

## Overhead Transmission - Program 35

### Program Overview

#### Program Description

Transmission companies are faced with issues such as improving safety and reliability, as well as cutting 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/refurbished equipment is another priority.

This EPRI research program is designed to address research needs of transmission asset owners. 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 and reference and field guides, together with longer-term research such as component aging tests and the development of sensors for monitoring line components and performance.

#### Research Value

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

- 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

#### Approach

EPRI research in overhead transmission will yield data and knowledge that will be beneficial to program members. This information will come 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 being 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 to identify levels of component deterioration and take corrective action in a timely fashion. The use of thermal and corona models of overhead conductors operating at high temperatures and understanding of the effect of high-temperature cycling on conductor systems can help operators to improve capacity. 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 the following:

- Conductor cleaning tool. This device is a more-efficient and 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.
- Inspection of Transmission Line Grounding Systems Field Guide. 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 line grounding systems. 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.
- EPRI has developed a PC-based software called Transmission Line Workstation Design Tools, Version 1.0. It is an application tool to examine audible noise, corona, ozone, and radio noise generation, as well as the electric and magnetic fields of transmission lines with various bundle configurations. The calculations are based on those implemented in the "Red Book" applets.
- Lightning Performance Prediction Software, TFlash, Version 5.1, is used to evaluate the performance of existing lines or help design new transmission lines. TFlash can also be used to evaluate the effect of individual lightning events that challenge 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 has helped to assist power utilities in achieving 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 (Yellow Book)
- Tools and mitigation techniques to address sub-grade and conductor corrosion
- Thresholds for compression connectors inspection tools, including a population assessment approach
- Inspection and assessment of crossarms
- Foundation analysis and design
- Update live working guide
- Transmission Line Workstation (TLW)
- Transmission Line Surge Arrester (TLSA) Guide
- Composite component accelerated aging results
- Software to aid in selection of corona rings (EPIC)
- Guidance on Specifying for Porcelain and Glass Insulators
- Update transmission capacity guidebook and complete development of a "smart tool" for selecting suitable options for transmission capacity upgrades
- Improve transmission capacity software and data analysis program for rating methodologies
- Develop additional instrumentation for increasing power flow

## Estimated 2010 Program Funding

\$6.5M

## Program Manager

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## Summary of Projects

### PS35F Design, Reliability and Performance for Overhead Transmission (069257)

#### Project Set Description

The Design, Reliability and Performance for Overhead Transmission project set leads in the exploration and deployment of promising new technologies and tools to help overhead transmission owners design, maintain, and operate cost-effective systems. The goals are to reduce operating and maintenance costs while maintaining or improving reliability and public safety.

Products include design tools and software, development and deployment of new technologies, laboratory evaluations of components, guides, reference books, workshops, and training.

Members further benefit through active participation in Task Force meetings, which provide engineers and supervisors invaluable information and networking opportunities. In short, members of the Design, Reliability and Performance for Overhead Transmission project set will be positioned to improve safety and reliability as well as to cut operations and maintenance (O&M) costs.

Project Number	Project Title	Description
P35.001	Overhead Transmission Line Inspection and Assessment Methods Guideline	This project is a mix of tools, training, and information that will help members improve their inspection and assessment techniques.
P35.002	Conductor, Shield Wire and Hardware Corrosion Management	This project identifies, develops, and assesses the tools and procedures required to deal with conductors, shield wires, and hardware exposed to atmospheric corrosion.
P35.003	Sub-Grade Corrosion Management of Transmission Line Structures	This project helps determine cycle times for reinspection of the assets and the best methods of mitigation and remediation of corrosion damage.
P35.004	Compression Connector Management	This project provides a holistic approach to the inspection and management of compression connectors.
P35.005	Crossarm Management	Research is primarily focused upon the assessment of inspection technologies for crossarms and the development of reject and ranking criteria for various construction materials.
P35.006	Lightning Performance of Transmission Lines and Surge Arresters	This project is a mix of tools, training, and information that will help members improve their transmission line lightning performance.
P35.007	Transmission Line Design Tools	This project will pursue the following activities: <ul style="list-style-type: none"> <li>• Examine individual modules in the Transmission Line Workstation one at a time.</li> <li>• Update and expand these modules to reflect changes that have occurred since they were last revised.</li> <li>• Develop a master program to facilitate efficient operation of these all modules and to minimize duplication of data entries.</li> <li>• Conduct a workshop for technology transfer.</li> </ul>

Project Number	Project Title	Description
P35.008	Foundation Analysis and Design	The project first establishes a common design practice within the electric power utility. The practice is critically reviewed for improvements. The reliability-based design approach that shows promising improvements to the design of foundations will be investigated in order to establish a methodology for the foundation design of overhead line structures. The project will continue to assemble design information for the preparation of a design manual. The manual will cover basic theories, equations, different design approaches for various foundation types, and commonly available software for the design and analysis of transmission structure foundations. It will contain information not only suitable for experienced designers but also for junior engineers who have little experience.
P35.009	Optimization of Transmission Design by Life-Cycle Costing	A life-cycle costing methodology for transmission line designs will be first established and then a model will be developed. The model establishes the relationship that dependability has on design decisions and associated costs. The life-cycle costing method helps designers and planners evaluate design alternatives based upon the present value of all costs on a common lifetime basis and choose the best overhead line during design stage. The model will be tested using data collected from utilities and further refined. A calculator using the spreadsheet will be developed to facilitate analysis of life-cycle costs.
P35.010	Live Working Research for Overhead Transmission Equipment	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.
P35.011	Polymer and Composite Overhead Transmission Line Components	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.
P35.012	Ceramic Insulator Integrity Assessment	This project focuses on how to assess the aging population of porcelain insulators and how to properly procure and apply new and replacement insulators.

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

### Key Research Question

There are several reasons why overhead transmission line inspection and assessment methods research is needed by utilities. The current transmission infrastructure is aging, and it is important to keep it both reliable as well as extend its life. To do so, utility managers need to keep abreast of new inspection and maintenance practices, tools and issues. If inspection and assessment of the transmission infrastructure is not thorough, the systems will eventually become less reliable and components will fail. In addition, utilities will not be able to plan accordingly because they won't have a system in place to recognize if and when components will fail.

### Approach

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

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

## Impact

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

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

## How to Apply Results

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

## 2010 Products

Product Title & Description	Planned Completion Date	Product Type
<b>New Versions of OHTL Inspection and Assessment Methods (IAM)</b> <b>Reference Guide:</b> This guide helps members initiate a new OHTL inspection and assessment program or refine an existing one.	12/31/10	Technical Report
<b>New Set of Pictorial Guides:</b> These field guides will be published both in printable and software form. The guides are designed for field use: pocketbook size (8"x4") and printed in color on glossy paper. Electronic versions are also available. Many members are distributing these guides to all field personnel, and they are forming the backbone of their inspection program.	12/31/10	Technical Update
<b>Future On-line E-Learning Modules, Workshop, and Webcasts:</b> On-line self-paced learning modules will continue to be developed around components or inspection technologies. This software can be used with members' current learning management systems.	12/31/10	Software
<b>Biannual Overhead Transmission Lines Conference:</b> The biannual Overhead Transmission Lines Conference will be held.	12/31/10	Workshop, Training, or Conference

## Future Year Products

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

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

### Key Research Question

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

### Approach

- This project provides tools and processes for inspecting and assessing overhead shield wires, conductors, and hardware, and it produces management and engineering guides. The project's goals will be achieved via research in the following task areas over the lifetime of project:
  - Inspection: This task addresses the question of how to gather data and information regarding the state and dynamics of corrosion activity.
  - Population Assessment: This task addresses the "what next?" questions stemming from an effective inspection and detection program. It will address how to inspect, what to sample, how to test, how to analyze results, and how to make a decision.
  - The Selection and Application of Wires: This task provides results to aid designers in the selection of the most appropriate conductor and shield wires to extend the life of these components in their specific environment and application.
  - Shield Wire and Phase Conductor Management Program: Progressive actions will proceed in a deliberate step-wise manner from year to year toward the completion of the tasks listed above. Eventually the tasks will culminate and integrate into a comprehensive management program applicable to designers, specification writers, engineers, operators, inspectors, and management.

## Impact

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

## How to Apply Results

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

## 2010 Products

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

## Future Year Products

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

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

### Key Research Question

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



## Approach

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

EPRI will divide the project into the following subtasks:

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

## Impact

This program may have the following impacts:

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

## How to Apply Results

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

## 2010 Products

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



## P35.004 Compression Connector Management (065547)

### Key Research Question

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

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

### Approach

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

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

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

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

### Impact

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

- Increase safety of transmission lines by reducing line droppings
- Reduce sustained unplanned outages due to compression connector failure
- Optimize spending of operations and maintenance (O&M) funding
- Improve productivity of field personnel with training and field tools
- Address the loss of institutional knowledge by providing training

### How to Apply Results

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

## 2010 Products

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

## Future Year Products

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

## P35.005 Crossarm Management (067437)

### Key Research Question

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

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

### Approach

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

and their application. Guidelines will be provided for their application, and promising new techniques will also be sought and identified.

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

## Impact

This project may have the following impacts:

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

## How to Apply Results

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

## 2010 Products

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

## Future Year Products

Product Title & Description	Planned Completion Date	Product Type
<b>Aging of Live Working Tools - Mechanical, Electrical</b>	12/30/11	Technical Update
<b>Evaluation Of Crossarm Inspection Technologies:</b> Technologies used for inspection and evaluation of crossarms will be evaluated, and a report will be prepared that details the findings for members.	12/30/11	Technical Update

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

## 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 is dependent on a variety of factors.

### Approach

The tasks addressed in this project are as follows:

*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 groundwires, steel lattice structures with grillage foundations, and two-pole structures. From 2004–2009, a technology that enables effective measurement of transmission line ground electrodes was developed and demonstrated, and an application guide was developed. In 2010, research will focus on adding additional functionality to the instrument.

*TFlash.* As understanding of lightning-related phenomena increases, the TFlash lightning performance prediction software is updated. In 2006 and 2007, TFlash was updated to version 5.0 with improved grounding models, an interface to utility databases, and bug fixes. In 2008 TFlash was compared against real line performance and provided guidance on effective TFlash use. In 2009 a new version of TFlash was developed that will be compatible with Microsoft™ Vista, and research addressed methods to improve lightning performance of transmission lines using TFlash and other tools. In 2010 improved models will be incorporated.

*Transmission Line Surge Arrestors (TLSA) Research.* This task develops the information for and publishes a TLSA application guide. In 2008 fundamental research was conducted on placement and energy handling capabilities. In 2009 the guide was completed and an application workshop based on the guide was held. In 2010 issues related to the long-term performance of TLSA will be addressed. These issues relate to attachment methods, housing, and more. This work will focus on deriving specific tests to address these issues.

*Alternative Ground Electrode.* Companies are currently struggling with issues surrounding the theft of copper. This task will investigate the use of alternative materials and electrode designs. Issues such as life expectancy, corrosion, and material compatibility and current handling capabilities will be addressed.

### 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 that are new to the field of lightning and grounding.
- Cost reduction by providing improved tools (e.g., Zed-Meter, EGGS, 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 TFlash software to optimize the lightning performance of transmission lines with internal resources, or they can outsource this work to the EPRI Lightning and Grounding Team. The TSLA workshop will provide design and O&M maintenance personnel with the knowledge on the application of TLSAs.

### 2010 Products

Product Title & Description	Planned Completion Date	Product Type
<b>Alternative Grounding Electrodes:</b> This product will continue work into alternative designs and materials for grounding electrodes.	12/31/10	Technical Update
<b>TLSA Testing:</b> There are a number of issues related to the long-term performance of TLSA. These relate to issues such as attachment methods, housing, and more. This work will focus on deriving specific tests to address these issues.	12/31/10	Technical Update
<b>Effect of Seasonal Variations on Transmission Line Grounding:</b> This report will document the effect of seasonal variations on transmission grounding.	12/31/10	Technical Update
<b>New Version of TFlash:</b> A new version of TFlash, incorporating the newly developed leader propagation model for tall structures, will be developed.	12/31/10	Software

### Future Year Products

Product Title & Description	Planned Completion Date	Product Type
<b>TLSA Testing:</b> This is a continuation of work initiated in 2010. There are a number of issues related to the long-term performance of TLSA. These relate to issues such as attachment methods, housing, and more. This work will focus on deriving specific tests to address these issues.	12/31/11	Technical Update
<b>Computer-based Training for TFlash:</b> A computer-based training module will be developed to assist new and experienced TFlash users. The training will be online and self paced, and it will include worked examples.	12/31/11	Software

## P35.007 Transmission Line Design Tools (060457)

### Key Research Question

In the early 1990s, EPRI developed a comprehensive transmission line design package, the Transmission Line Workstation (TLW)—a tool that facilitates effective design of transmission lines and has a large number of users. The TLW contains numerous design modules, many of which are based on outdated sources, such as the previous version of the Red Book. Given the increase in transmission line construction activities, the software modules need to be updated.

Revision of the software began in 2005. First, modules associated with the Red Book were updated with information from the most recent version of the Red Book, published in 2004. The module ACDCLINE for electrical designs was updated and has been available since March 2008. In addition to new information, the new module features an improved user interface with graphical feedback. The new software also provides architecture that can be linked to other software packages.

### Approach

This project continues to update different modules of the TLW. In 2008, upgrade of the foundation design and analysis (FAD) module, a popular design tool, was initiated. The algorithms and methodologies were reviewed, and the most current information, including applicable codes and standards, was incorporated. Additional foundation types that are not covered in the existing FAD software are being added. The user interface, input/output, and database are being improved. In 2009, foundation designs for H-frame structures are to be developed. In 2010, foundation designs for towers will be developed. By the end of 2010, the new FAD will cover foundation designs for all type of overhead line structures; that is, MFAD for poles, HFAD for H-frames, and TFAD for towers.

With the increased interests in HVDC transmission, the suitability of the ACDCLINE module for DC applications will be reviewed and modifications performed, if required. The Transmission Line Workstation will not only provide interface to these modules but will also provide interface with other EPRI software such as EPIC for insulator designs, TFLASH for overhead line lightning designs, and other EPRI-designed software, as well as the external software PLSCADD for line designs. New features will be added to enhance the application of the software package. The goal is to produce the most current, effective, comprehensive, and easy-to-use software for transmission designs.

### Impact

This project may have the following impacts:

- Enable designers in selecting 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 new module for foundation analysis and design enables transmission line designers to analyze existing structure foundations and develop new structure foundations for transmission lines. The prototype software for poles and H-frame was developed first in 2008, followed by thorough user testing and finalization in 2009. In 2010, software for towers will be developed. By then, the software will cover all types of foundations for overhead lines. A workshop covering the principles of foundation analysis and design, as well as application of the software, will be conducted.

## 2010 Products

Product Title & Description	Planned Completion Date	Product Type
<b>Foundation Designs and Analysis for Towers</b> : The foundation design and analysis software will be extended to cover foundations for towers. The FAD software will then cover foundations for all types of overhead line structures.	12/31/10	Software
<b>Transmission Line Workstation Master Program - Prototype</b> : EPRI will develop a master program controlling the interface of the TL Workstation with various design modules including EPRI and external software and containing a common database for these modules. This product will form a comprehensive software package for overhead line designs. A suitable framework for this master program is finalized, and a beta-version will be available the end of 2010.	12/31/10	Software

## Future Year Products

Product Title & Description	Planned Completion Date	Product Type
<b>Transmission Line Design Optimization</b> : EPRI developed a transmission line optimization program in 1984. The program optimizes the interdependent electrical, environmental, and structural design parameters with respect to factors such as initial or lifetime cost, electrical field strength, and right-of-way requirements. The existing program has been archived and updating is required. The report will outline the extent of updates required.	12/31/11	Technical Update
<b>Transmission Line Workstation Master Program</b> : In 2011, EPRI will thoroughly test the Beta-version of the master program controlling the interface of the TL Workstation with various design modules including EPRI and external software. The final version will be produced by the end of the year.	12/31/11	Software
<b>Workshop for Transmission Line Workstation</b>	12/31/12	Workshop, Training, or Conference
<b>Transmission Line Design Optimization - Prototype</b>	12/31/12	Software

## P35.008 Foundation Analysis and Design (067438)

### Key Research Question

Construction of new transmission lines is increasing recently due to lack of activities in the past and the continuous increase in demand of electric power. A major cost of a transmission line is the foundation for the supporting structures. Improper design of foundations is costly. The additional cost of over-design does not necessarily improve the reliability of a transmission line if it is not compatible with other line components or soil conditions. Under-designed foundations not only lower the overall reliability of the transmission line but may also require maintenance that could have been avoided. It is crucial that proper foundations be selected for a transmission line to accommodate the mechanical loading, the soil condition and the environment to produce structures that perform well initially and in the long term.

The project will provide the state-of-the-art information and design methods to assist foundation designers in evaluating, selecting, and designing foundations suitable for each type of transmission line structure. This project will take advantage of the knowledge gained in past research conducted by EPRI including the FAD



design tool and a report published in 2007 on Management of Transmission Line Structure Foundations (PID 1013783).

### Approach

The objective of the project is to provide transmission line designers the state-of-the-art tools for the design of 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 starts with a review of current information on the design of transmission line from publications, standards, and manuals such as those from American Society of Civil Engineers, the Institute of Electrical and Electronic Engineers, and the International Council on Large Electronic Systems (CIGRE).

A survey is first conducted among electric power utilities on the design of transmission structure foundations. The survey results establish a common practice for the design of transmission structure foundations, such as typical strength and safety factors applied to computed foundation nominal capacities.

In 2010, the reliability-based approach for transmission structure foundation designs will be investigated. The traditional deterministic design method using safety factors for the load and strength to cover unknowns provides a false sense of security without offering the real probability of structure failure. The reliability-based design selects a predetermined failure rate and is cost effective. A guide on such a design method will be prepared.

The project will continue assembling foundation design information. The goal of the project is to produce the most comprehensive manual for the design of transmission structure foundations covering different design approaches. Knowledge gaps will be identified and addressed by research.

### Impact

This project may have the following impacts:

- Provide state-of-the-art methods for the design of transmission structure foundations
- Provide information to evaluate risks of certain type 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 practice 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.

### 2010 Products

Product Title & Description	Planned Completion Date	Product Type
<p><b>Guide for Reliability-based Design of Transmission Structure Foundations:</b> Foundations are designed with a number of uncertainties. Safety factors are generally used to cover these uncertainties, resulting in higher cost. Often the safety factor provides unknown reliability and a false sense of security due to variations of foundation strength and the loads imposed on it. A methodology will be developed to improve the evaluation of the design's performance and thus, the overall reliability.</p>	12/31/10	Technical Update

Product Title & Description	Planned Completion Date	Product Type
<b>Workshop for Foundation Design and Analysis:</b> A member workshop will be conducted to demonstrate the concept and application of reliability-based design for transmission structure foundations. Attendees will perform case studies as part of the exercise.	12/31/10	Workshop, Training, or Conference

## Future Year Products

Product Title & Description	Planned Completion Date	Product Type
<b>Workshop for Foundation Design and Analysis:</b> A member workshop will be conducted on the design and analysis of transmission structure foundations. Topics will include theories, methods, and software application.	12/31/11	Workshop, Training, or Conference
<b>Transmission Structure Foundation Design Manual - Chapters:</b> A comprehensive design manual will be prepared a few chapters at a time. The manual will cover basic theories, equations, different design approaches for various foundation types, and commonly available software for the design and analysis of transmission structure foundations.	12/31/11	Technical Update
<b>Workshop for Foundation Design and Analysis:</b> A member workshop will be conducted on the design and analysis of transmission structure foundations including theories, methods, and the application of software.	12/31/12	Workshop, Training, or Conference
<b>Transmission Structure Foundation Design Manual - Chapters:</b> A comprehensive design manual will be prepared a few chapters at a time. The manual will cover basic theories, equations, different design approaches for various foundation types, and commonly available software for the design and analysis of transmission structure foundations.	12/31/12	Technical Update

## P35.009 Optimization of Transmission Design by Life-Cycle Costing (066075)

### Key Research Question

When an overhead line is designed, all costs incurred during the expected life of this future line should be considered. The total cost during the life of a transmission line (its life-cycle cost) is a combination of initial capital cost, operation and maintenance (O&M) cost, and cost of electrical losses over its entire life, as well as demand charges. The design is optimal when the life-cycle cost is the lowest. Utility engineers require a tool to help them readily select an appropriate design option instead of picking the lowest capital cost. Without such a tool, options with higher line component costs could be overlooked. These components may offer a longer life span, lower O&M costs, and reduced line and energy losses. Thus, a transmission line with a higher capital cost may be more cost-effective over its entire life than the lower capital cost option. The life-cycle costing method helps designers and planners evaluate design alternatives based upon the present value of all costs on a common lifetime basis and choose the best overhead line during design. Under today's high energy costs and difficulties in obtaining outages for maintenance, the life-cycle cost analysis has become even more critical than it has been in the past.

### Approach

This project will develop a tool for conducting life-cycle cost analysis of transmission line projects. The project first identifies major critical components—structures, conductors, insulators, and conductor configuration—associated with transmission line design and other factors—land acquisition and site work—that influence the life-cycle cost. This project focuses primarily on three main tasks: identification of data required on various

components (specifications), development of a methodology for life-cycle cost analysis, and development of prototype software as a decision tool for transmission line design.

### Impact

This project may have the following impacts:

- Provide designers information on key components and factors that affect life-cycle cost
- Provide an important tool for selecting an optimal transmission line design
- Reduce the life-cycle cost of new transmission lines

### How to Apply Results

The workshop will educate transmission line planners and designers on the life-cycle concept applied to transmission line designs. The software module will enable them to select the best alternative for the construction of a new transmission line. A supplemental project will develop a case study in which EPRI will work closely with members to identify issues related to the life-cycle analysis. The outcome will demonstrate the value of the project and provide a platform for additional research to improve the life-cycle model.

### 2010 Products

Product Title & Description	Planned Completion Date	Product Type
<b>Life-Cycle Cost Analysis for Overhead Transmission Lines:</b> In 2010, the software based on the methodology developed in the previous year is to be finalized. Participating members may first test the prototype software for improvements. It will then be beta-tested. The final version will be produced by the end of the year. The software provides a separate template for planning, preliminary design, and the final design to suit the data available at different stages. The software will only focus on factors that have major impact on the life-cycle cost of transmission lines. To provide a comprehensive cost analysis package, all other factors that may affect the life-cycle cost of a transmission will be included. Users will be able to bring each factor into the analysis as an option.	12/31/10	Software
<b>Workshop for Life-Cycle Cost Analysis for Overhead Transmission Lines:</b> A member workshop will be conducted to provide hands-on experience on the application of life-cycle costing to transmission line designs and on the use of the software.	12/31/10	Workshop, Training, or Conference

## P35.010 Live Working Research for Overhead Transmission Equipment (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 are becoming prohibitive. In search of solutions, transmission owners are increasingly turning to live-line working techniques as standard practice to perform required maintenance. When work on de-energized lines is possible, hazards of step-touch-transfer and induced voltages must be recognized and mitigated. New techniques, tools, and procedures are needed to ensure efficient and economic execution of live work, and training is vital to promoting safety during both energized and de-energized work.

### Approach

Over the last two decades, EPRI has helped many transmission companies achieve significant savings in the areas of live working and de-energized work by developing and implementing new technologies and training

materials for the maintenance and refurbishment of transmission lines. The results of this effort were consolidated with industry practices into a comprehensive *Live Working Guide for Overhead Lines* (1008747) and the on-line Live Working Resource Center. Building on that foundation, project activities in 2009 address specific issues in live and de-energized work. These include the following:

- Performance and use of rope in live working
- Aging and retirement criteria of live working tools and equipment
- Unique live work procedures documentation
- Technology transfer through training videos/DVDs, conferences, and seminars

## Impact

This program may have these impacts:

- Improve reliability and availability by enabling timely maintenance of transmission lines
- Improve transmission performance
- Increase worker safety
- Decrease maintenance costs

## How to Apply Results

Participation in this project will help overhead transmission owners and maintenance service providers improve transmission performance and enhance reliability by supporting worker safety when conducting live-line and de-energized maintenance on overhead transmission equipment. 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.

## 2010 Products

Product Title & Description	Planned Completion Date	Product Type
<p><b>Aging of Live Working Tools - Mechanical, Electrical:</b> Tools used in live work are exposed to various types of mechanical and electrical stresses. Mechanical stresses include tension, bending, twisting, and severe shock loading. Electrical stresses include steady-state AC voltage and high transient overvoltages. This project will continue and complete the research and testing initiated in previous years, with two objectives: (1) to understand in-use mechanical and electrical stresses and to assess the capability of existing tools to withstand those stresses, and (2) to determine the best methods for mechanical and electrical testing of tools, both in a utility test shop and at the worksite.</p>	12/31/10	Technical Update
<p><b>Potential Modernized Live Working Tools, Technologies and Robots:</b> The first live working tools were developed in 1910s—about 100 years ago—and they were made of wood. Fiberglass tools were introduced in the 1950s and have remained essentially unchanged. Similarly, technologies and procedures used in live work have seen rather limited modernization. This project will explore available modern technologies such as self-propelled robots, special coatings, various types of sensors, and control algorithms, and will assess their applicability to live work. Examples of modernized and futuristic tools and technologies will be analyzed.</p>	12/31/10	Technical Update

Product Title & Description	Planned Completion Date	Product Type
<b>Control of Fault Current at the Worksite:</b> Increasing line loading, use of high-temperature conductors, and dense utilization of transmission corridors often lead to an increase in fault current at a transmission or substation worksite. This in turn creates increased hazards in terms of step-touch-transfer voltages, arc flash exposure, and equipment-related damage. This project will explore ways of controlling, reducing, re-directing, and suppressing fault currents to minimize worksite hazards. Innovative approaches will be used and the possible impact on system operation will be considered.	12/31/10	Technical Update
<b>Live Work Incident Repository:</b> This project intends to collect technical descriptions of incidents and near-misses that occur during live work, including work on de-energized facilities. The objective is to derive "lessons learned" that can help formulate "barriers" against incident occurrence, develop incident-preventing procedures and guidelines, and develop useful instructional materials.	12/31/10	Technical Update

### Future Year Products

Product Title & Description	Planned Completion Date	Product Type
<b>Aging of Live Working Tools - Mechanical, Electrical:</b> Tools use in live work are exposed to various types of mechanical and electrical stresses. Mechanical stresses include tension, bending, twisting, and severe shock loading. Electrical stresses include steady-state AC voltage and high transient overvoltages. This project will continue and complete the research and testing initiated in previous years, with two objectives: (1) to understand in-use mechanical and electrical stresses and to assess the capability of existing tools to withstand those stresses, and (2) to determine the best methods for mechanical and electrical testing of tools, both in a utility test shop and at the worksite.	12/31/11	Technical Update
<b>Potential Modernized Live Working Tools, Technologies and Robots:</b> The first live working tools were developed in 1910s—about 100 years ago—and they were made of wood. Fiberglass tools were introduced in the 1950s and have remained essentially unchanged. Similarly, technologies and procedures used in live work have seen rather limited modernization. This project will explore available modern technologies, such as self-propelled robots, special coatings, and various types of sensors and control algorithms, and will assess their applicability to live work. Examples of modernized and futuristic tools and technologies will be analyzed.	12/31/11	Technical Update
<b>Control of Fault Current at the Worksite:</b> Increasing line loading, use of high-temperature conductors and dense utilization of transmission corridors often lead to increase in fault current at a transmission or substation worksite. This in turn creates increased hazards in terms of step-touch-transfer voltages, arc flash exposure, and equipment-related damage. This project will explore ways of controlling, reducing, re-directing, and suppressing fault currents to minimize worksite hazards. Innovative approaches will be used and the possible impact on system operation will be considered.	12/31/11	Technical Update

Product Title & Description	Planned Completion Date	Product Type
<b>Live Working on HVDC Lines:</b> EPRI has performed research related to live work on HVAC lines. Industry information, guidelines, and Minimum Approach Distance values for live work on HVDC lines is outdated, inadequate, and not backed up by sufficient research. In view of increased interest in the high-voltage direct current (HVDC) system, this project will perform research and full-scale tests and will develop needed guidelines for live work on HVDC lines.	12/31/12	Technical Update
<b>Training Materials for Live Work on HVDC Lines:</b> In view of increased interest in high-voltage direct current (HVDC) system, this project will build on the companion project on live work on HVDC lines and will develop training materials on the subject.	12/31/13	Workshop, Training, or Conference

## 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. However, these composite components have certain disadvantages and uncertainties.

### Approach

This ongoing multi-year project addresses a range of composite component concerns, including selection, application, and inspection, to increase member confidence and reliability in using these components. In 2008, the project expanded its primary focus on polymer insulators to include examination of all overhead transmission line composite components, such as guy strain insulators, composite/fiberglass cross-arms, and composite poles. There are many similarities among these polymer/composite technologies.

Specific topics and tasks will be added and removed under the direction of the Insulator Task Force. Following priorities determined by the task force topics planned for 2010 are as follows:

- Multi-stress accelerated aging test for polymer insulators, guy strain insulators, fiberglass cross-arms, and composite poles at 230 kilovolts (kV). A full evaluation of the insulators from the test will begin late 2009 and be compared to previous evaluations of in-service units. A web-based report for the inspection results of the multi-stress accelerated aging test will be delivered.
- A guide on specifying and procuring polymer insulators for specific applications.
- Short-term tests to evaluate the performance of composite components, including life expectancy. The intention is that utilities will include these 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 a database of the inspection results to help understand how insulators age and to validate the aging chamber.
- Updated information in the vintage insulator database.
- Development of software tool (EPIC) to aid with corona ring selection.
- Development of a protocol to assess an in-service population of polymer insulators and make informed decisions on replacement.

### Impact

- The project may have these impacts: Reduce construction costs and improves performance by correctly applying composite components

- Avoid sustained outages by inspecting and assessing both individual and populations of insulators
- Aid utilities developing 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 multi-stress aging test results to assess existing populations of composite components and evaluate different composite component designs.
- Transmission line design and procurement engineers will use the *Guide to Specifying and Procuring Polymer Insulators* in-house or request in-house training from EPRI as part of a supplemental project. Utilities will include the short-term tests in their procurement specifications to vendors.
- 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 application for better reliability and performance.
- The Corona Ring Selection Software Tool is used when designing new applications and evaluating the performance of existing applications in service.
- The vintage guide allows members to understand the strengths and weaknesses of the different designs they have in service.
- Either the utility or EPRI can use the population assessment methodology to determine whether to extend life of existing insulators in service.

### 2010 Products

Product Title & Description	Planned Completion Date	Product Type
<b>Short-Term Tests to Evaluate Aging Performance:</b> Short-Term Tests to Evaluate Aging Performance will continue to be developed and assessed. It is expected in 2009 that the first set will be completed and the second set addressing outstanding issues will be developed	12/31/10	Technical Update
<b>Composite Component Failure Database:</b> An update of the polymer insulator, guy strain insulator, fiberglass cross arm, and composite pole failure database will be published.	12/31/10	Technical Update
<b>E-field Modeling Software (Update):</b> An update of the EPIC software will be published. New vendors will be added, as well added functionality and features.	12/31/10	Software
<b>Test Plan for Accelerated Aging Chamber:</b> A plan for the 230 kV aging chamber will be developed based on input from the task forces.	12/31/10	Technical Update

### Future Year Products

Product Title & Description	Planned Completion Date	Product Type
<b>Short-Term Tests to Evaluate Aging Performance</b>	12/31/11	Technical Update
<b>E-field Modeling Software (Update)</b>	12/31/11	Software



Product Title & Description	Planned Completion Date	Product Type
<p><b>Update of the Polymer Insulator Vintage Guide:</b> Short-Term Tests to Evaluate Aging Performance: EPRI is working on developing short term aging performance tests that can be recreated easily and consistently. These tests will evaluate the insulator's ability to withstand some harsh environmental factors such as corona under wet and dry conditions. This report provides an update to the progress of developing these tests.</p> <p><b>E-field modeling Software (Update):</b> This software is very valuable for calculating the E-field magnitudes of insulator configurations. The software will be updated to include additional configurations.</p> <p><b>Update of the Polymer Insulator Vintage Guide:</b> The polymer insulator industry is constantly adjusting their designs to better meets the needs of the industry. The effort of this guide is to capture those changes so the utilities can correctly identify what is installed on their systems and understand how recommendations have changed.</p> <p><b>Progress Update for the 115/138 kV Accelerated Aging Test:</b> This report will provide information on the setup and running of the 115/138kV accelerated aging test.</p> <p><b>Population Assessment Guideline for Transmission Line Polymer Insulators:</b> This report will help members properly assess a population of polymer insulators and make decisions for maintenance.</p>	12/31/11	Technical Update
<b>Progress Update for the 115/138 kV Accelerated Aging Test</b>	12/31/11	Technical Update
<b>Population Assessment Guideline for Transmission Line Polymer Insulators</b>	12/31/11	Technical Update

## 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. While 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 plants have learned over the past decades of manufacturing may not have been transferred to the new plants. Further, 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. However, utilities lack experience with this technology.

### Approach

This project will initially focus on suspension porcelain insulator bells, addressing the following three tasks:

*Inspection and Assessment Tool:* This task investigates the development of field tools to assess the condition of insulator strings. In 2006, a promising technology was identified that could provide an indication of mechanical and electrical (M&E) strength without removing units from service. The technology also showed promise as a standoff technique to identify cracked porcelain insulators.

*Evaluation of New Porcelain Discs Units:* This task assesses issues with porcelain disc insulators procured from new manufacturing plants. In 2007 and 2008, simple M&E tests were performed and compared against standards. This testing will be expanded in 2009, and issues and concerns will be documented.

*Procurement of Glass and Porcelain Disc Insulators:* This task will develop a selection and procurement guide for glass and ceramic insulators. The document will review the fundamentals as well as provide guidance on how to write a specification.

*Contamination Performance:* This task will address the following two topics:

- 1) Develop a guide to maintaining insulators in a contaminated environment.
- 2) Evaluate best practices for dimension insulators in a contaminated environment.

### 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 guide to maintenance of insulators in a contaminated environment will provide users with options on how to improve the performance of existing installations.
- Members will be able to dimension insulators with confidence in a contaminated environment by applying the state-of-the-art approaches.

### 2010 Products

Product Title & Description	Planned Completion Date	Product Type
<b>Guide to Specifying and Procuring Glass and Porcelain Insulators (Draft):</b> This report will finalize the draft guidelines developed in the previous years.	12/31/10	Technical Update
<b>Evaluation of Aged and New Porcelain Insulators:</b> This report will summarize the testing of new and aged porcelain insulators that has been ongoing since 2007, providing a benchmark for members to compare their populations against.	12/31/10	Technical Update
<b>Workshop on Procurement of Porcelain and Glass Insulators:</b> This workshop will train members on how to write up specifications for porcelain/glass insulators and how to verify that the products received meet their company's specifications.	12/31/10	Workshop, Training, or Conference

## Future Year Products

Product Title & Description	Planned Completion Date	Product Type
<b>Guide to Specifying and Procuring Glass and Porcelain Insulators:</b> This report will finalize the draft guidelines developed in the previous years.	12/31/11	Technical Update
<b>Evaluation of Aged and New Porcelain Insulators:</b> This report will summarize the testing of new and aged porcelain insulators that has been ongoing since 2007, providing a benchmark for members to compare their populations against.	12/31/11	Technical Update
<b>Evaluation of Porcelain Insulators Using Vibration Response:</b> This report updates on the development of contact and non-contact methods of non-destructively evaluating the integrity of porcelain insulators.	12/31/11	Technical Update

## PS35G Increased Overhead Transmission Capacity (069258)

### Project Set Description

This project set develops and delivers reference materials, training, software tools, and methodologies to increase or optimize the power capacity of overhead lines without the capital costs of major new construction and permitting. A Transmission Circuit Ratings Workstation will help engineers, operators, and planners to optimize the power transfer capabilities of transmission lines and entire circuits safely, reliably, and in a scientifically justified manner that meets the requirements of the Federal Energy Regulatory Commission (FERC) and other regulatory bodies. The effects of high operating conductor temperature and reduction in conductor ground clearance, loss in conductor strength, and damage to connectors and other overhead line components will be studied, along with mitigation techniques. New conductors with higher current carrying capacity also will be studied. A state-of-the-science guidebook, along with workshops and conferences, are used for educating power industry engineers about the general concepts and how best to apply them.

Project Number	Project Title	Description
P35.013	Increased Power Flow Guidebook and Ratings for Overhead Lines	This project provides state-of-the-science reference and training materials for optimizing and increasing power flow through transmission lines. It will help companies optimize the power transfer capabilities of transmission circuits safely, reliably, and in a scientifically justified manner that meets the requirements of FERC and other regulatory bodies.
P35.014	Impact of High Temperature Operations on Conductor Systems and Thermal and Corona Models	This project will collect all available information on high-temperature operations, conduct laboratory tests to address knowledge gaps, and prepare software to facilitate the risk evaluation of high-temperature operations.
P35.015	Advanced Conductors	The project will investigate the long-term performance of advanced HTLS conductors to complement the field demonstration project that provided information on handling and stringing of these conductors. Maintenance procedures for this new type of conductor will also be established.

## 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 at a faster rate than the construction of new transmission facilities. This trend has pushed the capacity of most existing transmission circuits to their design limits. In addition, much of the grid has already aged beyond its original design specifications, resulting in an increasing number of bottlenecks, brownouts, and other severe reliability issues. With the proper technology, and with the proper training and guidance, greater power capacities can be reliably and safely realized without making large capital investments, and can be used to meet mandated regulatory requirements on the establishment of transmission circuit ratings.

### Approach

This project develops and delivers an industry guidebook, training, software tools, and methodologies for the purpose of increasing or optimizing the power capacity of transmission circuits without the capital costs of major new construction and permitting. The **Increased Power Flow Guidebook** documents state-of-the-science technical options for increased power flow (IPF) on transmission and substation equipment. The guidebook, along with its **IPF Wizard** and training materials, provides a means to guide engineers, operators, designers, and planners in applying increased power flow strategies for transmission lines, and it provides learning materials for the next generation of power industry personnel. In 2008, the *IPF Guidebook* was published with a “platinum” color and became part of EPRI’s color book series. In 2010 EPRI will publish a new edition of the *IPF Guidebook*. The new edition will feature case studies related to design, engineering, system planning, and operations. Also, the existing material will be updated to incorporate the latest developments, and the presentation of visual materials will be improved. Information on improved thermal models and developments of new instruments and other hardware also will be included. The IPF Wizard and training materials also will be revised to include the most recent information.

In addition, this project will continue to develop software and methodologies for increasing and optimizing the power transfer capabilities of transmission lines. The software products being developed can be used for: real-time ratings; rating studies to help meet the FERC requirements regarding setting reliable and safe line ratings; and forecasting circuit ratings hours or days into the future to facilitate bulk power transfer planning. They also can be used to help operators get through emergency situations safely.

The real-time capability is particularly useful in riding out emergency situations and for optimizing daily power flows. The software being developed includes:

- Dynamic Thermal Circuit Rating (DTCR)
- Data Analysis Program (DAP)

The DTCR and DAP programs will be significantly improved to make them more accurate, robust, user friendly, and acceptable to a conservative company culture, and new features will be added. Ultimately, they will be combined into a single workstation environment in order to make their features more widely applicable. The project also develops methodologies for establishing transmission circuit ratings to optimize power capacity within the practical constraints of the company’s operating philosophy, while fulfilling FERC, and other, requirements.

This project focuses on overhead lines, and is executed in coordination with corresponding projects for underground cables (project P36.004) and for substation equipment (P37.012).

### Impact

- This project may have the following impacts: Provide guidance and training to new and experienced technical personnel
- Increase and optimize power flow through entire transmission circuits, particularly overhead lines
- Defer capital expenditures

- Improve transmission circuit reliability and safety
- Meet new mandatory FERC requirements for circuit ratings
- Optimize power transfer planning
- Optimize energy transactions through rating forecasts
- Ride out emergency situations safely and reliably
- Avoid unnecessary system outages

## How to Apply Results

Companies can use the *IPF Guidebook* as a reference source for implementing IPF strategies and to train their engineers in IPF technology. The *IPF Guidebook* compares the economic benefits of each available IPF technology, enabling EPRI members to make informed decisions when choosing IPF options for their applications. The IPF Transmission Circuit Rating Wizard software will also help engineers decide on options.

Transmission operators, planners, researchers, IT personnel, and engineers will use the computer programs and methodologies to optimize the ratings of their circuits. The software products can be applied for the various reasons discussed above, and the methodologies on how best to apply all results can be obtained through EPRI reports, training materials, and workshops held regularly.

## 2010 Products

Product Title & Description	Planned Completion Date	Product Type
<b>Increased Power Flow Conference:</b> As part of its technical transfer activities, EPRI sponsors a biennial conference on the topic of Increased Transmission Capacity. Project P35.013 will cosponsor the activity in 2010 and will present sessions on the recent developments and applications of the technology.	11/30/10	Workshop, Training, or Conference
<b>IPF Guidebook (Platinum Book), Third Edition :</b> A technical report will be published as the next version of the <i>IPF Guidebook</i> (also known as "Platinum Book") as part of the EPRI color book series.	12/31/10	Technical Report
<b>IPF Transmission Circuit Rating Wizard , 2.0:</b> The IPF Wizard will be updated to reflect the latest IPF developments discussed in the <i>IPF Guidebook</i> .	12/31/10	Software
<b>DTCR 5.1:</b> The DTCR will continue to be developed and enhanced in 2010 to make it more accurate, robust, and user friendly to a conservative company culture. Several significant features will be added.	12/31/10	Software
<b>DAP 2.0:</b> A software product designed to work in conjunction with other programs, particularly DTCR, for the purpose of pre-processing and post-processing data, performing data analysis, and providing data plots and graphical user interfaces for ease of application. It is particularly useful for performing statistical data analyses of rating data for the purpose of optimizing approach to static ratings that meets the scientifically rigorous requirements of regulatory bodies. The product also provides tools to help ride out emergency situations.	12/31/10	Software

## Future Year Products

Product Title & Description	Planned Completion Date	Product Type
<b>Transmission Circuit Ratings Workstation 1.0:</b> Following the development of updated versions of the DTCR and DAP software, they will be integrated	12/31/11	Software

Product Title & Description	Planned Completion Date	Product Type
into a comprehensive workstation.		
<b>Transmission Circuit Ratings Workshop:</b> A workshop will be provided covering the Transmission Circuit Rating Workstation, including presentation of the underlying concepts and hands-on software exercises.	12/31/11	Workshop, Training, or Conference
<b>Increased Power Flow Guidebook, Technical Update:</b> New material on the latest IPF technologies will be produced as a Technical Update.	12/31/12	Technical Update
<b>Transmission Circuit Ratings Workstation 2.0:</b> The Transmission Circuit Ratings Workstation will go through its first revision following a year of experience with it. It will be improved using feedback from EPRI member engineers, operators, designers, and planners.	12/31/12	Software
<b>Increased Power Flow Conference:</b> This project will cosponsor and participate in an open technical transfer activity, such as an IPF Conference.	12/31/13	Workshop, Training, or Conference
<b>Increased Power Flow Guidebook, Fourth Edition:</b> Following four years of application and new developments, an updated version of the <i>IPF Guidebook</i> will be planned for release in 2014.	12/31/14	Technical Report

## P35.014 Impact of High Temperature Operations on Conductor Systems and Thermal and Corona Models (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 in conductor strength, and damage to connectors and other overhead line components. Research is needed to investigate premature failures of conductor and conductor accessories from thermal cycling of these components 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. 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. Appropriate mitigation measures can also be taken to raise the limit.

In addition, it is necessary to update research on the mechanical performance of an overhead line at high temperatures because the corona and thermal models used in evaluating the electrical and heat-transfer performance of an overhead line were based on a conductor at ambient temperature. Although the assumption was valid when an overhead line typically operated at 49°C (120°F), these models must be revised for conductor temperatures that are now well above 100°C.

### Approach

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

Performance of common compression fittings in an electric power system is studied at various conductor temperatures above 100°C. 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 impact of high temperatures on the fittings to allow an overhead line to operate reliably at high temperatures. The knowledge gaps of other critical conductor accessories for high-



temperature operations will also be addressed. The project summarizes all research results conducted both by 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 in the form of a progress report and an applet software. The matrix in the applet identifies 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 applet.

The project will also assess the accuracy of existing thermal and corona models at elevated operating temperatures. Required tests will be identified and performed. In addition, the empirical models will be updated to account for the new data, and algorithms will be provided to update prediction software products.

### Impact

This project may have the following impacts:

- Raise confidence in operating overhead lines at high temperatures
- Avoid damage to overhead line components and subsequent line failures
- Adopt mitigations to achieve increased power flows
- Provide accurate prediction of electrical and thermal conductor performance

### 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, the electrical and thermal performance of these overhead lines can be evaluated more accurately. A company can then establish internal guidelines for high-temperature operation of overhead lines.

### 2010 Products

Product Title & Description	Planned Completion Date	Product Type
<p><b>Guide for Operating Overhead Lines at High-Temperatures - 2010 Update:</b> Based on data and research results from previous years, a guide will be developed to help the electric power industry raise the current capacity of an overhead line to an acceptable level. For the benefit of less-experienced staff, the guide will also include the fundamental and basic information behind high temperature operations. The guide will first be developed in draft form in 2010, and in final form in the following year.</p>	12/31/10	Technical Update
<p><b>HTC (High-Temperature Conductor) Matrix: Version 3.0:</b> The HTC Conductor Knowledgeable Matrix applet will be revamped completely in 2010 to be consistent with other EPRI software in input and output formats. New information will be added and data and research results will be updated. A calculator will be included to evaluate the life expectancy of single-stage splices, based on the methodology developed under another EPRI research project. In addition, the features of the Matrix will be further enhanced.</p>	12/31/10	Software
<p><b>Impact of High Conductor Temperature on Corona and Thermal Models</b></p>	12/31/10	Technical Update



## Future Year Products

Product Title & Description	Planned Completion Date	Product Type
<b>Guide for Operating Overhead Lines at High-Temperatures:</b> The draft guide will be reviewed critically by members for its ease of use and practical applications. Comments and suggestions will be incorporated into the final version. The final guide will be useful not only to experienced staff but also for junior staff who would like to gain sufficient knowledge to become an expert in this area.	12/31/11	Technical Update
<b>HTC (High-Temperature Conductor) Matrix: Version 3.1:</b> The HTC Conductor Knowledgeable Matrix applet will be updated with new information, data, and research results from the previous year. New calculators for predicting component lives, when available, will be added to the Matrix. Information on the basics of high-temperature operation will be included.	12/31/11	Software
<b>Increased Transmission Capacity Options and Impact:</b> The workshop will provide the fundamentals of increased transmission capacity options and the impact of each option on the existing power system. It will present the "how to" of different options and discuss the advantages and disadvantages of these options.	12/31/11	Workshop, Training, or Conference
<b>Prediction of End-of-Life of Transmission Line Components Operated at High-Temperatures</b>	12/31/12	Technical Update
<b>HTC (High-Temperature Conductor) Matrix: Version 3.2</b>	12/31/12	Software

## P35.015 Advanced Conductors (065550)

### Key Research Question

A field demonstration on the application of advanced conductors (also known as high-temperature low-sag or HTLS conductors) was successfully conducted under a supplemental project with 20 participating utilities. While positive, the field trial raised a number of issues such as the long-term performance of some of these conductors as well as the maintenance method for the conductors. These issues must be addressed before utilities will accept these conductors and take advantage of the benefits they offer. Further, a new aluminum conductor steel supported (ACSS) "advanced" conductor with a high-strength steel core has since been developed. This ACSS conductor should be evaluated and compared with the other HTLS conductors for its performance.

### Approach

This project addresses the outstanding issues identified in the HTLS conductor field demonstration project: long-term performance of some of these HTLS conductors and maintenance of lines using HTLS conductors. The cores of these HTLS conductors are different than conventional aluminum conductor, steel reinforced (ACSR) conductors, and some must be handled differently. The operating temperature of these advanced conductors will be much higher than that of conventional conductors. The tool requirements and maintenance procedures will be different.

This project will first investigate the longevity of carbon fiber composite core HTLS conductors. It will establish a test protocol for design engineers to qualify this type of conductor. It will then conduct an accelerated aging test for all commercially available HTLS conductors, including a conductor splice and dead-end. The project will also evaluate and establish methods that are suitable for maintaining overhead lines using HTLS conductors. A field trial of the high-strength ACSS conductor may also be carried out under a supplemental project.

## Impact

The project may have the following impacts:

- Provide engineers with a tool to evaluate the long-term performance of different HTLS conductors
- Ensure the safety of utility personnel and reliability of transmission lines with proper maintenance procedures

## 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 HTLS conductors. The accelerated aging test provides useful information on the long-term performance of these advanced conductors that members can use to compare and select proper HTLS conductors for their application. Maintenance methods and procedures developed for HTLS conductors can be incorporated in a member's maintenance manuals.

## 2010 Products

Product Title & Description	Planned Completion Date	Product Type
<b>Methods and Tools for Maintenance of HTLS conductors:</b> Preliminary procedures developed for maintenance of HTLS conductors in the previous year will be demonstrated and refined in the laboratory or in the field in 2010 to produce a practical and useful guide for maintenance of HTLS conductors in 2011.	12/31/10	Technical Update
<b>Performance of HTLS Conductors under an Accelerated Aging Test - Progress Report:</b> In 2010, the behavior of HTLS conductors under six months of accelerated aging test will be observed, and initial test results will be available. To simulate conductor aging in actual applications, the test will be extended to the following year for additional aging. Subsequent forensic and diagnostic tests will also be performed to provide insights into the long-term performance of these conductors.	12/31/10	Technical Update

## Future Year Products

Product Title & Description	Planned Completion Date	Product Type
<b>Guide for Maintenance of HTLS conductors:</b> A guide for maintenance of different HTLS conductors will be developed. The guide provides will provide guidelines on methods and tools that are suitable for maintaining HTLS conductors.	12/31/11	Technical Update
<b>Methodology for Aging Evaluation of Metallic Fiber Composite Core Conductors:</b> In 2011, a test protocol is developed to qualify metallic fiber composite core HTLS conductors. Detail specifications for the test will be provided. Test protocols for other HTLS conductors will be developed in the future.	12/31/11	Technical Update
<b>Procedure for Maintenance of HTLS conductors:</b> Procedures, including details on the method and tool for the application, will be finalized and documented for the maintenance of HTLS conductors.	12/31/12	Technical Report

Product Title & Description	Planned Completion Date	Product Type
<b>Performance of HTLS Conductors under an Accelerated Aging Test - Final Report:</b> Results from thermal cycling of advanced HTLS conductor-connector systems provide valuable information in determining the expected life of these conductors. A model based on the 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.	12/31/12	Technical Report