

Asset Management

Program Overview

Program Description

For 2010, EPRI is offering three strategic collections of research projects or programs in “virtual programs.” These virtual programs have been designed to provide focus for solutions of key issues the industry is facing.

Utilities that operate transmission and distribution systems continue to look for ways to do more with their existing assets. The Asset Management virtual program includes projects from overhead and underground transmission as well as substations and distribution systems. Life cycle management, condition assessment, inspection techniques and methodologies and monitoring and diagnostics are just some of the key topics covered among the 17 projects included.

Overhead Transmission

Project Set Description

This research focuses on specific components (e.g. insulators, compression connectors, crossarms, etc.) as well as on projects focused on issues (e.g. lightning and grounding, live working, etc.). The work delivers a blend of short-term tools such as software, reference and field guides together with longer-term research such as component aging tests and the development of sensors for monitoring line components and performance.

Project Number	Project Title	Description
P35.001	Overhead Transmission Line Inspection and Assessment Methods Guideline	This project is a mix of tools, training, and information that will help members improve their inspection and assessment techniques.
P35.002	Conductor, Shield Wire and Hardware Corrosion Management	This project identifies, develops, and assesses the tools and procedures required to deal with conductors, shield wires, and hardware exposed to atmospheric corrosion.
P35.003	Sub-Grade Corrosion Management of Transmission Line Structures	This project helps determine cycle times for reinspection of the assets and the best methods of mitigation and remediation of corrosion damage.
P35.004	Compression Connector Management	This project provides a holistic approach to the inspection and management of compression connectors.
P35.005	Crossarm Management	Research is primarily focused upon the assessment of inspection technologies for crossarms and the development of reject and ranking criteria for various construction materials.

P35.001 Overhead Transmission Line Inspection and Assessment Methods Guideline (052001)

Key Research Question

There are several reasons why overhead transmission line inspection and assessment methods research is needed by utilities. The current transmission infrastructure is aging, and it is important to keep it both reliable as well as extend its life. To do so, utility managers need to keep abreast of new inspection and maintenance practices, tools and issues. If inspection and assessment of the transmission infrastructure is not thorough,

the systems will eventually become less reliable and components will fail. In addition, utilities will not be able to plan accordingly because they won't have a system in place to recognize if and when components will fail.

Approach

Our research team recognizes the work processes and challenges of our members. This research project will employ a tiered approach that will develop a number of materials and then help utility workers quickly incorporate these materials into their everyday work routines. Application of the project's results should simplify their jobs and help them to do their jobs better.

- Our research team continues to develop an understanding of indicators and symptoms of component failure and to update and keep current our technical reference guide, the Yellow Book.
- Our team develops computer-based instruction systems to help in learning about assessments and technologies and components.
- Our team develops field guides for field personnel which help to identify and provide information on the state of a specific component and the action to take if it is compromised.
- Our team develops and hosts hands-on workshops and conferences where inspection and assessment information is disseminated.

Impact

This research project may affect operations in a number of ways. There are also public benefits of this research.

- These tools should help to improve reliability of power delivery components.
- The inspection and assessment process should be enhanced.
- The public should get more reliable power delivery.
- Public safety issues may arise if a component fails. With tools and techniques to help prevent component failures, safety can be enhanced in areas where the public live and play.
- Hands-on events can help to improve utility workers skill sets; they train members regarding inspection methods and available tools and help workers identify high risk components before they fail.

How to Apply Results

The research program had been structured in a way so the tools are ready to be incorporated into a member's standard procedures. Members will be able to supply field guides to their field inspectors. Managers can use guides to set up their assessment programs. Hands-on training can provide staff with knowledge that they can apply immediately in the field. Computer-based training can be used throughout all levels of the organization, including field personnel and managers, as they apply what they learn from the Yellow Book reference material.

2010 Products

Product Title & Description	Planned Completion Date	Product Type
New Versions of OHTL Inspection and Assessment Methods (IAM) Reference Guide: This guide helps members initiate a new OHTL inspection and assessment program or refine an existing one.	12/31/10	Technical Report
New Set of Pictorial Guides: These field guides will be published both in printable and software form. The guides are designed for field use: pocketbook size (8"x4") and printed in color on glossy paper. Electronic versions are also available. Many members are distributing these guides to all field personnel, and they are forming the backbone of their inspection program.	12/31/10	Technical Update

Product Title & Description	Planned Completion Date	Product Type
Future On-line E-Learning Modules, Workshop, and Webcasts: On-line self-paced learning modules will continue to be developed around components or inspection technologies. This software can be used with members' current learning management systems.	12/31/10	Software
Biannual Overhead Transmission Lines Conference: The biannual Overhead Transmission Lines Conference will be held.	12/31/10	Workshop, Training, or Conference

Future Year Products

Product Title & Description	Planned Completion Date	Product Type
New Versions of OHTL Inspection and Assessment Methods (IAM) Reference Guide: This guide helps members initiate a new OHTL inspection and assessment program or refine an existing one.	12/31/11	Technical Report
New Set of Pictorial Guides: These field guides will be published both in printable and software form. The guides are designed for field use: pocketbook size (8"x4") and printed in color on glossy paper. Electronic versions are also available. Many members are distributing these guides to all field personnel, and they are forming the backbone of their inspection program.	12/31/11	Technical Update
Future On-line E-Learning Modules, Workshop and Webcasts: On-line self-paced learning modules will continue to be developed around components or inspection technologies. This software can be used with members' current learning management systems.	12/31/11	Software
Biannual Overhead Transmission Lines Workshop: The biannual Overhead Transmission Lines workshop (classroom and field training) will be given. Inspection technologies will be discussed and member practices shared.	12/31/11	Workshop, Training, or Conference

P35.002 Conductor, Shield Wire and Hardware Corrosion Management (063280)

Key Research Question

Corrosion is a natural and unavoidable phenomenon that all utilities must face to a degree at some point. For some utilities, overhead wire failure due to accelerated atmospheric and galvanic corrosion is an immediate concern and major cause of unplanned outages and increased maintenance costs. One utility surveyed reported that failed shield wires were the foremost cause of unplanned outages. Reliability and availability of overhead transmission systems are a major concern in an ever-growing market with anticipated load growth.

Approach

- This project provides tools and processes for inspecting and assessing overhead shield wires, conductors, and hardware, and it produces management and engineering guides. The project's goals will be achieved via research in the following task areas over the lifetime of project: Inspection: This task addresses the question of how to gather data and information regarding the state and dynamics of corrosion activity.
- Population Assessment: This task addresses the "what next?" questions stemming from an effective inspection and detection program. It will address how to inspect, what to sample, how to test, how to analyze results, and how to make a decision.

- The Selection and Application of Wires: This task provides results to aid designers in the selection of the most appropriate conductor and shield wires to extend the life of these components in their specific environment and application.
- Shield Wire and Phase Conductor Management Program: Progressive actions will proceed in a deliberate step-wise manner from year to year toward the completion of the tasks listed above. Eventually the tasks will culminate and integrate into a comprehensive management program applicable to designers, specification writers, engineers, operators, inspectors, and management.

Impact

The project may help to: reduce unplanned outages, improve reliability, and reduce associated repair costs by providing corrosion control and management practices for both overhead ground wires and phase conductors. It could also provide a more accurate picture of the status of the power delivery infrastructure, enabling more informed maintenance and fiscal decisions.

How to Apply Results

Transmission designers, engineers, operators, and inspectors will use the results of this project to inspect and assess overhead shield wires and conductors. Employing the knowledge gained from the project's results will help members develop a cost-effective maintenance program that will improve reliability by identifying and assessing high-risk shield wires and conductors prior to failure.

2010 Products

Product Title & Description	Planned Completion Date	Product Type
Overhead Shield Wires Management Guide - Final: A final guide will be published on assessing overhead shield wires and the appropriate technologies.	12/31/10	Technical Report
Assessment of Shield Wire Inspection Technologies: The final results of the technologies assessed to evaluate overhead shield wires will be published.	12/31/10	Technical Update

Future Year Products

Product Title & Description	Planned Completion Date	Product Type
Inspection and Assessment of Overhead Transmission Line Hardware: This technical update will document the current state of industry inspection methods and examine new and emerging technologies for the identification of degraded hardware.	12/31/11	Technical Update
Environmental Factors Governing Corrosion Rates on Overhead Transmission Line Hardware: To optimize the hardware inspection process, circuits can be profiled for environmental factors that control the start of corrosion. This technical update is designed to help prioritize circuits based upon age, current rating, proximity to shorelines or industrial activities, prevailing weather patterns, and many other environmental factors.	12/31/11	Technical Update

P35.003 Sub-Grade Corrosion Management of Transmission Line Structures (063281)

Key Research Question

The total cost of corrosion to U.S. industry is more than \$276 billion annually, of which more than 30% could be prevented through the use of optimum corrosion-management practices. Even within the electricity industry, the costs associated with corrosion range from \$5–\$10 billion each year. Transmission and distribution lines are also greatly affected by the effects of sub-grade corrosion. These effects are manifest in costly outages and increased operation and maintenance (O&M) costs. Visual inspection by excavation is the predominant method of inspection, but this process is costly and labor intensive. Thus, research is needed to provide members with methods for effective sub-grade corrosion management.

Approach

This project addresses the issues surrounding sub-grade corrosion of transmission line structures by providing O&M staff tools and techniques to make the most informed and cost-effective decisions. This will be achieved through development and refinement of inspection techniques and methodology, informed assessment, and effective remediation techniques. This project will culminate in the production of a comprehensive corrosion management program, with the ultimate goal of reducing total O&M costs associated with sub-grade corrosion.

EPRI will divide the project into the following subtasks:

- *Sub-grade Corrosion Inspection.* This task will research practices and tools used by the industry, as well as develop new technologies centered on sub-grade inspection.
- *Sub-grade Corrosion Assessment Tools and Techniques.* This task will research all environmental effects affecting sub-grade components, including soil properties, climate, industrial proximity, shared right-of-way, and stray current issues. Ultimately, degradation mechanisms and failure mechanisms will be more fully understood.
- *Sub-grade Corrosion Remediation and Prevention.* This task will research available treatment options when corrosion is discovered or detected. It will also address how corrosion may be prevented from a design and construction perspective by building innate resistance into structures and components.
- *Overarching Sub-grade Corrosion Program.* Finally, this research will culminate in a comprehensive sub-grade corrosion management program.

Impact

This program may have the following impacts:

- Provide new tools and inspection methods to address sub-grade corrosion problems
- Defer inspection and replacement costs
- Reduce O&M costs
- Reduce outages
- Mitigate the corrosion process impact on utility assets (new construction)

How to Apply Results

Transmission Operations and Maintenance staff will use the tools and knowledge delivered in this project to develop a cost-effective maintenance program to inspect, assess, and refurbish sub-grade infrastructure, hence extending life. This may improve reliability by identifying and assessing high risk sub-grade components prior to failure.

2010 Products

Product Title & Description	Planned Completion Date	Product Type
Sub-grade Corrosion Guide: Sub-grade Corrosion Management Guide: This technical update reports and summarizes the project's findings and provides a sub-grade corrosion reference book for engineers, designers, and planners.	12/31/10	Technical Report
Assessment of Remediation Techniques: This report will evaluate various techniques to remediate corrosion concerns, such as coatings and sacrificial anode technologies.	12/31/10	Technical Update

P35.004 Compression Connector Management (065547)

Key Research Question

Predicting the remaining life of compression connectors (splices and dead-end) is a major challenge. Splice failures are expected to increase with increased demand for heavier loading operations. Due to the limitations of existing inspection techniques, isolating the components early enough to avoid failure is difficult. Inspection techniques and population evaluation methodologies are needed.

The performance of compression connectors is directly related to installation practices and procedures. Conductor cleaning and field personnel training remain two key priorities to address these issues.

Approach

Inspection of Compression Connectors. Technologies currently used to inspect splices include micro-ohm measurement and infra-red inspection. However, the reliability, repeatability, application methods, and threshold levels for these technologies are not well defined. In addition, each of these techniques provides limited information or is costly to implement. This task will increase understanding of the currently available techniques, their performance, and their application. Guidelines will be provided for their application, and promising new techniques will also be sought and identified.

Compression Connector Population Management. This task aims to develop a methodology to evaluate an entire population of connectors. An approach will be developed and documented, potentially including high-risk design, application, and environment identification, as well as inspection techniques, sampling, laboratory testing, results analysis, and decisionmaking.

Connector Installation Techniques. EPRI will develop training for field personnel and tools to improve the reliability of newly installed connectors. The task will use the DVD-based training developed and the conductor cleaning techniques currently being developed under supplemental projects.

Compression Connector Refurbishment. This task will evaluate the application of "shunt"-type devices that are being proposed to address compression connectors that have been identified as high risk by field inspection. This research will address issues such as the performance of these devices, their life expectancy, application concerns, and inspection and assessment. *Failures Database.* This task will develop and maintain a failure database. The database will be used to highlight issues and help guide the research.

Impact

The research project may affect the utility's operation in a number of ways:

- Increase safety of transmission lines by reducing line droppings
- Reduce sustained unplanned outages due to compression connector failure
- Optimize spending of operations and maintenance (O&M) funding

- Improve productivity of field personnel with training and field tools
- Address the loss of institutional knowledge by providing training

How to Apply Results

Members will modify their current inspection practices as a result of the research. Operations and maintenance personnel can implement the developed EPRI population assessment methodology themselves or as part of a supplemental project. Field personnel will be able to use the provided training material (e.g., DVD) as part of their in-house training programs.

2010 Products

Product Title & Description	Planned Completion Date	Product Type
Identification of New Compression Connector Inspection Technologies: This task focuses on identifying new compression connector inspection technologies and demonstrating promising ones.	10/30/10	Technical Update
Compression Connector Population Management: This report will document an approach to compression connector population management. The document will include indentifying high risk units, inspection techniques, and decisionmaking.	12/31/10	Technical Update
Evaluation of Remediation Techniques.: This report will document the investigation and testing of different techniques used to remediate compression connectors that have been identified as high risk.	12/31/10	Technical Update

Future Year Products

Product Title & Description	Planned Completion Date	Product Type
Field Guide Inspection Techniques and Evaluations: A field guide will be developed that lists, describes, and evaluates available inspection techniques.	12/30/11	Technical Update
Workshop on Compression Connector Inspection Technologies: A workshop will be delivered based on EPRI research, and inspection techniques will be demonstrated.	12/30/11	Workshop, Training, or Conference
Evaluation of Remediation Techniques: This report will detail remediation techniques and will include technology type and performance.	12/30/11	Technical Update
Online Training Module on Inspection Techniques and Evaluations: A computer-based training module will be developed that details inspection techniques and evaluations. This software will be able to be used with members' current learning management systems.	12/30/12	Software

P35.005 Crossarm Management (067437)

Key Research Question

Predicting the remaining life of structure crossarms is a major challenge to electric utilities. An increase in crossarm failures should be expected as transmission structures age. Due to the limitations of existing inspection techniques, identifying the components early enough to avoid failure is difficult. Improved inspection techniques and population evaluation methodologies are therefore needed.

The cost and physical performance of crossarm assets is directly related to inspection practices and decisions. Identification of crossarm degradation and timely replacement decisions by field personnel remain two key priorities.

Approach

Inspections of Crossarms. Technologies and techniques currently used to inspect crossarms consist primarily of visual or sounding techniques. However, the reliability, repeatability, application methods, and results for these processes are not well defined. In addition, each of these processes provides limited information and not well-defined results. This task will increase understanding of the current techniques, their performance, and their application. Guidelines will be provided for their application, and promising new techniques will also be sought and identified.

Crossarm Population Management. This task aims to develop a methodology to evaluate an entire population of crossarms. An approach will be developed and documented, potentially including high-risk design, application, and environmental issues, as well as inspection techniques, sampling, laboratory testing, results analysis, and decisionmaking.

Impact

This project may have the following impacts:

- Increase safety of transmission lines by reducing crossarm failures
- Reduce sustained unplanned outages attributable to crossarm failures
- Address loss of institutional knowledge by providing training
- Optimize spending of operations and maintenance (O&M) funding
- Improve productivity of field personnel with training and field tools

How to Apply Results

By assisting in the development or enhancement of maintenance practices, members will modify their current inspection practices as a result of the research. This project also improves the expertise of the workforce and addresses the loss of knowledge in the industry. This will culminate in reliability improvement by identifying and assessing high-risk components prior to failure. Operations and maintenance personnel can implement the developed EPRI population assessment methodology themselves or as part of a supplemental project.

2010 Products

Product Title & Description	Planned Completion Date	Product Type
Literature Survey of Crossarm Inspection Tools and Techniques: This technical update will document the currently available inspection tools and published information on their application. A survey of utility practices and experiences may be performed.	12/30/10	Technical Update
Report on Crossarm Degradation Modes: This technical update will summarize literature on crossarm degradation and outline a research plan to investigate and understand degradation further. This work will form the foundation of the population management that will be developed.	12/30/10	Technical Update
Test Setup for Evaluation of Crossarm Technologies: A test setup will be developed to evaluate crossarm inspection technologies. An initial evaluation of some limited technologies will be performed to assess the test setup.	12/30/10	Technical Update

Future Year Products

Product Title & Description	Planned Completion Date	Product Type
Aging of Live Working Tools - Mechanical, Electrical	12/30/11	Technical Update
Evaluation Of Crossarm Inspection Technologies: Technologies used for inspection and evaluation of crossarms will be evaluated, and a report will be prepared that details the findings for members.	12/30/11	Technical Update
Development of Crossarm Failure Database: A database of crossarm failures will be implemented to help better understand the failure modes and frequencies on crossarms. A standard format for crossarm failure reporting will be developed to support information gathering.	12/30/11	Technical Resource
Report on Crossarm Inspection Tools ,Techniques, and Evaluations: A report will be prepared providing information on the failure modes, inspection tools and techniques an evaluation considerations for the inspection of crossarms	12/30/11	Technical Update
Field Guide on Crossarm Inspections and Evaluations: A field guide for use by field personnel will be prepared covering the failure modes, inspection tools, and techniques as evaluation considerations for crossarm inspection.	12/30/12	Technical Report
OTLOT Module on Crossarm Inspections and Evaluation: A online training module will be developed to train field personnel in failure modes, inspection tools, and techniques as evaluation considerations for crossarm inspection.	12/30/12	Software

Underground Transmission

Project Set Description

This research leads the exploration and deployment of promising new technologies and tools to help underground transmission owners design and operate cost-effective cable systems with increased power capacity and longer lives, diagnose problems before outages occur, and repair them at minimum cost and within acceptable time periods.

Project Number	Project Title	Description
P36.002	Extruded Dielectric Cable Systems	This project provides understanding of performance factors, tools and techniques for inspection, as well as novel materials to enhance the viability and operation of extruded dielectric cable systems.
P36.003	Laminar Dielectric Cable Systems	This project provides understanding of cable degradation and life-limiting factors, effective methods for maintaining the integrity of cable system components, and tools and techniques for on-line inspection to enhance the reliability and manage the life cycle of laminar dielectric cable systems.

P36.002 Extruded Dielectric Cable Systems (062105)

Key Research Question

The amount of extruded dielectric (ED) cable being installed at HV and EHV levels, some with transmission capacities approaching 1 GW, is growing substantially. The reliability of long, high-capacity lines is very important. However, many utilities lack experience with these newer systems and face uncertainties associated with selecting various cable sub-types, installation designs, field commissioning tests, operation, and maintenance. Simultaneously, emerging new extruded dielectrics promise to decrease losses, extend useful length for alternating current applications, reduce cable diameter, and extend pulling lengths. Challenges posed by these dielectric systems include understanding and controlling thermally induced mechanical behavior under cyclic loading, operation at sustained high temperatures and emergency overloads, and effective application of improved condition assessment techniques, such as partial discharge (PD) measurements—especially as a commissioning test at elevated test voltages or during on-line monitoring. The costs, benefits, and risks associated with embedded temperature sensing optical fibers also need better definition.

At the same time, utilities need a better understanding of cable system aging and failure mechanisms, and assurances that the performance and longevity of ED cable systems will be at least as good as the proven fluid-filled systems that have historically been the backbone of U.S. underground transmission technology. EHV cable splices are a major concern because of high electrical and mechanical stresses at critical interfaces, temperature-dependent aging effects, and the influence of high thermal-mechanical (T-M) forces with some splicing vault layouts.

Approach

This project will investigate and improve new materials, equipment, and methods for HV and EHV ED cable systems, including use of advanced sensors and techniques. Solutions will be applicable to selecting, installing, commissioning, testing, operating, and maintaining an overall system. The project is task driven, as prioritized by members and available funding. Research will address:

- Experimental verification of T-M models for ED cables in ducts and pipes. EPRI-sponsored research has formulated a theoretical basis for T-M behavior of ED cable systems. The models have not been verified experimentally. A full-sized test rig containing an extruded dielectric cable in a representative part of a duct-manhole system is being constructed at EPRI's Charlotte lab. A rigorous experimental procedure will obtain the data needed to validate the accuracy of the EPRI models and amend them as necessary. Guidelines for T-M-resistant designs will be developed after validation of the models.
- Inspection and condition assessment for ED cable systems. The research team will first identify and evaluate opportunities for innovative tools and methods. A prime focus will be assessment of cable health with advanced sensors monitoring electrical, mechanical or thermal behaviors (e.g., on-line PD detection/monitoring and T-M damage). Solutions to transmitting data in near real time will be explored. A key technology is the design and use of fiber optics for PD measurement or other novel applications. Research will address effective detection of fiber damage during installation and operation, and the long-term impact of integral fibers on the health of transmission cable.
- High-stress cable and accessories using nano-composites. This research supports ongoing activities to commercialize nano-dielectric materials for use in underground transmission cables. Research will be directed toward performance testing of model cables; development and testing of suitable accessories; understanding and development of wet design insulation enhancements; and development of reduced-diameter cables using nano-composites.

Impact

Project research will produce new materials and monitoring tools that may substantially improve the ability of extruded dielectric HV and EHV cable systems to meet system reliability, maintainability and safety requirements, and will establish technical standards of design that can help extend life for these systems.

- Laboratory testing of thermal-mechanical behavior of ED cables in ducts and pipes will lead to standardized designs and confidence in high-reliability UT systems for their intended design life.
- Greater knowledge of high-temperature operation implications will ensure desired reliability and possibly increased transmission capacity at low additional cost.
- Development and deployment of advanced sensors and inspection techniques will reduce maintenance costs and increase system reliability
- Development and effective application of new nano-dielectric materials will significantly reduce initial and lifetime costs of UT.

How to Apply Results

Underground transmission engineers, designers, and managers can use the guidelines, methods, and technologies developed or assessed in this project to improve productivity and lower costs for designing, installing, commissioning, testing, operating, and maintaining extruded dielectric cable systems. Engineers will use T-M model validation results to implement T-M-resistant duct and vault designs. Operators and maintenance departments will deploy new sensors and tools to obtain real-time and near real-time information on cable system health. Planners will take advantage of smaller diameter, longer-lived nano-dielectric cables to provide additional options for increasing transmission system throughput and extending cable life.

2010 Products

Product Title & Description	Planned Completion Date	Product Type
<p>Experimental Verification of TM Models for Extruded Dielectric Cables in Ducts and Pipes: This product comprises experimental test rigs to produce distress in XLPE cable samples in ducts and pipes to verify existing models. Contingent upon adequate funding, fabrication and deployment of the test rig in Charlotte will be completed and data collection and analysis begun. The rigs will provide validation results for one or more cable construction types.</p>	12/31/10	Hardware
<p>Advanced Sensors and Inspection Techniques for Extruded Dielectric Transmission Cable Systems: This is a multiyear task beginning in 2010. A technical update will document interim results of research and development on advanced sensors and data transmission techniques for on-line inspection of cable system condition and operational status, with a focus on the use of fiber-optic sensor systems.</p>	12/31/10	Technical Update
<p>High Stress Cable and Accessories Using Nano-Composites: This multiyear task will build upon prior-year activities by EPRI and its joint development partner to commercialize nano-dielectric materials for use in underground transmission cables. In 2010, results from host utility demonstrations will be reported.</p>	12/31/10	Technical Report

Future Year Products

Product Title & Description	Planned Completion Date	Product Type
<p>Guidelines for Thermo-mechanical Design of Extruded Dielectric Cable Systems: This task in 2011 will build on previous EPRI work on T-M behavior of ED cables in ducts, pipes and manholes. It will provide a concise source of practical engineering knowledge to help cable engineers successfully design ED cable systems with respect to T-M effects in all common installation configurations. For various cable types, recommendations would consider design factors such as: duct/cable diameter ratio; vault dimensions as a function of cable type, joint dimensions, and relative duct/pipe diameter; cable and joint orientation in vault; cable and joint clamp spacing and clamp design, including non-axial-symmetric forces; and cable and joint clamp type and dimensions.</p>	12/31/11	Technical Report
<p>Experimental Verification of TM Models for Extruded Dielectric Cables in Ducts and Pipes: This project will employ experimental test rigs to produce distress in XLPE cable samples in ducts and pipes to verify existing models. The rigs will provide validation results for one or more cable construction types. An interim report will provide an update on research results.</p>	12/31/11	Technical Update
<p>Advanced Sensors and Inspection Techniques for Extruded Dielectric Transmission Cable Systems: This is a multiyear task that began in 2010. A technical update will document interim results of research and development on advanced sensors and data transmission techniques for on-line inspection of cable system condition and operational status, with a focus on the use of fiber-optic sensor systems.</p>	12/31/11	Technical Update
<p>High Stress Cable and Accessories Using Nano-Composites: This multiyear task will build upon prior-year activities by EPRI and its joint development partner to commercialize nano-dielectric materials for use in underground transmission cables. An interim report will document research and solutions to commercialization issues such as developing and testing suitable accessories, and understanding and developing wet design insulation enhancements.</p>	12/31/11	Technical Update
<p>Integrity of Laminated Moisture Barriers in XLPE Cable: Increased use of foil laminate moisture barriers in XLPE cable presents increased potential for failure associated with thermal and mechanical stresses in cable in ducts (e.g., extreme bending). Researchers will obtain cable samples and use experimental bending rigs to cyclically stress the cables to failure at operating temperatures in order to determine their resistance to potential failure. This product will be an interim report on experimental testing of foil laminate cables in EPRI's TMB bending rig.</p>	12/31/11	Technical Update
<p>Methods for Improved Installation Quality in Extruded Dielectric Cable Accessories: This task will consist of a multiphase approach to improving the quality of installation in ED cable accessories. Activities will include one or more of the following: Investigate practices and procedures currently used by different utilities; investigate current diagnostic and inspection techniques to address the main root cause of cable accessory failures; develop greater understanding of design and operation issues for EHV splices and terminations, such as electrical and mechanical stresses, temperature-dependent aging effects, and influence of high thermal-mechanical forces; develop guidelines for cable accessory installation quality assurance; assess the feasibility of robotic technology and machine tools for cable end preparation; and recommend further research or development.</p>	12/31/12	Technical Update

Product Title & Description	Planned Completion Date	Product Type
<p>Impact of High Temperature Operation on Extruded Dielectric Cable Systems: This task will increase knowledge about the reliability and cost implications of operating UT systems at high temperature to increase capacity. It will utilize the EPRI T-M model to calculate the impact on insulation geometry for a variety of cable designs and installation and operation scenarios. It will also define alternative design/operation scenarios to achieve the desired reliability as well as identify the cost impact.</p>	12/31/12	Technical Update
<p>EHV XLPE Cable Workshop: This task is a workshop to inform and help utilities apply results reported by EPRI in <i>Cable System Technology Review of XLPE EHV Cables, 220 kV to 500 kV (2002)</i> and <i>Mechanical Effects on Extruded Dielectric Cables and Joints Installed in Underground Transmission Systems in North America (2004)</i>. Development and deployment experiences of XLPE transmission cables in recent years will be addressed in the context of these reports. Lessons will be drawn for application to current or planned cable systems.</p>	12/31/12	Technical Update

P36.003 Laminar Dielectric Cable Systems (063284)

Key Research Question

Much of the installed UT infrastructure in the United States is high-pressure fluid-filled (HPFF) "pipe-type" cable. Along with self-contained fluid-filled (SCFF) cable systems, most of these systems have performed well, surpassing their original design life expectations. The growing age of many of these assets is a cause for concern, in some instances related to system integrity, including the impact of pipe corrosion and thermal-mechanical movement of cable cores inside the pipes. Replacement costs for laminar dielectric systems are very high, driving efforts to extend life through selective upgrades, retrofits, and an increased focus on operation and maintenance. Cable system loadings often increase with age, such that some older systems are required to operate at ever higher loads and temperatures. Concurrently, changes in their thermal environment since commissioning have often occurred without the knowledge or control of the utility—and frequently with negative effects on ratings.

Knowledge-based cable system condition assessment and rerating in such circumstances is a key reliability and economic issue. The following are specific research needs for HPFF and SCFF cable systems:

- Effective methods for rapid leak detection and location to reduce operational and environmental impacts
- Effective methods for maintaining corrosion protection of pipes, including location and repair of compromised pipe sections
- Engineered optimal procedures for depressurization, repair, and re-pressurization of pipe-type systems to reduce dependence on contractors and improve maintenance practices
- Post-construction inspection and assessment guidelines
- Development and validation of research and tools that will model thermal mechanical bending (TMB) in pipes. Solutions are analogous to extruded insulation cable behavior in ducts or pipes.
- Partial discharge (PD) diagnostic techniques are known to have limited effectiveness for pipe-type cables, but continued research and development may ultimately enable the industry to benefit from using PD techniques on these cable types.

Approach

This project will investigate and develop new equipment, methods, and procedures to improve reliability and reduce costs for installation, operation, maintenance, and eventual replacement of laminar dielectric (LD) cable systems. The project is task driven, as prioritized by members and available funding. Research will address the following areas:

- Corrosion of Steel Pipes used with Pipe-type Cable Systems. This two-year project, which began in 2009, assesses corrosion prevention and mitigation techniques as well as innovative corrosion inspection and monitoring techniques through field tests at the Klondike corrosion test facility, laboratory tests in Charlotte, and an industry practices survey. Laboratory studies also investigate pipe corrosion rates and other characteristics to assist in pipe life prediction. Of particular concern are techniques for inspecting steel pipes in close proximity to electrified railroads, techniques for mitigating pipe corrosion before it leads to pipe failure, and methods to predict pipe life. A guide on cathodic protection system operation and maintenance will be developed.
- Leak Detection and Location in HPFF and SCFF Cables. This multiyear task will build on prior EPRI research to develop novel methods for economical, easy-to-use, and rapid leak detection and location in HPFF and SCFF cable systems. Research will focus on new inspection techniques or tools that will give near real-time results at very low levels of leak rate or lost volume, and provide rapid location of leaks without extensive staff or equipment infrastructure. Efforts will build on results from a supplemental project in 2009, but will seek to exploit different, simpler techniques.
- Condition assessment techniques for LD cable systems. This multiyear task will provide advanced techniques for in-field condition assessment of LD transmission cable systems. Research will explore new methods and tools for: on-line PD detection, tan delta, fluid condition or combustible gas measurement, continuous PD monitoring, and other effective condition assessment systems. Development and validation of sensors, digitizers, recorders and telemetry systems to deliver distributed, near real-time in-situ data during on-line monitoring will be pursued. Fiber optic and semiconductor sensor technology will be evaluated.
- Thermal-mechanical bending in HPFF (pipe-type) cable systems. Researchers will follow a path similar to that taken for extruded dielectric cables. An experimental protocol and designs for test rigs to produce distress in cable samples will provide the basis for testing. Test rigs will be constructed at an EPRI lab and testing conducted to replicate, accelerate, and detect cable deterioration. Diagnostic methods to detect cable distress at an early stage will be evaluated. Collaboration with other members who have funded work in this area will be pursued as well.

Impact

Project research will produce new methods and monitoring tools that will substantially improve the ability of engineers and planners to assess the condition of laminar dielectric cable systems, and to take proactive steps in operating and maintaining these systems to extend asset life and prevent unexpected outages.

- Methods for inspecting steel pipes for corrosion damage, enhanced corrosion protection, and pipe life prediction will improve the longevity and reliability of pipe-type cable systems and help avoid expensive unplanned outages for repairs.
- Rapid detection and location of fluid leaks will reduce costs associated with extended outages and improve environmental responsiveness.
- Development and deployment of advanced sensors and inspection techniques will reduce maintenance costs.
- Real-time monitoring of the condition of aging cable system assets and better understanding of potential failure mechanisms (such as TMB in pipes) will lead to maintenance intervention prior to spontaneous failure, resulting in lower repair costs and higher reliability.

How to Apply Results

Underground transmission engineers, designers, and managers can use the knowledge base, guidelines, methods, and technologies developed in this project to improve productivity and lower costs for operating, maintaining and extending the life of laminar dielectric cable systems. Reliability and safety will be enhanced and asset replacement strategies improved. Maintenance personnel will make effective use of staff time and budget resources by applying new inspection methods and monitoring technology. Planners will learn where to apply selective upgrades and retrofits through better understanding of the relative condition of their asset fleet and where cable systems are most susceptible to damage from corrosion, TMB, and other potential failure mechanisms.

2010 Products

Product Title & Description	Planned Completion Date	Product Type
Corrosion of Steel Pipes used in Pipe-type Cable Systems: This product is a final technical report on steel pipe corrosion mechanisms, corrosion prevention and mitigation techniques, assessment of innovative corrosion inspection and monitoring techniques, common industry practices, laboratory studies on corrosion rates to assist in pipe life prediction, and a guide on cathodic protection system operation and maintenance.	12/31/10	Technical Report
Leak Detection and Location in HPFF and SCFF Cables: This product is an interim progress report on the development of effective methods of rapid leak detection and location in HPFF and SCFF cable systems.	12/31/10	Technical Update
Condition Assessment Techniques for Laminar Dielectric Cable Systems: This report will describe progress in finding and developing advanced techniques for in-field condition assessment of LD transmission cable systems.	12/31/10	Technical Update
Experimental Protocol and Test Rigs for Study of TM performance of HPFF Cables: This report will describe progress in the development of experimental protocols and test rig design.	12/31/10	Technical Update

Future Year Products

Product Title & Description	Planned Completion Date	Product Type
Test Rig for Experimental Study of TM performance of HPFF Cables: This multiyear product comprises design and construction of a test rig to produce distress in HPFF cable samples, cycling them to failure and analyzing the results.	12/31/11	Hardware
Condition Assessment Techniques for Laminar Dielectric Cable Systems: This product continues research in finding and developing advanced techniques for in-field condition assessment of LD transmission cable systems.	12/31/11	Technical Update
Leak Detection and Location in HPFF and SCFF Cables: This multiyear task develops novel methods for economical, easy-to-use, and rapid leak detection and location in HPFF and SCFF cable systems. Research will focus on finding new inspection techniques or tools that will give near real-time results.	12/31/11	Technical Update
PD Diagnostics for Pipe-Type and Self-Contained Cable System: This product will report on investigations to understand and validate PD diagnostic techniques and determine their effectiveness for HPFF and SCFF cables.	12/31/12	Technical Update

Substations

Project Set Description

This research helps substation owners enhance safety, reliability, equipment life and performance despite shrinking maintenance budgets. The work offers a complete portfolio of tools and technologies such as transformer monitoring. It also includes resources to improve transformer and circuit breaker life management such as failure databases and aging models.

Project Number	Project Title	Description
P37.001	Transformer End-of-Life and Condition Assessment	Effective transformer life management via novel condition-monitoring techniques and new algorithms for turning that condition monitoring data into actions.
P37.002	Transformer Life Extension	This project provides a mix of field tools and forensics analysis to extend transformer life and improve decisionmaking on these critical substation devices.
P37.003	Maintenance, Condition Assessment and Life Extension Guidelines for Substation Equipment	Provide practical reference material for integrated and consistent best practice actions for maintenance, condition assessment and life extension actions for substation equipment.
P37.004	Risk Mitigation and Maintenance Strategies for Substation Equipment	Analytics for Substations Asset Performance: Development of data models and analytics which combine condition information with fundamental understanding of the equipment to provide decision support for improved performance and risk management.
P37.005	Integrated Monitoring and Diagnostics	This project provides immediate and comprehensive knowledge of substation sensors and fast-tracks examination of new sensors from other industries in the EPRI Sensor Laboratory—allowing for confident decisionmaking on potential substation applications.
P37.006	Industry-wide Equipment Performance Database	This project builds and maintains a unique, independent repository and analysis tools to collect and analyze equipment performance data to provide information that supports maintenance and asset management decisions.
P37.007	Balance of Substation – Inspection, Assessment and Maintenance Strategies	Balance of substation inspection, assessment and maintenance strategies

P37.001 Transformer End-of-Life and Condition Assessment (062154)

Key Research Question

There is an increasing need for electricity companies to use assets to the fullest while maintaining system reliability. In this environment, management of the aging population of power transformers has become the most critical issue facing today's substation managers and engineers. Central to transformer management is effective transformer diagnostics, condition assessment, and knowledge retention and transfer. This project addresses these key issues through three focused themes and a multiyear plan of tasks to support those themes.

Approach

Three broad themes guide the research:

- 1) EPRI Power Transformer Guidebook Development
- 2) Develop and Demonstrate New Condition Monitoring Sensors and Techniques
- 3) Develop and Demonstrate Tools to Convert Transformer Data into Useful Information for Action

Each year, results are delivered through tasks performed to address each theme. The stability in the themes supports a clear multiyear plan approach. Members have two distinct areas of influence on the multiyear plan: in the selection of themes and in the prioritization of the annual tasks that support these themes.

The themes that steer this project are described in detail below:

Copper Book (EPRI Power Transformer Guidebook) Development

In 2010 we plan to add four chapters to the Copper Book. In each year of development, the work-to-date is published to allow members to use the materials as they are produced. The ultimate goal is a comprehensive reference book that can be used by members responsible for all aspects of transformer operation, maintenance, procurement, and life-cycle management. It can be used as a training aid and as a repository for all pertinent information on transformer ownership. The electronic version includes applets that perform some of the more common calculations necessary for transformer management.

Develop and Demonstrate New Condition Monitoring Sensors and Techniques

Under this theme EPRI conducts vital research on improved techniques for assessing transformer condition. The research develops new transformer diagnostic tools and evaluates existing hardware and software for transformer and LTC condition assessment. The project develops specialized sensor hardware to provide insights into transformer health that are not obtainable using traditional techniques. Develop and Demonstrate Tools to Convert Transformer Data into Useful Information for Action

Under this theme EPRI uses the knowledge and experience of the world's leading transformer engineers to develop diagnostic algorithms and expert system modules to convert transformer monitoring data into useful information for action. The results address the need that staff face in distilling large volumes of monitoring data into clear maintenance or planning actions. EPRI's results will be produced in a way that enables companies to easily and rapidly apply the results.

Impact

- Enables effective transformer life management via condition-monitoring techniques and their application
- Advances detection and analytical techniques for evaluation of partial discharges, acoustic emissions, vibration, and dissolved gasses in oil in transformers and LTCs for better decisionmaking
- Through the Copper Book, this project produces the first comprehensive collection of transformer knowledge designed specifically for utility owners and operators

How to Apply Results

Substation engineers, designers, and operations and maintenance personnel can use this project's results to obtain complete information about the condition of a transformer, enabling them to make decisions on the disposition of transformers without additional consultation, testing, and analysis. Results will take the form of hardware, software, and guidebooks. The Copper Book will be a comprehensive reference book that can be used by utility personnel responsible for all aspects of transformer operation, maintenance, procurement, and life-cycle management. It will be used as a training aid and as a repository for all pertinent information on transformer ownership. The electronic version will include applets that will be used to perform some of the more common calculations necessary for transformer management.

2010 Products

Product Title & Description	Planned Completion Date	Product Type
Novel Sensors for Transformer Diagnosis: This product will consist of research into novel sensors that return critical data from transformers.	12/31/10	Technical Update
EPRI Copper Book Development (Power Transformer Guidebook): In 2010 we will add four more chapters to the Copper Book.	12/31/10	Technical Update
Tools to Convert Transformer Data into Action: EPRI will continue to develop diagnostic algorithms and expert system modules to convert transformer monitoring data into useful information for action.	12/31/10	Technical Update

Future Year Products

Product Title & Description	Planned Completion Date	Product Type
Field validation results from transformer algorithm development		Technical Update
Novel Sensors for Transformer Diagnosis - field data gathering	12/31/11	Technical Update
EPRI Copper Book Development - Additional Chapters	12/31/11	Technical Update

P37.002 Transformer Life Extension (058559)

Key Research Question

A structured life extension program can help energy companies make informed decisions on maintenance, replacement or refurbishment, and operating practices to ensure safe, reliable, and cost-effective transformer use.

Approach

This project has three broad themes in Transformer Life Extension that guide the research:

- 1) Research into new markers in the oil, to improve estimates of remaining life.
- 2) Application of novel online filtration materials and techniques to extend life.
- 3) Development of a forensic library to better predict future failures in an aging transformer fleet.

Each year results are delivered through tasks performed under each theme. The stability in the themes supports a clear, multiyear plan approach.

The themes that steer this project are described in detail below: Research into new markers in the oil, to improve estimates of remaining life Improved estimates of a transformer's remaining life offer significant financial and reliability benefits. EPRI is researching new markers in the oil that hold the potential for large improvements in the accuracy of paper life estimates. The research has progressed from paper studies through to laboratory trials. In 2010 research will move to the first of the field pilots.

Application of novel online filtration materials and techniques

New research has demonstrated the possibility for online filtration of oxygen and moisture without the need for cartridge replacements. In 2010 EPRI research will take the successes gained in the laboratory into the field for the first pilot trials on member transformers.

Forensics Library

EPRI research examines failed units that have aged to full maturity (i.e., excluding design, materials, or workmanship flaws). The resulting forensics library provides members with new insights into likely end-of-life scenarios for the increasing population of aging transformers. Each forensic study includes both the physical evidence of the internal inspection and the life history of the unit (including historical test information, monitored data, and loading). EPRI's collaborative approach to this research will bring multiple members' forensics to the study—allowing for a far more rapid development of typical failure and aging mechanisms. Presently these valuable lessons are often lost after a unit is retired. EPRI's research in this area will capture

and share this vital knowledge. This multiyear effort will be paced by access to transformer failures and historical data. Each year will produce an updated library based on all prior investigations.

Impact

The impacts of this research include the following:

- Improved estimates of the remaining life in transformers
- Extended transformer life through application of novel filtration materials and techniques
- New insights into likely end-of-life scenarios for the increasing population of aging transformers
- Improved decision making on replacement or refurbishment of transformers

How to Apply Results

The research results have been structured to allow for ready application by members. In the case of the online filtration research, EPRI is demonstrating the results through pilots in member substations. The results are shared with the broader membership, and the feedback is being incorporated into refined approaches. In the case of the forensics library, the results will be made available in an easily searchable format that will enable members to focus in rapidly on the forensic studies that directly relate to their particular situations.

2010 Products

Product Title & Description	Planned Completion Date	Product Type
Novel techniques to both estimate and extend transformer life: Building on earlier research, EPRI will move to the field to pilot of new techniques for accurately estimating transformer paper life based on novel tracer compounds in the oil.	12/31/10	Technical Update
Forensics Library: Assessments of aged transformers: The Forensics Library will provide new and valuable insights into end-of-life scenarios for the increasing population of aging transformers.	12/31/10	Technical Update
Novel online filtration materials and techniques: EPRI will research, trial, and document novel ideas for cartridge-free transformer filtration.	12/31/10	Technical Update

Future Year Products

Product Title & Description	Planned Completion Date	Product Type
New tracer compounds to estimate transformer life on-line:	12/31/11	Technical Update
Extension of the Forensics Library of aged transformers:	12/31/11	Technical Update
New materials for transformer insulation and cooling: laboratory studies and early field experiences:	12/31/11	Technical Update

P37.003 Maintenance, Condition Assessment and Life Extension Guidelines for Substation Equipment (062155)

Key Research Question

Utility companies need to obtain maximum value from their assets—both current performance and future service life—while fully utilizing dwindling technical staff and limited financial resources. In this environment, an organization's success depends, in part, on the availability and usability of up-to-date knowledge, data, procedures, and best-of-breed or recommended practices for substation equipment maintenance, condition assessment, and life extension. New engineers, or those reassigned to different job functions, face a steep learning curve in developing and implementing a substation equipment maintenance and asset management program. Time-constrained maintenance personnel and asset managers need to quickly locate and access the know-how and procedures stored in the industry's collective memory. Much valuable information is subject to loss upon the retirement or departure of experienced personnel.

Cost-effectively developing a user-friendly, easily updatable reference source requires addressing the following questions:

- How to capture key knowledge that utilities would lose as a result of an aging workforce?
- How to capture the industry's best practices in inspection, monitoring, maintenance, and equipment diagnostics?
- How to organize a self-learning repository for new hires and employees in transition?
- How to ensure that the material contains the most current practice and standards?

Approach

- Gather and distill information on practical aspects of equipment life extension.
 - Condition assessment
 - Field tests
 - Corrective maintenance
- Develop practical reference sources for:
 - Substation operations and maintenance personnel.
 - Task selection and resource allocation
 - Engineers in transition.
 - Equipment behavior and understanding techniques
- Provide inputs to utility job aid and training program development.
- Develop a user group that facilitates ongoing content review, updating, and expansion.
- Enhance usability and accessibility of technical content through technology transfer activities: field guides, workshop seminars, and electronic media.

Impact

Improve Reliability and Reduce Applied O&M: Provide a readily accessible source of information that can contribute to reduced life-cycle costs while enabling improvement in the reliability of critical equipment and help optimize a maintenance program.

Knowledge Retention/Training: Provide a centralized knowledge repository to serve as an on-the-job training tool for new recruits to help them accelerate their learning in the area of substation equipment maintenance.

Knowledge Retention/Application: Offer a user-friendly and regularly updated reference support tool to help asset and maintenance personnel to carry out their work in the most cost-effective and efficient manner.

How to Apply Results

Asset managers, operations and maintenance supervisors/staff, and equipment technical subject matter experts can use the results of this project to better understand and implement best practices in substation equipment life extension, maintenance, and condition assessment. The revised and updated versions of the life extension guidelines can be accessed as annually issued hard copy "color book" version and a series of field guides developed as a result of needs assessment. In addition EPRI will continue to offer workshops and services to assist utilities with implementing the practices identified in the technical reports.

2010 Products

Product Title & Description	Planned Completion Date	Product Type
New Versions of Guidelines for the Life Extension of Substation Equipment: This guide is specifically designed to assist substation owners in their responsibility to operate and maintain equipment. This guide helps members initiate a new maintenance, condition, and/or life extension program or refine an existing one. New sections on equipment and technologies will be added.	12/31/10	Technical Update
New Set of Pictorial Guides: These field guides will present selected material from life extension guidelines in formats suitable for the field personnel. Many members are distributing these guides to field personnel, and they are becoming an integral component of their maintenance, condition assessment, and/or life extension program.	12/31/10	Technical Update
Maintenance, Condition Assessment, Life Extension and Diagnostics Workshop: This member workshop will expose personnel to the latest technologies and approaches.	12/31/10	Workshop, Training, or Conference

Future Year Products

Product Title & Description	Planned Completion Date	Product Type
New Versions of Guidelines for the Life Extension of Substation Equipment: This guide is specifically designed to assist substation owners in their responsibility to operate and maintain equipment. This guide helps members initiate a new maintenance, condition, and/or life extension program or refine an existing one. New sections on equipment and technologies will be added.	12/31/11	Technical Update
Future On-Line E-Learning Modules, Workshop and Webcasts: On-line self paced learning modules will continue to be developed either around maintenance or condition assessment methodologies or technologies. This software can be used with members' current learning management systems.	12/31/11	Technical Update

P37.004 Risk Mitigation and Maintenance Strategies for Substation Equipment (058560)

Key Research Question

Best practice maintenance decisions for minimizing equipment lifecycle costs are based upon risks associated with the actual equipment condition and performance. There are four key steps involved: understanding existing performance, understanding required performance, projecting future performance, and understanding how to bridge gaps. Ongoing R&D efforts are focused on developing condition assessment algorithms to understand existing performance for transformers and circuit breakers. This research will enhance decision making confidence and results, providing the ability to achieve the following:

- Ensure optimal allocation of limited resources and selection of the most appropriate O&M tasks.
- Forecast reliability and manage the risk of deferring maintenance, and identify assets that deserve more attention in relation to others in a fleet.
- Quantify the value of performance improvements resulting from investments made in equipment monitoring, maintenance, or replacement.
- Evaluate risk moving forward (as compared to “current state” evaluation) and determine the impact of incremental dollars added or subtracted from the “current state” maintenance and investment portfolio.

Collectively the suite of algorithms serves as the framework for Analytics for Substation Asset Performance.

Approach

The approach focuses development on several key challenges: defining data requirements and availability, developing tools for risk assessment, linking risk assessments with decision support for mitigation, and tools to track and gauge the effectiveness of risk mitigation and maintenance strategy changes. Developments under proposed research include the following:

- Guidance on data collection.
- Methodologies to forecast reliability and assess risk.
- Predictive modeling techniques focused on the use of readily available data.
- Methodologies to select the most appropriate actions to mitigate risk.

The basic objective for past, ongoing, and proposed research is to provide continually improved decision support methodologies primarily in the form of an integrated framework for asset risk assessment, mitigation and performance improvement – Analytics for Substations Asset Performance.

Impact

- Reduces overall maintenance costs, forecasts O&M cash flow, minimizes unplanned expenses, and maximizes the benefit/value of planned work
- Improves reliability and availability via reduced reliance on time-based maintenance by using analytics based on asset health and condition analysis to determine maintenance actions
- Enables more effective use of existing infrastructure and data and efficient use of maintenance personnel to manage operational risk

How to Apply Results

Project participants will work with a group of equipment and maintenance experts to collect pertinent data that helps define performance metrics and models for relevant equipment. Funders can then use developed algorithms, key performance indicators (KPIs), and ranking methodologies in close coordination with other equipment-focused projects. Funders can also use products to test and validate end-of-life models being pursued in other equipment-focused projects.

2010 Products

Product Title & Description	Planned Completion Date	Product Type
Equipment Risk and Performance Assessment: This product provides methodologies to help project future performance based on current condition and required future performance. It will also provide methodologies for evaluating risk mitigation measures to help select appropriate actions to achieve a desired cost and reliability, as well as other performance goals. Collectively this work will support intelligent fleet management.	12/31/10	Technical Update

Product Title & Description	Planned Completion Date	Product Type
<p>Catalogue and Assessment of Industry Maintenance Best Practices for Substation Equipment: This product will catalogue and assess current industry practices and procedures (including lessons learned by utility experts) and identify gaps and issues with existing practices. Ongoing efforts focus on key substation equipment: transformers and circuit breakers. Over time, through task force feedback and needs assessment, other substation equipment areas will be identified and added.</p>	12/31/10	Technical Update
<p>Maintenance Effectiveness Assessment: This product will be a set of appropriate key performance indicators (KPI's) for measuring maintenance effectiveness. It will provide guidance on how to apply, use, and track these KPI's to improve benefits for current O&M and project incremental benefits for future O&M spending.</p>	12/31/10	Technical Update

Future Year Products

Product Title & Description	Planned Completion Date	Product Type
<p>Equipment Risk and Performance Assessment: This product will provide methodologies to help project future performance based on current condition and required future performance. It will also provide methodologies for evaluating risk mitigation measures to help select appropriate actions to achieve a desired cost and reliability, as well as other performance goals. Collectively this work will support intelligent fleet management.</p>	12/31/11	Technical Update
<p>Catalogue and Assessment of Industry Maintenance Best Practices for Substation Equipment: This product will catalogue and assess current industry practices and procedures (including lessons learned by utility experts) and identify gaps and issues with existing practices. Ongoing efforts focus on key substation equipment: transformers and circuit breakers. Over time, through task force feedback and needs assessment, other substation equipment areas will be identified and added.</p>	12/31/11	Technical Update

P37.005 Integrated Monitoring and Diagnostics (058561)

Key Research Question

Utilities are continuously seeking to improve their cost-benefit ratios by reducing the human intervention in equipment condition monitoring. Diagnostics and sensors plays a strong role. Informed decision-making on the array of sensors available—plus the true value they can provide in a substation—are difficult to quantify. This project provides the supporting industry data and research results to make these important decisions.

Approach

Research in this project is built on two broad, guiding themes:

Sensor awareness across multiple industries

Any utility attempting to apply sensors effectively in a substation is faced with the enormous hurdle of first accurately quantifying the entire range of sensors available and then determining how these sensors relate to the substation applications. EPRI expertise in both the sensor and substation realm have enabled the development of a unique database that allows members to rapidly comprehend the full spectrum of options available and make efficient implementation decisions. EPRI will be publishing this database in 2010 and then updating it on a regular basis.

Cross-industry sensor research and testing

Substation diagnostics can benefit significantly from the sensor developments in other industries (e.g., defense, automotive, space, medical). EPRI's sensor laboratory, partnered with its substation experts, provide a unique test-bed to rapidly evaluate the potential benefits offered by these new sensors. The results will enable the utility industry to effectively gain knowledge from other industries, while the collaborative research on the issues will allow for cost-effective and rapid decisions through laboratory simulations that closely mirror the field.

Impact

- Immediate and comprehensive knowledge of substation sensors, currently available and under development
- Fast-track examination of new sensors from other industries in the EPRI Sensor Laboratory, allowing for confident decisionmaking on potential substation applications.
- Business case development for substation diagnostics, based on the supporting facts and field experience provided through this project

How to Apply Results

Members can apply the results through data-mining of the industry-wide sensor database. The results can help aid the development of effective business cases for substation diagnostics. Members can further validate their business decisions through the laboratory research results in the EPRI Sensor laboratory, - which is designed to closely simulate the field environment.

2010 Products

Product Title & Description	Planned Completion Date	Product Type
Leverage of sensor developments from multiple industries: Through the EPRI Sensor Laboratory and the substation expertise, new sensor technologies from other industries are rapidly evaluated for substation applications.	12/31/10	Technical Update
Industry Sensor awareness database: The database will provide members with a searchable software tool that presents the full spectrum of commercial sensors and those in the research stage.	12/31/10	Software

Future Year Products

Product Title & Description	Planned Completion Date	Product Type
Field trials of sensor developments from multiple industries:	12/31/11	Technical Update
2011 Industry Sensor awareness database:	12/31/11	Software

P37.006 Industry-wide Equipment Performance Database (060471)

Key Research Question

Energy companies can maximize their return on assets by ensuring that existing equipment is not replaced before it reaches the end of its "useful" life, while still maintaining reliable system operations. However, without historical performance data of assets with similar characteristics, this task can be difficult. Companies

can benefit from an easily accessible repository of industry-wide equipment performance and failure data to more accurately project future performance.

Approach

This project provides members with aggregated data and information resources not currently available to individual companies, to assist in developing repair/refurbish/replace strategies for aging substation equipment fleets. The project collects equipment performance and failure data in a common format from many sources to establish a database that enables statistically valid analysis to determine equipment failure rates, identify “bad actors” early, and help identify best maintenance and specification practices. Data models and software applications will be developed and presented to task force advisors for comment and further refinement. Associated supplemental projects may be launched to populate the Industry-wide Equipment Performance Database (IDB) with historical data and develop company-specific applications. Transformers, tap-changers, circuit breakers and other substation equipment are included in this development.

Impact

- Improve management of existing infrastructure using pooled performance and condition-related data from all participating utilities.
- Achieve savings by using consistent data sharing and analyses based on industry common information model (CIM) standards.
- Simplify assessment of key performance indicators and metrics via automated data mining and decision-making tools.
- Enable identification of “bad actors” early, reducing unplanned outages.

How to Apply Results

Using project results, participants can detect equipment risks early and implement risk-informed maintenance and asset management decisions based on industry-wide equipment performance and failure data.

2010 Products

Product Title & Description	Planned Completion Date	Product Type
Equipment Performance and Failure Database – Analysis: This product compiles and analyzes the performance and failure data of transformers, tap-changers, circuit breakers, and other substation equipment. The transformer data collection and analysis started in 2006 and now contains records on over 15,000 transformers. The circuit breaker database is under development, with results expected to be made available in 2010.	12/31/10	Software
Equipment Performance and Failure Database – Populated Data Models: This product develops and tests data models for efficient and effective collection of test, diagnostics, performance, and failure data, for use in industry and utility database application and performance analysis. Transformers, tap-changers, circuit breakers, and other substation equipment are included in this development.	12/31/10	Software
Guidelines for failure investigation and root cause analysis: This technical update report will provide guidance to perform failure mode and effect analysis. The results can also be used in combination with the Equipment Performance Database and Intelligent Fleet Management methodology to manage reliability and extend life. Transformers, tap-changers, circuit breakers, and other substation equipment are included in this development.	12/31/10	Technical Update

Future Year Products

Product Title & Description	Planned Completion Date	Product Type
<p>New Versions: Equipment Performance and Failure Database – Analysis: This product compiles and analyzes performance and failure data of transformers, tap-changers, circuit breakers, and other substation equipment. The transformer data collection and analysis started in 2006 and now contains records on over 15,000 transformers. The circuit breaker database is under development, with results expected to be made available in 2010. New versions will contain results of analysis using data sets with updated (new) data.</p>	12/31/11	Software
<p>New Versions: Equipment Performance and Failure Database – Populated Data Models: This product develops and tests data models for efficient and effective collection of test, diagnostics, performance and failure data for use in industry and utility database application and performance analysis. Transformers, tap-changers, circuit breakers, and other substation equipment are included in this development.</p>	12/31/11	Software
<p>New Versions: Guidelines for failure investigation and root cause analysis: This technical update report will provide guidance to perform failure mode and effect analysis. The results can also be used in combination with the Equipment Performance Database and Intelligent Fleet Management methodology to manage reliability and extend life. Transformers, tap-changers, circuit breakers, and other substation equipment are included in this development.</p>	12/31/11	Technical Update

P37.007 Balance of Substation – Inspection, Assessment and Maintenance Strategies (065593)

Key Research Question

Increasing the reliability, safety, and life of substation equipment requires timely and effective maintenance based on accurate inspection and knowledge of equipment condition. To achieve these objectives, personnel need to understand balance of substation equipment, their degradation and failure modes, and current industry inspection and assessment practices. Availability of new technology, coupled with a loss of institutional knowledge, heightens the challenge facing substation owners. Engineering and maintenance staffs need to remain abreast of the latest inspection developments and assessment techniques to be able to select the appropriate course for their particular circumstances. In addition, field personnel need field tools and training to ensure that correct and consistent decisions are made.

Approach

To address these issues, this project provides the following:

- Needs Assessment – Balance of Substation
- Development of an R&D roadmap to identify and address outstanding issues
- Development of specific guidance for balance of substation equipment: disconnect switches (manual and motor operated), CTs, VTs, capacitor banks, and ground switches. For each of these equipment types, participants will gain the following;
 - Better understanding of associated fundamental issues such as design, vintage and type issues, failure mechanisms, and degradation modes
 - Ability to use this information to develop operation, maintenance, and diagnostic techniques for the associated equipment

Impact

- Reduces overall maintenance costs, projects O&M cash flow, minimizes unplanned expenses, and maximizes the benefit/value of planned work
- Improves reliability and availability via reduced reliance on time-based maintenance by using asset health and condition analysis to determine maintenance actions
- Enables more effective use of existing infrastructure and data and efficient use of maintenance personnel to manage operational risk

How to Apply Results

Using project results, participants can detect equipment risks early and implement risk-informed maintenance and asset management decisions based on industry-wide best practices and the most advanced techniques. Results will facilitate knowledge retention and aid in training personnel.

2010 Products

Product Title & Description	Planned Completion Date	Product Type
<p>Balance of Substation Equipment – Research Needs Assessment Roadmap: This technical update will provide results of the research needs assessment and an R&D roadmap to identify and address outstanding issues for balance of substation equipment.</p>	12/31/10	Technical Update
<p>Balance of Substation – Equipment Specific Condition Assessment and Life Extension Techniques: This technical update will develop specific guidance for balance of substation equipment: disconnect switches (manual and motor operated), CTs, VTs, capacitor banks, and ground switches. For each of these equipment types, participants will gain the following.</p> <ul style="list-style-type: none"> • Better understanding of associated fundamental issues such as design, vintage and type issues, failure mechanisms, and degradation modes • Ability to use this information to develop operation, maintenance, and diagnostic techniques for the associated equipment. <p>The 2010 research will focus on disconnect switches. Future year research will address other equipment for balance of substation using a similar approach.</p>	12/31/10	Technical Update

Future Year Products

Product Title & Description	Planned Completion Date	Product Type
<p>Balance of Substation – Equipment Specific Condition Assessment and Life Extension Techniques: This technical update will develop specific guidance for balance of substation equipment: disconnect switches (manual and motor operated), CTs, VTs, capacitor banks, and ground switches. For each of these equipment types, participants will gain the following.</p> <ul style="list-style-type: none"> • Better understanding of associated fundamental issues such as design, vintage and type issues, failure mechanisms, and degradation modes • Ability to use this information to develop operation, maintenance, and diagnostic techniques for the associated equipment. <p>A prioritized list of equipment will be developed working with the Task Force. Information provided in this deliverable will continue to build on the previous year's research. Future year research will address equipment for balance of substation using a similar approach.</p>	12/31/11	Technical Update

Distribution Systems

Project Set Description

This research program addresses the challenges of reliability, system performance and aging infrastructure by providing guidance to utilities on managing distribution assets, reducing O&M costs, and improving reliability and system performance.

Project Number	Project Title	Description
P30.001	Advanced Diagnostics for Underground Cable and Cable Systems	<ul style="list-style-type: none"> This project expands on earlier EPRI work to correlate the results of common condition-assessment techniques for distribution cables with actual and accelerated aging of XLPE insulated cables. Recently completed EPRI research of both off-line and on-line nondestructive diagnostic test methods reveals the potential of several new methods. Techniques such as off-line polarization and depolarization as well as isothermal return current and return voltage, when combined with conventional partial discharge dissipation-factor diagnostic techniques, could enhance the prediction of future performance and service life of XLPE cable. EPRI intends to expand the scope of this project and build on its collaborative effort with the help and partnership of other industry expertise such as NEETRAC and the CDFI.
P30.002	Sensors for Underground Systems	<p>This project seeks to integrate advanced sensor technology that monitors underground distribution assets with asset planning processes for developing optimum asset investment plans. The project will address the industry need to develop new ways to manage and invest in underground distribution assets by taking advantage of asset condition information conveyed through advanced sensors. This use of sensors will enable members to move from traditional cyclical inspection, maintenance, and replacement approaches to more cost-effective targeted approaches enabled by asset condition information.</p> <p>EPRI will produce a set of guidelines developed through an industry survey, laboratory test results, and use case research. Members will be able to use these guidelines to develop and implement asset planning process steps that consider asset condition information.</p>

P30.001 Advanced Diagnostics for Underground Cable and Cable Systems (063276)

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 so they can develop and prioritize cost-effective strategies to address aging facilities.

Knowledge of cable condition provides utilities with a basis for implementing a staged rejuvenation or replacement program over a number of years and helps them avoid unpredictable peaks and unexpected rises in 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.

Currently available diagnostic techniques have not proven to be accurate, effective, and reliable. As a result, utilities are faced with issues of cost justification and accuracy. To develop a workable replacement strategy, research must be done to help develop effective diagnostic techniques. Moreover, research is needed to understand how to interpret diagnostic information and apply it to replacement and rejuvenation strategies.

Approach

- This project expands on earlier EPRI work to correlate the results of common condition-assessment techniques for distribution cables with actual and accelerated aging of XLPE insulated cables.
- Recently completed EPRI research of both off-line and on-line nondestructive diagnostic test methods reveals the potential of several new nondestructive methods. Techniques such as off-line polarization and depolarization as well as isothermal return current and return voltage, when combined with conventional partial discharge dissipation-factor diagnostic techniques, could enhance the prediction of future performance and service life of XLPE cable.
- EPRI intends to expand the scope of this project and build on its collaborative effort with the help and partnership of other industry experts such as the National Electric Energy Testing, Research and Applications Center (NEETRAC) and the Cable Diagnostic Focused Initiative (CDFI).

Impact

- Delivers technology and case study reviews
- Provides methods to establish the condition state of aged extruded distribution cables
- Enables prioritization of cable replacement, minimizing the present value cost of cable replacement programs
- Fosters improved reliability through enhanced knowledge of the condition states 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 the planned Industry Summit Workshop on Advanced Diagnostics. They will be able to apply degradation models for each diagnostic method and correlate this information with the life model developed from the accelerated cable life test to determine which diagnostic methods best serve their needs.

2010 Products

Product Title & Description	Planned Completion Date	Product Type
Advanced Diagnostics for Underground Cable and Cable Systems	12/31/10	Technical Update

P30.002 Sensors for Underground Systems (060491)

Key Research Question

As members implement and refine their processes for developing optimum investment plans for their distribution assets (that is, implement asset planning processes), they must decide how to use information collected via remote sensing technology to help inform investment decisions.

Many utilities record distribution asset performance information. The types of data collected and the application of this data can vary greatly among utility companies. Data can range from information about asset type (such as rated voltage, vintage, and manufacturer) to records of asset performance and condition (such as number of operations, number of failures, inspection findings, and diagnostic measures such as voltage or temperature). This information is collected in a variety of ways, from personal inspections to the

use of advanced sensors and communication systems that gather information remotely and transmit it electronically.

Utilities are increasingly using remote sensor technology to collect such data. Collection of substation data has increased substantially, and more and more utilities are using low-cost sensors to understand distribution asset condition outside the substation. As utilities increase their use of advanced sensors to monitor and understand distribution asset performance, they will build an information database that can be factored into asset investment decisionmaking.

Approach

This project seeks to integrate advanced sensor technology that monitors underground distribution assets with asset planning processes for developing optimum asset investment plans. The project will address the industry need to develop new ways to manage and invest in underground distribution assets by taking advantage of asset condition information conveyed through advanced sensors. This use of sensors will enable members to move from traditional cyclical inspection, maintenance, and replacement approaches to more cost-effective targeted approaches enabled by asset condition information.

EPRI will produce a set of guidelines developed through an industry survey, laboratory test results, and use case research. Members will be able to use these guidelines to develop and implement asset planning process steps that consider asset condition information.

Impact

- Members will be better able to achieve their financial, customer service, and reliability goals through more effective investment and maintenance strategies.
- Members will be able to increase system reliability, ultimately improving regulatory and customer relations.
- Members will be able to improve safety and health of the general public and utility personnel by gaining knowledge of potentially dangerous components on the verge of failure.

How to Apply Results

Members can apply the results of this project by:

- Participating in expanded trials of advanced sensor technology to monitor distribution asset condition
- Applying learned methods for tying in monitored information with other asset information to create an overall picture of asset condition
- Learning how the industry is utilizing information monitored via advanced sensors along with other asset information to ascertain asset health
- Applying methods for using this information to perform risk analysis and quantification
- Understanding methods for incorporating this information into the process of making investment decisions and optimizing maintenance approaches (Asset Management Processes)
- Employing tools that capitalize on monitored information to help members decide on optimum investment plans

2010 Products

Product Title & Description	Planned Completion Date	Product Type
Sensors for Distribution Systems	12/31/10	Technical Update

PS128A Inspection and Assessment of Overhead Distribution Systems (062120)

Project Set Description

This Project Set builds on a component reliability dataset by addressing components on an individual basis each year. The dataset will build over time, with at least one new component being examined every year. Laboratory testing is combined with survey and field data from various utilities to build the dataset and provides a better understanding of individual component reliability, as well as operational parameters that affect reliability. The laboratory component of this work can include electrical, mechanical, accelerated aging, and flammability testing using a host of test and analysis equipment.

Information gained through this work will be published in annual test reports and also incorporated into a *Distribution Component Reliability and Specification* guidebook. In addition, this information will be part of a broader knowledge base that contributes to distribution inspection guides, procurement guides, field books, and other training materials.

In addition, this Project Set focuses on providing distribution utilities with the information necessary to accurately perform meaningful inspections that will enhance distribution system operations. This information can run the gamut from improved methods for performing basic inspections to the development and implementation of new inspection technologies.

Project Number	Project Title	Description
P128.001	Component Reliability	This project aims to build a component reliability dataset by addressing components on an individual basis each year. The dataset will build over time, with at least one new component being examined every year. Laboratory testing is combined with survey and field data from various utilities to build the dataset and provide a better understanding of individual component reliability as well as the operational parameters that affect reliability.
P128.003	Inspection and Assessment Technologies and Guidelines	This project may help to improve distribution inspection techniques and evaluate and assess the impact of new inspection techniques. The findings will be documented in a field guides and guidebooks.

P128.001 Component Reliability (065443)

Key Research Question

Quantifying distribution component reliability can be challenging for utilities, especially without a formal analysis program. The issue becomes even more muddled as manufacturers make seemingly small design and material changes that can have significant impacts on equipment reliability. Improved understanding of component reliability can be gained through a framework of testing and data collection. This information can then be used to assess unit risk and improve specification, purchasing, operation, and inspection criteria.

Approach

This project aims to build a component reliability dataset by addressing components on an individual basis each year. The dataset will build over time, with at least one new component being examined every year. Laboratory testing is combined with survey and field data from various utilities to build the dataset and provide a better understanding of individual component reliability as well as operational parameters that affect reliability. The laboratory component of this work can include electrical, mechanical, accelerated aging, and flammability testing using a host of test and analysis equipment.

Information gained through this work will be published in annual test reports and also incorporated into a *Distribution Component Reliability and Specification Guidebook*. In addition, this information will be part of a

broader knowledge base that contributes to distribution inspection guides, procurement guides, field books, and other training materials.

Impact

Optimized distribution component selection, application, and inspection yields:

- 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 and 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. This work also helps counter the industry-wide trend of knowledge drain by creating a repository of component information that can serve as a training tool for new utility personnel.

2010 Products

Product Title & Description	Planned Completion Date	Product Type
Design of Overhead Distribution Systems – Component Reliability and Specification Guidelines: This project will provide ongoing updates and expansions to the <i>Distribution Component Reliability and Specification Guidebook</i> as a result of testing and evaluation projects prioritized by members.	12/31/10	Technical Update

P128.003 Inspection and Assessment Technologies and Guidelines (067465)

Key Research Question

Outages are costly for utilities and for end-use customers. Electrical outages interrupt industrial processes, disrupt commerce, and cause a variety of problems for residential customers. For utilities, outages are costly since they increase worker overtime, disrupt energy sales, and draw the attention of regulators. Routine inspection programs are one tool 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 and reliability of electric service.

Approach

This project aims to provide distribution utilities with the necessary information to accurately perform meaningful inspections that will enhance distribution system operations. This information can run the gamut from improved methods for performing basic inspections to the development and implementation of new inspection technologies.

Information learned through this work will be published in annual technical reports and also incorporated into a *Distribution Circuit Inspection and Assessment Guidebook*. In addition, this information will be part of a broader knowledge base that contributes to distribution inspection field guides, procurement guides, and other training materials.

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 test reports, field and inspection guides, and other training materials. Results will also be compiled into the *Distribution Circuit Inspection and Assessment Guidebook*. Members can directly apply this information to enhance their procurement, design, operation, and inspection practices. This work also helps counter the industry-wide trend of knowledge drain by creating a repository of inspection procedures and best practices that can serve as a training tool for new utility personnel.

2010 Products

Product Title & Description	Planned Completion Date	Product Type
Inspection and Assessment Technologies and Guidelines	12/31/10	Technical Update