Overhead Transmission - Program 35

Program Overview

Program Description
Transmission companies face issues such as improving safety and reliability, as well as reducing operations and maintenance (O&M) costs. They are also seeking ways to increase transmission capacity without making large capital investments. Reducing capital expenditures for new and refurbished equipment is another priority.

This EPRI research program is designed to address the research needs of transmission asset owners and operators. The program includes projects focused on specific components (e.g., insulators, compression connectors, and crossarms) as well as projects focused on issues (e.g., lightning and grounding, live working, and transmission capacity). The program delivers a blend of short-term tools such as software, reference guides, and field guides, together with longer-term research such as component-aging tests and the development of sensors for monitoring the performance of line components.

Research Value
With the knowledge acquired through this research program, program members will have access to information that can provide them:

- Improved management of aging transmission line components
- Improved inspection and assessment tools and techniques
- Enhanced lightning performance reliability
- Tools to increase efficiency of transmission line design
- New live working techniques and procedures
- Schemes to get more capacity out of existing overhead lines
- Improved approaches to selecting, applying, inspecting, and assessing insulators
- Information on emerging transmission line sensing and inspection technologies

Approach
EPRI research in overhead transmission will yield data and knowledge that will benefit program members. This information will be provided in a number of forms and is expected to offer members both short- and long-term value. A comprehensive transmission line inspection and assessment reference guide, the Yellow Book, is continuously updated to ensure that it provides members with the most up-to-date, comprehensive understanding of transmission component behavior, inspection technologies, and line effects. Field guides and training software help workers identify levels of component deterioration and take corrective action in a timely fashion. Operators can learn to improve capacity through the use of thermal and corona models of overhead conductors operating at high temperatures and through understanding of the effect of high-temperature cycling on conductor systems. Methods and tools are being developed to maintain transmission components and extend their life. Transmission line and foundation design tools enable members to incorporate the most current industry knowledge into their development plans.

The program also performs long-term laboratory experiments to better understand the aging and failure mechanisms of structures and line components. Corrosion labs create environments to better understand the impact of corrosion above and below ground. Insulators are tested for aging and degradation to better understand their long-term performance characteristics.

Accomplishments
The Overhead Transmission program has delivered valuable information that has helped its members and the industry in numerous ways. Some examples include:
• EPRI Software for Polymer Insulators Electric Field Calculations (EPIC): Version 3.1 is used to evaluate the corona performance of polymer insulators, whether in-service or as part of a new design. An EPIC 3D model can be created from scratch in under 15 minutes, whereas the same model in traditional software can take hours. The software helps users reduce the risk of transmission line polymer insulators failures caused by the degradation of the rubber weathershed system due to corona activity.

• Conductor Cleaning Tool: This device is a more efficient, less costly tool for cleaning high-voltage conductors. The new tool uses a detergent-like solution, enabling crews to thoroughly clean conductors without the traditional steps of unstranding the wires in the conductor and then restranding them after each strand is cleaned.

• Visual Inspection of Avian Issues on Transmission Structures: This EPRI report, one in a series of practical guides designed as reference aids for personnel working in the field, visually catalogs the various condition issues that commonly affect transmission lines due to avian interaction. It presents photographs and short written descriptions of the conditions, and lists associated causes, failure modes, and impacts. The guide is printed in color on high-quality paper and is ring-bound.

• Lightning Performance Prediction Software: TFlash, Ver 6.1, is used to evaluate the performance of existing lines or help design new transmission lines. It enables users to build models of transmission lines and then analyze their susceptibility to lightning. The software provides many tools to help users design improvements to power lines to reduce lightning outages.

• Rating methodologies and complementary software have helped power utilities achieve higher transmission capacity ratings safely and reliably for existing systems.

**Current Year Activities**

In the coming year, this research program expects to accomplish these objectives:

• Updated Inspection and Assessment Guidelines for Transmission Lines (the *Yellow Book*)
• Tools and mitigation techniques to address sub-grade and conductor corrosion
• Thresholds for compression connectors inspection tools
• Inspection and assessment of crossarms
• Foundation analysis and design
• Live work with high-temperature conductors
• Transmission Line Workstation (TLW)
• Composite component accelerated aging results
• Software to aid in selection of corona rings (EPIC)
• Updating of transmission capacity guidebook, and development completed of a “smart tool” for selecting suitable options for transmission capacity upgrades
• Improvement of transmission capacity software and data analysis program for rating methodologies
• Development of additional instrumentation for increasing power flow
• Guide for the selection and application of various types of high-temperature conductors

**Estimated 2012 Program Funding**

$8.0M

**Program Manager**

Fabio Bologna, 704-595-2590, fbologna@epri.com
## Summary of Projects

<table>
<thead>
<tr>
<th>Project Number</th>
<th>Project Title</th>
<th>Description</th>
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<tbody>
<tr>
<td>P35.001</td>
<td>Overhead Transmission Line Inspection and Assessment Methods Guideline</td>
<td>This project is a mix of tools, training, and information that will help members improve their inspection and assessment techniques.</td>
</tr>
<tr>
<td>P35.002</td>
<td>Conductor, Shield Wire and Hardware Corrosion Management</td>
<td>This project identifies, develops, and assesses tools and procedures required to deal with conductors, shield wires, and hardware exposed to atmospheric corrosion.</td>
</tr>
<tr>
<td>P35.003</td>
<td>Structure and Foundation Corrosion Management</td>
<td>This project helps determine cycle times for re-inspecting assets and the best methods of mitigating and remediating corrosion damage.</td>
</tr>
<tr>
<td>P35.004</td>
<td>Compression Connector Management</td>
<td>This project provides a holistic approach to the inspection and management of compression connectors.</td>
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<tr>
<td>P35.005</td>
<td>Crossarm and Composite Pole Management</td>
<td>Research is primarily focused upon assessing inspection technologies for crossarms and developing reject and ranking criteria for various construction materials.</td>
</tr>
<tr>
<td>P35.006</td>
<td>Lightning Performance of Transmission Lines and Surge Arresters</td>
<td>This project is a mix of tools, training, and information that will help members improve their transmission line lightning performance.</td>
</tr>
<tr>
<td>P35.007</td>
<td>Transmission Line Design Tools</td>
<td>This project will pursue the following activities:</td>
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<td>• Upgrade modules in the TLW-GEN2 software program and investigate new line design modules for inclusion one at a time.</td>
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<td>• Update and expand these modules to reflect changes that have occurred since they were last revised.</td>
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<td>• Review information in the Red Book that requires revision to enable members to take full advantage of the research results.</td>
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<td>• Conduct a workshop for technology transfer.</td>
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<tr>
<td>P35.008</td>
<td>Foundation Design and Research</td>
<td>This project develops a comprehensive design manual to assist foundation designers in evaluating, selecting, and designing cost-effective foundations suitable for single pole, H-frame, lattice tower, and guyed-V structures. A practical reliability-based design approach is first developed. Specific and practical topics such as specification for sub-surface investigation are to be developed and added to the manual until all key topics are covered.</td>
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<tr>
<td>P35.010</td>
<td>Live Working Research for Overhead Transmission Equipment, Techniques, Procedures and Protective Grounding</td>
<td>This project develops tools, procedures, and training materials for live and de-energized work to enhance worker and public safety, work efficiency, and reduction in cost and duration of maintenance outages.</td>
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<tr>
<td>P35.011</td>
<td>Polymer and Composite Overhead Transmission Line Components</td>
<td>This project addresses the use and maintenance of composite transmission line components. Through this project, members learn how to select, install, inspect, and maintain composite transmission line components used throughout the world.</td>
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<tr>
<td>P35.012</td>
<td>Ceramic Insulator Integrity Assessment</td>
<td>This project focuses on how to assess the aging population of porcelain and glass insulators, and how to properly procure and apply new and replacement insulators.</td>
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<tr>
<td>P35.013</td>
<td>Increased Power Flow Guidebook and Ratings for Overhead Lines</td>
<td>This project provides state-of-the-science reference and training materials for optimizing and increasing power flow through transmission lines and entire transmission circuits. It also provides software tools to optimize power flow in real-time, for predictive assessments of power capacities, and for performing off-line rating studies.</td>
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<tr>
<td>P35.014</td>
<td>High Temperature Operation of Overhead Lines</td>
<td>This project will collect all available information on high-temperature operations, conduct laboratory tests to address knowledge gaps, and prepare software to facilitate risk evaluations of high-temperature operations. The project addresses the impact of high-temperature operations on the mechanical, electrical, and thermal behavior of overhead lines.</td>
</tr>
<tr>
<td>P35.015</td>
<td>Performance and Maintenance of High-Temperature Conductors</td>
<td>This project addresses all outstanding issues related to high-temperature conductors, one at a time. It will investigate the long-term performance of all commercially available advanced conductors to complement the field demonstration project, which provided information on handling and stringing these conductors. Maintenance tools and procedures for this new type of conductor will also be identified and established. A comprehensive guide for the selection and application of high-temperature conductors will be prepared.</td>
</tr>
<tr>
<td>P35.016</td>
<td>New and Emerging Inspection and Sensing Technologies</td>
<td>This project documents the latest inspection and sensing technologies for overhead transmission lines, as well as early adopters experiences with these technologies. Test results and demonstrations help members make more informed decisions when deciding whether to deploy such technologies.</td>
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<tr>
<td>P35.017</td>
<td>Design and Construction - Approach and Practices</td>
<td>This research develops a comprehensive, single source guide for the coordination of design and construction practices. Overhead line designs may be optimized to allow good construction practices while construction practices will be developed for new designs that requires unique or new approaches.</td>
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**P35.001 Overhead Transmission Line Inspection and Assessment Methods Guideline (052001)**

**Key Research Question**

Utilities need research results on overhead transmission line inspection and assessment methods for several reasons. 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. Without this understanding, utilities may not have a recovery plan in place when failures occur.

**Approach**

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

- Develops and documents an understanding of indicators or symptoms of component degradation failure and inspection technologies in the Inspection and Assessment Methods (IAM) Reference Guide, the Yellow Book.
- Develops computer-based instruction systems to help in learning about assessments, technologies, and components.
Develops field guides for field personnel that help identify and provide information on the state of a specific component and the action to take if it is compromised.
Develops and documents an approach to transmission line faults investigation and analysis.
Develops and hosts hands-on workshops and conferences where inspection and assessment information is disseminated.
Develops and maintains failure databases of line components such as connectors and crossarms.

Impact
This research project may affect operations and benefit the public in a number of ways:

- These tools should help improve the 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 improve utility workers' skill sets by training members on inspection methods, available tools, and identification of high-risk components before they fail.

How to Apply Results
The research program is structured 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.

2012 Products

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<tr>
<th>Product Title &amp; Description</th>
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<tbody>
<tr>
<td><strong>New version of OHTL Inspection and Assessment Methods (IAM) Reference Guide (Yellow Book)</strong></td>
<td>12/31/12</td>
<td>Technical Report</td>
</tr>
<tr>
<td>This guide helps members initiate a new overhead transmission line inspection and assessment program or refine an existing one. It focuses on degradation of line components, and procedures and technologies for inspecting and assessing components. Additional material will be added to the guide.</td>
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<tr>
<td>New Pictorial Guide: These field guides are designed for field use both in electronic format and in pocketbook size (8 by 4 inches). Many members are distributing these guides to all field personnel, and the guides are forming the backbone of these companies’ inspection program.</td>
<td>12/31/12</td>
<td>Technical Update</td>
</tr>
<tr>
<td>Future On–line E–Learning Module: Online self–paced learning modules will continue to be developed around components or inspection technologies. These can be used on a desktop computer or with members' current learning management systems.</td>
<td>12/31/12</td>
<td>Software</td>
</tr>
<tr>
<td>Proceedings of the Biannual Overhead Transmission Lines Conference: The proceedings of the biannual Overhead Transmission Lines Conference will be compiled into a technical update. Various new inspection technologies, applications, and utility use cases may be presented at the conference.</td>
<td>12/31/12</td>
<td>Technical Update</td>
</tr>
<tr>
<td>Approach to Transmission Line Fault Inspection and Analysis (Draft): This product will build on research conducted in prior years and will document the approach and technologies for locating line faults, including their accuracy.</td>
<td>12/31/12</td>
<td>Technical Update</td>
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Future Year Products

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<td>This guide helps members initiate a new overhead transmission line inspection and assessment program or refine an existing one. It focuses on degradation and inspection of line components, and procedures and technologies for inspecting and assessing components.</td>
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<td>Future On-Line E-Learning Module: Online self-paced learning modules will continue to be developed around components or inspection technologies. These can be used on a desktop computer or with members’ current learning management systems.</td>
<td>12/31/13</td>
<td>Software</td>
</tr>
<tr>
<td>Approach to Transmission Line Fault Inspection and Analysis: This product will build on research done in prior years and will document utility experience (approach, technologies and lessons learned) in locating line faults</td>
<td>12/31/13</td>
<td>Technical Update</td>
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P35.002 Conductor, Shield Wire and Hardware Corrosion Management (063280)

Key Research Question

Atmospheric corrosion is a natural and unavoidable phenomenon that can lead to premature failure of conductors, shield wires, hardware, or components and result in momentary or even sustained outages. The primary environmental factors controlling the occurrence and severity of this corrosion are airborne salts, acid rain, and time of wetness, but of equal importance are the initiation mechanisms for the protection systems such as galvanizing. Understanding this timeline allows utilities to establish inspection cycles based upon levels of risk, provide a population assessment utilizing new tools or techniques, and develop O&M budgets tied to corresponding maintenance practices.

Approach

This project provides tools and processes for inspecting and assessing overhead shield wires, conductors, and hardware. It also produces management and engineering guides, and provides guidance to asset managers. The project’s goals will be achieved via research in inspection, selection, application, and population assessment of phase conductors and shield wires and a hardware management program. The following are tasks underway:

- Development of a Near Infra-red (NIR) Spectroscopy Remote Inspection Tool to locate conductors with various levels of corrosion byproducts deposited on the conductor and structure or hardware surfaces.
- Understanding corrosion rates on test specimens and the associated tensile strengths. A corrosion laboratory has been developed in Charlotte to study the effects of the environment on corrosion rates for conductors and hardware in atmospheric service. Exposure testing of these components will help quantify those areas and allow utilities to establish inspection cycles based upon actual corrosion rates and allowable sectional losses.
- Replicate conditions needed for contractors and service providers to demonstrate and test new and emerging inspection and assessment technologies. Flaws are installed with specific sectional losses, and inspection methods are evaluated in the context of accuracy, cost, risk, and probability of locating damage.
- Population assessment methods based upon environmental factors and material exposure.
- Workshops to disseminate research findings, technology demonstrations and hands on training for inspection and assessment techniques.
Impact
The project will help reduce unplanned outages, improve reliability, and reduce associated repair costs by providing corrosion control and management practices for overhead ground wires, phase conductors, and hardware. 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, asset managers 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.

2012 Products

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<tbody>
<tr>
<td>Inspection and Assessment of Overhead Transmission Line Hardware (Draft):</td>
<td>12/31/12</td>
<td>Technical Update</td>
</tr>
<tr>
<td>This technical update will document the current state of industry inspection methods and examine new and emerging technologies for identifying corroded conductors and hardware.</td>
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<tr>
<td>NIR Spectroscopy Development and Alternate Technology Uses:</td>
<td>12/31/12</td>
<td>Technical Update</td>
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<tr>
<td>This product is the continuation of the NIR spectroscopy technology development and other structural inspection applications.</td>
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<tr>
<td>Member Survey of Industry Issues for Hardware and Conductors:</td>
<td>12/31/12</td>
<td>Technical Resource</td>
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<tr>
<td>A survey designed to highlight potential pending issues concerning atmospheric corrosion on hardware exposed to the environment.</td>
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<tr>
<td>State of the Art Field Evaluation Methods for Galvanize Coatings:</td>
<td>12/31/12</td>
<td>Technical Update</td>
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<tr>
<td>Field evaluations of galvanizing coating systems are varied and sometimes subjective. This technical update is designed to allow field personnel and technicians to understand and quantify galvanize coatings in the field with minimal equipment requirements and training.</td>
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Future Year Products

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<tbody>
<tr>
<td>Inspection and Assessment of Overhead Transmission Line Hardware (Final):</td>
<td>12/31/13</td>
<td>Technical Update</td>
</tr>
<tr>
<td>Trending for corrosion has always been the most accurate method for targeting O&amp;M budgets. This product may help identify areas more prone to corrosion issues that could allow members to focus on pending issues and be proactive in avoiding costly outages.</td>
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<tr>
<td>Inspection Optimization and Environmental Factor Modeling With GIS Overlays:</td>
<td>12/31/13</td>
<td>Technical Resource</td>
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<tr>
<td>System modeling using existing government data and optimization by converging inspection results will allow a better understanding of the environment and its role in corrosion issues.</td>
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<tr>
<td>Understanding Galvanizing Life, Degradation Modes and Inspection Methods:</td>
<td>12/31/13</td>
<td>Technical Update</td>
</tr>
<tr>
<td>Inorganic protective coatings are applied in the molten state and can be subject to many issues when not properly processed. In addition to manufacturing issues, there are many environments where galvanized surfaces should not be installed. This research provides an overview of the metallurgy, the degradation modes, and a method to determine the effectiveness of the remaining galvanizing system.</td>
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P35.003 Structure and Foundation Corrosion Management (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 billion to $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 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 corrosion of transmission line structures by providing O&M staff with tools and techniques to make the most informed and cost-effective decisions. Improved corrosion management will be achieved through developing and refining inspection techniques and methodology, informing assessment practices, and creating 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 structure and foundation corrosion. The following core tasks are underway:

- Assessment of commercially available coating systems to understand corrosion initiation mechanisms and cycle time for future inspections.
- Replication of conditions on test specimens at the EPRI outdoor test facilities to characterize the performance of different inspection technologies and mitigation methods provided by vendors.
- Evaluation of inspection and assessment techniques dedicated to anchor rod inspections.
- Evaluation of inspection and assessment technologies for tubular structures.
- Evaluation of inspection and assessment technologies for lattice structures with grillage foundations.
- Development of electrochemical test techniques to measure corrosion rates on structures and grounding systems in situ, which will prioritize service areas and allow the development of inspection cycles for lattice and pole populations.
- Understanding corrosion rates on test specimens through soil exposure testing at the EPRI corrosion laboratory will allow an understanding of the environmental factors occurring within members’ service areas. These tests are designed to quantify the effects of these factors on the corrosion kinetics and help design mitigation methods to arrest the corrosion.
- Research and development of cathodic protection systems for the internal surfaces of tubular structures.
- Future workshops to provide education and hands-on training for inspection, mitigation, and remediation techniques.

Impact

This program will:

- Reduce outages by understanding the life cycle of various structure types.
- Provide new tools and inspection methods to address structure and foundation corrosion problems.
- Defer inspection and replacement costs by understanding the features and benefits of new and emerging inspection, mitigation, and remediation technologies.
- Reduce O&M costs by matching cycle times with mitigation and remediation techniques.
- Help engineering to reduce the probability of corrosion that may occur in 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 structure and foundation infrastructure, and consequently extend its life. This program may improve reliability by identifying and assessing high-risk sub-grade components prior to failure.

## 2012 Products

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<tr>
<td><strong>Coating Assessment - Continuing:</strong> Started in 2008 with the development of a coating assessment protocol, EPRI reviews and evaluates the performance of new and emerging coating systems. This evaluation takes into account the service conditions and exposure to environmental factors to understand the strengths and weakness of each system. A review of these coating characteristics allows utility personnel to match their structure needs to the appropriate coating system and optimize their O&amp;M budgets.</td>
<td>12/13/12</td>
<td>Technical Update</td>
</tr>
<tr>
<td><strong>Evaluation of New and Emerging Corrosion Sensors:</strong> This product will evaluate new or existing corrosion sensors and identify new concepts to quantify the kinetics governing corrosion rates. This environmental data will then be correlated with the associated corrosion rates measured through electrochemical and mass loss techniques. The long-term plan is to monitor system degradation (corrosion) through trending.</td>
<td>12/13/12</td>
<td>Technical Update</td>
</tr>
<tr>
<td><strong>Structural Repair Methods for Lattice Structures &amp; Grillage Foundations:</strong> The last aspect of inspection and assessment programs is how the structure is returned to its original condition at the time of installation. This technical update highlights available structural repair methods and the caveats associated with each method.</td>
<td>12/31/12</td>
<td>Technical Update</td>
</tr>
<tr>
<td><strong>Mitigation Methods for Tubular Structures (Draft):</strong> This product will highlight the development of tools required to protect the internal surfaces of tubular structures. Studies have shown that traditional cathodic protection systems will not provide sufficient passivation to prevent the formation of corrosion cells on internal surfaces of the poles, and a high percentage of poles have standing water inside.</td>
<td>12/31/12</td>
<td>Technical Update</td>
</tr>
<tr>
<td><strong>Corrosion Probe Development (Draft):</strong> This product summarizes the development of a corrosion probe that is designed to measure the effects of the environment on specific materials used in the construction of the structure, foundations, and grounding system. Corrosion rates may be obtained by using electrochemical polarization resistance or impedance spectroscopy tests on specimens of various materials that are connected to the structure during the evaluation.</td>
<td>12/31/12</td>
<td>Technical Update</td>
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## Future Year Products

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<tr>
<td><strong>Inspection, Assessment and Remediation Methods for Concrete Foundations:</strong> There are many accepted passive and active half-cell techniques that will allow an understanding of reinforcing steel condition within concrete. This technical resource will provide a hands-on understanding of how to apply these electrochemical inspection techniques and what technologies are available to restore the condition of the concrete.</td>
<td>12/31/13</td>
<td>Workshop, Training, or Conference</td>
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### Mitigation Methods for Tubular Structures (Final):

The potential for corrosion on the inside of a tubular structure was unknown until recently. Cleaning issues before the galvanizing operation have resulted in premature structural failures and that has alerted the industry to the need for advanced mitigation techniques. This product is focused upon potential methods or techniques to deliver and apply uniform sacrificial anode, cathodic protection to the internal surfaces of a tubular structure.

Planned Completion Date: 12/31/13
Product Type: Technical Update

### Field Methods for the Evaluation of Concrete Structures and Foundations:

This is a field guide that summarizes the best-in-class inspection techniques and how to interpret the findings. Included with this guide are visual coupons for comparison and the remediation or mitigation methods most appropriate as a corrective action.

Planned Completion Date: 12/31/13
Product Type: Technical Update

### Inspection and Assessment State of the Art Report (Draft):

This deliverable is the summary report of past evaluations of inspection techniques and technologies. Included are new and emerging methods of inspection with an assessment of accuracy, potential for finding corrosion, risk, and cost of implementation.

Planned Completion Date: 12/31/13
Product Type: Technical Report

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**P35.004 Compression Connector Management (065547)**

**Key Research Question**

Predicting the remaining life of compression connectors (splices and dead-ends) is a major challenge. Compression connector 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.

Technologies currently used to inspect compression connectors are not always reliable and repeatable, and application methods and threshold levels for these technologies are not well defined. This project 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.

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**

This project addresses the issues surrounding inspection, assessment, and remediation of compression connectors by providing O&M staff tools and information to make the most informed and cost-effective decisions.

Field Guide for the Inspection of Compression Connectors: In 2010 and 2011, EPRI undertook a study to determine temperature threshold limits for inspecting compression connectors using infra-red imaging. In 2012, this work will be documented in the form of a visual field guide. The field guide will provide guidance on factors to consider when doing a field inspection.

Online Training Module: EPRI will develop a training module for field personnel on the installation, maintenance, inspection, and remediation of compression connectors. The training will detail the latest inspection technologies, as well as present best practices for the use of existing inspection technologies and connector installation.
Evaluation of New Technologies: EPRI will continue to evaluate new and emerging technologies that could be used for determining the condition of compression connectors. This work could include the improvement of existing technologies, the development of new technologies/devices, as well as the application and evaluation of nontraditional compression connector inspection techniques.

Failure database: Continued maintenance of compression connectors failure databases (ongoing since 2009) to aid in selection and replacement decisions.

Impact
This research project may affect members' operations in a number of ways:
- Increase safety of transmission lines by reducing line dropping
- Reduce sustained unplanned outages due to compression connector failure
- Optimize spending of 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. Field personnel will be able to use the provided workshop training material as part of their in-house training programs.

2012 Products

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<tr>
<th>Product Title &amp; Description</th>
<th>Planned Completion Date</th>
<th>Product Type</th>
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<tbody>
<tr>
<td><strong>Online Training Module on Inspection Techniques and Evaluations:</strong> 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.</td>
<td>12/31/12</td>
<td>Software</td>
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<tr>
<td><strong>Field Guide: Inspection Techniques and Evaluations:</strong> A field guide for personnel will be prepared with inspection tools and techniques as evaluation considerations for compression connectors.</td>
<td>12/31/12</td>
<td>Technical Update</td>
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<tr>
<td><strong>Evaluation of New Inspection Technologies and their Application:</strong> This task will evaluate promising new inspection technologies. These technologies will be tested and evaluated to determine feasibility as an inspection technology.</td>
<td>12/31/12</td>
<td>Technical Update</td>
</tr>
<tr>
<td><strong>Connector Failure Database:</strong> Information on connector failures received from utilities will be analyzed and trends determined. This will enable the identification of future areas of research.</td>
<td>12/31/12</td>
<td>Technical Update</td>
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P35.005 Crossarm and Composite Pole Management (067437)

Key Research Question
Predicting the remaining life of structural crossarms and composite poles is a major challenge to electric utilities because of limited inspection techniques that align with that type of component. Degradation must be identified early enough to avoid failure and allow maintenance groups sufficient time to anticipate and plan for replacement or remediation operations. Improved inspection techniques and population evaluation methodologies are needed to support this effort or an increase in crossarm failures can be expected as transmission structures age.
The application of composite materials used in the construction of crossarms and poles needs extensive research through exposure testing and forensic studies, because little is known of the degradation modes and initiation mechanisms. Effects due to electric field exposure, airborne particulates, and aerosols will be included in this study so that the limitations and applications can be better understood.

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

**Approach**

This multiyear project addresses a range of crossarm and pole concerns, including selection, application, and inspection to increase members' confidence in using these materials of construction. In 2009, the project focused on the degradation modes of dimensional lumber crossarms and the existing tools and techniques available for inspection and assessment programs. In 2010, a test jig was designed, developed, and constructed in Charlotte to facilitate the assessment of inspection technologies. Building on that foundation, future project activities include:

- Desk study on composite materials, manufacturing methods, and contraindications in the construction and use of composite crossarms and poles.
- Evaluation of existing inspection and assessment tools for wood/composite crossarms and poles.
- Development of new and emerging technologies for laminated crossarms with the associated features/benefits.
- Field guide to aid maintenance personnel in the inspection and assessment of laminated wood crossarms.
- Development of a crossarm failure database to track failures by material, age, size, type of construction, and environmental factors will provide invaluable information for inspection program optimization.
- Evaluation and development of remediation techniques for wood and composite crossarms and poles.
- Development of new and emerging technologies for dimensional crossarms with the associated features/benefits.
- Assessment of existing inspection and assessment tools for steel crossarms.
- Population assessment methods based upon environmental factors, initiation mechanisms, and failure modes.
- Remediation techniques for steel crossarms.
- E-learning module for field personnel training.

**Impact**

This project may have the following impacts:

- Increase safety of transmission lines by reducing crossarm failures
- Understand the application and inspection of composite pole structures
- Reduce sustained unplanned outages attributable to crossarm failures
- Address loss of institutional knowledge by providing training
- Optimize spending of O&M funding
- Improve productivity of field personnel with training and field tools.

**How to Apply Results**

Members will modify their current inspection practices as a result of the research focused upon inspection and assessment of crossarms. This project improves the expertise of the workforce and addresses the loss of knowledge in the industry. The project may culminate in reliability improvements 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.
2012 Products

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<th>Product Title &amp; Description</th>
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<tr>
<td><strong>Member Survey on Steel Crossarms:</strong> The number of failures attributed to corrosion or the number of crossarms that are taken from service are unknown. This survey will afford us a better understanding of what issues are on the horizon and provide guidance for further degradation mode research.</td>
<td>12/13/12</td>
<td>Technical Update</td>
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<tr>
<td><strong>Degradation Modes of Composite Crossarms and Poles, Desk Study:</strong> This research is designed to understand environmental and operational factor effects on the performance of composite materials. Included are electric field effects, the effects of ultraviolet light, and pollutants such as sulfates or chlorides. As composite materials age, it becomes necessary to determine degradation rates and modes of failure based upon construction standards.</td>
<td>12/31/12</td>
<td>Technical Update</td>
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<tr>
<td><strong>Evaluation of Member Supplied Crossarms and poles:</strong> This product will provide an understanding of failure modes and initiation mechanisms of construction materials in various types of applications. Project-member-supplied components will be tested and analyzed at the EPRI facilities. The results will be provided to project members so that a better understanding of the material limitations may be shared and disseminated.</td>
<td>12/31/12</td>
<td>Technical Update</td>
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Future Year Products

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<tr>
<td><strong>E-learning Module on Crossarm Inspections and Evaluation:</strong> A online training module will be developed to train field personnel in failure modes, inspection tools, and techniques as evaluation considerations for crossarm inspection.</td>
<td>12/31/13</td>
<td>Software</td>
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<tr>
<td><strong>Evaluation of Composite Crossarm and Pole Inspection Methods:</strong> Evaluation methods for composite materials differ from wood and steel construction. This can be attributed to the material properties but also the failure modes. This research quantifies new and emerging inspection technologies or techniques in terms of accuracy, risk, probability of locating degradation, and cost of implementation.</td>
<td>12/31/13</td>
<td>Technical Update</td>
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<tr>
<td><strong>Field Guide on Crossarm Inspections and Evaluations:</strong> A field guide for field personnel will be prepared covering the failure modes, inspection tools, and techniques as evaluation considerations for crossarm inspection.</td>
<td>12/31/13</td>
<td>Technical Update</td>
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P35.006 Lightning Performance of Transmission Lines and Surge Arresters (051989)

Key Research Question

Lightning activity is the leading cause of momentary outages on transmission lines. Addressing numerous aspects of a transmission line—shielding, grounding, insulation, and transmission line surge arresters—can improve lightning performance. However, identifying the most effective and lowest cost aspects is difficult. Transmission line grounding influences both the lightning performance and safety of transmission lines, and the most effective ground electrode design depends on a variety of factors.
**Approach**

The tasks addressed in this project set are:

**Lightning Performance Prediction Software (TFlash Module):** In 2011, TFlash was integrated into the Transmission Line Workstation Generation 2 (TLW-Gen2) software as a module. In 2012, the TFlash module will be expanded from only performing lighting performance calculation to include the calculation of structure currents under fault conditions. Participants in this project will get access to the TFlash module of TLW-Gen2.

**Field Tool to Evaluate Transmission Line Grounds (EPRI Zed-Meter®):** Commercial ground electrode measurement techniques do not accurately measure structures that are grounded in multiple locations, such as transmission lines with overhead ground wires, steel lattice structures with grillage foundations, and two-pole structures. From 2004 to 2011, a technology that enables effective measurement of transmission line ground electrodes was developed and demonstrated, and an application guide was developed. In 2012, research will focus on adding additional functionality such as soil resistivity to the instrument.

**Transmission Line Surge Arrestors (TLSA) Research:** This task develops information resulting in a TLSA application guide. In 2009, the first version of a guide was completed, and in 2010, an application workshop based on the guide was held. In 2011, a review of current knowledge on gapped line arrestors was done. In 2012, current disconnector standards will be reviewed, and applicable test methods and gaps identified. Evaluation of units removed from service and the TLSA failures database will be continually updated.

**Grounding:** Companies are currently struggling with issues surrounding copper theft, electrode corrosion and sizing of OPGW. This task will investigate the use of alternative materials, electrode designs and provide guidance on the sizing OPGW. Issues such as design practices, life expectancy, corrosion, material compatibility, and current-handling capabilities will be addressed.

**Improved Quantification of Lightning Detection Networks:** In 2011, a document comparing the lightning data provided by three lightning location networks in the United States was developed. In 2012, an understanding of the accuracy and limitation of the information provided will be documented. Results could help enhance the usefulness of lightning detection information.

**Impact**

This project may have the following impacts:

- Improve lightning performance and safety of transmission lines by providing engineers with effective tools and an improved knowledge base.
- Address the loss of institutional knowledge by providing guides and tools for engineering staff who are new to the field of lightning and grounding.
- Reduce costs by providing improved tools (e.g., Zed-Meter and TFlash) for both field inspection and engineering staff.
- Improve public and worker safety, as well as transmission reliability, by identifying alternative ground electrodes.

**How to Apply Results**

Operations and maintenance personnel can apply the EPRI Zed-Meter to measure the tower footing resistance of structures on their systems. Transmission line engineers can use the lightning performance prediction software to optimize the lightning performance of transmission lines with internal resources, or can outsource this work to the EPRI Lightning and Grounding Team. Information on TLSAs will provide design and O&M maintenance personnel with knowledge on the application and inspection of TLSAs.
## 2012 Products

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<th>Product Title &amp; Description</th>
<th>Planned Completion Date</th>
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<tr>
<td><strong>Evaluate the performance of new and current Lightning Detection Networks:</strong> There are new and currently operated sensor (network) technologies that have undergone technical upgrades over the past years. Utilities are interested in understanding the type and accuracy of the information provided. This product will compare utility lightning fault data with lightning data currently delivered by those systems.</td>
<td>12/31/12</td>
<td>Technical Update</td>
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<tr>
<td><strong>Sizing of Overhead Ground Wires with Respect to Lightning:</strong> Traditionally, steel conductors have been used for overhead ground wires, but increasing OPGW is being used. These newer ground wires may not be as tolerant to direct lightning strikes, and therefore, dimensioning with respect to lightning currents is becoming increasingly important. This product will document an approach for dimensioning these conductors.</td>
<td>12/31/12</td>
<td>Technical Update</td>
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<tr>
<td><strong>Transmission Line Workstation (Gen2) Ver 1: TFlash module update:</strong> The TFlash module will be updated to include the calculation of structure currents under fault conditions.</td>
<td>12/31/12</td>
<td>Software</td>
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<tr>
<td><strong>Investigate methods to determine corrosion of ground electrodes:</strong> This product will document the current inspection methods and examine new and emerging technologies for identifying corroded ground electrodes.</td>
<td>12/31/12</td>
<td>Technical Update</td>
</tr>
<tr>
<td><strong>Review of TLSA Disconnectors Specifications:</strong> This deliverable will review applicable test methods for disconnectors. Aged disconnector units will be collected from member utilities for future testing. In future years, these results will be analyzed and refined to develop tests and specification requirements.</td>
<td>12/31/12</td>
<td>Technical Update</td>
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## Future Year Products

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<tr>
<td><strong>Transmission Line Workstation (Gen2): TFlash Module update:</strong> A feature to estimate soil parameters will be added to the TFLash module in TLW (Gen2). This feature will enable the user to derive a two-layer soil model from one or more measured soil resistivity profiles. Multiple profiles can then be compared to choose an appropriate soil model for calculating the ground electrode resistance.</td>
<td>12/31/13</td>
<td>Software</td>
</tr>
<tr>
<td><strong>Document Use Cases for Lightning detection networks:</strong> Working with a member utility, EPRI will assess the performance of National Lightning Detection Network (NLDN) data by identifying and correlating flashes with transmission line events.</td>
<td>12/31/13</td>
<td>Technical Update</td>
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<tr>
<td><strong>Calculation of Structure Currents Under Fault Conditions:</strong> When a fault occurs on a line, the fault current divides between the OHGW, the ground leads, and ground electrode. The division of current needs to be known to a) Calculate the size of the grounding conductors, and b) Calculate the prospective Ground Potential Rise (GPR) along the line. The methodology to calculate the current division and structure GPRs will be documented.</td>
<td>12/31/13</td>
<td>Technical Update</td>
</tr>
<tr>
<td><strong>Transmission Line Surge Arrestors: In-service Inspection Technologies:</strong> There is a need to determine the in-service condition of TLSA’s. Existing methods include detailed visual inspections, inspections using infra-red imaging, and direct measurement of leakage current through the zinc oxide blocks. This product will provide an update on available and emerging technologies and how they are applied.</td>
<td>12/31/13</td>
<td>Technical Update</td>
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P35.007 Transmission Line Design Tools (060457)

Key Research Question

In 2010, EPRI developed an alpha version of the TLW-GEN2 software package. The TLW-GEN2 software is a program that integrates the user interface and data of a collection of software tools that are used for line design or performance evaluation purposes. TLW-GEN2 intends integrates all of the EPRI design software into a single package and enables easier importing from packages such as PLS-CADD. In 2011, the ACDCLine and TFlash modules were added to the package. Each year new modules may be added to the TLW-Gen2 software package, or existing modules may be upgraded, based on the latest available technical information. Furthermore, in order to take advantage of the most current research results that have become available since the 3rd Edition of the Red Book was published in 2005, chapters of the Red Book will also be updated.

Approach

The project continues to develop and upgrade EPRI design software of interest to the members for inclusion in TLW-GEN2. Improvements and updates to the ACDCLine module (which is to be released as an beta Version in 2011) are to be made. An improved final version of ACDCLine module of TLW-Gen2 will be delivered in 2012.

Further in 2012, the Aeolian vibration software for single overhead conductors will be reviewed, upgraded, and brought into TLW-GEN2. A beta version of the software with extensive testing and input from members will be completed by the end of the year. The software will be finalized in the following year. By the end of 2012, the final version of ACDCLine and a beta version of Single-Conductor Vibration software will be available in TLW-GEN2 under this project. Other design software packages to be selected by members will be brought into TLW-GEN2 in future years.

In addition, one of the chapters of the Red Book will be updated and revised starting in 2012. Revision of the Red Book will be carried out continuously, chapter by chapter. The number of chapters to be revised each year may be adjusted according to the needs of the members and funding available for the year. The updated Red Book will be available in electronic format.

Impact

This project may have the following impacts:
- Help designers select optimal transmission line design parameters and designs
- Improve designer productivity
- Improve overhead transmission line reliability
- Reduce maintenance and repair costs.

How to Apply Results

The TLW-Gen2 provides an efficient and effective tool to help overhead line engineers design lines. It allows designers to evaluate different aspects of designs—electrical, mechanical, and others—without duplicating input data. Because all the modules have the same look and feel, TLW-GEN2 will improve the productivity of the designers when using different modules. The new ACDCLINE module will be extended to analyze the electrical effects of DC lines.

Members can take advantage of the most current information available in the revised Red Book which has been a core reference for transmission line engineers for decades.
2012 Products

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<tr>
<td><strong>TLW-GEN2: ACDCLine Module &amp; Single-Conductor Vibration Design and Control Module - Beta Version:</strong> The existing software for the design and control of single-conductor vibration will be reviewed, updated, and upgraded for new features. The user interface will be improved to facilitate the use of the software. A beta version of the software will be available as a module in the TLW-GEN2 software package and is to be extensively tested by users. By the end of 2012, the final version of ACDCLine and a beta version of Single-Conductor Vibration software will be available in TLW-GEN2 under this project.</td>
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<td>Planned Completion Date: 12/31/12</td>
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<tr>
<td><strong>Updated Red Book - One New Chapter:</strong> One chapter of the Red Book will be updated. The chapter with the most outdated information will generally be chosen for the year. Input from members will be sought for the final decision. The updated Red Book with one new chapter will be available in electronic format.</td>
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<td>Planned Completion Date: 12/31/12</td>
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Future Year Products

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<tr>
<td><strong>TLW-Gen2: ACDCLine Module &amp; Single-Conductor Vibration Design and Control Module:</strong> The software for the design and control of single-conductor vibration will be finalized. By the end of 2013, the final version of ACDCLine and the final version of Single-Conductor Vibration software will be available in TLW-GEN2 under this project.</td>
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<td>Planned Completion Date: 12/31/13</td>
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<tr>
<td><strong>Updated Red Book - An Additional New Chapter:</strong> One chapter of the Red Book will be updated. The chapter with the most outdated information will generally be chosen for the year. Input from members will be sought for the final decision. The updated Red Book with two new chapters will be available in electronic format.</td>
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<td>Planned Completion Date: 12/31/13</td>
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<tr>
<td><strong>Updated Red Book - An Additional New Chapter:</strong> One chapter of the Red Book will be updated. The chapter with the most outdated information will generally be chosen for the year. Input from members will be sought for the final decision. The updated Red Book with three new chapters will be available in electronic format.</td>
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<td>Planned Completion Date: 12/31/14</td>
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<tr>
<td><strong>Addition of a Design Module in TLW-GEN2:</strong> An extra module for overhead line designs will be integrated into the TLW-GEN2 software package. The module that is to be included will be decided upon based on member input. The new module will be in addition to the existing ACDCLine and Single-Conductor Vibration software modules.</td>
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<td>Planned Completion Date: 12/31/14</td>
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P35.008 Foundation Design and Research (067438)

**Key Research Question**

New transmission lines are required to meet increasing demand of electric power and to improve system reliability. The foundation for an overhead line structure is a major component of the transmission line. An improperly designed foundation could be costly and unreliable and may require high maintenance. A reliable overhead line requires properly designed foundations that are compatible with the surrounding soil. The uncertainty in the behavior of soil and the lack of soil information have made this compatibility challenging.
The objective of the project is to provide transmission line designers state-of-the-art tools for designing transmission structure foundations. Tools include design methods and associated assumptions, approaches, formulae, sample calculations, and data that are required to design structure foundations properly and efficiently.

The project provides the state-of-the-art information and design methods to assist foundation designers in evaluating, selecting, and designing foundations suitable for single pole, H-frame, lattice tower, and guyed-V structures.

**Approach**

The project started in 2009 with a review of current information on the design of transmission line foundations from publications, standards, and manuals such as those from the American Society of Civil Engineers, the Institute of Electrical and Electronic Engineers (IEEE), and the International Council on Large Electronic Systems (CIGRE). A survey was conducted among electric power utilities on the design of transmission structure foundations. The survey results established a common practice for the design of transmission structure foundations, such as typical strength and safety factors applied to computed nominal foundation capacities.

In 2010, an investigation was initiated of the reliability-based approach for transmission structure foundation designs, and a general guide for the reliability-based approach was developed. In 2011, specification for sub-surface investigations for reliability-based designs, and methods to determine geotechnical design parameters between borings are being developed for inclusion in the guide. For 2012 and beyond, topics considered are: research various methods for designing rock anchors such as Micropile, develop mini-pile and helical anchor foundation designs, improve geotechnical data by taking new measurements or obtaining data from other industries, improve soil and rock correlation for geotechnical design parameters, conduct full-scale foundation testing to verify strength factors, and conduct full-scale laboratory bending tests of reinforced concrete drilled shafts to evaluate economic benefit of longitudinal steel in resisting shear stresses. The topics for each year will be prioritized and selected by members.

This project will take advantage of the knowledge gained in past research conducted by EPRI. The goal of the project is to produce a comprehensive manual using different approaches for the design of single-pole, H-frame, lattice tower, and guyed-V transmission structure foundations. The manual will bring a common foundation design practice to the electric power industry.

**Impact**

This project may have the following impacts:

- Provide state-of-the-art methods for designing transmission structure foundations
- Provide information to evaluate risks of certain types of foundation designs
- Avoid expensive maintenance and repair costs
- Improve and provide uniformity to overall transmission line reliability.

**How to Apply Results**

The project will provide members with the most current practices on foundation design for overhead lines. Transmission line foundation designers can use this information to fine-tune their own design practice to produce reliable, cost-effective transmission structure foundations. The knowledge transfer to members, especially those with less experienced staff, is enhanced by attending training offered under this project.
2012 Products

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<th>Product Title &amp; Description</th>
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<tr>
<td><strong>Workshop for Foundation Design and Analysis</strong>: A member workshop will be conducted on the design and analysis of transmission structure foundations, including theories, methods, and the application of software.</td>
<td>12/31/12</td>
<td>Workshop, Training, or Conference</td>
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| **Transmission Structure Foundation Design Manual**: A comprehensive design manual is to be prepared. New chapters based on topics selected by members that year are to be developed and added to the manual. The manual will cover basic theories, equations, specifications, data, different design approaches for various foundation types, and commonly available software for designing and analyzing transmission structure foundations. Case studies are included. | 12/31/12 | Technical Update |

Future Year Products

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<td><strong>Workshop for Foundation Design and Analysis</strong>: A member workshop will be conducted on the design and analysis of transmission structure foundations including theories, methods, and the application of software.</td>
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| **Transmission Structure Foundation Design Manual**: A comprehensive design manual is to be prepared. New chapters based on topics selected by members that year are to be developed and added to the manual. The manual will cover basic theories, equations, specifications, data, different design approaches for various foundation types, and commonly available software for designing and analyzing transmission structure foundations. Case studies are included. | 12/31/13 | Technical Update |

| **Workshop for Foundation Design and Analysis**: A member workshop will be conducted on the design and analysis of transmission structure foundations including theories, methods, and the application of software. | 12/31/14 | Workshop, Training, or Conference |

| **Transmission Structure Foundation Design Manual**: A comprehensive design manual is to be prepared. New chapters based on topics selected by members that year are to be developed and added to the manual. The manual will cover basic theories, equations, specifications, data, different design approaches for various foundation types, and commonly available software for designing and analyzing transmission structure foundations. Case studies are included. | 12/31/14 | Technical Update |

P35.010 Live Working Research for Overhead Transmission Equipment, Techniques, Procedures and Protective Grounding (051995)

Key Research Question

Deregulation and the economic realities of today’s electric utility business are forcing utilities to ensure that transmission and distribution lines remain in service every day. Outages for maintenance are more difficult to obtain, and the associated congestion costs for taking lines out of service are becoming prohibitive. In search of solutions, transmission owners are increasingly turning to live-line working techniques as standard practice to perform required maintenance. Live-line work must be performed safely. Work on de-energized lines, when it is possible, still involves hazards that include step-touch-transfer and induced voltages. These hazards in de-energized work must also be recognized and mitigated. New techniques, tools, and procedures are needed for: work on high-temperature conductors, live work on HVDC lines, minimum approach distances for helicopters in...
energized environments, design of structures to facilitate safe, efficient, and economic execution of live work, energized rescue, and training of crews to promote safety during both energized and de-energized work, including such situations as construction in the vicinity of energized lines.

Live working under HVDC conditions is not as widely practiced as under HVAC conditions. This project will study and conduct tests to determine the best practices for HVDC live working. The Live Line studies in this project will be done jointly with the Live Line studies undertaken in Program 162. This arrangement will allow for shared resources, expertise, and results.

**Approach**

Over the past two decades, EPRI has helped many transmission companies achieve significant safety improvements and cost savings in the areas of live working and de-energized work by developing and implementing new technologies and training materials for maintaining and refurbishing transmission lines. The results of this effort were consolidated with industry practices into a comprehensive *Live Working Reference Book* (the *Tan Book*, 1018974) and the online Live Working Resource Center. Building on that foundation, project activities in 2012 will address specific issues in live and de-energized work. These activities will include:

- Robotic technologies for live working
- Live work with high-temperature conductors
- Ropes for live work and energized rescue
- Technology transfer through updating the Tan Book, training videos/DVDs, meetings, and webcasts
- Live work on HVDC lines

**Impact**

The impacts of this program can include:

- Increase worker safety
- Improve reliability and availability by enabling timely maintenance of transmission lines, both energized and de-energized
- Improve transmission performance
- Decrease maintenance costs
- Application of innovative ideas and tools, such as robotics to live work

**How to Apply Results**

Participation in this project will help overhead transmission owners, maintenance service providers and linemen improve safety and transmission performance, enhance reliability, and reduce maintenance costs by supporting worker safety when conducting live-line and de-energized maintenance on overhead transmission equipment, as well as through the development of new tools, equipment and procedures. New methods will be documented in written reports and the online Live Working Resource Center. Training materials will be developed in electronic media using live action videos, computer generated scenarios, and live narration.

**2012 Products**

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<tr>
<td><strong>Robotic Technologies for Live Working:</strong> This product will continue the development, initiated in 2011, of robotized autonomous and semi-autonomous devices for live work, such as automated cotter key handler, remotely deployable portable protective air gaps and temporary grounding switches, and remotely controlled insulator string strain release robots. This product will also build on research performed in prior years on further adaptation of available and developing robotic technologies such as autonomous robots, programmable actuators, and various types of sensors and control algorithms to live work. A Technical Update report will be published.</td>
<td>12/31/12 Technical Update</td>
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<td><strong>LW with high-temperature conductors</strong>: This product will build on research performed in prior years and will address areas of concern regarding live work on conductors operating or designed to operate at high temperature, identify issues, and discuss optimal solution approaches and new live working tools that could help facilitate safe and efficient work on energized hot conductors. A Technical Update report will be published.</td>
<td>12/31/12</td>
<td>Technical Update</td>
</tr>
<tr>
<td><strong>Ropes for live work and energized rescue</strong>: This product will continue research on ropes suitable for use in energized environments and will develop functional specifications for ropes for use in rescue operations from energized lines. Plans include testing of ropes and development of training materials and a field guide for energized rescue.</td>
<td>12/31/12</td>
<td>Technical Update</td>
</tr>
<tr>
<td><strong>Update Chapters of the EPRI Live Working Reference Book</strong>: The EPRI Live Working Reference Book (the Tan Book, 1018974) was published in 2009. Since then, new materials and information have become available, and applicable revised standards have been published. This product will produce updated and new chapters of the Tan Book, for example: live work on HVDC lines, live work on friendly/unfriendly structures, transmission and substations arcflash issues, minimum approach distances for helicopter-based work, and live work on high-temperature conductors.</td>
<td>12/31/12</td>
<td>Technical Update</td>
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### Future Year Products

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<tr>
<th>Product Title &amp; Description</th>
<th>Planned Completion Date</th>
<th>Product Type</th>
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<tbody>
<tr>
<td><strong>Training Materials for LW with high-temperature conductors</strong>: This product will build on the companion project on live work on high-temperature conductors, and will develop training materials on the subject.</td>
<td>12/31/13</td>
<td>Workshop, Training, or Conference</td>
</tr>
<tr>
<td><strong>LW friendly/unfriendly structures</strong>: This product will summarize work performed to date related to live work on friendly/unfriendly structures, and will develop training materials on the subject. The training materials will highlight issues that the maintenance crew should bring to the attention of the design team prior to completion of structure designs.</td>
<td>12/31/13</td>
<td>Workshop, Training, or Conference</td>
</tr>
<tr>
<td><strong>Training Materials for Live Work on HVDC Lines</strong>: In view of increased interest in high-voltage direct current (HVDC) systems, this project will build on the companion project on live work on HVDC lines in Program 162, and will develop training materials on the subject. This arrangement will allow for shared resources, expertise, and results.</td>
<td>12/31/14</td>
<td>Workshop, Training, or Conference</td>
</tr>
<tr>
<td><strong>Robotic Devices for Live and De-Energized Work</strong>: This product will continue the development, initiated in 2011, of robotized autonomous and semi-autonomous devices for live work, such as automated cotter key handler, remotely deployable portable protective air gaps and temporary grounding switches, and remotely controlled insulator string strain release robots. This product will also build on research performed in prior years on further adaptation of available and developing robotic technologies such as autonomous robots, programmable actuators, and various types of sensors and control algorithms to live work.</td>
<td>12/31/15</td>
<td>Hardware</td>
</tr>
</tbody>
</table>
Emerging Issues in Live and De-Energized Work above 800 kVAC and 600 kVDC: Transmission systems at voltage levels above 800 kVAC and 600 kVDC have moved from research stage to construction and full operation. When these lines need to be maintained live, new tools and procedures must be developed, and new as yet unknown issues must be addressed. De-energized work near such lines also raises many new questions that have not been researched. This product will initially monitor live and de-energized issues on new lines operating at voltages above 800 kVAC and 600 kVDC, and in later years develop guidelines, tools, and training materials for linemen. Technical Update reports will be published periodically.

P35.011 Polymer and Composite Overhead Transmission Line Components (051993)

Key Research Question
Due to their reduced cost, ease of handling, improved contamination performance, and resistance to vandalism—as well as a lack of availability of traditional components—composite components such as polymer insulators are proliferating on the electricity system. These components, however, have certain disadvantages and uncertainties. This project will address a range of composite component concerns including selection, application, inspection and population assessment, and can help to increase member confidence and reliability in using these components.

Approach
This ongoing multiyear project addresses a range of composite component concerns and includes examination of composite components, such as polymer insulators, guy strain insulators, fiberglass crossarms.

Specific topics and tasks will be added and removed under the direction of the Insulator Task Force. Activities in 2012 include:

- Multistress accelerated aging test for polymer insulators, guy-strain insulators, fiberglass crossarms, and composite poles at 230 kilovolts (kV). A full evaluation of the composite components will be performed and compared to previous evaluations of in-service units. A web browser report of the inspection results of the multistress accelerated aging test will be delivered.
- Development of short-term tests to evaluate the performance of composite components, including life expectancy. The intention is that utilities will include these tests in their specifications.
- Continued maintenance of polymer insulator and fiberglass components failure databases (ongoing since 1997) to aid selection and replacement decisions.
- Continued assessment of service-aged insulators and maintenance of an inspection database result in an understanding of how insulators age and how to validate the aging chamber.
- Development of a software tool (EPIC) to calculate E-fields to aid in the correct selection of corona rings for different applications.
- Development of a protocol to assess an in-service population of polymer insulators to make informed decisions on replacement.
- Develop plans to evaluate the corona threshold on end fitting seals, evaluate corona ring use and durability, and assess life expectancy of corona damaged insulators.
- Starting in 2012, an insulator book will be developed based on existing EPRI material and new research findings. The Book will be updated and revised continuously, chapter by chapter. The number of chapters to be revised/updated each year may be adjusted according to the needs of the members and funding available for the year. The Book will be available in electronic format.
Impact

The project may have these impacts:

- Reduce construction costs and improve performance by correctly applying composite components
- Avoid sustained outages by improved methods for inspecting and assessing both individual and populations of insulators
- Help members develop effective specifications, ensuring long-term performance of composite components
- Improve engineer productivity by providing information and tools.

How to Apply Results

- Engineers will use the multistress aging test results to assess existing populations of composite components and evaluate different composite component designs.
- The failure database information will help evaluate aging populations of units and selection of new designs.
- The inspection of service-aged insulators will aid in understanding how insulators age and the factors of aging. Members can use this information to improve applications for improved reliability and performance.
- The Corona Ring Selection Software Tool is used when designing new applications and evaluating the performance of existing applications in service.
- Either members or EPRI can use the population assessment methodology to determine whether to extend the life of existing insulators in service.
- Understanding the impact of corona on the end fitting seal will help transmission line design strategies to improve the length of component life.

2012 Products

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<tr>
<th>Product Title &amp; Description</th>
<th>Planned Completion Date</th>
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<tbody>
<tr>
<td><strong>End Fitting Seal Evaluation:</strong> The E-field levels needed on an end fitting seal to cause corona damage have not been well investigated. In this task, small-scale testing will be performed to evaluate what E-field levels are needed to initiate water-drop corona on the end fitting seal. As part of this task, the end fitting seal for each manufacturer will be defined. This product will present the results of the small-scale tests and propose E-field limits for each of the end fitting seal designs tested.</td>
<td>12/31/12</td>
<td>Technical Update</td>
</tr>
<tr>
<td><strong>E-field Modeling Software: Corona Ring E-field:</strong> The EPRI software for E-field on Polymer Insulator Calculations (EPIC) will be upgraded to calculate the e-field on the surface of corona rings.</td>
<td>12/31/12</td>
<td>Software</td>
</tr>
<tr>
<td><strong>Polymer Insulator Population Assessment Software: Ver. 2:</strong> A new version of software will be developed that will include an analysis report feature and references to relevant polymer insulator inspection and assessment guides.</td>
<td>12/31/12</td>
<td>Software</td>
</tr>
<tr>
<td><strong>Short term tests for Polymer Insulators: Discharges in Rods:</strong> This product will document the development of a short-term aging test to assess the impact of discharge activity internal to a fiberglass rod on the life of an insulator.</td>
<td>12/31/12</td>
<td>Technical Update</td>
</tr>
<tr>
<td><strong>Results from the 230 kV Aging Chamber:</strong> The 230 kV Accelerated Aging Chamber has been running for nearly 6 years, with more than 40 polymer components being aged. This product documents the aging test results throughout the test in a format that is easy to navigate.</td>
<td>12/31/12</td>
<td>Software</td>
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</table>
Update of Polymer Insulator Failures Through 2012: EPRI regularly tracks polymer insulator failures across the industry to watch for potential batch problems, application problems, or other trends across the industry that might otherwise be overlooked by utilities with a much smaller dataset. This report summarizes the failures collected through 2012.

Polymer Insulators Reference Book: This reference book will be a compilation of existing EPRI reports and new research findings as a single source of information.

Future Year Products

E-field Modeling Software: Refinement: The EPIC software for calculating electric fields on transmission line insulators will be updated to increase usability and fix any bugs discovered in previous releases.

Polymer Insulator Population Assessment Software: Ver. 3: This product will include further improvements to the user interface, improve on the output reports based on user feedback, and address any bugs discovered. Lessons learned from population assessment research will also be implemented into the software.

Short term tests for Polymer Insulators: This product will evaluate the results of short-term aging of polymer insulators to determine how the tests and the results can be used to help utilities refine their procurement requirements.

Results from the 230 kV Aging Chamber: The 230 kV Accelerated Aging Chamber has been running for a number of years, with more than 40 polymer components being aged. This product documents the aging test results throughout the test in a format that is easy to navigate.

Polymer Insulator Vintage Guide Update: EPRI assesses information related to polymer insulator vintages to ensure that the information is up to date. This product will add information of insulator design changes made by manufacturers and include any new and relevant manufacturers as decided by the Insulators Task Force

P35.012 Ceramic Insulator Integrity Assessment (060456)

Key Research Question

Currently, millions of ceramic insulators are approaching or have exceeded the end of their intended service life. Since a large number of transmission lines were built in the 1950s and 1960s, these ceramic insulators are 50 years old. Although the performance of ceramic insulators has traditionally been very good, the number of problems observed is rising. Simultaneously, the number of ceramic insulators in service for more than 30 to 40 years has also increased significantly. Concerns are growing about performance issues with the current population of insulators and the availability of inspection techniques to identify high-risk units prior to failure.

Concerns have also been raised over the performance of new insulators acquired from manufacturing facilities that have not supplied utilities with insulators in the past. Lessons that traditional manufacturing plant personnel have learned over past decades of manufacturing may not have been transferred to the new plants. In addition, many utilities that have not traditionally used glass insulators are considering this technology. Glass and
porcelain insulators that are coated with silicone rubber in manufacturing are also being considered, and utilities lack experience with this technology.

**Approach**

This project will initially focus on suspension insulator bells, addressing the following areas:

- **Inspection and Assessment Tool:** This project investigates the development of field tools to assess the condition of insulator strings. In 2009, the technology was shown to be effective in identifying insulators with cracks outside the metal from a distance of 40 feet. The technology is being further developed to be remotely controlled with some automated features. In addition, the technique is being refined to identify cracks in the insulators located underneath the metal cap.

- **Insulator Identification:** When performing population assessments, it is important to know what manufacturer is installed and the year of manufacture. This project will develop a guide to identify insulators and describe their design characteristics so that informed decisions about population management can be made.

- **Evaluation of New Porcelain/Glass Discs Units:** This project assesses issues with porcelain/glass disc insulators procured from new manufacturing plants. In 2007 through 2009, M&E tests were performed and the results compared against standards and over 3000 M&E historical test results. In 2010, the testing expanded to include thermal mechanical cycling tests and includes samples of aged porcelain and glass insulators to provide a reference for comparison. In 2011 & 2012, increased thermal limits will be explored.

- **Electric Field Modeling:** This project will enhance the EPRI's Polymer Insulators E-field Modeling software, adding the ability to calculate the E-field around porcelain or glass insulators.

**Impact**

This project may have these impacts:

- Help members evaluate and identify high-risk ceramic insulator strings or populations of insulator strings prior to failure.
- Provide members with a greater choice of vendors and technologies, enabling lower cost or improved technical solutions.
- Assist members in addressing both existing and new insulation applied in contaminated environments.

**How to Apply Results**

- Operation and maintenance personnel can apply the new inspection technologies developed to evaluate in-service populations of porcelain insulators.
- Design and procurement personnel will use the information provided on the testing of new porcelain discs and glass insulators to make better-informed decisions when selecting and procuring insulators.
- The EPIC electric field modeling software will help users to understand the magnitude and impact of electric field grading designs on insulator strings.
- Knowing the make and model of insulators will help assess in-service populations.
2012 Products

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<tr>
<td><strong>Testing and Evaluation of New Porcelain/Glass Disc Insulators (Thermal – Mech. Increased temp. extremes):</strong> New standards are being developed with greater temperature extremes. By testing at these greater extremes, EPRI will gain understanding of insulator performance limits and quality of insulator manufacturing. The extreme temperature test will be useful to utilities operating in such environments.</td>
<td>12/31/12</td>
<td>Technical Update</td>
</tr>
<tr>
<td><strong>Porcelain / Glass Insulator Vintage Guide:</strong> Knowing what type of insulator is installed is key to effective population assessments. This document will be a guide on how porcelain and glass insulator designs changed over the years and what distinguishes different manufacturers from each other. This guide will also help utilities identify the manufacturer and vintage of insulators installed on their system.</td>
<td>12/31/12</td>
<td>Technical Update</td>
</tr>
<tr>
<td><strong>E-field modeling:</strong> This software will calculate the voltage distribution along a string of porcelain or glass insulators. Utilities can use this information to improve grading of the insulators to reduce the effect of pin corrosion and corona.</td>
<td>12/31/12</td>
<td>Software</td>
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Future Year Products

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<tbody>
<tr>
<td><strong>Testing and Evaluation of New Porcelain/Glass Disc Insulators (Thermal – Mech. Increased temp. extremes):</strong> New standards are being developed that include increased thermal -mechanical temperature limits. New and aged insulators will be tested at increased thermal limits to determine insulator performance and impact on the M&amp;E testing. This product will document the findings of this work.</td>
<td>12/31/12</td>
<td>Technical Update</td>
</tr>
<tr>
<td><strong>Failure Database:</strong> As the population of porcelain and glass insulators age, failures are likely to occur. This task will collect porcelain and glass failure information and document manufacturer trends, vintage, and installation environments.</td>
<td>12/31/12</td>
<td>Technical Update</td>
</tr>
<tr>
<td><strong>Developing Vibration Tests to Q&amp;A New Units:</strong> Tests currently used to inspect porcelain insulators for internal cracking are destructive. This task will develop a new nondestructive method for evaluating porcelain insulator strings for internal cracks. This product will provide an update on the development and its effectiveness.</td>
<td>12/31/12</td>
<td>Technical Update</td>
</tr>
<tr>
<td><strong>E-field modeling software update:</strong> The EPIC software will be updated to include the results of laboratory tests, increase the insulator library selection, and fix any bugs found in previous versions.</td>
<td>12/31/12</td>
<td>Software</td>
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P35.013 Increased Power Flow Guidebook and Ratings for Overhead Lines (069259)

**Key Research Question**

The demand for electric power over transmission circuits is increasing faster than transmission assets can manage. This trend has pushed the capacity of many existing transmission circuits to their design limits. In addition, much of the grid has already aged beyond its original design specifications. These issues are affecting the grid with an increasing number of bottlenecks, and other congestion and reliability problems. The power
industry is realizing that the electric power infrastructure requires attention, and there is a need to identify methods and obtain tools for pushing more power through their existing assets. In addition, there have been recent mandated regulatory requirements on the establishment of transmission circuit ratings, and power companies need to have tools available to establish line ratings in a scientifically rigorous manner.

Approach

To meet the research needs of the power industry in this area, EPRI will continue to develop software tools and methodologies related to the design, engineering, system planning, and operation of overhead transmission lines (and other transmission circuit components), and investigate and document information on the state-of-the-science and best-practices on increasing and optimizing power flow through existing assets. Information on improvements in applications, thermal models, instrumentation, secure telemetry, and case studies will be identified, developed, and documented. Training and technology transfer activities and tools, such as tutorials, guides, workshops, and conferences, will continue to be developed in parallel with the research and development work.

This project focuses on overhead transmission lines, and is executed in coordination with corresponding projects for underground cables (Project P36.004) and substation equipment (P37.107). Feedback from EPRI member engineers, operators, designers, and planners will be sought during advisory meetings and workshops to identify future improvements.

Application of the R&D products that result from this project will aid electric power companies to more fully utilize their existing assets more economically, and with continued reliability, safety, and public acceptance.

Impact

The results from this project will provide the tools, information, training, and guidance needed by power companies to assess and implement increased and optimized power flow strategies for their specific needs, and with continued reliability, safety, and public acceptance. These results will help enable power companies to:

- Provide guidance for experienced technical staff, as well as reference and training materials for the next generation of power industry technical leaders
- Increase and optimize power flow through overhead lines and entire transmission circuits
- Defer capital expenditures and new construction
- Improve transmission circuit reliability and safety
- Optimize energy transactions through rating forecasts
- Ride out emergency situations safely and reliably
- Avoid unnecessary system outages

How to Apply Results

Transmission engineers, operators, planners, researchers, and IT personnel will use the computer programs and methodologies of this project to increase and optimize the ratings of their circuits. Software products can be applied for the benefits described above, and the methodologies on how best to apply all results can be obtained through EPRI guidebooks, reports, and training materials.

Members can use delivered reports as reference sources and guides for implementing increased power flow strategies, and for training their engineers in increased power flow technologies. Reports and references also compare the economic benefits of increased power flow technologies, enabling EPRI members to make informed decisions when choosing options for their specific applications.
### 2012 Products

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<tbody>
<tr>
<td>Increased Power Flow Guidebook - 2012: The Increased Power Flow Guidebook (Platinum Book) will continue to be augmented with more and new material on the state-of-the-science and best practices for increasing and optimizing power flow through existing circuits. The needs for the guidebook are identified by industry experts and EPRI member advisory groups. An Increased Power Flow Wizard will be included with the Platinum Book.</td>
<td>12/31/12</td>
<td>Technical Update</td>
</tr>
<tr>
<td>Transmission Ratings Workstation (TRW) 1.0: The Transmission Ratings Workstation (TRW) will be initiated in 2012. This will incorporate EPRI's Dynamic Thermal Circuit Rating software (DTCR) and other ratings-related software modules under one roof. The product will be designed for performing rating studies, evaluating and optimizing static ratings, real-time ratings, and forecasted ratings for overhead lines and entire transmission circuits.</td>
<td>12/31/12</td>
<td>Software</td>
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<tr>
<td>Evaluation of Instruments for Line Ratings: Laboratory and Field Studies: Over the past several years, there have been many developments in the area of field instruments for monitoring the thermal state of overhead lines for rating purposes. These instruments monitor various parameters, such as conductor sag, temperature, tension, local weather conditions, etc. Several new instruments have recently come to market, and others are being developed and/or improved. EPRI has been at the forefront of assessing these technologies, and has used a wide range of these instruments in several projects. In 2012, EPRI will document the experiences with instruments from these projects, and will perform some basic laboratory assessments of potentially useful instruments. The results will be delivered in this Technical Update.</td>
<td>12/31/12</td>
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<td>Increased Power Flow Guidebook - 2013: The Increased Power Flow Guidebook (Platinum Book) will continue to be augmented with more and new material on the state-of-the-science and best practices for increasing and optimizing power flow through existing circuits. The needs for the guidebook are identified by industry experts and EPRI member advisory groups. An Increased Power Flow Wizard will be included with the Platinum Book.</td>
<td>12/31/13</td>
<td>Technical Update</td>
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<tr>
<td>Verification of Overhead Line Ratings using LiDAR Technologies: The use of LiDAR technologies is gaining a foothold in the industry for use in defining overhead line ratings, and LiDAR technologies are being improved at an increasing pace. This Technical Update will provide an overview of the subject, and provide guidelines for the application of the technology.</td>
<td>12/31/13</td>
<td>Technical Update</td>
</tr>
<tr>
<td>Proceedings of the Increased Power Flow Workshop: An IPF Workshop, covering all aspects of increasing power flow, will be held in 2013. Proceedings of the workshop will be published.</td>
<td>12/31/13</td>
<td>Technical Update</td>
</tr>
<tr>
<td>Transmission Ratings Workstation (TRW) 2.0: The Transmission Ratings Workstation (TRW) will continue to be developed in 2013. This program will incorporate EPRI's Dynamic Thermal Circuit Rating software (DTCR) and other ratings-related software modules under one roof. The product will be designed for performing rating studies, real-time ratings, and forecasted ratings for overhead lines and entire transmission circuits.</td>
<td>12/31/13</td>
<td>Software</td>
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P35.014 High Temperature Operation of Overhead Lines (069260)

Key Research Question

Electric power companies can increase the power transfer capacity of transmission lines by raising the conductor operating temperature. The effects of high operating conductor temperature are reduction in conductor ground clearance, loss of conductor strength, and damage to connectors and other overhead line components. In addition to the mechanical performance, transmission line owners, operators, and designers must also be aware of the effects of high temperatures on the existing corona and thermal models. These models were based on conductor temperatures much lower than those encountered by an overhead line today. Inaccurate models may produce results that could exceed the limits imposed by state or federal regulatory agencies.

Research is needed to investigate premature failures of conductor and conductor accessories from thermal cycling due to high-temperature operations. Conductor accessories include conductor splices and dead-ends, dampers, spacer dampers, and all hardware attached to the conductor of an overhead line. Research is also needed to investigate high-temperature effects on corona, thermal, and other models used to evaluate electrical effects, heat-transfer capability, and other performance indicators of an overhead line.

With accurate data, electric power companies are able to assess the risks of high-temperature operations. They can then establish a temperature limit below which overhead lines can operate reliably. This limit can further be raised by developing appropriate mitigation measures.

Approach

This project evaluates the impact of high-temperatures on the mechanical, electrical, and thermal performance of overhead lines. Solutions are developed and models enhanced to allow power companies to raise transmission line capacities safely, reliably, and with confidence.

Every component of an overhead line will be studied. The project started with the investigation of the most vulnerable component. Because fittings at the connection point are the weakest links in a transmission system, the project first focuses on establishing temperature and duration limits for these fittings beyond which they may encounter thermal or mechanical failure. It then investigates and tests different mitigation methods to alleviate the thermal impact. The project also assesses the accuracy of existing thermal and corona models at elevated operating temperatures. Research results will be used to update these models. All other knowledge gaps for high-temperature operations will be identified. Research and tests will be performed to address these gaps.

A report is prepared every year, summarizing all research results conducted by both EPRI and other organizations on the performance of conductors and conductor accessories operating beyond the conductor annealing temperature of 93°C. The information is updated each year. To facilitate the users in selecting the right temperature for an overhead line, a high-temperature matrix software is also developed. The matrix identifies readily the line components that may fail when an overhead line is operated at a given temperature. Detailed information can be accessed by drilling down into the matrix. In addition, calculators for conductor annealing, current capacity at various temperatures, and methodologies to evaluate component life, when available, are included in the matrix. The project provides a holistic approach to high-temperature operations.

Impact

This project may have the following impacts:

- Raise confidence in operating overhead lines at high temperatures to increase transmission capacities
- Avoid damage to overhead line components and subsequent line failures
- Adopt mitigation measures to achieve additional transmission power
- Provide accurate prediction of electrical and thermal performance of overhead lines
How to Apply Results

Transmission engineers can use information from the project to evaluate the risks of raising a conductor to a given temperature. Mitigation methods developed in the project can be adopted to increase the operating temperature of an overhead line. By using this information and the methods, transmission engineers can more accurately evaluate the electrical and thermal performance of overhead lines. Members can then establish internal guidelines for high-temperature operation of their overhead lines.

2012 Products

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<th>Product Title &amp; Description</th>
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<th>Product Type</th>
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<tbody>
<tr>
<td>Guide for High-Temperature Operation - Progress Report:</td>
<td>12/31/12</td>
<td>Technical Update</td>
</tr>
<tr>
<td>The guide provides an holistic approach for high-temperature operations. The guide is updated annually based on new results from internal and external research. Results from testing of mitigation measures for high temperature operations and from the development of a model for life-prediction of two-new connectors may be included. The section on fundamentals of high-temperature operations will be expanded.</td>
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HTC (High-Temperature Conductor) Matrix: Version 4.1: The HTC Conductor Knowledgeable Matrix applet will be updated with new information, data, and research results from the previous year's high-temperature operation guide. Preliminary data from testing of mitigation measures will be added to the applet. User interface will be improved based on input from members. A calculator to cover high-temperature corona and thermal models may be included.

Performance of Compression Fittings at High Temperatures: A report providing an update on the performance of various types of compression connectors at high temperatures based on the most recent test data from EPRI research will be published. The report will include description of the test setup, test protocol, observations, conclusions and recommendations.

Future Year Products

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<tbody>
<tr>
<td>Guide for Operating Overhead Lines at High-Progress Report:</td>
<td>12/31/13</td>
<td>Technical Update</td>
</tr>
<tr>
<td>The guide provides an holistic approach for high-temperature operations. The guide is updated annually based on new information from internal and external research. Preliminary test data on the impact high temperature on conductor hardware and accessories will be reported. The section on fundamentals of high-temperature operations will continue to be expanded.</td>
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HTC (High-Temperature Conductor) Matrix: Version 5.0: The HTC Conductor Knowledgeable Matrix applet will be updated with new information, data, and research results from the previous year's high-temperature operation guide. Final data from testing of mitigation measures will be added to the applet. User interface will be improved based on input from members. A calculator to predict the life expectancy of two-stage connectors may be added.

Measures to Mitigate High-Temperature Effects on Connectors: This update will detail the work done in determining the effect of mitigation devices on the performance of connectors operated at temperatures above their rated temperature levels.
Guide for Operating Overhead Lines at High-Progress Report: The guide provides an holistic approach for high-temperature operations. The guide is updated annually based on new information from internal and external research. Final test data on the impact high temperature on conductor hardware and accessories will be reported. The section on fundamentals of high-temperature operations will continue to be expanded.

12/31/14 Technical Update

HTC (High-Temperature Conductor) Matrix: Version 5.1: The HTC Conductor Knowledgeable Matrix applet will be updated with new information, data, and research results from the previous year. Preliminary test data on the impact high temperature on conductor hardware and accessories will be included. Information on the basics of high-temperature operation will continue to be expanded. The software will be reviewed for minor improvements. A new calculator to facilitate high-temperature operations may be added.

12/31/14 Software

Increased Transmission Capacity Workshop Proceedings: The proceedings of the Increased Transmission Capacity Workshop will be compiled into a technical update. Various new technologies and applications of technologies as well as utility use cases may be presented at the workshop.

12/31/14 Technical Update

P35.015 Performance and Maintenance of High-Temperature Conductors (065550)

Key Research Question
Recently developed high-temperature conductors offer the advantages of higher current capacity, lower conductor sag, and lower line losses than conventional ACSR (aluminum conductor steel-reinforced) conductors. These conductors are also known as advanced conductors, high-temperature low-sag conductors, or simply HTLS conductors. Short-term experience of these conductors was gained through an EPRI field demonstration project that was completed in 2009. Knowledge of the long-term performance of these high-temperature conductors, especially those with a carbon fiber composite core, is lacking. A number of issues have to be addressed to assist the power industry to apply this new technology properly. Furthermore, existing tools and procedures for conventional conductors have to be evaluated for applying live-line maintenance to these high-temperature conductors.

Approach
This project addresses critical issues related to the long-term performance of high-temperature conductors. The most immediate needs are for carbon fiber core conductors, which are the least known and the most novel of all high-temperature conductors. The core of this type of conductor consists of carbon and glass fibers that are more sensitive to heat and other environmental conditions than steel used for conventional ACSR (aluminum conductor steel-reinforced) conductors.

A test protocol to qualify this type of conductor was developed and applied to a carbon fiber core conductor in 2009. In 2010, the performance of two different carbon fiber core conductors was evaluated using the same protocol. In 2011, the same protocol is to be applied to a third carbon fiber core conductor. Concurrently, an accelerated aging test is to be carried out on a range of commercially available high-temperature conductors for evaluating the long-term performance of these conductors, their splices, and dead ends. Results of the accelerated aging test, which takes a year to complete, will be compared with that of the much shorter qualifying test. Reference will be made to the experience gained on non-ceramic insulators that apply similar technology for their core to develop additional tests to evaluate these high-temperature conductors with the goal of providing a purchase specification for carbon fiber composite core conductors to the users.
Starting in 2012, preparation of a comprehensive guide for the selection and application of various types of high-temperature conductors will be initiated. The guide will include the most current information from manufacturers, experience gained from users, results obtained from research, purchase specifications for procurement as well as maintenance tools and procedures for high-temperature conductors. The guide will be updated annually as new research results and data become available.

Impact
The project may have the following impacts:
- Provide information and tools that are currently not available to evaluate the performance of various high-temperature conductors.
- Provide maintenance procedures and recommend tools to ensure the safety of utility personnel and the reliability of transmission lines.

How to Apply Results
The test protocol developed under this project provides design engineers with a tool to qualify and compare different carbon fiber composite core conductors. The accelerated aging test provides useful information on the long-term performance of these high-temperature conductors. All research results provide members with information for comparing and selecting proper high-temperature conductors for their applications. Developed maintenance procedures and recommended tools for advanced conductors can be incorporated into members' maintenance manuals.

2012 Products

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<tr>
<th>Product Title &amp; Description</th>
<th>Planned Completion Date</th>
<th>Product Type</th>
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<tbody>
<tr>
<td>Maintenance Issues of High-Temperature Conductors: Research Results:</td>
<td>12/31/12</td>
<td>Technical Update</td>
</tr>
<tr>
<td>Test results from the current year will be documented in a report. The report will also provide an update on live-line maintenance procedures for high-temperature conductors, including details on the method and tool for the application.</td>
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| Accelerated Aging Test of High-Temperature Conductors and Connectors: | 12/31/12 | Technical Update |
| Results from thermal cycling of high-temperature conductor-connector systems provide valuable information for determining the expected life of these conductors. A model based on thermal-cycling results and studies of connector materials and designs will be developed to provide engineers with a valuable tool to determine the life expectancy of these conductors. |

| An outline of the guide will be developed. Topics to be included in the guide will be identified. A brief description of what will be covered under each topic will be provided. |

Future Year Products

<table>
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<th>Product Title &amp; Description</th>
<th>Planned Completion Date</th>
<th>Product Type</th>
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</table>

Guide for Maintenance of High-Temperature Conductors: Test results and reports from previous years will be used to develop a guide on the maintenance of high-temperature conductors. The guide will also provide an update on live-line maintenance procedures for high-temperature conductors, including details on the method and tool for the application. | 12/31/13 | Technical Update |
**Product Title & Description**

| Guide for Selection and Application of High-Temperature Conductors: A guide will be developed based on the outline developed in 2012. Topics to be expanded for the year will be identified. Detailed information will be prepared for these topics. | Planned Completion Date: 12/31/13 |
| Guide for Maintenance of High-Temperature Conductors: The guide developed in the previous year will be updated to include the latest findings of research conducted. The guide may also be expanded to include further high-temperature conductor maintenance issues relevant to member utilities. | Planned Completion Date: 12/31/14 |
| Guide for Selection and Application of High-Temperature Conductors: The guide developed in 2013 will be updated and expanded in 2014. Topics to be expanded for the year will be identified. Detailed information will be prepared for these topics. | Planned Completion Date: 12/31/14 |

**P35.016 New and Emerging Inspection and Sensing Technologies (070600)**

**Key Research Question**

As assets age beyond their design margin, the ability to inspect and assess their condition has become vital. New and emerging inspection and sensing technologies are essential to meet this need. Many utilities are unaware of new technologies, and in many cases unsure of their performance due to lack of field experience. As new issues emerge, new technologies must be identified and possible solutions investigated.

**Approach**

The project will take a three-pronged approach to addressing the research needs:

- Identify and document new and emerging inspection/sensing technologies to increase members' awareness.
- Document use cases where new and emerging technologies have been utilized in the field.
- Identify gaps in currently available inspection technologies and possible applicable technologies to meet members' requirements.

In 2011, a database with applicable technologies was developed, where members were able to look up the component to be inspected (e.g., insulators, sub-grade components, or others) and determine applicable sensing and inspection technologies. The database also included use cases documenting utility experiences with specific technologies. A report detailing new and emerging technologies was also delivered. Building on that foundation, project activities in 2012 will include:

- Updating the inspection/sensing technologies database based on member input and new information
- Add use cases to the database
- Document gaps or needs, and develop a vision for future inspection and sensing technologies
- Laboratory and field evaluation of new and emerging technologies

In future years, if experience with new inspection/sensor technologies is not available, round-robin-style testing will be performed in controlled and field environments to provide members with knowledge and performance information on inspection/sensing technologies that they have not applied to date.

**Impact**

By being aware of the latest technologies and having easy access to other utilities' experience as well as performance testing, members will be able identify appropriate technologies more easily and have more confidence in their application.
By identifying gaps and possible technologies, future research and development needs can be addressed.

**How to Apply Results**
When faced with an issue concerning a specific component, members would utilize the database to become aware and informed of all applicable inspection/sensing technologies. In addition, they would have easy access to other members’ experiences in addition to third-party performance results.

**2012 Products**

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<tr>
<th>Product Title &amp; Description</th>
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<th>Product Type</th>
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<tbody>
<tr>
<td>Evaluation of Emerging Technologies: New and emerging inspection and sensing technologies will be evaluated in laboratory and field testing. This product will document the performance and provide users with a basis for their application. Members will be invited to attend a demonstration of the technologies being evaluated.</td>
<td>12/31/12</td>
<td>Technical Update</td>
</tr>
<tr>
<td>Inspection &amp; Sensing Technology Database (including use cases): This is an update to the database initiated in 2011. This product will contain new inspection and sensing information and will include additional utility use cases.</td>
<td>12/31/12</td>
<td>Software</td>
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**Future Year Products**

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<th>Product Title &amp; Description</th>
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<tr>
<td>Update Inspection &amp; Sensing Technology Database (including use cases): This is an update to the database initiated in 2012. This product will contain new inspection and sensing information and will include additional utility use cases.</td>
<td>12/31/13</td>
<td>Software</td>
</tr>
<tr>
<td>Evaluation of Emerging Technologies: New and emerging inspection and sensing technologies will be evaluated. This product will document the performance and provide users with a basis for their application. Members will be invited to attend a demonstration of the technologies being evaluated.</td>
<td>12/31/13</td>
<td>Technical Update</td>
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**P35.017 Design and Construction - Approach and Practices (072004)**

**Key Research Question**
The power industry wants to construct reliable and cost-effective overhead lines. A reliable and cost effective line requires not only a line that performs well but also a line that be constructed easily and safely. Well-coordinated designs for ease of construction are required. It is therefore crucial that close coordination is maintained and information is shared between design and construction staff. In the Overhead Transmission program, research is being conducted on line components, maintenance procedures, methods, and work practices for overhead lines in separate areas and often involves separate members. The research has produced products that may be useful but often overlooked by one another.

This research will develop a comprehensive, single source guide for the coordination of design and construction practices. Overhead line designs may be optimized to allow good construction practices while construction practices will be developed for new designs that requires unique or new approaches.
Approach
The project will focus on issues that have major impact between design and construction and that are critical to the cost and safety of the overall line. The project will review research products developed in other projects within the Overhead Transmission program, evaluate their suitability, and adapt them for use in the design and construction of overhead lines. Information includes technical data as well as experiences gained from constructing, operating, and maintaining overhead lines. Tools include software, equations, and methodologies. The information will be assembled in a form that is easily available to overhead line designers and construction engineers. The project will cover materials, designs, construction, practices, and approaches and will include various line components. The most current information beyond that being used by overhead line designers and construction engineers will be developed and possible gaps identified.

Impact
The project may have the following impacts:
- Enable overhead line designers to select proper designs and line components
- Enable overhead line construction staff to build lines safely and easily
- Develop construction practices for unique and new designs
- Reduce construction, operation, and maintenance costs

How to Apply Results
Overhead line designers can apply guidelines developed under this project in selecting proper and cost-effective designs, materials, components that can be constructed easily and safely. Overhead line constructors can apply approaches and practices developed under this project to build lines safely and cost-effectively.

2012 Products

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<th>Product Title &amp; Description</th>
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<tbody>
<tr>
<td><strong>Guide for Evaluation of Overhead Line Components</strong>: Research data on different overhead line components from the Overhead Transmission program are to be assembled and reviewed for suitability of its use for the Transmission Line Design Practice and Approach. One or more components will be reviewed each year, and a document will be prepared to assist designers in evaluating the technical merits of line components. A guide addressing all the components and including design approach and construction practice will be prepared in a future year.</td>
<td>12/31/12</td>
<td>Technical Update</td>
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</table>

| **Design and Construction - Approach and Practices**: Research data on maintenance and construction practices influenced by designs are to be assembled. The impacts on the practices by different designs are to be reviewed. Construction approach will be evaluated and practices will be developed. | 12/31/12                | Technical Update     |

Future Year Products

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<tr>
<td><strong>Guide for Selection of Overhead Line Components:</strong> Research data on different overhead line components from the Overhead Transmission program are to be assembled and reviewed for suitability of its use for the Transmission Line Design Practice and Approach. One or more components will be reviewed each year, and a document will be prepared to assist the designers in selecting a proper component for the application. The selection will include both technical and economic evaluations.</td>
<td>12/31/13</td>
<td>Technical Update</td>
</tr>
<tr>
<td><strong>Guide for Evaluation and Selection of Overhead Line Components:</strong> A guide for evaluation and selection of overhead line components may be developed based on the work done in preceding years. The guide may include technical and economic information to assist users in evaluating the overall costs of line components for the selection of a proper product for their application.</td>
<td>12/31/14</td>
<td>Technical Update</td>
</tr>
<tr>
<td><strong>Design and Construction - Approach and Practices:</strong> Research data on maintenance and construction practices influenced by designs are to be assembled. The impacts on the practices by different designs are to be reviewed. Construction approach will be evaluated and practices will be developed.</td>
<td>12/31/14</td>
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</tr>
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Unmanned Air Vehicles for Transmission Lines (072005)

Background, Objectives, and New Learnings

There is a potential that unmanned air vehicles (UAVs) could be a valuable asset to utilities to help in their inspection of transmission lines. This project will evaluate UAVs and remote sensing technologies for inspection and condition assessment of overhead transmission lines. Researchers will first identify functional requirements for UAV inspection and perform a market survey to identify available UAV inspection technologies, inspection services, and their costs. Based on the findings, the project team will then conduct laboratory and field demonstrations of promising UAV inspection technologies.

Results of the project will help utilities understand additional options for inspecting transmission lines and may also help identify future research, development, and demonstration needs.

Although requirements for transmission reliability and availability have increased, utilities are also seeking to reduce costs while squeezing more performance from existing—and often aging—assets. Advanced technologies such as UAVs may enable utilities to maintain or increase transmission reliability with smaller budgets and fewer personnel.

EPRI evaluated UAVs for transmission inspection in the late 1990s. Tests demonstrated that the concept of using fixed- and rotary-wing UAVs for line inspections was sound; however, the low-cost sensor packages used in the tests could not accurately determine the position of individual structures, or identify a significant number of conditions and defects. With the advances in sensor technologies, and additional development and experience in military applications, UAV technology has matured and is ready for reevaluation as a transmission inspection tool.

Project Approach and Summary

The project team will first identify applications and functional requirements for UAV inspection of transmission lines and will create a vendor and technology inventory to identify vendors and technologies that can meet the functional requirements for rotary- and fixed-wing UAVs. This inventory may include sensor, navigation, and communications technologies, UAV inspection service providers, and costs. With this information, the project team will perform a gap analysis to identify and understand the issues and barriers that must be addressed before developing functional specifications for UAV transmission inspection systems.

Benefits

Transmission line inspections are essential to pinpoint stressed or at-risk components prior to failure, preventing outages and optimizing maintenance efforts.

Traditional transmission line inspection methods are costly and labor-intensive. Utilities use manned aircraft for fast and slow fly-by patrols, and also conduct walking or driving line patrols, as well as climbing or bucket truck inspections. UAVs offer the potential to improve transmission line inspection by reducing labor costs, improving safety of personnel and equipment, increasing operational flexibility, and providing expanded inspection capabilities.

Today’s UAVs can carry an array of remote sensing equipment including high-resolution digital still and video cameras, infrared cameras, and light detection and ranging (lidar) systems. These sensors, coupled with GPS navigation and data communications systems, may enable UAVs to augment or replace traditional methods for performing a variety of inspections.

Fixed-wing UAVs could potentially perform flyby patrols for assessment of transmission structures and components at lower costs than manned aircraft. Portable rotary-wing UAVs could be deployed to hover near a tower to provide a high-definition, birds-eye view to enable field inspectors to assess the condition of insulators, conductors, and other components of interest. After severe storms or during flooding, when ground response is limited, UAVs could be used to assess damage and provide the information to the emergency response planners.
115/138kV Accelerated Aging Test to Evaluate Polymer Insulators Installed with and without Corona Rings (069303)

Background, Objectives, and New Learnings

Since 2006, utilities have experienced mechanical failures of polymer insulators on 115 kV and 138 kV transmission lines. Many inspections by utilities have revealed significant levels of discharge activity on their 115 kV and 138 kV polymer insulators, which is a key element in mechanical failures. Examination by EPRI revealed that corona activity is responsible for accelerated aging and in some cases significant degradation of the rubber and the end fitting seal. The correct application of corona rings can mitigate the high electric fields (E-fields) that cause corona activity, reducing the risk of failure.

For many years, it has been recommended that corona (grading) rings are not necessary for voltages at or below 161 kV. Although some manufacturers are now recommending the standard application of corona rings on polymer insulators for voltages of 115 and 161 kV, the in-service population of polymer insulators installed without corona rings needs to be addressed. Utilities need to understand the options to deal with the significant population of polymer insulators that may be at risk of failure.

EPRI has been investigating these failures and their mechanisms and has provided detailed recommendations on how to address the issue when specifying new units and inspecting in-service units for problems. These recommendations can be found in EPRI report 1015917, “Application of Corona Rings on 115/138 kV Polymer Transmission Line Insulators”.

There are still a number of open questions regarding this subject:
- What is the expected loss of life of units that have been in-service without corona rings
- What is the difference between the different insulator designs
- At what point is retrofitting a corona ring more cost effective than insulator replacement

Continuous dry discharge activity is harmful to the rubber weathershed and end fitting seals of polymer insulators. The prolonged exposure to discharge activity rapidly ages the rubber in as little as six to seven years, leading to cracking and eventually exposure of the rod to the environment. This damage, in turn, may result in failure of the polymer insulator, either electrical or mechanical. Preventing discharge activity reduces the risk of polymer insulator failure. Prior research has shown that this prevention can be achieved by applying corona rings at the lower voltages.

EPRI has been running accelerated aging tests on polymer insulators for the past 15 years. Utilities have used the results of the tests to improve installation practices, improve their purchasing specifications, improve their inspection techniques, as well as to make effective population assessment decisions.

Project Approach and Summary

Approach
This project will investigate these questions by conducting multiyear, multistress accelerated aging on full-scale insulators. The current plan is to place 30 or more suspension, dead end, and braced post units from five different insulator designs under electrical and mechanical stress equivalent to that found in service. New units will be aged with and without corona rings. Service-aged units provided by participating utilities will be included in the test to show the effect of retrofitting a corona ring onto the insulator and the impact of not installing a ring. The electrical stress (the E-field magnitude) of the participating utility configurations, as well as the aging test, will be calculated by 3-D modeling. The modeling is vital to the test design, but it also provides useful information to the participants on their configuration's performance. EPRI's EPIC and other E-field modeling software will be utilized.
Project Summary
This project will consist of 30 polymer insulators from five manufacturers. The test frames will be located outdoors in Lenox, MA. An artificial rain system will be installed to enhance wet discharge activity and accelerate aging. The insulators will also be exposed to all four seasons. The insulators will be inspected visually and for loss of hydrophobicity semi-annually. An IR/UV inspection will occur annually. A detailed set of evaluation tests will be performed at the end of the test.

Benefits
This project strives to develop decision support information necessary for utilities to manage populations of 115/138 kV units installed without corona rings. Utilities may be able to create and time a replacement program for insulators in service, prioritized by design and expected remaining life. Utilities will also be able to make informed decisions on proper application of corona rings when developing standards for new installations. Addressing the application of corona rings for both service-aged and newly installed insulators may increase their service life and increase the reliability of utilities’ systems.
Inspection And Assessment for Lattice Structures using Guided Waves and Electrochemistry (070972)

Background, Objectives, and New Learnings

A huge gap has been identified in the inspection and assessment of lattice transmission structures. Traditional techniques have been limited to direct assessment and soil diagnostics, and each of these technologies has limitations in cost and accuracy. EPRI has created a supplemental project that is designed to test a new application of an existing technology against a newly developed technology. Linear Polarization Resistance is an electrochemical technique that quickly measures corrosion rates. Electro-Magnetic Acoustic Transducer (EMAT) is an acoustic technique has been tested with various levels of success on steel poles and anchor rods. The concept is to utilize both methods and then confirm the results through excavation in a series of field trials in the participant’s service areas.

The purpose of this project is to identify the accuracies, costs, and risk of new and emerging inspection technologies.

Project Approach and Summary

The first activity through a participant’s service area will be assessing the structures using EMAT and a new EPRI portable terminal station, followed by an excavation and a direct visual assessment down to four feet below grade. This dual inspection is necessary to understand the effectiveness of the assessment technique under test. Once a suspect structure has been identified as having significant degradation, a full excavation will be made to confirm the assessment. This excavation will be completed on 2% of all structures inspected.

Benefits

A supplemental project in 2009 was completed for inspection and assessment of galvanized steel poles. This project is similar in concept as it is designed to be a round robin evaluation of two emerging technologies for a structure type that is mature and in need of an inspection method.

Lattice structure inspections below grade can be costly due to loading issues and the associated stabilization required during excavation. Few of these structures can be excavated to the bottom of the grillage unless they are a tangent structure without transverse loads. This practice can also lead to a backlog of open structures that have not been repaired and have been disturbed.

The public may benefit from keeping the rates affordable even with the higher need to inspect the aging transmission infrastructure and maintain it at lower cost.
**Daylight (UV Imaging) Discharge Inspection Interest Group (064856)**

**Background, Objectives, and New Learnings**

The technology for viewing corona and arcing discharges in full daylight has been around for a number of years. Many utilities now possess this technology and are using it for operation and maintenance of power lines. One of the difficulties in fully applying this technology is the interpretation of the data or visual images. This is because arcing is often interpreted as corona and vice versa, and the location of the discharges and their effect are sometimes misdiagnosed. This failure may lead either to unnecessary intervention or to equipment failure.

The Daytime Discharge Inspection Interest Group was initiated in 2007 to help the industry maximize the use of Daylight UV camera technology for inspection and maintenance of the power network. An ongoing challenge is the improved understanding and diagnosis of the visual images taken from the camera.

The objectives of this project are to move this technology forward by:

- Developing training material and updating existing material with new research findings
- Undertaking fundamental research on UV & IR inspection of transmission line components
- Providing a hands-on workshop and training

**Project Approach and Summary**

The focus of this project is the establishment of a Daytime Discharge Inspection Interest Group. DDIIG will act as the forum by which utilities can maximize the benefit of using this technology. In essence, the DDIIG will allow participants to share information, including vendor and utility experience, and have access to field guides, training, and a bulletin board for queries and advice. It will also provide the framework for setting inspector requirements.

This project also caters for those wishing to limit their participation to User Group meetings. This allows participants to share utility experience, keep abreast of vendor technologies, and facilitate user needs.

The Interest Group will be non-vendor-specific, encompassing all of the optical daytime corona inspection technologies currently available. The Interest Group’s mission will be to provide unbiased, technically sound, and current information.

**Benefits**

- Improve decision making when using this technology
- Receive training
- Share utility experiences
- Ensure consistent inspection standards

These benefits can ultimately translate into O&M cost savings.
Comparative Assessment of DTCR Technologies (072006)

Background, Objectives, and New Learnings

The demand for electric power over transmission circuits is increasing at a faster rate than the construction of new transmission facilities. This trend is pushing the capacity of transmission circuits to their design limits. The power capacity (i.e., the rating) of most overhead transmission lines is prescribed by the so-called “static rating” based on both the conductor configurations and the environmental conditions. Typically, very conservative worst-case assumptions about environmental conditions were used when developing these “static ratings”. Due to this conservative approach, significant extra power capacity exists beyond the design margin on most lines most of the time.

As part of its ongoing research in this area, EPRI has developed monitors, rating calculation methodologies, the Dynamic Thermal Circuit Rating (DTCR) software, workshops, and other products. Prior to undertaking capital intensive activities—such as building new lines, reconductoring, raising structure heights, replacing transformers, and putting lines underground—utilities can use this technology to maximize power throughput of existing assets, defer capital expenditures, and simultaneously increase safe and reliable operation of their assets.

Several types and classes of field instruments can be used to monitor the thermal state of overhead conductors for performing real-time ratings or for performing off-line rating studies. Some of these instruments are commercialized, and some are still in development. Power companies considering real-time or off-line ratings often have the question as to what instruments are best for them technically and economically. The answer is not always known, and the answer may depend on the details of the specific application.

In this project, EPRI will perform side-by-side comparisons of several instruments of different types, and document the results to help utilities understand and apply these technologies. A host utility will be needed for the field tests, or the project can be performed in a full-scale laboratory environment.

Project Approach and Summary

Tests and evaluations of instruments that may be used to monitor the physical state of overhead conductors for rating purposes will be performed in the field. A host utility will be needed for the field tests, or the project can be performed in a full-scale laboratory environment.

Benefits

The results of this project will help utilities apply rating technologies for the purpose of increasing or optimizing the power throughput of existing assets while maintaining reliability, power quality, and safety.
Full-Scale Verification of ArcFlash Thermal Energy Model at Transmission Voltages (072145)

Background, Objectives, and New Learnings

Arc flashes are a serious hazard that may potentially put people in life-threatening situations and cause great damage to existing assets. National Electrical Safety Code (NESC) and Occupational Safety and Health Administration (OSHA) safety rules have introduced requirements for electric utilities to perform arc flash hazard analysis of all electric facilities operating at and above 1000 volts. Most methods available at this time for analyzing the arc flash incident thermal energy were developed for low- and medium-voltage industrial and commercial settings. Previous extensive EPRI testing and analysis concluded that the currently available methods for calculation of incident thermal energies are not applicable to practical transmission situations and lead to inaccurate estimates of incident thermal energy. Hence, an improved computations method is needed to meet NESC and OSHA rules.

A new empirical arc model was developed, and more realistic curves were developed of incident thermal energy versus arc energy (current and duration), arc gap length, and distance from the arc gap axis (working distance) based on long gap tests (arc gaps up to 5 ft long). The research performed is expected to enhance the safety of live work on overhead lines and in substations. Summaries of EPRI's research, general conclusions, and a new calculation equation are contained in EPRI reports 1022632 and 1022633.

Project Approach and Summary

In this next stage in this research, the arc model developed under laboratory conditions will be adapted to realistic live work transmission and substations situations through full-scale testing. This project will perform high-current tests, using instrumented mannequins on realistically mocked-up transmission structures and substation equipment. The developed equations will be verified and adjusted, if necessary, for these conditions. Conclusions and findings will be shared with the utility industry through improved computation equations, reports, and workshops.

This project meets EPRI’s mandate of conducting original research for the benefit of the public and its members. The project’s results are expected to answer how arc flashes affect personnel and may lead to improved safety of personnel. It fills the knowledge gap in modeling long arcs in practical situations on overhead lines and in substations.

Benefits

Participants will have access to the most recent information on arc flash issues as they relate to work on transmission lines and in substations, and to the necessary science and tools to develop the basis for compliance with NESC and OSHA safety rules. Tests planned as part of this project can also be witnessed.

This project is expected to improve the understanding of the impact of arcing on personnel in various work situations. Application of the results of this research may also allow live work in cases where this was previously not permissible or practical based on currently available computation methods. This capability may allow the utilities to perform necessary inspections and maintenance operations live, thus increasing the overall reliability and availability of the transmission grid.

EPRI computational methods and comprehensive reports on arc flash issues could benefit utilities that are developing their own processes and procedures to comply with NESC and OSHA standards that can ultimately lead to safer environments for workers and the public.
Evaluation of Emerging Line Surveying Technologies (071879)

Background, Objectives, and New Learnings

Many utilities are performing detailed surveys of transmission lines to address the regulatory alert issued by the North American Electric Reliability Corporation (NERC). This alert requires all transmission operators to assess by 2014 the precise physical characteristics of their high-voltage transmission lines relative to design specifications.

Some utilities are considering using LiDAR (Light Detection And Ranging) surveys, together with engineering software, such as PLS-CADD, to determine whether conductors comply with the NERC requirements. The surveys determine whether transmission lines have the required clearances under full rating conditions and specified environmental conditions.

An important factor utilized by the engineering software when processing the LiDAR data is the conductor temperature at the time of the survey. A number of approaches are used to determine this—for example, positioning weather stations along the transmission line and calculating the conductor temperature at the time of the survey. Uncertainty remains as to the applicability of this approach.

Alternate approaches are being proposed including measuring conductor temperature directly using a RF Sensor; utilizing infrared sensors from the LiDAR helicopter, or measuring wind speed in the helicopter directly and calculating the conductor temperature from knowledge of the load, wind velocity, ambient temperature, and solar intensity.

This project will identify and document technologies, perform testing to determine their applicability.

Project Approach and Summary

Identification and Documentation of Available Solutions

Emerging technologies and approaches will be identified and documented. Their fundamental concepts will be documented together with the published accuracy. Any fundamental limitations will be identified.

Full Scale Test Development

A full-scale transmission line at the EPRI Lenox Laboratory will be enhanced to control conductor temperature and sag. Conductors of various emissivity and diameters will be instrumented for direct conductor temperature measurement and sag and local environmental conditions.

Full Scale Testing

A scientific approach and test plan will be developed and agreed upon by the participants to perform. Blind testing of the technologies will be performed. The test condition will be unknown to the surveyors.

Field Assessment

EPRI has a number of utility test sites with spans instrumented to continuously measure conductor temperature, sag, and environmental parameters. These spans will be surveyed with the technologies and results compared against the direct measurements.

Participation in the development of test setups and approach plans will be encouraged.

Analysis of Data and Reporting

The survey data will be compared against the direct measurements documenting the performances.

Benefits

Through this project, participants can bring the knowledge they gain in developing new line surveying techniques that could benefit the industry, leading to greater safety.
Developing the capability to verify that the as-built line performance matches the line design specifications can help utilities to operate the line safely, meeting the intended safety and performance characteristics and increasing reliability.