# Distribution Systems - Program 180

## Program Overview

### Program Description

Utility distribution systems are at the center of the smart grid revolution and are challenged by aging infrastructure, legacy systems that must be integrated with new technologies, changing load characteristics (such as electric vehicles), and the requirement for integration of widespread distributed energy resources. 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, usually under severe budget constraints. The efficiency of the distribution system operation continues to increase in importance and, of course, safety always takes the highest priority.

New technologies will be critical to future smart grid operation. A smart grid must integrate widespread distributed energy resources as part of the normal operation of the system. In addition, the distribution management system, automation systems, protection systems, and planning tools must be designed to overcome this challenge.

EPRI's Distribution Systems Program has been structured to provide utilities with research and application knowledge to support smart grid implementation and with 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 realm 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.
- Provide 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 research 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 the solid-state transformer, 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 collecting 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 2010, EPRI research determined that portable electronic device technology (PEDs) will present significant opportunities in the handheld meter/diagnostic device arena and could become a major component of the smart grid sensor market. These devices will be used to stream, store, and selectively upload data from a remote location to a centralized location. EPRI has evaluated five potential applications and completed successful demonstrations.
- EPRI recently published the first edition of the *Underground Distribution Systems Reference Book (Bronze Book)*. This reference book contains the most up-to-date technical information on underground distribution systems, with sections on the state of the industry, underground distribution design, reliability, construction and installation practices, operations and maintenance, and distribution equipment. Authored by industry recognized experts and supported by almost 40 different utilities, this reference directly supports a key strategic need of utilities facing a rapidly changing business and technical environment — to capture and document institutional knowledge.
- EPRI and Consolidated Edison of New York (Con Edison) have collaborated to develop technology that will alert workers to the presence of low-voltage system cable faults (arcing) in underground structures. The result of this collaboration is the development of a prototype safety device that warns workers of electrical arcing before they enter a structure and continuously monitors for arcing as crews work.
- EPRI has conducted groundbreaking research on distribution systems arc flash issues in collaboration with over 20 utility members. This research has included extensive laboratory testing and analysis. This effort has uncovered important new learning about arc flash behavior that can inform utilities about arc flash energy calculation methodologies, system operation and work rule implications, and personal protective equipment. Participating utilities have implemented results that have "moved the needle" for the safety of utility workers.
- The OpenDSS Software has provided an open source platform for the industry to evaluate new distribution system modeling and simulation concepts that apply to both planning and real time applications. It has been used as a foundation for new load model development (voltage optimization collaborative and green circuits), energy storage integration modeling (AEP), electric vehicle penetration assessments, and many other applications.

- EPRI has published an industry database of leading distribution systems practices. The knowledge base is providing a growing library of innovative practices for managing and operating distribution systems that can be directly applied by members to improve their own operations. EPRI uses a research in action method known as immersion to capture and collect the information, immersions have been conducted at over 20 utilities.

### Current Year Activities

In the current year, research program objectives include:

- 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 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 aid utilities in integrating distributed resources and applying Distribution Management Systems (DMS)

### Estimated 2012 Program Funding

$7.0M

### Program Manager

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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), there is a 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 developing and demonstrating advanced analysis tools 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 is used to demonstrate these concepts so that they can easily be incorporated into a variety of commercial systems. |

| Project Number | Project Title | Description |
|---|---|---|
| P180.002 | Load Forecasting for the Modern Distribution Grid | This project includes the development of new methods for short-and long-term load forecasting for planning and operation of the smart distribution grid. These new methods must take into account the effects of widespread distributed generation, demand response, and energy efficiency measures on the distribution feeder and growing potential for zero net energy residences and commercial establishments. |

## 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.

### Approach

This project will develop modeling approaches and analysis methods for evaluating the dynamic effects of distributed energy resources and associated controllers on distribution system performance, efficiency, and reliability. The modeling methods will be implemented in Open Source software using actual distribution system designs and models to demonstrate the new approaches. Important issues to be addressed include:

- Detailed modeling of dynamic elements, including distributed generating (DG) units and associated controllers. What new information is needed to properly model distributed energy resources (DERs), including customer owned generating equipment that is connected to the distribution feeder.
- The types and sizes of DERs that need to be considered in the analysis. Can some small units be ignored without impacting the analysis.
- Real-time and non-real-time information needed to support the analysis. This includes electrical parameters as well as weather-related information that impacts the output of renewable energy resources (wind, solar, etc.).
- New capabilities required in distribution engineering analysis tools for performing dynamic analysis.

### Impact

The tools and guidelines developed 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 smart distribution applications through an understanding of application requirements and performance under different circumstances.
- Members will be able to use the Open Distribution System Simulation software (OpenDSS) 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.

### 2012 Products

| Product Title & Description | Planned Completion Date | Product Type |
|---|---|---|
| **Tools, Methods & Modeling for Dynamic Distribution Systems:** The report will focus on developing and demonstrating advanced analysis tools 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 is used to demonstrate these concepts so that they can easily be incorporated into a variety of commercial systems. | 09/30/12 | Technical Update |

## P180.002 Load Forecasting for the Modern Distribution Grid (070608)

### Key Research Question

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 for short-term and long-term load forecasting to evaluate and mitigate the impact of these resources 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.

### Approach

Distribution system modeling tools can now accommodate distributed generation, new customer load characteristics such as voltage dependency (more detailed models are being developed as part of an industry wide supplemental project), and even demand response. These tools enable distribution engineers to evaluate and mitigate the impact of distributed energy resources (DERs) on electric system performance, efficiency, and reliability. Now we need to develop tools and methods for determining the effects of DERs on short-term and long-term load forecasting and develop the guidelines for using these tools as part of the basic distribution planning process.

This project will develop load forecasting guidelines for planning electric distribution systems that include a high penetration of DERs resources. The potential impact of zero-energy residences, commercial establishments, and communities pose special challenges for traditional load forecasting methods. The load forecasting guidelines will consider the impacts of distributed generation (including renewables), storage, voltage optimization, and demand response.

### Impact

- New distribution designs and investment decisions will be able to take advantage of widespread demand response and other distributed resources.
- Implementation of planning processes that incorporate demand response and distributed resources will permit more optimum investment decisions.

- Distribution benefits of distributed resources are included in the business case for these technologies. Therefore, the methods for assessing the actual value and impacts on distribution designs must be available.

### How to Apply Results

Distribution planners will use the methods and protocols to evaluate distribution investment decisions, including the impacts of energy efficiency and demand response programs and technologies.

### 2012 Products

| Product Title & Description | Planned Completion Date | Product Type |
|---|---|---|
| **Load Forecasting for the Modern Distribution Grid:** This report includes development of the new methods for short- and long-term load forecasting for planning and operation of the smart distribution grid. These new methods must take into account the effects of widespread distributed generation, demand response, and energy efficiency measures on the distribution feeder and growing potential for zero net energy residences and commercial establishments. | 11/30/12 | 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 builds and maintains an industry equipment reliability and performance database that addresses components, equipment performance, failure characteristics, and fleet populations. |
| 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 without a formal 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, selecting the right component for the task, assuring proper component installation, performing focused inspection and assessment, and prioritizing replacements.

### Approach

This project focuses on components on an individual basis and also on component systems (overhead capacitor installations, for example) and builds and maintains an industry database. Laboratory testing is combined with utility survey and field data to enhance the database and provide a better understanding of individual component reliability and operational parameters that affect reliability. The laboratory component of this work features a multi-stress accelerated aging method that includes electrical, mechanical, ultra-violet, salt fog, and flammability testing.

### 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 an annual industry workshop, test reports, field references, inspection guides, and other training materials. Results will also be compiled into the *Distribution Component Reliability and Specification Guidebook,* and members can directly apply this information to enhance their procurement, design, operation, and inspection practices.

### 2012 Products

| Product Title & Description | Planned Completion Date | Product Type |
|---|---|---|
| **Component Reliability:** This project builds and maintains an industry equipment reliability and performance database that addresses components, equipment performance, failure characteristics, and fleet populations. The industry workshop will provide a summary of all results in a training style format. | 10/31/12 | Workshop, Training, or Conference |

## 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 and the development and implementation of new inspection technologies.

### Impact

Optimized distribution inspection technologies and procedures yield:

- Fewer service outages
- Improved power quality and reliability
- Reduced outage repair costs

### How to Apply Results

Project results will be delivered in an annual workshop, 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.

### 2012 Products

| Product Title & Description | Planned Completion Date | Product Type |
|---|---|---|
| **Inspection and Assessment Methods:** Research results will provide utility asset managers with distribution system inspection methods, practices, techniques and unbiased technology evaluations of new products and services. | 10/31/12 | Technical Update |

## 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 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 will conduct 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.

### 2012 Products

| Product Title & Description | Planned Completion Date | Product Type |
|---|---|---|
| **Cable Fleet Management - Strategy, Technology and Implementations:** This technical update will document progress of the multi-year project to identify optimal practices for life-cycle management strategies for distribution cable systems. | 12/31/12 | Technical Update |

## 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 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.
- Fosters 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.

### 2012 Products

| Product Title & Description | Planned Completion Date | Product Type |
|---|---|---|
| **Advanced Cable Diagnostics:** This report will document EPRI-directed research into advanced cable system testing and diagnostic techniques. A progress update of the Department of Energy–sponsored Cable Diagnostic Focused Initiative (CDFI) will be included. | 12/31/12 | Technical Update |

## PS180D Distribution Reliability Management (070615)

### Project Set Description

This project set is focused on managing distribution reliability. The project set will help develop and evaluate advanced approaches for calculating, tracking, and reporting reliability performance, including coordination with the activities of IEEE 1366. In addition, the project set will develop and evaluate approaches for designing distribution systems for reliability (applying analytical tools) and selecting the optimum methods for improving reliability as a function of distribution system characteristics. This work involves both technical and economic assessment methods. Managing fault performance is a key aspect of managing reliability. 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 Metrics and 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 2011 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 2011 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
- 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.

### 2012 Products

| Product Title & Description | Planned Completion Date | Product Type |
|---|---|---|
| **Fault Location & Anticipation:** Research results applied will reduce restoration times and help make fault location systems easier for utilities to install and use. | 10/31/12 | Technical Update |

## P180.008 Reliability Practices and Drivers (070617)

### Key Research Question

Distribution reliability continues to be an important part of utility customer service, and regulators are increasingly using reliability as a measure of utility performance.

In a number of areas, further research could help members identify and implement noteworthy reliability practices, better manage reliability programs, and improve reliability, addressing questions such as:

- Is our hazard-tree program working
- Where can we best apply reclosers
- Can we show regulators the impact of a particularly severe storm season
- Where should we target investment money
- How do we compare with our utility peers
- What practices would be most effective in improving the reliability of our system
- Which practices best prepare our system for additional smart technology

### Approach

This project identifies leading practices being employed industry-wide and provides guidelines for maintaining and improving reliability. EPRI will conduct “immersions,” where EPRI resources reside on site at participating utilities to understand, identify, and document practices of note being employed to maintain and improve

reliability. These practices will then be shared with other members to facilitate the identification of alternative approaches for improving reliability.

### Impact

- Reduce customer interruptions (for example, System Average Interruption Frequency Index [SAIFI], Momentary Average Interruption Frequency Index [MAIFI]).
- Improve restoration times (for example, System Average Interruption Duration Index [SAIDI], Customer Average Interruption Duration Index [CAIDI]).
- Meet regulatory requirements more efficiently.
- Apply reliability improvement programs ore efficiently.

### How to Apply Results

Members can use the results of the project research to identify preferred methods for improving the reliability of their system, including refining existing approaches and applying new approaches.

### 2012 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. | 07/31/12 | Technical Update |

## P180.009 Reliability Metrics and Special Topics (070618)

### Key Research Question

There is an ongoing challenge to apply reliability metrics in ways that are more useful and provide a representation of system reliability performance that can be used to compare and benchmark performance effectively, while also providing the information necessary to prioritize investments.

### Approach

EPRI will engage with experts from the IEEE 1366 Working Group of the Distribution Subcommittee in order to identify industry priorities for advanced statistical approaches and analytical methods that can be applied with reliability metrics to better characterize system performance. The project will also coordinate with the Cost/Benefit Framework for assessing smart grid projects developed by the DOE and EPRI. his work will focus specifically on characterizing the performance of smart grid investments in the area of reliability improvement.

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
- Assessing reliability metrics using advanced metering system data
- Using reliability metrics to assess vegetation management programs
- Defining metrics for evaluating the effectiveness of fault location and fault performance improvement
- Developing reliability benchmarks as a function of distribution system characteristics

### Impact

- Better use of reliability metrics for characterizing system performance in ways that can be used for assessment of investment effectiveness

- Reliability metrics for evaluating smart grid investments
- More accurate and useful reliability metrics incorporating outage management systems (OMSs) and advanced metering infrastructure (AMI) data

### How to Apply Results

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

### 2012 Products

| Product Title & Description | Planned Completion Date | Product Type |
|---|---|---|
| **Reliability 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. | 10/31/12 | Technical Update |

## PS180E Safety (070619)

### Project Set Description

This project set is focused on safety, and for 2012 the topics to be covered will be distribution arc flash and arc detection to enhance worker safety. The goal is to provide timely and relevant knowledge to members on issues related to these two topics. It is expected that this knowledge will enable members to take appropriate action immediately.

| Project Number | Project Title | Description |
|---|---|---|
| P180.010 | Distribution Arc Flash | There is an industry need to better evaluate many of the design, technology, and process options to reduce arc flash hazards. EPRI will coordinate with other industry groups, including the IEEE 1584 and the American Society for Testing and Materials (ASTM) working groups. |
| P180.011 | Arc Detection and Contact Voltage | Advance Sensing Algorithms and Hardware: The project will provide state of the art insights into how to understand, measure and resolve safety related concerns for arcing and contact voltages |

## P180.010 Distribution Arc Flash (070620)

### Key Research Question

There is an industry need to better evaluate many of the design, technology, and process options to reduce arc flash hazards. Arc flash hazard reduction and mitigation involve system protection and device coordination, equipment design and specification, work procedures, and protective clothing and equipment. Each of these aspects can play a role in reducing arc flash hazards. Although much research has been performed, some areas still need attention. Moreover, certain regulatory guidelines, including the National Electrical Safety Code (NESC) Section 410 and Occupational Safety and Health Administration (OSHA) 1910.269 and 1926 Subpart V, continue to evolve. This research will help guide that evolution and help utilities comply. Protective clothing has advanced significantly in the last decade, and further advances are expected. Ongoing work is needed to evaluate clothing performance in practical use and in arc flash scenarios that may be encountered by utility workers.

This project also supports a Distribution Arc Flash interest group. The interest group allows open exchange of information on practices with utilities. Session focus topics can include best ways to implement arc flash programs, specific work practices, clothing acceptability and performance, and specific application areas like secondary networks.

### Approach

EPRI supplemental research work has provided the industry considerable experimental data on incident energies from a variety of arc flash hazards. EPRI will build on this and other research by coordinating with other industry groups, including the IEEE 1584 and the American Society for Testing and Materials (ASTM) working groups.

This project expands on earlier supplemental work to address the following:

- Case studies of approaches for addressing arc flash hazards
- Targeted testing of distribution-specific equipment (specific equipment to be determined)
- Testing of fabrics and clothing systems
- Development and reviews of improvement options

### Impact

- Improved worker and public safety
- More efficient implementation of arc flash programs
- Validation of predictive modeling and simulation tools
- Better industry standards

### How to Apply Results

Safety engineers can use the results to design and integrate safety programs. Protection engineers can improve coordination of protective relays and reclosers with arc flash hazards. Distribution engineers can apply new arc flash knowledge to work procedures.

### 2012 Products

| Product Title & Description | Planned Completion Date | Product Type |
|---|---|---|
| **Arc Flash:** There is an industry need to better evaluate many of the design, technology, and process options to reduce arc flash hazards. EPRI will coordinate with other industry groups, including the IEEE 1584 and the American Society for Testing and Materials (ASTM) working groups. | 09/30/12 | Technical Update |

## P180.011 Arc Detection and Contact Voltage (070621)

### Key Research Question

The state of the art in understanding and mitigating shock and other contact voltage–related concerns has evolved to the point where advanced diagnostics technologies can be used to better understand and resolve virtually any concern type. The objectives of this research are to conduct research and field tests that produce more practical diagnostics technologies and algorithms that improve public and worker safety—and may in certain cases improve system reliability. While continuing to support traditional stray voltage regulatory and standards development issues, this project will focus on more advanced technology development over the next several years.

### Approach

This collaborative research project provides the latest techniques for understanding and dealing with virtually all related concerns at readily accessible human and animal contact locations. The main goal of the project in 2012 is to utilize new technology to more readily understand source and coupling mechanisms for arc detection and the more traditional for contact and stray voltage. These technologies include handheld electric field sensors and a mobile diagnostics platform that combine low- and high-frequency data acquisition in real time. The goals are to develop a suite of diagnostics technologies that make it easier to locate, remediate and understand contact voltage sources such as high impedance and open neutrals and a multitude of other concerns. In addition, the wealth of material developed in prior years will be maintained on the contact voltage website to support staff training, industry awareness, regulatory inquiries, and overall understanding of related subjects.

### Impact

- Lower the risks and costs of potential problems, providing savings on future engineering investigations by providing evaluation methods and field-proven solution methodologies.
- Reduce the possibility of humans and animals experiencing perceptible levels of elevated voltage.
- Enhance members' ability to comply with existing or anticipated regulatory limits related to stray voltage.

### How to Apply Results

Project members can use this work to develop comprehensive methodologies and processes for handling customer complaints and regulatory inquiries about elevated neutral to earth (NEV) and urban stray voltage; prioritize and standardize the means by which members repair or provide mitigation solutions for identified voltage concerns and how they support customer-initiated remediation; and develop training tools and standardized investigation procedures for their staff that result in a well-defined, structured process from the initial complaint to final follow-up.

### 2012 Products

| Product Title & Description | Planned Completion Date | Product Type |
|---|---|---|
| **Advance Sensing Algorithms and Hardware:** The project will provide state of the art insights into how to understand, measure and resolve safety related concerns for arcing and contact voltages. | 07/31/12 | Assembled Package |

## PS180F Smart Distribution Applications (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 distribution management systems with model-based management of the system. The Distribution Management System (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 and also works with member utilities to demonstrate advanced functions for development of application guidelines and identification of gaps in the technologies.

The project set will also support a Distribution Management System Interest Group. This interest group will provide an information sharing forum for development of requirements for DMS implementations, sharing experience from actual implementations, and brainstorming for future applications. Gaps identified will help EPRI in prioritizing future research in this project set.

| 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 development of a software tool (an Excel spreadsheet) 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, microgrid 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.

### Approach

This project uses the results of the DMS Interest Group (DMSIG) as a foundation for the proposed deliverable. To be successful, the DMS must support important business drivers and objectives established by the individual electric utilities. The proposed methodology will describe processes for identifying these important business needs and then translating the business needs into the DMS requirements. An "opportunity matrix" will be provided to aid in translating business needs to appropriate DMS applications. The project will provide functional descriptions of the major application functions and will also supply guidelines for selecting a "conceptual" architecture for the system (centralized scheme versus decentralized application). This information will lay the

foundation for developing more detailed specifications that a utility needs to procure the hardware, software, and services necessary to procure, install, and commission the DMS. The proposed planning guide will also include budgetary and scheduling guidelines, list of required resources, installation guidelines, and information on making the transition to DMS-based operations.

### Impact

- Provide a foundation for implementing voltage optimization systems as a function of distribution system characteristics and existing infrastructure.
- Provide tools for assessing voltage optimization performance at the design stage (support of business case development).
- Provide field experience from actual implementations.
- Identify new functionality that can improve the performance of voltage optimization systems.

### How to Apply Results

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

### 2012 Products

| Product Title & Description | Planned Completion Date | Product Type |
|---|---|---|
| **Distribution Management Systems Planning Guide:** This report 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 identify a generalized (conceptual) architecture, implementation and sustainment strategies, and other important information. | 11/30/12 | 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 investment total 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, there is no well-established procedure for converting improved reliability 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 develop an Excel spreadsheet that 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.

### Impact

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

- Performance assessment for advanced reconfiguration functions
- Benefits that can be achieved with advanced reconfiguration functions
- Requirements for advanced reconfiguration functions

### How to Apply Results

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

### 2012 Products

| Product Title & Description | Planned Completion Date | Product Type |
|---|---|---|
| **Benefit Cost Analysis Software Tool for Smart Distribution Applications:** This product includes development of a software tool (an Excel spreadsheet) 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 | 12/31/12 | 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) (distributed generation, including renewables, and energy storage). The expanded role of DERs in volt-VAR optimization, reliability improvement measures, system reconfiguration, microgrid operation and control, and other Distribution Automation (DA) and DMS applications will be explored.

### 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-VAR optimization, system reconfiguration (including microgrids), and other applications will be explored. The approach will involve implementation of models for the basic functionality of DERs 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.

### 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 operations 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 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.

### 2012 Products

| Product Title & Description | Planned Completion Date | Product Type |
|---|---|---|
| **Smart Distribution Applications for Distributed Energy Resources:** This report will include an in-depth investigation of smart distribution applications for monitoring and controlling distributed energy resources (DER) (distributed generation, including renewables, and energy storage). The expanded role of DER in volt-var optimization, reliability improvement measures, system reconfiguration, microgrid operation and control, and other DA/DMS applications will be explored. | 11/30/12 | 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 are 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:

- 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
- 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 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 2012, this project builds on preliminary work conducted through EPRI's Technology Innovation initiative to characterize a variety of sensor technologies that could become part of the smart distribution system in both overhead and underground applications. The work will focus on the cataloguing and assessment of current industry practices and procedures. It will also perform research into other available sensor technologies presently under development or in use outside the electricity industry. The project will conduct actual field assessments of new sensor and transducer technologies with integrated communications.

### Impact

Improving energy efficiency requires the grid to minimize energy delivery losses and perform in a proactive manner in order to most optimally balance supply with demand. With the increased performance expectations of the modern distribution network, accomplishing this task requires a form of intelligence on the grid that to date has not been available or i necessary. The absence of an economical sensing and communications infrastructure that parallels the electrical infrastructure poses one of the largest challenges facing the electric distribution system.

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

### 2012 Products

| Product Title & Description | Planned Completion Date | Product Type |
|---|---|---|
| **Sensor Database:** This database will allow members to rapidly comprehend the full spectrum of options available and make efficient and effective implementation decisions. It will contain information that catalogs and categorizes available technologies and unbiased test results. | 12/31/12 | Software |
| **Guide of Sensor Technology Application Practices:** This report will contain methodologies for successful implementations of sensing technologies. | 12/31/12 | Technical Update |

## P180.016 Advanced Meters (070628)

### Key Research Question

Many utilities are in the process of evaluating and deploying advanced solid-state meters. These technologies have been in limited use for many years, but are now being rolled out in large numbers as AMI deployments drive wholesale meter replacements. However, utilities still have limited experience with these products, and important questions remain regarding reliability, robustness, and functionality. Utilities need to understand important field applications, life cycle characteristics, and the technology's ability to withstand a wide range of environmental stress conditions.

### Approach

This project focuses on evaluating meter products and application issues that will become part of the smart distribution system. It will use a combination of laboratory testing and actual field performance assessments to develop conclusions about advanced meter capabilities and lifetime characteristics. This research has a number of important components:

- Environmental testing in the laboratory. This project will use accelerated lifetime tests to understand the ability of solid state meters to withstand environmental conditions over the long term.
- Abnormal voltage and current testing in the laboratory. This project includes testing the communications interfaces for the meters as well as voltage and current monitoring performance under adverse conditions.
- Characterization of the effect of harmonics and power factor on meter accuracy. Future meters may need to characterize customer impacts on harmonic distortion and power factor. This feature will require the ability to characterize customer load and generation accurately for both fundamental and harmonic conditions. Laboratory testing will characterize meter performance for non-sinusoidal conditions and for characterizing load power factor.
- Evaluation of important field application issues and performance through experience with initial advanced metering deployments.
- Advanced meters will need to continue to operate during power outages to provide functionality for smart distribution systems (for example, integration with outage management systems). The project will evaluate super capacitor battery performance and meter performance during and after outages.

### Impact

- Understand new application and issues for advanced meters as they are integrated with smart distribution systems.
- Understand the expected lifetime for solid-state meters for planning and budgeting of maintenance and replacement plans.
- Understand the performance of solid-state meters during transients and for characterizing harmonics and power factor. These could be important functions in the smart distribution system.
- Understand the impact of integrated communications with advanced meters on application issues (such as lifetime, maintenance requirements, and installation issues).

### How to Apply Results

- Members will be able to develop more accurate budgets and plans for advanced meter deployments.
- Members will be able to develop better plans for integrating advanced meters with smart distribution systems by understanding important application issues and meter limitations.

### 2012 Products

| Product Title & Description | Planned Completion Date | Product Type |
|---|---|---|
| **Solid State Meter Accuracy in the Presence of Low Frequency Conducted Signals:** A number of new technologies, including electric vehicle chargers, photovoltaic inverters, and compact florescent lighting, are generating new and increased sources of noise on customer power systems. This project will perform extensive laboratory evaluation of the ability of solid-state meters to perform accurately in the presence of these signals. | 12/31/12 | 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 and collecting 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.
- 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.

### 2012 Products

| Product Title & Description | Planned Completion Date | Product Type |
|---|---|---|
| **Urban Network Practices:** This Technical Update report will summarize practice findings. | 12/31/12 | Technical Update |
| **Urban Network Practices Survey:** EPRI will conduct an industry survey of urban network practices. The results will be issued as a technical update. | 09/30/12 | Technical Update |
| **Urban Network Practices Repository:** Practices will be incorporated into a data repository to facilitate comparison and analysis by research participants. Updates to the repository will be issued as a technical update. | 12/31/12 | 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.

### 2012 Products

| Product Title & Description | Planned Completion Date | Product Type |
|---|---|---|
| **OH Lineworker Practices:** This Technical Update report will summarize the practices identified through practices immersions conducted in 2012. | 12/31/12 | Technical Update |
| **OH Practices Repository:** Practices summaries from immersions will be populated into a data repository and issued to research participants as a technical update. | 12/31/12 | 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.

## 2012 Products

| Product Title & Description | Planned Completion Date | Product Type |
|---|---|---|
| **Hotline:** 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 industry technical developments. | 12/31/12 | Technical Resource |

## Supplemental Projects

### Hybrid Transformer Demonstrator (072113)

#### Background, Objectives, and New Learnings

The ever-increasing expectation for efficient, reliable energy to power today's digital economy has undoubtedly challenged the suitability of the existing ac system. Today's distribution system is expected to supply power to loads for which it was not designed. Moreover, high penetration of distributed generation units is redefining the requirements for the design, control, and operation of the electric distribution system. Globally, the electric power industry has turned toward smart grid–enabled equipment installed on distribution systems. "Smart grid components" are components with microprocessor-based controllers that can communicate with a master controller. These components either control power flow or power quality in the network. In addition smart grid technologies can enable the large-scale integration of renewable generation needed to meet the rising demand for electricity from low-carbon sources.

#### Project Approach and Summary

EPRI, in collaboration with the ABB Group plans to demonstrate a power-electronics-enhanced transformer (hybrid transformer), based on a conventional transformer and a power-electronics active voltage conditioner (AVC). The hybrid transformer is expected to provide more functionalities than simply voltage transformation and galvanic isolation and will be demonstrated in three phases:

- In the first phase of the project, the hybrid transformer will be capable of continuous ±10% voltage regulation and communication with a central control center.
- The second phase is planned to incorporate VAR compensation capability onto the same power platform. Studies to determine the technical and market requirements for VAR compensation will be conducted in this phase.
- Finally, the third phase of the project will study the requirements for the integration of energy storage systems with the hybrid transformer.

#### Benefits

The device will encompass all the necessary technical features that will allow testing of the control capabilities on a component and system level at the host site. Working closely with utilities will aid in developing a commercialization strategy for the hybrid transformer.

## Arc Flash for Medium-Voltage Equipment (072114)

### Background, Objectives, and New Learnings

EPRI has had a series of projects on distribution arc flash. One of the most consistent findings is that arc flash is 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 test more equipment and use results to develop arc flash models for that equipment. We plan to share results with the IEEE 1584 Working Group to help it improve future versions of the *IEEE Guide for Performing Arc Flash Hazard Calculations*.

### 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.

### Benefits

This project should help utilities implement better arc flash programs. Results will help utilities to coordinate protective clothing, relaying, and work practices.

Testing will help to answer several questions on arc flash in gear:

- 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

## Cable Validation for Fleet Management (072115)

### Background, Objectives, and New Learnings

Reliability and fleet management of underground cable systems begin at the most fundamental level with ensuring that quality products are procured from approved vendors. The quality of cables has steadily improved over the years as a result of enhanced testing requirements in industry standards. However, mistakes are still made in manufacturing processes, and pressures for profitability in the marketplace can adversely impact product quality. In addition, new lower cost suppliers enter the market with little or no performance history. New Learnings will include statistical analysis and validation of the quality of products sourced from long-standing domestic sources as well as new market entrants from outside the United States.

### Project Approach and Summary

This project will provide testing, quality validation, and statistical analysis of materials to ensure that only the highest quality materials are placed in service. Tasks may include sample testing, full reel testing, plant quality audit support, statistical analysis, and trending of data versus a database of industry suppliers. Testing and inspection of materials at the manufacturing plant or sample testing prior to delivery ensures that the product meets the utility's raw materials and purchasing specifications. Applicable industry standards for production of quality cables include:

- ASTM B-8
- ASTM B-231
- ANSI/ICEA S-94-649
- AEIC CS-8
- RUS U-1

### Benefits

This research will benefit the public through reduced outages by ensuring that only high quality materials are installed. Participants will benefit from the validation of quality incoming cables to ensure system reliability, cable fleet performance, and reduced overall cost. Members will have access to the growing EPRI database of cable fleet management statistics and practices.

## Distribution Robotics (072116)

### Background, Objectives, and New Learnings

A number of considerations make robotics a viable option for distribution systems applications in the overhead and underground areas. Overhead Line workers are often exposed to inclement weather, strenuous work conditions, heights, and heavy machinery. Underground Line worker entering structures can be exposed to risks including electrical discharges, heat, gases, moisture, and cramped conditions.

Specifying, developing and applying novel and unique robotics during routine operations, to perform environmental safety assessments, eliminating dangerous electrical conditions, and performing damage assessment, will be invaluable. Cost-effective robotic solutions need to be developed where they can increase the safety, productivity, and comfort of employees.

The project aims to develop functional specifications and prototypes for a selection of robotics technologies for safer, more effective work on distribution systems. The work will be scoped such that separate efforts will address the underground and overhead areas.

### Project Approach and Summary

A platform of technologies will be investigated for robotics that can be applied to both overhead and underground distribution systems. The goal is to build and demonstrate prototype robots using a disciplined research method whereby functional specifications are first documented and development follows.

Overhead Systems: Use of aerial vehicles.
The potential of aerial vehicles (fixed wing manned and unmanned) to inspect/assess and assist with damage assessment of infrastructure is unknown. Enabling rapid damage assessment will allow electric power companies to reduce restoration time. EPRI will define the functional requirements necessary to perform aerial assessment and data collection.

Underground Systems: Use of remote controlled robotics.
Underground structure entry and work can be accomplished more safely when done by a robot under remote control. Remote operations eliminate worker exposure to confined space hazards, and this technology application will improve many facets of asset ownership. Adding visual technologies will improve consistency on decisions regarding structural integrity by allowing additional experts to remotely view a structure from their office while crews are at the inspection location.

### Benefits

For overhead distribution systems, wide scale inspection and assessment through the use of aerial vehicles will dramatically improve overall asset management and when used for storm damage can reduce restoration and recovery efforts.

For underground distribution systems a structure entry and work robot will be researched. A manhole inspection robot should help utilities perform safer, more effective manhole and vault inspections. Robots may also be developed to improve other manhole work.

## Occupational Exposure to Physical Stressors (072036)

### Background, Objectives, and New Learnings

Occupational exposures to physical stressors such as noise are prevalent within the electric utility industry. During 1995-2009, the EPRI Occupational Health and Safety Database, which tracks illness and injury for eighteen member utilities, showed that hearing loss or impairment resulted in 3% of total utility worker injuries. If constantly exposed to noise, workers may experience progressive hearing loss slowly over time, which in turn may affect their ability to perform safely and translate to an indirect number of acute workplace injuries.

Noise-induced hearing loss has been implicated in workplace accidents. Auditory changes are progressive, possibly placing workers at risk for accidents. Traditionally, workers are enrolled in hearing conservation programs after an action level of 85 decibels (dB) is met. Noise surveys capture environments requiring action but are not conducted at multiple time points; consequently, noisy environments may be underestimated. According to published studies in the aluminum industry, annual audiometry data capture hearing loss once it has occurred and the most vulnerable workers actually may fall below the accepted permissible exposure limit. Since opportunities to intervene prior to hearing loss are limited using annual audiometry, data gaps exist for workers who may be just below 85 dB and who may potentially have preventable workplace hearing loss.

Workers may use personal protective gear such as ear muffs and ear plugs that modify exposure; hence, measured ambient or personal exposure levels may not reflect actual exposure. Novel in-ear dosimetry technology—devices that fit like an earplug and measure attenuated noise from within the ear canal—could be used to address worker discomfort and potential exposure modification issues. In addition, the dosimeter could be programmed to advise the worker and/or her/his supervisor when pre-set exposure limits are exceeded. Thus, a worker would get feedback on exposure above that pre-set limit and on her/his daily dose at the end of the shift, both of which could assist in guiding personal protective equipment use.

### Project Approach and Summary

In this project, research will evaluate the dosimeter using built-in feedback systems as an intervention method for preventing noise-induced hearing loss and will examine the relationship between noise levels and risk of acute occupational injury. Results will provide quantitative noise dosimetry, an assessment of the dosimeter as an intervention method and a potential leading indicator for noise-induced hearing loss and other injuries. By the end of the project, results should provide a method for assessing a state-of-the-art intervention method and an assessment of noise-induced hearing loss as a leading indicator for a number of acute workplace injuries.

### Benefits

Workplace injuries are traditionally targeted using interventions proximal to the acute event, such as behavioral factors, rather than distal factors, such as other exposures. Furthermore, hearing loss is often attributed to workers' lack of compliance, lack of supervision, or inappropriate use of personal protective equipment. This project assesses a potential leading indicator, not only of hearing loss, but also of workplace injuries. The developed intervention, if successfully applied, may result in reduced frequency of hearing loss and occurrence of acute injuries in the workforce, with associated potential cost savings and improved worker health and performance.

Occupational hygienists, managers, and safety specialists within electric utilities may use the in-ear dosimeter as a means to train their workers on the effective use of hearing protection and to clarify whether workplace noise is a contributor to other occupational injuries. Additional benefits derived from the work include an improved method to comply with OSHA "Employee Notification" requirements (1910.95).