enables detailed assessment of equipment performance, application issues, and aging characteristics.
3. **Development of application and assessment guidelines and approaches**. Basic research results need to be translated into approaches that can be used by members to plan, manage, and operate the distribution system of the future.
4. **Industry knowledge databases**. EPRI collaboration facilitates the collection of industry-wide information that can help program members understand important trends and characteristics related to equipment and systems.
5. **Technical information transfer and sharing**. This strategy includes active participation in industry groups such as the Institute of Electrical and Electronics Engineers (IEEE); a 24/7 hotline to deal with specific member issues; interest groups to coordinate information sharing on urgent topics; and workshops, conferences, and training in emerging research areas.

Accomplishments

EPRI's Distribution Systems research program has delivered valuable information that has helped its members and the industry in numerous ways:

- In 2012, EPRI research identified a number of key analytical capabilities that will enable distribution planning engineers and designers to use the wealth of new information and advanced control capabilities available through grid modernization for improved asset utilization, efficiency, reliability, and overall distribution system performance.
- EPRI developed a unique reference manual on distribution voltage optimization, which is one of the major elements of grid modernization that is producing significant improvements in energy efficiency and demand reduction. Electric utilities are currently using this reference manual to guide the deployment of advanced volt-VAR (volt-volt ampere reactive) control systems. This reference manual contains the most up to date technical information on approached to volt-VAR control and optimization, as well as sections on Volt-VAR Optimization (VVO) benefits and costs, detailed design guidelines, case studies of successful VVO deployments by electric utilities, and descriptions of innovative vendor offerings.
- In 2012, EPRI assumed a leadership role in fostering the development of Distribution Management Systems (DMS), which are rapidly becoming the “heart and soul” of distribution grid modernization. EPRI convened meetings that have enabled industry leaders from electric utilities and DMS subject matter experts from EPRI to exchange ideas on ways to address the many challenges and barriers to successful deployment.
- EPRI produced and published a compendium of leading industry practices for managing urban underground, reliability, and overhead line worker practices. This information helps member utilities identify leading practices that they can apply to improve efficiency, reliability, and customer satisfaction.

Current Year Activities

In the current year, research program objectives include the following:

- Perform component and accelerated aging analysis on key industry assets such as electronic recloser control systems.
- Develop, apply, and demonstrate advanced fault prediction and location algorithms.
- Conduct workshops on distribution systems' leading industry practices and key reliability drivers.
- Conduct technology assessments and evaluations for smart distribution system applications such as voltage optimization and automatic circuit reconfiguration.
- Develop guidelines to help utilities integrate distributed resources and apply Distribution Management Systems (DMS).

Estimated 2013 Program Funding

$7.0M

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Summary of Projects

PS180A Distribution Planning, Design, and Analysis (070606)

Project Set Description

This project set focuses on modern tools for planning and design of distribution systems, new analysis methods, new modeling approaches, and incorporation of distributed resources into the planning process. Planning and design of electric distribution systems are undergoing dramatic changes in the world of the smart grid. In the past, distribution planning focused on maintaining acceptable electrical conditions in the steady state during peak load conditions and minimum load conditions. With the growing penetration of distributed energy resources (including highly variable renewable generating resources), utilities need to analyze and plan for dynamic operating conditions that can occur at any time throughout the year. The rapid growth of small-scale distributed generation (such as rooftop solar) has created the potential for a considerable number of “zero net energy” homes, which presents a major challenge for short- and long-term load forecasting.

Modern tools are needed to evaluate and mitigate the impact of these fundamental changes to the distribution system characteristics. Planning tools must be able to evaluate distribution performance over annual profiles with many factors affecting load levels and characteristics.

Project Number	Project Title	Description
P180.001	Tools, Methods, & Modeling for Dynamic Distribution Systems	This project focuses on methods for modeling and planning modern distribution systems that include a high penetration of distributed energy resources, including renewable generating resources with highly variable output. Open-source software, and where possible, commercial software tools, are used to demonstrate these concepts so that they can easily be incorporated into a variety of commercial systems.
P180.002	Protecting the Modern Distribution Grid	This project includes the development of new methods for protecting the modern distribution grid. These new methods must take into account the effects of widespread distributed generation and advanced control schemes on the distribution feeder.

P180.001 Tools, Methods, & Modeling for Dynamic Distribution Systems (070607)

Key Research Question

Smart distribution systems will incorporate a variety of new control and system optimization functions, as well as the ability to integrate a wide variety of distributed resources. These functions will take advantage of advanced sensors, system communication infrastructure, new switchgear technologies, and new modeling and simulation capabilities. These functions, which may be implemented as part of overall distribution management systems (DMS), need to be characterized and evaluated within the distribution planning and design process. Key research issues involve the evaluation of modeling requirements and approaches for the design of distribution systems that take into account these advanced functions. For 2013, this project will develop a distribution planning guidebook that describes methods for using advanced software tools to plan and design modern distribution systems. This project will build upon the significant work done in 2011 and 2012, which has focused on fostering the development of new capabilities in commercial software tools for planning and design of future distribution systems.

Approach

This project is a multi-year effort that will develop a planning guidebook that outlines some of the specific planning methods for the modern/future distribution systems that include high penetrations of Distributed Energy Resources (DERs), plug-in electric vehicles (PEVs), demand response, and advanced controls. Electric distribution utilities are faced with the need to modernize their distribution grid to the current and future needs of customers and communities. In the face of such factors as growth in demand, climate change-related system impacts, and human resource shortages, companies will have to change how they plan, design, and operate their distribution grid to continue to provide customers with reliable power at low cost

Planning and design methods for the modern distribution grid must combine elements of traditional power engineering with advanced digital sensing and monitoring technology, information technology, and communications, to provide better grid performance and to support a wide array of additional services to customers. The planning and design objective is to identify the lowest cost option to overcome the foreseen constraints and to maintain a secure and reliable power delivery system into the future.

The proposed distribution planning manual will provide consistency in planning criteria and will guide planners and field service engineers in the way they plan a modern grid. The manual will document a suggested asset management framework for planning, which specifies the objectives, performance requirements, and long-term distribution planning process, including the capital plan, the distribution planning cycle, and load forecasting. The manual will also provide guiding criteria for distribution planning, including primary system configurations, system expansion, voltage regulation, distribution losses, system protection, control and automation, and distributed generation.

Impact

The methods will be demonstrated with real-world distribution systems to illustrate the new approaches:

- The true value of advanced automation functions and distributed resources cannot be realized until these technologies and systems are incorporated into the distribution system planning and design process.
- The project will continue to develop the planning and design tools and methods so that distribution system designs can be optimized based on available technologies and systems.
- The project will publish guidelines for system planning and design that take into account requirements for reliability improvement, with design objectives for reduced losses and improved voltage control.

How to Apply Results

- Members will be able to better plan investments in grid modernization through an understanding of system requirements and performance under different circumstances.
- Members will be able to use the Open Distribution System Simulation software (OpenDSS) and/or commercially available software as a platform for evaluating advanced applications for their own distribution systems. Example applications will provide templates for these evaluations.
- Members will be able to assess the economics and benefits of different applications as a function of their implementation costs.

2013 Products

Product Title & Description	Planned Completion Date	Product Type
Tools, Methods, & Modeling for Dynamic Distribution Systems: Technical Update report on Tools, Methods, and Modeling for Dynamic Distribution Systems project research results. This project focuses on methods for modeling and planning modern distribution systems that include a high penetration of distributed energy resources, including renewable generating resources with highly variable output. Open-source software, and where possible, commercial software tools, are used to demonstrate these concepts so that they can easily be incorporated into a variety of commercial systems.	08/31/13	Technical Update

P180.002 Protecting the Modern Distribution Grid (070608)

Key Research Question

The basic time over current protection schemes used on electric distribution systems have served the industry well for many years. However, the recent industry objective to achieve a "self healing" grid as part of grid modernization is imposing new requirements on existing distribution protection schemes. High penetrations of distributed energy resources that can contribute significant levels of fault current and the presence of advanced control schemes that can automatically reconfigure the electric distribution feeders have added complexity to distribution protection practices. For example, fault current contributions from multiple generation devices at multiple locations on the feeder may alter the time coordination of distribution protection devices that "see" different fault current levels. Furthermore, feeder reconfiguration by advanced control schemes such as fault location, isolation, and service restoration (FLISR) and optimal network reconfiguration may extend the required reach of a protective device beyond the normal settings of the protective devices.

For these reasons and others, utilities need "adaptive" protection schemes that automatically switch to the most appropriate setting group based on current system conditions. Protection systems for the modern distribution grid may also include directional protection schemes that operate based on a combination of fault direction and magnitude. In some cases, distance relays may be needed for the protection of long, lightly loaded feeders.

This proposed project will explore the new requirements and challenges imposed by grid modernization.

Approach

This project will include a review of existing protection practices for electric distribution systems and an investigation of how these practices will need to change as grid modernization occurs. Particular attention will be given to the impact of distributed energy resources (DERs) and advanced controls on existing protection philosophy. Reclosing practices (e.g., protection, placement, type) on overhead and underground distribution systems will be thoroughly explored, and the affect of new reclosing technology (e.g., Pulse Closing) will be determined (for example, does removing multiple high-energy reclosing attempts reduce the likelihood of self clearing?)

The project will review software tools and models for performing protection and short-circuit studies and will investigate the increasing role of distribution protection facilities in distribution feeder automation (FLISR application), distribution feeder "sensorization," and data mining (fault location and anticipation). A related topic that will be covered is the communication infrastructure that is needed to support distribution protection schemes for the modern grid, including suitable communication media, communication standards (DNP versus IEC 61850), and security issues.

Impact

- Help electric utilities accomplish a "self healing" design philosophy for the modern grid.
- Prepares utilities to meet the evolving challenges for distribution system protection associated with grid modernization.
- Identify the role of protective relay Intelligent Electronic Devices (IEDs) as a protective devices and an intelligent sensor.
- Investigate new software tools and models needed for conducting short circuit and protection studies for the modern grid.

How to Apply Results

Distribution protection engineers will use the methods and protocols to evaluate distribution protection schemes and philosophies, including the impacts of energy-efficiency and demand-response programs and technologies.

2013 Products

Product Title & Description	Planned Completion Date	Product Type
Protecting the Modern Distribution Grid: This project includes the development of new methods for protecting the modern distribution grid. These new methods must take into account the effects of widespread distributed generation and advanced control schemes on the distribution feeder.	10/31/13	Technical Update

PS180B Distribution Inspection, Maintenance, Asset Planning (070609)

Project Set Description

This project set is designed to help utility asset managers by providing component reliability and infrastructure inspection-assessment information and knowledge. Laboratory testing is combined with actual field data to build an industry database and provide a better understanding of component reliability, equipment remaining life, fleet populations, and life cycle cost.

Project Number	Project Title	Description
P180.003	Component Reliability	This project addresses one or more components each year with the goal of building and maintaining an industry reliability and performance database. The database addresses components performance, failure characteristics, and fleet population aging and provides a convenient conduit for aggregating, organizing, and utilizing all of EPRI's distribution component research.
P180.004	Inspection, Diagnostics & Life Extension	This project will provide utility asset managers with distribution system inspection methods, practices, and techniques and will conduct unbiased technology evaluations of new inspection techniques.

P180.003 Component Reliability (070610)

Key Research Question

Quantifying distribution component reliability can be challenging for utilities, especially for those without a formal laboratory evaluation and analysis program. The issue becomes more difficult when manufacturers make design and material changes that can have impacts on reliability. Improved understanding of component reliability can be gained through a framework of testing and data collection. This information can then be used to support the fundamental cycle of asset management, including evaluating component design, specifying performance standards, selecting the right component for the task, ensuring proper installation, performing focused inspection, ascertaining component health, and prioritizing replacements.

Approach

This project focuses on components on an individual basis and also on component systems (overhead capacitor installations, for example). This research aims to build and maintain industry knowledge focused on new and legacy distribution components:

- How do the components perform in the field?
- How are they affected by in-service stressors?
- What maintenance activities and schedule provide a balance of cost and longevity?
- When is replacement warranted?

Laboratory testing is combined with utility and industry data to provide a better understanding of individual component reliability and operational parameters that affect reliability. The laboratory part of this work features multi-stress aging methods designed to focus on the stressors present during field service. The laboratory research also includes industry standard and custom-designed experiments to evaluate and validate the performance and durability of distribution system components.

Applying industry test standards alone is not enough to fully evaluate distribution components and rank performance among available products. EPRI addresses this issue by combining field data, industry surveys, and custom laboratory testing for comprehensive component reliability investigations.

The distribution system is comprised of many different components and this project focuses on one or more of these components each year. For 2013, this project will focus on composite pole materials and distribution reclosers. Composite pole research will focus on assessing the performance of currently available composite pole products through laboratory testing and documenting utility experience. For reclosers, the project will focus on understanding leading practices around recloser maintenance and their affect on performance and longevity. The research will focus on aggregating recloser maintenance practices from a diverse set of utility companies, analyzing industry-wide recloser failure data, recloser tear-down analysis, and correlating this information to determine optimized maintenance and replacement practices for hydraulic and electronic reclosers.

Impact

Optimized distribution component selection, application, and inspection yield

- Improved specification and purchasing decisions,
- Enhanced distribution system reliability,
- Reduced distribution system operating costs,
- Improved safety for utility personnel and the general public.

How to Apply Results

Project results will be delivered in test reports, field references, inspection guides, and other training materials. Results will also be compiled into the Distribution Component Reliability and Specification Guidebook. Members can directly apply this information to enhance their procurement, design, operation, and inspection practices. Additional attention will be given to helping utility engineers make asset management decisions regarding their existing component fleet and ensure that the proper information is being tracked to support future decision making.

2013 Products

Product Title & Description	Planned Completion Date	Product Type
Component Reliability: This project addresses one or more components each year with the goal of building and maintaining an industry reliability and performance database. The database addresses components performance, failure characteristics, and fleet population aging. It also provides a convenient conduit for aggregating, organizing, and utilizing all of EPRI's distribution component research.	11/30/13	Technical Update

P180.004 Inspection, Diagnostics & Life Extension (070611)

Key Research Question

Outages that are caused by failing infrastructure are costly for utilities and end-use customers. Routine inspection programs are one tool that utilities can use to reduce failures on their circuits and minimize customer outages. By identifying problems that need repair before they develop into failures, inspection programs can be a cost-effective method for enhancing the quality, reliability, and safety of electric service.

Approach

This work will provide distribution utilities with the necessary information to accurately perform meaningful inspections that will enhance distribution system reliability and operations. This information includes improved methods for performing basic inspections, evaluations of new inspection technologies, and guidance for creating or refining utility line inspection programs.

This year's research aims to provide an updated and holistic look at how utility companies are utilizing infrared inspections and how those programs can be fine-tuned for optimal results. Tasks for this research include:

- Documenting mature and effective utility infrared inspection programs.
- Aggregating and analyzing industry data on the use and effectiveness of infrared inspection programs.
- Laboratory research to enhance infrared inspection severity grading criteria.
- Developing decision support documents for prioritizing and following up on inspection findings.

Impact

Optimized distribution inspection technologies and procedures yield

- fewer service outages,
- improved power quality and reliability,
- reduced outage repair costs, and
- enhanced worker and public safety.

How to Apply Results

Project results will be delivered in workshops, test reports, field and inspection guides, and other training materials. Results will also be compiled into the *Distribution Circuit Inspection and Assessment Guidebook,* and members can directly apply this information to enhance their procurement, design, operation, and inspection practices.

2013 Products

Product Title & Description	Planned Completion Date	Product Type
Inspection, Diagnostics & Life Extension: This project will provide utility asset managers with distribution system inspection methods, practices, and techniques. It also will conduct unbiased technology evaluations of new inspection techniques.	08/30/13	Workshop, Training, or Conference

PS180C Cable Systems Management (070612)

Project Set Description

This project set focuses on the cables and cable systems associated with underground distribution systems. The goal is to provide members with guidance for cable and cable systems selection, installation, operation, and maintenance, as well as a basis for justifying a replacement management strategy for cable fleet populations. The project set builds on previous work in to assess the latest approaches for diagnostics and cable fleet management.

Project Number	Project Title	Description
P180.005	Methods for Cable Fleet Management	Develop, adapt, and enhance risk-based research to help identify optimal fleet management strategies for installation, replacement, rejuvenation, and maintenance of underground cables and cable systems.
P180.006	Advanced Cable Diagnostics	This project expands on earlier EPRI work and will build on its collaborative effort with the U.S. Department of Energy and in the Cable Diagnostics Focused Initiative (CDFI) with the help and partnership of other industry and utility experts.

P180.005 Methods for Cable Fleet Management (070613)

Key Research Question

Segments of the electric distribution system underground infrastructure have been in service for many years, and in some cases beyond their design life. Many companies face substantial future costs to replace aging underground distribution cables and cable systems. Today, utility decisions are made under stringent expense controls, limited capital, and increased public concern about reliability. These factors combine to make well-informed decision making more crucial and yet more elusive than ever. Developing and justifying a replacement management strategy for cable fleet populations, and the rational basis for it, are increasingly important.

Approach

EPRI has been conducting research to help identify optimal fleet management strategies for installation, maintenance, health assessment, rejuvenation, and replacement of underground cables and cable systems. Essential steps in this development include identification of economic and business case scenarios, assessment of the quality and availability of data relevant to these types of problems through detailed work with host utilities, and identification of the successful application of cable fleet management methodology concepts.

Impact

- Help utility asset managers deal with the problem of aged cable and cable system populations
- Formulate innovative methodologies to justify investment strategies
- Ensure effective cable management programs

How to Apply Results

Underground cable fleet managers can use the results of this project to better understand and improve cable selection, procurement, replacement, rejuvenation, and maintenance strategy.

2013 Products

Product Title & Description	Planned Completion Date	Product Type
Cable Fleet Management Workshop: Develop, adapt, and enhance risk-based research to help identify optimal fleet management strategies for installation, replacement, rejuvenation, and maintenance of underground cables and cable systems. Lessons learned will be catalogued and shared with the collaborative membership in the form of a best practices cable fleet-management workshop.	07/01/13	Workshop, Training, or Conference

P180.006 Advanced Cable Diagnostics (070614)

Key Research Question

North America has a significant underground electric distribution system that is nearing the end of its design and service life. Global replacement of aging underground facilities is not an option, and utilities require better diagnostic methods, technologies, and tools to assess the condition of installed systems. Knowledge of cable condition provides utilities with a basis for implementing a staged rejuvenation or replacement program over a number of years and helps avoid unexpected costs associated with increasing failure rates. The utility industry has focused on cable diagnostics for many years, but is still facing uncertainty and confusion regarding the effectiveness and accuracy of cable diagnostic testing techniques and methods.

Approach

This project expands on a body of earlier EPRI work on diagnostics methods and approaches. Particularly challenging are hybrid circuits with mixed paper-insulated lead-covered (PILC), cross-linked polyethylene (XLPE), and ethylene propylene rubber (EPR) dielectric systems, as well as highly branched networks. Recently completed research on new diagnostic technologies reveals the potential of new methods that, when combined with conventional partial discharge and dissipation factor measurements, could enhance the prediction of future performance and service life of cable circuits. EPRI intends to expand the scope of this project and will build on its collaborative effort with the U.S. Department of Energy–sponsored Cable Diagnostics Focused Initiative (CDFI).

Impact

- Deliver technology and case study reviews
- Provide methods to establish the condition of aged PILC and extruded dielectric distribution cables
- Enable prioritization of cable replacement, minimizing the present cost of cable replacement programs
- Foster improved reliability through enhanced knowledge of the condition of installed underground assets and active replacement of those with the least remaining life

How to Apply Results

Utility engineers will be able to apply information from technical reports, webcasts, and workshops on cable diagnostics to more effectively identify those assets in need of repair or replacement due to aging.

2013 Products

Product Title & Description	Planned Completion Date	Product Type
Advanced Cable Diagnostics: This workshop expands on earlier EPRI work and will build on its collaborative effort with the U.S. Department of Energy and in the Cable Diagnostics Focused Initiative (CDFI) with the help and partnership of other industry and utility experts.	07/01/13	Workshop, Training, or Conference

PS180D Distribution Reliability Management (070615)

Project Set Description

Direct and sustained improvements to electric system reliability are clearly key benefits of this research. Taking advantage of the collaborative experiences of participating members, coupled with information about the state-of-the-art in technology, programs and practices will provide member utilities with the information necessary to structure and prioritize a reliability improvement program. This project set is focused on managing distribution reliability and will develop and evaluate approaches for designing distribution systems for reliability and selecting the optimum methods for improving reliability as a function of distribution system characteristics. Managing fault performance is a key aspect of managing reliability and the project set includes continued advancement of fault location approaches, fault analytics, and methods to reduce the number of faults.

Project Number	Project Title	Description
P180.007	Fault Location & Anticipation	EPRI has developed and tested technologies to make fault location systems easier for utilities to install and use. Such systems allow operators to view the estimated location of a fault, which helps operators direct crews to do switching and locate faults faster.
P180.008	Reliability Practices and Drivers	This project identifies leading practices and guidelines for improving distribution reliability. The core activity of this research is the identification and documentation of leading practices for maintaining and improving distribution system reliability.
P180.009	Reliability Special Topics	This project will coordinate with the activities of IEEE 1366 to help advance the state of the art in calculating reliability metrics, adjusting for major events, and applying normalization approaches to make the reporting more useful.

P180.007 Fault Location & Anticipation (070616)

Key Research Question

Previous EPRI research in this project and utility implementation experience have shown that fault location can be used successfully to reduce repair and restoration times. Work in 2012 is showing excellent preliminary results for applying advanced fault location algorithms to incipient fault events that can be precursors to cable splice failures and arrester failures. Key research questions include determining the extent to which this technology can be applied for different types of distribution systems and establishing the percentage of cable splice failures and arrester failures that could exhibit these precursor events.

Approach

EPRI has developed and tested systems to make fault location systems easier for utilities to install and use. Such systems allow operators to view the estimated location of a fault, which helps operators direct crews to do switching and locate faults faster. These systems also locate temporary faults, so that problem locations can be identified before permanent faults occur. Along these lines, current research is extending the algorithms for locating incipient faults. The main goal in 20131 is to test the performance of this system based on a larger library of field events and then to investigate ways that the effectiveness can be improved through combinations of technologies such as

- integration of fault indicator data with substation-based fault location;
- advanced meters and triangulation; and
- integration of data from automated feeder devices such as reclosers, switches, capacitors, and regulators.

Impact

- Identify temporary fault locations to improve maintenance strategies.
- Improve restoration time for enhanced System Average Interruption Duration Index (SAIDI) and Customer Average Interruption Duration Index (CAIDI).
- Eliminate or reduce repeated momentary faults.
- Improve repair times with reduced susceptibility to cascading failures.
- Locate precursors of equipment failure, so failing equipment can be removed before it fails.
- Provide information to operators on fault types based on waveform signatures.

How to Apply Results

Distribution system operators can integrate this system with their own monitoring and information systems to dispatch crews to estimated fault locations in near real time. The fault-location system includes fault location algorithms, interfaces to a variety of distribution modeling databases and monitoring equipment, and a user interface for operators.

2013 Products

Product Title & Description	Planned Completion Date	Product Type
Fault Location & Anticipation: EPRI has developed and tested technologies to make fault location systems easier for utilities to install and use. Such systems allow operators to view the estimated location of a fault, which helps operators direct crews to do switching and locate faults faster.	12/31/13	Technical Update

P180.008 Reliability Practices and Drivers (070617)

Key Research Question

Reliability of service is one of the fundamental responsibilities of electric utilities. Every year utilities face the same question, “How should I best spend my reliability budget to effect the greatest improvement to key reliability metrics, affording my customers the most reliable service possible, in a manner that is economically prudent?” Reliability is the type of issue that is not addressed with a single solution. Continuous vigilance on multiple fronts is required to simply keep reliability at the same level, particularly when considering the infrastructure gets a year older every year. Utilities around the globe routinely invest in programs as diverse as tree trimming, cable replacement, thermal inspection, protective device audits, overhead inspection, insulator cleaning, storm preparedness drills and distribution automation to meet reliability targets in this ever more electricity dependant world.

Of particular note are recent increases in investment in distribution automation. Utilities have been deploying distribution automation systems in one form or another for over twenty years, and in a few cases far longer. These systems tend to be highly diverse in scale, purpose, architecture, capacity, maintainability and communications. This research project aims to integrate distribution automation into Reliability Immersions top enable documentation of a Distribution Automation practices database and the development of a generalized distribution automation application guide.

Approach

Utilities and vendors have developed new approaches, techniques, triggers and technologies in each of these reliability program areas. This research project utilizes the Immersion process to gather, analyze and publish leading practices from a number of diverse utilities to serve as a learning resource for members, as well as identifying opportunities for further EPRI research.

This project is based on a multi-year plan designed to provide near term benefits to members by documenting the wide variety of existing approaches to reliability improvement, in a format that will allow members to evaluate future plans against a rich set of peer examples. This effort of documenting existing practices will lead to a number of results including:

- Collation of meaningful case studies demonstrating the results of different approaches, prioritizations, and triggers for traditional reliability improvement programs.
- Generalized guideline equipping members with a leading practices based approach to effecting meaningful and lasting improvement to reliability
- Generalized guideline equipping members with a logical roadmap for planning, architecting, deploying, operating and maintaining a distribution automation system, focused on the key business drivers unique to each particular utility.
- Identification and scoping of new research and development activities focused on reliability improvement.

Impact

Direct and sustained improvements to electric system reliability are key benefits of this research. Taking advantage of the collaborative experiences of participating members, coupled with information about the state of the art in technology, programs and practices will provide member utilities with the information necessary to structure and prioritize a reliability improvement program. As an example, using knowledge of the state of the art in communications, switching devices, sensors and analyses and control systems, members will be well positioned to start new distribution automation programs or evolve their existing programs. Application of the distribution automation guide will ensure that members are well informed with alternatives and rationale behind each of the major decision points along the path towards distribution automation.

How to Apply Results

- Members will be able to view Reliability Program technologies, program triggers and practices of those who have participated in immersions.
- Members will be able to view Distribution Automation architectures and practices who have participated in immersions.
- Members will be able to implement the guidelines documented in the Reliability Improvement Program Guide.
- Members will be able to implement the guidelines documented in the Distribution Automation Application Guide.
- Members will get a head start on awareness of new Distribution Automation technologies that may enable or complement their requirements.

2013 Products

Product Title & Description	Planned Completion Date	Product Type
Reliability Practices and Drivers: This project identifies leading practices and guidelines for improving distribution reliability. The core activity of this research is the identification and documentation of leading practices for maintaining and improving distribution system reliability.	07/01/13	Workshop, Training, or Conference

P180.009 Reliability Special Topics (070618)

Key Research Question

Utilities face an ongoing challenge to manage reliability and to determine the best approaches to prioritize investments in reliability programs. Reliability programs typically must consider customer impact, concentration of customers, infrastructure demographics, and the system response to routine events and particularly to major storms.

Approach

This work will focus specifically on characterizing the performance of traditional and smart grid investments for reliability improvement and storm performance.

Specific areas of work may include:

- Developing advanced approaches for weather normalization
- Assessing the benefits of specific automation investments on a feeder-by-feeder basis
- Effectively using data from outage management systems
- Using reliability data to assess vegetation management and other maintenance programs
- Relating reliability performance to distribution system characteristics

EPRI will engage with experts from the Institute of Electrical and Electronics Engineers (IEEE) 1366 Working Group of the Distribution Subcommittee to identify industry priorities to better characterize system performance and prioritize investments. The project will also coordinate with the cost/benefit framework for assessing smart grid projects developed by the U.S. Department of Energy (DOE) and EPRI. EPRI will also engage subject-matter experts from the utility membership to provide guidance and input on research activities. Specific project work plans will be developed at the direction of sponsoring utilities.

Impact

- Better use of reliability data for characterizing system performance in ways that can be used for assessment of investment effectiveness
- Reliability metrics for evaluating smart grid investments
- More effective use of available funds for improving reliability performance

How to Apply Results

Members will be able to apply these techniques directly to their own internal reliability cost-benefit calculation systems.

2013 Products

Product Title & Description	Planned Completion Date	Product Type
Reliability Special Topics: This work will focus specifically on characterizing the performance of traditional and smart grid investments for reliability improvement and storm performance.	12/31/13	Technical Resource

PS180E Risk Mitigation Strategies (070619)

Project Set Description

This project set is focused on safety. For 2013 the topics to be covered will be trends in risk mitigation and grounding. The goal is to provide timely and relevant knowledge to members on issues related to these two topics. This knowledge is expected to enable members to take appropriate action immediately.

Project Number	Project Title	Description
P180.010	Trends and Developments in Risk Management	The objective of this project is to identify and investigate new developments related to risk management for utility workers and the public. Areas include new equipment, new testing methods, new training materials, and new practices.
P180.011	Grounding and Personal Protection on Underground Systems	This project will develop a reference guideline for distribution grounding of underground distribution systems, including conventional underground systems (ducted manhole systems), network systems, and URD systems. This project will fill a gap by providing comprehensive grounding guidelines for underground distribution.

P180.010 Trends and Developments in Risk Management (070620)

Key Research Question

This project aims to identify and investigate new developments related to risk management for utility workers and the public. Areas include new equipment, testing methods, training materials, and practices.

Approach

This work will focus specifically on evaluating new developments in risk management. Specific areas of work may include the following:

- Clothing performance for arc flash
- Updates on testing approaches for contact voltage and elevated neutral-to-earth voltage

- Updates and evaluation of regulatory changes (e.g., National Electrical Safety Code® [NESC], Occupational Safety and Health Administration [OSHA])
- New approaches to personal protection
- Evaluation of personal grounding equipment
- Testing methods for tools and personal protective equipment (PPE)
- Methods of identifying failing or otherwise hazardous utility equipment

Specific project work plans will be developed at the direction of sponsoring utilities.

Impact

Benefits will include improved regulatory compliance and improved management of risk to workers and the public.

How to Apply Results

Specific tasks will be developed based on the direction of sponsoring utilities. Annual work will include evaluations of new equipment and new scientific developments related to risk management. An annual online workshop will be held in addition to the Jodie Lane conference.

2013 Products

Product Title & Description	Planned Completion Date	Product Type
Trends and Developments in Risk Management: Specific tasks will be developed based on the direction of sponsoring utilities. Annual work will include evaluations of new equipment and new scientific developments related to risk management. An annual online workshop will be held in addition to the Jodie Lane conference.	11/30/13	Workshop, Training, or Conference

P180.011 Grounding and Personal Protection on Underground Systems (070621)

Key Research Question

Distribution grounding is a key area of focus for utilities in managing and operating their distribution system. Grounding of the electric supply system provides a means to safely dissipate electrical current into the earth to protect equipment, utility workers, and the public. Although several references on grounding are available, including EPRI's Distribution Grounding Handbook (TR-106661-V1, 1996), IEEE standard 1048, and OSHA 29 CFR Part 1910, a review of these existing guidelines for grounding reveals that they focus on overhead systems, and that a need exists for guidelines for grounding underground distribution systems, including network systems, conventional radial systems, and underground residential distribution (URD).

The industry requires guidance on proper grounding of new construction of underground systems, proper grounding when rehabilitating or upgrading existing underground infrastructure, and finally, guidance for utility workers for applying personal protective grounds for safely working on underground equipment. This project builds upon a literature and technology review developed in 2012 focusing on grounding and personal protection on underground systems.

Approach

This project will develop a reference guideline for distribution grounding of underground distribution systems, including conventional underground systems (ducted manhole systems), network systems, and URD systems. The guideline will include content addressing the following three areas:

- New construction -- the guideline will describe preferred grounding practices for building new underground distribution systems, including grounding of submersible vaults and manholes, padmounted equipment, and duct bank / conduit systems for conventional UG, network, and URD designs.
- Existing construction -- the guideline will describe approaches for rehabilitating existing underground infrastructure to ensure proper grounding.
- Worker protection -- the guideline will describe worker practices for positioning grounds when working on underground facilities to ground the work zone, including working in vaults and manholes, and working with padmounted equipment. This section will consider single point and bracket grounding, as well as the use of tools such as portable ground mats. This section will include descriptions of existing leading practices for worker protective grounding being employed by utilities around the country.

Impact

The enhanced knowledge developed in the grounding reference should improve equipment protection and improve safety for workers and the public.

How to Apply Results

Using the resulting reference, members will be able to use the content to improve their approaches to protective grounding.

2013 Products

Product Title & Description	Planned Completion Date	Product Type
Grounding and Personal Protection on Underground Systems: The objective of this project is to develop a reference guideline for distribution grounding of underground distribution systems, including conventional underground systems (ducted manhole systems), network systems, and URD systems. This project will fill a gap by providing comprehensive grounding guidelines for underground distribution.	11/30/13	Technical Update

PS180F Grid Modernization (070622)

Project Set Description

This project set develops and evaluates advanced distribution system applications for reliability improvement, system optimization, asset management, and distributed resource integration. These applications involve implementation of monitoring equipment (sensors), communications infrastructure, and advanced protection and control functions. The program will support utilities in the migration to a Distribution Management System (DMS) with model-based management of the system. The DMS of the future will need to integrate many functions to optimize system performance, reduce losses, optimize voltage and VAR control, improve reliability through system reconfiguration and fast restoration, and integrate distributed resources. The project set builds on the analytical capabilities of the Open Distribution Simulator Software (OpenDSS) software for analytical assessment of advanced distribution management functions. It also works with member utilities to demonstrate advanced functions for development of application guidelines and identification of gaps in the technologies.

Project Number	Project Title	Description
P180.012	Distribution Management Systems Planning Guide	This project will provide guidelines and detailed information needed to plan for distribution management system (DMS) implementation. The project includes criteria (an “opportunity matrix”) for selecting DMS applications to address important business drivers, functional descriptions of key applications, guidelines for identifying a generalized (conceptual) architecture, implementation and sustainment strategies, and other important information.
P180.013	Benefit-Cost Analysis for Smart Distribution Applications	This project includes enhancing the software tool (an Excel spreadsheet) that was developed in 2012 for analyzing the costs and benefits of smart distribution applications. Program users will be able to select smart applications of interest, enter required data (application-specific parameters, distribution system data, financial information, unit cost estimates) and obtain outputs such as analysis of revenue requirements, benefit-cost ratio, payback period, return on investment, and other information needed to determine the economic justification for smart distribution investments.
P180.014	Smart Distribution Applications for Distributed Energy Resources	This project will include an in-depth investigation of smart distribution applications for monitoring and controlling distributed energy resources (DERs) (distributed generation, including renewables, and energy storage). The expanded role of DERs in volt-VAR optimization, reliability improvement measures, system reconfiguration, micro grid operation and control, and other DA/DMS applications will be explored.

P180.012 Distribution Management Systems Planning Guide (070623)

Key Research Question

As electric utilities embark on a plethora of new smart grid projects to develop and deploy new technologies on their electric distribution systems, they face numerous organizational challenges. The smart grid will provide a wealth of new information and many new intelligent controllers and control schemes that will enable electric utilities to improve the performance, reliability, efficiency, and safety of the electric distribution system. To enable the distribution system operators or dispatchers to effectively manage these systems and information, the control center needs to become much “smarter.” One of the key elements of the new smart control center is the distribution management system (DMS).

Transitioning from mostly manual processes for managing and operating the electric distribution system to automated processes requires careful planning and a well-thought-out strategy. This project will provide a methodology for developing a detailed plan for DMS implementation. The *DMS Planning Guide* developed in 2012 provided a roadmap for DMS implementation. The 2013 project will delve considerably deeper into the DMS commissioning process, including consideration of the business process re-engineering needed in the distribution operations area for successful implementation.

Approach

Making the transition from mostly manual, paper-driven processes to electronic computer-assisted decision-making with some fully automatic controls requires careful planning and a considerable amount of business process reengineering. Existing operating procedures must be rewritten to address the new job requirements and responsibilities, and new skill sets and possibly new organizational structures are needed within the distribution control center. Training and certification of dispatchers who must interact with the new advanced monitoring and control systems are important new issues that must also be thoroughly explored and addressed. This project will provide guidance on the business process reengineering that is needed to address these issues.

Another set of implementation issues that will be addressed by this project is commonly referred to as "operating technology versus information technology" (OT vs. IT). Today's DMS interfaces with numerous enterprise IT systems (e.g., OMS, geographic information systems [GIS]) using common IT standards (e.g., Enterprise Service Bus). However, such technologies may not be effective for transmitting real-time information and control commands with proper security. The project will examine issues like this and provide guidance on resolving these issues without compromising operating needs or IT standards.

Finally, the project will provide guidelines for determining the IT infrastructure and communications to support grid modernization.

Impact

- Provide a foundation for incorporating new DMS-based business processes in existing control centers.
- Develop mechanisms for operator training and certification.
- Estimate communication bandwidth need to support DA and DMS functions.

How to Apply Results

Members will use the results to help specify distribution management systems as part of overall smart distribution development, develop the business cases for DMS functions, and evaluate performance of systems being implemented.

2013 Products

Product Title & Description	Planned Completion Date	Product Type
Distribution Management Systems Planning Guide: This project will provide guidelines and detailed information needed to plan for distribution management system (DMS) implementation. The project includes criteria (an “opportunity matrix”) for selecting DMS applications to address important business drivers, functional descriptions of key applications, guidelines for identifying a generalized (conceptual) architecture, implementation and sustainment strategies, and other important information.	08/30/13	Technical Update

P180.013 Benefit-Cost Analysis for Smart Distribution Applications (070624)

Key Research Question

A major obstacle to deploying smart distribution applications is lack of economic justification. Some smart distribution applications require a substantial investment of technical and financial resources; therefore, it is important to determine if the benefits achieved outweigh the total investment cost of ownership. Many of the benefits provided by the smart distribution applications do not translate easily into monetary terms; consequently, cost–benefit comparisons can be difficult to perform. For example, the application “Fault Location Isolation and Service Restoration” provides significant improvement in customer outage duration. However, no well-established procedure for converting improved reliability exists to direct monetary benefits to determine if these benefits outweigh the high implementation cost for this application. EPRI will perform the necessary research to develop algorithms to compute the benefits and costs of each application.

Without a clear understanding of the business case, an electric utility may not be able to proceed beyond a limited-scale demonstration project.

The proposed software tool will help electric utilities make informed decisions as to whether the benefits of smart distribution applications outweigh the costs.

Approach

EPRI plans to build upon the Excel spreadsheet that was created as part of the 2012 results. This project will enable electric utilities to perform a benefit-cost analysis to determine if smart distribution benefits outweigh the costs. The spreadsheet will include facilities to enable electric utilities to select the application functions of interest and enter the technical and financial information needed to compute benefits and costs. Outputs will include an analysis of revenue requirements, benefit-cost ratio, payback interval, return on investment, and other economic indicators.

The program inputs will include items that are readily available at most utilities. Suitable default values will be provided where possible.

The spreadsheet developed during 2012 included algorithms for estimating the costs and benefits of implementing Volt-VAR Optimization (VVO) and fault location, isolation, and service restoration (FLISR). 2013 activities will include the addition of distributed energy resource (DER) management functions and plug-in electric vehicle (PEV) smart-charging strategies to the spreadsheet.

The 2013 work activities will also develop guidelines for addressing the business aspects of adopting new technology (including, for example, depreciation, rate of return, regulatory treatment and acceptance) and for influencing regulations.

Impact

The project results will provide the resources for needs assessment, business case development, and specification of advanced control functions that could be implemented as part of a distribution management system including:

- performance assessment for advanced control functions,
- benefits that can be achieved with advanced control functions, and
- requirements for advanced control functions.

How to Apply Results

Members will use the results to help determine the economic justification for smart distribution expenditures.

2013 Products

Product Title & Description	Planned Completion Date	Product Type
Benefit-Cost Analysis for Smart Distribution Applications: This project includes enhancing the software tool (an Excel spreadsheet) that was developed in 2012 for analyzing the costs and benefits of smart distribution applications. Program users will be able to select smart applications of interest, enter required data (application-specific parameters, distribution system data, financial information, unit cost estimates), and obtain outputs such as analysis of revenue requirements, benefit cost ratio, payback period, return on investment, and other information needed to determine the economic justification for smart distribution investments.	12/31/13	Software

P180.014 Smart Distribution Applications for Distributed Energy Resources (070625)

Key Research Question

This project will include an in-depth investigation of smart distribution applications for monitoring and controlling distributed energy resources (DERs), which include distributed generation, renewables, and energy storage. The projects will explore the expanded role of DERs in volt-VAR optimization, reliability improvement measures, system reconfiguration, micro grid operation and control, and other distribution automation and distribution management system applications.

Approach

This project will evaluate the application of advanced monitoring and control functions for DERs that accomplish multiple objectives. The potential to integrate DERs into volt-volt ampere reactive (VAR) optimization, system reconfiguration (including micro grids), and other applications will be explored. The approach will involve implementation of models for the basic functionality of DER monitoring and control systems. The models will be applied for different distribution system characteristics, load characteristics, and fault profiles. Using models to evaluate performance issues will permit development of basic requirements for these systems and assessment of the potential benefits without actually deploying systems in the field. The result of the analysis will be an assessment of requirements and expected benefits of advanced reconfiguration functions.

As part of the ongoing project that is partially funded by the U.S. Department of Energy (Funding Opportunity 479) , the project team will implement smart grid features defined above into a family of inverters ranging from 60 kilovolt-ampere (kVA) to 500 kVA. The team will also interface multiple PV inverters to a utility supervisory control and data acquisition or distributed control system, reducing the communication and control burden of large plants with many elements that support plant operation (e.g., inverters, trackers, monitors for PV, and storage). In this way, utilities engineers can coordinate a more effective distribution operation and increased distribution line stability.

Impact

- Members will gain insight into new distribution functions and operational benefits that can be derived from advanced metering infrastructure (AMI) investments through characterization of important distribution applications and their associated requirements.
- Business cases for advanced metering that rely on distribution operations benefits as part of the plan will be more accurate.
- Members can develop accurate implementation and deployment plans for distribution operation functions that are built on AMI investments.

How to Apply Results

Members will be able to better plan investments in smart distribution applications through an understanding of application requirements and performance under different circumstances. Members will be able to use the OpenDSS (Distribution System Simulator) software as a platform for evaluating advanced applications for their own distribution systems. Example applications will provide templates for these evaluations. Members will be able to assess the economics and benefits of different applications as a function of their implementation costs.

2013 Products

Product Title & Description	Planned Completion Date	Product Type
Smart Distribution Applications for Distributed Energy Resources: This project will include an in-depth investigation of smart distribution applications for monitoring and controlling distributed energy resources (DERs) (distributed generation, including renewables, and energy storage). The expanded role of DERs in volt-VAR optimization, reliability improvement measures, system reconfiguration, micro grid operation and control, and other DA/DMS applications will be explored.	11/30/13	Technical Update

PS180G Technologies Evaluation & Assessment (070626)

Project Set Description

This project set evaluates and assesses new technologies for smart distribution systems that could become an integral part of the future distribution infrastructure. The rigorous unbiased evaluation and assessment methodology includes laboratory-specified testing combined with practical field experience to produce fact-based results.

Project Number	Project Title	Description
P180.015	Sensors	This project will research and evaluate sensor technologies for current and voltage monitoring, as well as equipment diagnostics and asset management methodologies. It will also investigate the key considerations involved and possible implementation methodologies for the development of a valuable and successful integrated condition-monitoring program.
P180.016	Advanced Meters	This project will use a combination of laboratory and field testing to characterize application issues and develop lifetime characteristics of advanced metering equipment.

P180.015 Sensors (070627)

Key Research Question

Sensors support a number of applications key to improvements in distribution system reliability and efficiency. In some cases sensor measurements directly drive analyses and control applications. Sensors are also fundamental to distribution network state estimation, which is fast becoming a prerequisite for smart grid functionality. Transition from a passive to an active distribution network through condition monitoring allows for improved performance and flexibility of network operation as it

- enables applications to improve grid efficiency,
- provides self-healing capabilities to improve or maintain quality of service and reduce costs,
- increases the capacity of the grid to host distributed generation,
- defers investments and keeps up with possible higher load demands, and
- improves asset management decisions.

Other drivers for deploying an active monitored investment include assuring security of supply, system safe operation, and environmental compliance. Monitoring extensive distribution systems is challenging due to the investment associated with the deployment and maintenance of sensors and the scale of the resulting data. Sensing technologies should be low cost to allow widespread deployment, and must incorporate cost-effective communications to allow integration with the smart distribution system infrastructure. This project will research sensor technologies and infrastructures for the management of electricity distribution networks considering all the above factors.

Approach

This project is based on a multi-year plan designed to provide short-term benefits to members as well as perform more fundamental research to take advantage of new learnings and developments with the experience and knowledge established from previous years. In 2013, this project continues to expand the Sensor Application Guide by incorporating a new set of distribution applications. Additionally, laboratory testing will continue to evaluate the effectiveness of two new classes of sensors to meet specific application requirements. Finally, the project will evaluate field trials initiated in 2012 to determine to effectiveness of the deployed sensors to meet application requirements

Impact

Application of sensors on the distribution system supports many key applications that drive benefits, including improved reliability, improved energy efficiency, reduced maintenance costs, improved power quality, and increased operational awareness. This research will build upon the work initiated in 2012 by adding more future leaning applications to the Sensor Application Guide, enabling utilities to plan sensor deployments in a manner that is future-proofed for cutting-edge applications.

This project will help members with the following:

- Understanding and assessing the performance of new sensor technologies that can be part of smart distribution systems
- Development of application guidelines for new sensor technologies
- Enabling integration of new sensor technologies with overall distribution management systems

How to Apply Results

- Members will gain an understanding of new sensor technologies.
- Members will understand the benefits and limitations of important new sensor technologies and will receive application guidelines from actual field experiences.
- New sensor technologies must be integrated with overall distribution management systems and can provide the basis for new real-time system performance optimization. This project will research and document methodologies to help achieve this.
- Members will get a head start on developing and implementing these advanced applications through documentation of sensor functionality, accuracy, and applications
- Members will get a head start on awareness of cutting-edge sensor technology for application on the distribution system through involvement with research in this area.

2013 Products

Product Title & Description	Planned Completion Date	Product Type
Distribution Sensors: This project will research and evaluate sensor technologies for current and voltage monitoring, as well as equipment diagnostics and asset management methodologies. It will also investigate the key considerations involved and possible implementation methodologies for the development of a valuable and successful integrated condition monitoring program.	10/31/13	Technical Update

P180.016 Advanced Meters (070628)

Key Research Question

Utilities continue to evaluate and deploy advanced solid-state meters for many reasons, including the driving out of operational cost, smart grid support, and demand side controls. These technologies have been in limited use for many years, but are now being rolled out in large numbers as deployments drive meter replacements. However, many utilities still have limited experience with these products and many of the advanced feature sets they offer, and for those with large rollouts, may be having performance related questions and/or experiencing issues manifesting themselves in the performance of the meter itself. With this, the important questions remain regarding reliability, robustness, and functionality. Utilities continue to express the need to understand important field applications, failure modes, performance characteristics, total cost of ownership, and the technology's ability to operate within a wide range of stress environments.

Approach

This project focuses on evaluating meter products, appurtenances, and their application issues that will become part a smart grid system. It will use a combination of laboratory testing and actual field performance assessments to develop conclusions about advanced meter capabilities and performance characteristics. In addition, some of the research findings may also provide input to other efforts in support of financial and other metrics related to the advanced meter and its application. This research has a number of important components:

- Overstress testing in the laboratory. This project effort will utilize steady state and/or dynamic overstress test protocols such as temperature / humidity, electrical, and mechanical, to understand realistic failure modes and life performance characteristics over extended periods of time.
- Abnormal voltage and/or current testing in the laboratory. This project effort includes testing to determine failure modes, performance characteristics, and safety related performance aspects such as fail-safe, of meters and appurtenances when subjected to highly elevated electrical conditions that may be induced upon a meter under adverse field conditions.
- Characterization of the effects of electrical conditions, such as superimposed signals, harmonics, and power factor, on meter accuracy. While in a highly dynamic and electrically evolving network, meters will be expected to perform accurately and reliably over time, in addition to providing data for the characterization of the utility’s electrical system operation. As new types of loads and sources of energy are connected to the utility’s network, a very challenging and dynamic electrical state will be developed. The meters performance under these and other newly evolving conditions will require characterization. Laboratory testing will characterize meter performance and other operational parameters for steady state and dynamic conditions.
- Evaluation of important field application and performance issues through experience with initial advanced metering deployments.

Impact

- Understand new application and issues for advanced meters as they are integrated with smart distribution systems.
- Understand modes of failure, safety implications of meter designs, and performance characteristics of solid-state meters for risk assessment, planning, and budgeting of maintenance and replacement plans.
- Understand the performance characteristics of solid-state meters when exposed to a newly evolving electrical environment induced by advanced loads such as VFD’s, and sources of energy through devices such as inverters. These new conditions have an elevated importance for assessing existing meter products as they may have significant exposure as the electrical environment continues to evolve around them.
- Understand the impact of integrated communications with advanced meters on application issues, such as, performance characteristics, maintenance requirements, and installation issues.

How to Apply Results

- Members will have the necessary information to be able to develop increasingly accurate budgets and plans for advanced meter deployments and maintenance activities.
- Financial and technical buyers of the members will be provided with additional information to allow for more informed decision making. Being able to consider more advanced information in determining total cost of ownership and expected performance characteristics throughout the products expected lifetime.
- Members will be able to develop better plans for integrating advanced meters with smart distribution systems by understanding important application issues and meter limitations / capabilities, and performance characteristics.

2013 Products

Product Title & Description	Planned Completion Date	Product Type
Advanced Meters: This project will use a combination of laboratory and field testing to characterize application issues and develop lifetime characteristics of advanced metering equipment.	09/30/13	Technical Update

PS180H Technology Development (070629)

Project Set Description

The Technology Development project set is designed to provide utilities with new technological developments applicable to distribution systems. As pressures to improve efficiency, reliability and cost of service continue to grow, solutions to monitor and control the distribution system in real-time becomes ever more vital. Going far beyond the basic measurements familiar in the SCADA systems of the last century, the next generation of distribution sensing systems must provide near power quality monitor capabilities, at reasonable total ownership costs, and with highly scalable installation and commissioning processes.

Project Number	Project Title	Description
P180.022	Innovative Distribution Sensors	This project will research and develop new class(es) of sensors for application on the distribution system beyond current and voltage monitoring to support asset management applications such as incipient failure detection and cable failure prediction. This is the first of a multi-year effort to scope, design, prototype, test, field validate and commercialize the sensor hardware, power supplies, communications interfaces, protocol interfaces, and information technology algorithms to enable deployment of high- value solutions.
P180.023	Integrated Technology for Distribution Systems Applications	The results of this research will be directly applicable to specific power system measurement, diagnostic and benchmarking activities. Developed technology would be directly integrated with power system hardware and measurement points to provide more useful power system information.

P180.022 Innovative Distribution Sensors (073563)

Key Research Question

Sensors for the Electric Distribution System have primarily focused on the measurement current and voltage, and calculated parameters based on these measured quantities. These measurement devices support a host of operational applications including distribution management systems (DMS), Volt-VAR, CVR, and Fault Location. Analogous to the substation and transmission environment, there exists a set of additional measurements that may yield value in the areas of asset management, particularly in the areas of incipient failure prediction, detection, and prevention.

Inspiration for this new breed of electric distribution sensors may be derived from the extensive research that has taken place in recent years into measurement systems on the transmission and substation systems. Measurements such as temperature, vibration, partial discharge, and others, coupled with existing precise and accurate measurements of voltage and current will potentially yield solutions that provide an entirely new set of benefits. This project will research new sensor technologies and infrastructures for the management of electricity distribution assets considering all the above factors.

Approach

This new project is based on a multi-year plan designed to provide high-risk/high-value benefits to members by performing fundamental research to develop a new class of distribution sensor, in part by taking advantage of innovations in transmission and substation sensing systems. This project will initiate in 2013 with a review of relevant advancements in substation and transmission sensing, looking for synergies and opportunities to bring these technologies to the distribution system in a cost- effective manner, considering the widely distributed locations and communications requirements inherent in applications on the distribution system. Along with deriving inspiration from these existing technologies, teams of subject matter experts within and outside of EPRI will be formed to brainstorm on potential new avenues of research and development.

Impact

Application of this new class of asset management-focused sensor on the distribution system supports a set of new applications that have never before been widely supported. These applications will enable utilities to predict failures, prevent failures and/or detect failures before they result in equipment damage, customer outages, or safety issues. Examples of these applications include the following:

- Detection/location of high impedance faults (downed overhead [OH] conductors)
- Detection/location of vegetation contact with OH conductors
- Prediction of underground/underground residential distribution (UG/URD) cable failures
- Detection of incipient faults, failed lightning arrestors, cracked insulators, loose connections, and more
- Dynamic rating of conductors

How to Apply Results

- Members will participate in identification of high-value future applications driving sensor requirements.
- Members will get a head start on awareness of cutting-edge sensor technology for application on the distribution system through involvement with research in this area.
- Members will be able to participate in testing new sensors and new sensor-based applications to validate benefits.

2013 Products

Product Title & Description	Planned Completion Date	Product Type
Innovative Distribution Sensors: This project will research and develop new class(es) of sensors for application on the distribution system beyond current and voltage monitoring to support asset management applications such as incipient failure detection and cable failure prediction.	12/31/13	Technical Update

P180.023 Integrated Technology for Distribution Systems Applications (073564)

Key Research Question

There is an emerging opportunity (and corresponding need) to introduce the breakthroughs for basic “power and environmental” sensor technologies—in a similar fashion to what has been accomplished with tablet PCs and smart phones. The concept is to integrate many individual technologies and features into a single, low-cost package with universal or multi-purpose application. The objectives of this project are to identify applications where an information or data gap presently exists and to then develop prototype sensing devices that integrate multiple low-cost concepts, technologies, and features into packages suitable for field evaluations.

Approach

To accomplish the project objectives, research will be undertaken to identify and document the most pressing or prioritized applications where an information or data gap exists related to sensing and diagnostic technology (for distribution system-specific applications). Once the information and data gaps have been defined, project sponsors will assist in prioritizing the technologies and cost targets suitable for use in development of prototype devices. It is expected that these prototypes would be suitable for field validation testing—but they would not necessarily be optimized to meet final costs targets and packaging requirements until field testing and debugging is completed. Possible designs or technology suitable for the low-cost/low-power objective may include the following:

- Fast, nanowatt microprocessor with analog/digital capability and memory and temperature compensation
- Physical design specification (e.g., ability to integrate into splices, hang on lines, mount)
- Microwatt Hall sensors with 100 kilohertz (kHz) bandwidth
- Integrated Bluetooth communication capability
- >1 megabyte(MB) flash non-volatile memory
- Pockels cell e-field voltage sensing
- Low-power, low-cost cellular modem capability
- Solar, E or H field energy harvesting technologies
- Low-power, low-cost analog ASP harmonics processors
- High-speed packet radio-on-a-chip devices
- Digital signal processing (DSP) algorithms to identify and quantify power line parameters [software]
- Possible detection of signature indicative of component failures [hardware and software]
- Consideration of supervisory control and data acquisition (SCADA) interfaces (Common Information Model [CIM], IEC 61850, and others) [software]

Impact

- Cost reduction for utility system monitoring and diagnostics
- Better real-time and near-real-time system status information
- Better visibility on the number of and locations needed for new sensors for smart grid applications
- Promotes industry standardization for sensing technologies

How to Apply Results

The results of this research will be directly applicable to specific power system measurement and diagnostic, and benchmarking activities. Developed technology would be directly integrated with power system hardware and measurement points to provide more useful power system information.

2013 Products

Product Title & Description	Planned Completion Date	Product Type
Integrated Technology for Distribution Systems Applications: The results of this research will be directly applicable to specific power system measurement, diagnostic, and benchmarking activities. Developed technology would be directly integrated with power system hardware and measurement points to provide more useful power system information.	12/31/13	Technical Update

PS180I Distribution Systems Practices (070632)

Project Set Description

This project set focuses on overhead and underground distribution system practices, with the intent of capturing and documenting leading utility practices for all functional areas. Participating members can expect to measure, compare, and validate their current practices and determine if any are in need of adjustment. By identifying better methods, utilities can improve efficiency, reliability, and safety.

Project Number	Project Title	Description
P180.019	Underground Practices	This project focuses on identifying, collecting, and communicating leading underground distribution systems key functional practices.
P180.020	Overhead Practices	This project focuses on identifying and collecting leading overhead distribution systems key functional practices.

P180.019 Underground Practices (070633)

Key Research Question

Underground systems are a crucial part of the industry and deliver high levels of reliability and customer service. However, underground systems also present challenges, such as high costs for construction and maintenance, and require unique skill sets for effectively managing urban network systems, typically held by a few key individuals. Moreover, the loss of experienced engineering staff to mergers and attrition has left many utilities with a gap in the expertise needed for optimal planning, design and engineering, construction, and operation and maintenance of urban underground and network systems.

Approach

This project focuses on urban underground distribution systems and uses a research approach where an EPRI project team visits a utility and immerses itself in the utility operation, collecting practice information firsthand from utility planners, engineers, operators, and field work crews. The research results are published in reports that summarize key practices and are populated in an online dynamic industry data repository. The data repository enables research participants to identify, analyze, and compare peer company approaches to managing urban underground distribution systems.

Impact

- Improve the reliability of underground distribution systems through the identification and application of alternative, optimal reliability practices of both domestic and international peer companies
- Improve the safety of utility activities involving construction and operation of underground systems through the identification and application of alternative, optimal safety practices
- Improve the efficiency associated with planning, designing, engineering, constructing, and operating distribution systems through the identification of alternative, optimal management practices

How to Apply Results

Members can use the leading practice database to perform in-depth, peer-to-peer comparison of current practices to identify optimum methods to manage their underground systems.

2013 Products

Product Title & Description	Planned Completion Date	Product Type
Underground Practices Report - Utility Host TBD: This project focuses on identifying, collecting, and communicating leading underground distribution systems key functional practices.	12/31/13	Technical Update

P180.020 Overhead Practices (070634)

Key Research Question

Overhead distribution systems represent the largest percentage of the industry asset base and are built to many different standards and in many different ways. A fresh look at the typical functional overhead practices is needed on an industry scale. The loss of experienced engineering staff and field construction expertise to mergers and attrition has left many utilities with gaps in planning, design and engineering, construction, and operation and maintenance of overhead systems.

Approach

This project focuses on overhead distribution systems, using a research practice where an EPRI project team visits a utility and collects practice information firsthand from utility planners, engineers, operators, and field work crews. The research results are published in reports and populated in an online dynamic industry database tool. The tool enables utility peer-to-peer comparison and analysis.

Impact

- Improve the reliability of overhead distribution systems
- Improve the safety of utility activities involving construction and operation of overhead distribution systems
- Reduce the costs associated with planning, designing, engineering, constructing, and operating overhead distribution systems

How to Apply Results

Members can compare and contrast their current practices with their industry peer group.

2013 Products

Product Title & Description	Planned Completion Date	Product Type
Overhead Practices - Utility Host TBD: This project focuses on identifying, collecting and communicating leading overhead distribution systems key functional practices.	12/31/13	Technical Update

PS180J Tech Transfer and Industry Coordination (070635)

Project Set Description

The Distribution Technology Transfer and Industry Coordination project set is designed to provide utilities with high-impact resources that cover topics relevant to distribution systems and to keep members up to date on the latest technology advancements and industry issues.

Project Number	Project Title	Description
P180.021	Tech Transfer and Industry Coordination	EPRI's distribution knowledge-based services cost-effectively support utility distribution engineering managers and staff with technical resources, training, and standards information.

P180.021 Tech Transfer and Industry Coordination (070636)

Key Research Question

Distribution companies face a variety of pressures and technical challenges. Utility planners, engineers, and operators must stay familiar with the latest technologies, software tools, standards, and procedures for optimizing distribution system performance. At the same time, many utilities are losing valuable experience as the aging workforce retires.

Approach

EPRI's distribution knowledge-based services cost-effectively support utility distribution engineering managers and staff with technical resources, training, and standards information. Members gain access to the best distribution engineering expertise in the industry to deal with specific challenges in a timely manner and stay informed on key technical developments. The project includes the following:

- Standards and Industry Activities: EPRI participates in important industry organizations and standards development efforts. This participation includes the IEEE Distribution Subcommittee, Smart Distribution Working Group, U.S. National Committee of the International Conference on Electricity Distribution (CIRED), Association of Edison Illuminating Companies (AEIC) Working Groups, and International Electrotechnical Commission (IEC) Working Groups.
- Conferences: IEEE Power Meetings, CIRED conferences, and other important conferences will be summarized for members to increase awareness of important developments.
- Distribution Hotline Access: Members will have access to a distribution hotline, gaining quick-response access to EPRI's power system experts to help answer technical questions related to distribution engineering, operations, and maintenance.
- Member Forum: Members can participate in a web-based forum, with topics covering any issue related to distribution system design and operations, such as equipment problems, maintenance strategies, application of equipment, and reliability problems.

Impact

- Increase the productivity and technical expertise of staff.
- Represent members' interests with respect to standards development.
- Provide cost-effective and timely updates on industry developments.

How to Apply Results

Utility managers and staff can immediately use the knowledge provided by this program to improve distribution system design, maintenance, and troubleshooting practices. The service is provided through a member forum, which allows for easy access to knowledge, discussions, and expert staff.

Supplemental Projects

Arc Flash for Medium-Voltage Equipment (072114)

Background, Objectives, and New Learnings

Prior EPRI research showed that arc flash characteristics and behaviors are equipment specific. Energies depend strongly on electrode configurations and enclosure geometries. One of the most surprising results was from tests on a medium-voltage pad-mounted switch that produced incident energies three times higher than predicted by IEEE 1584 models. This particular switch had a bus configuration that focused the arc and fireball out the front of the enclosure in the direction where a worker would be standing.

The main objective of this project is to develop, apply, and verify existing arc flash models for additional equipment types and designs. We plan to share results with the Institute of Electrical and Electronics Engineers (IEEE) 1584 Working Group to help it improve future versions of the *IEEE Guide for Performing Arc Flash Hazard Calculations*. The results are expected to apply to utility substation and power plant equipment, as well as consumer owned equipment.

The new learning may help utilities to coordinate protective clothing, relaying, and work practices, and strives to answer the following questions:

- Do existing IEEE 1584 models accurately predict energy in real gear?
- How much energy is blocked by the circuit breaker for a fault in the back of the switchgear?
- How does the incident energy change with equipment size and bus spacings?
- How does the incident energy vary with time?

Project Approach and Summary

The main work will involve testing equipment at a high-current laboratory. Tests will be instrumented with calorimeters and high-speed cameras to allow us to capture more data on the physics behind arc flash events. As much as possible, we plan to use actual switchgear, but because arc flash testing is destructive, we may need to use mockups or substitute key components that are burned during testing. We plan to test station-type switchgear and padmounted gear.

Types of equipment to be tested will be provided by utility members. For switchgear, this input will include ratings and sizes as well as styles of supply. Similarly for padmounded gear, ratings and sizes will be needed. Since bus configurations are critical to arc flash energies, those will have special attention. Utility input on work practices will also be important to help identify experiment parameters. This will help frame the fault current ranges, fault initiation modes, worker positioning, worker distance ranges, and fault duration ranges. This input will also help to prioritize equipment to be tested.

Results from high-speed videos, voltage and current measurements, and calorimeter measurements should allow for the development of better arc-flash-prediction models for different types of equipment.

Benefits

This project should help utilities implement better arc flash programs. Results will help utilities to coordinate protective clothing, relaying, and work practices. Workers may benefit from increased safety around medium voltage equipment.

Results may lead to better industry analysis methods and industry standards.

Distribution Modernization Demonstration (073531)

Background, Objectives, and New Learnings

The Distribution Modernization Demonstration is addressing the R&D smart grid challenges identified by over 1400 industry and public advisors along with the EPRI board of directors over a two year period. The project will employ “learning-by-doing” by developing and demonstrating data management and analytics to support distribution operations, planning and asset management applications. A vast amount of data is being generated on the distribution grid from sensors, devices and systems and it is beginning to outpace the ability to process, analyze and use the data for applications that benefit the distribution system. As electric utilities are implementing or planning to implement advanced distribution applications to improve distribution system efficiency, reliability, performance, and equipment utilization, there is a gap to fully take advantage of turning this vast amount of data into actionable information with industry standard methods and tools.
The Distribution Modernization Demonstration objectives include development and demonstration of standard definitions and specifications for advanced distribution applications such as On-Line Power Flow or Volt-VAR Optimization. The specifications will define the detailed functional requirements for each application along with the data management and integration requirements associated with the application. Members of this project will demonstrate advanced application(s) based on the detailed specifications developed by EPRI and the collaborative members of this project.

This demonstration initiative will utilize the identified requirements to implement the emerging advanced applications in a practical approach preserving legacy systems as appropriate while also developing and architecture that uses emerging standards such as the Common Information Model (CIM).

Project Approach and Summary

This project is a collaborative demonstration project with an opportunity for members to be demonstration host-sites that implement and integrate advanced distribution applications where EPRI supports those efforts in research plan development and cost benefit analysis. Lessons learned will be shared through a combination of meetings, media and reports. Specific activities include:

- An assessment of the current state of the distribution operations and benchmarking with other utilities.
- Development of a vision statement for the future functionality of distribution operations including advanced distribution applications and integration points with other systems.
- Create a roadmap (including an “opportunity matrix” and Key Performance Indicators) to achieve the business benefits that include application functionality, best practices, organizational change management, architecture, and integration strategy based on the utility’s business drivers.
- Creation of member defined deliverables such as reports, web casts, training and other media content to add value to the participants own efforts.

Benefits

This project may help to reduce the total cost to procure, implement, and sustain advanced distribution applications. Developing functional and technical specifications is time-consuming and costly, but when done in a collaborative manner becomes a cost effective process. The use of new and emerging standards for analytical

methods, tools and algorithms avoids vendor lock-in and enables a more nimble system to implement new applications as requirements evolve.

The benefits of this project include:

- The public can expect to benefit from improved grid operational performance from advanced distribution applications.
- Use of standardized functional specifications and enterprise integration of methods, tools and algorithms will help utilities avoid specifying applications that require considerable customization and development effort.
- The operational benefits include system operators being to handle more information and empowering them to make informed decision more reliably and faster with actionable information.
- The utility IT benefits may include anticipated lower integration costs, lower IT operational costs, and lower risk of integration implementation.

Airborne Damage Assessment Module Integration (ADAM Phase 2) (073547)

Background, Objectives, and New Learnings

There are numerous reasons for utilities to routinely perform assessment and inspection of distribution assets, from understanding storm damage to evaluating asset condition. Typically, the methods used to perform assessment and inspection of these assets is labor intensive, time consuming and expensive. New technologies have evolved over the last decade that can provide utilities with superior alternatives to the traditional methods of assessment and inspection. A key tool that could enable a more comprehensive information collection is the use of, or drone, technology.

The Electric Power Research Institute (EPRI) is researching the potential of drone technology for the damage assessment (ADAM) inspection of distribution lines and assets. This includes understanding the types of vehicles that could be used by utilities as well as the sensor technologies that would be used to gather information and images that will serve as the source for all the analysis.

Project Approach and Summary

Integrating the ADAM system with the utility's Information technology infrastructure and back office system is important to be effective. The ADAM system will need to integrate with three key distribution operations backend systems, the OMS, GIS, and the asset management system. All three of these are important for allowing incident command operators to understand and access situational information in real-time.

Outage Management System: At the heart of any storm response and damage assessment is the outage management system, which gathers outage information from a variety of sources and helps to direct restoration efforts. An OMS enables a focused response, allowing utilities to prioritize restoration efforts, reenergize restored feeders, give customers and the public restoration time estimates, and coordinate with governmental organizations. The OMS is built around a model of the utility's network, usually derived from a GIS, and contains algorithms to estimate the locations of damage. Because modern OMS software is already set-up to receive outage data from a variety of sources, integrating information from ADAM UAVs should not pose a significant technical challenge as long as the current interfaces can accommodate UAV provided data.

Geographical Information System: GIS is rapidly becoming the foundation of distribution system documentation, because the map-based database is suited perfectly to tracking assets and monitoring the state a geographic dispersed assets. GIS has been used for decades in other industries, so the technology is almost mature, and it offers a simple way to present the information held in databases in cartographic form and make it available for real-time analysis. Importantly, for the UAV integration, GIS systems can integrate database information, images, and video-feeds, tying them to a specific location via map graphics. GIS integrates data and allows users to look for trends and patterns, using information layered on maps, and this information can be sent to mobile devices. GIS already has a good performance track record during storm-related outages. During the Hurricane Isabel outages, of September 2003, Dominion Electric's GIS system was an invaluable part of the

storm response, allowing the utility to track damage, provide engineers with an analysis of outages, prioritize work orders, and organize logistics. Using UAV analysis will simply be adding another source of data to this: the underlying architecture and adaptability is already in place.

Asset management system: As with any industry, keeping track of assets is crucial for utilities, because this provides an interface between the engineering and the accounting sides of the business. An asset register allows utilities to maintain a database of what assets they own, their predicted lifecycle, and their technical specifications. Most modern asset management suites can be integrated with GIS, allowing utilities to track the exact location of assets. For the ADAM program, knowing the location of assets is important, because they are plotted on the user interface, allowing the UAV operators and control center to pinpoint the exact location of damage and also specify what repair equipment will be needed.

Benefits

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