

## **37 Substations**

### **Program Overview**

#### **Program Description**

This program helps substation owners enhance safety, reliability, equipment life, and performance despite shrinking maintenance budgets. The program offers a complete portfolio of tools, technologies, and resources to improve transformer and circuit breaker life management; extend equipment life; optimize maintenance to cut costs and reduce outages; enhance SF<sub>6</sub> management; and improve switching safety, fault current management, and grounding.

#### **Industry Needs and Issues Addressed**

- Ensuring safety of personnel, general public, and equipment during operations and outages
- Enhancing system reliability, performance, and life of equipment on ever-decreasing maintenance budgets
- Providing advanced technologies and tools to maintain and operate substation equipment in an increasingly competitive energy marketplace

#### **Impact**

- Extend equipment life by 5-10 years with maintenance guidelines
- Reduce maintenance costs by up to 30% via condition-based maintenance
- Reduce losses by up to 50% via improved SF<sub>6</sub> management
- Implement predictive maintenance practices for reduced outages
- Prevent failure of critical transformers, realizing potential savings per unit of \$1-5 million

#### **Key Accomplishments**

- Life Extension Guidelines, a web-enabled database and stand-alone guidebook, providing substation engineers and maintenance crews with up-to-date knowledge, data, procedures, and best practices for substation equipment maintenance, condition assessment, and life extension
- Transformer Expert System V 2.0 (XVISOR), system software to assist nonexperts in determining transformer and component conditions

#### **Current Year Objectives**

- Transformer aging models
- Transformer diagnostic and risk assessment tools and software
- Maintenance best practice guidelines
- Life-extension guidelines
- Circuit breaker life management and lubrication
- Development of fault current limiters to the 69 kV level
- Protection and metering for circuit breaker diagnostics
- Switching safety and reliability

#### **Industry Involvement**

- Estimated 2009 funding: \$6.3M

#### **Program Technical Lead**

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## Summary of Projects

### PS37A Transformer Life Management (056064)

**Project Set Description:** This project set remains the greatest single focus within the Substations Program. It addresses management of the aging population of power transformers and load tap changers (LTCs) from the aspect of diagnostics, monitoring, and on-line condition assessment. Recently, it has been expanded to include the design aspects relating to geomagnetically induced currents (GICs) within transformers. Even if GIC is not a current key concern for a company, the focus on design provides invaluable insights that will help companies with future transformer specifications.

Project Number	Project Title	Value
P37.001	Transformer End-of-Life & Condition Assessment	Evaluates and develops new transformer diagnostic tools and evaluates existing hardware and software for transformer and load tap changer (LTC) condition assessment. Benefits include: <ul style="list-style-type: none"> <li>• Enables effective transformer life management</li> <li>• Advances detection and analytical techniques for better decision making</li> <li>• Produces first comprehensive collection of transformer knowledge specifically for utility owners and operators</li> </ul>
P37.002	Transformer Life Extension	Develops on-line systems to evaluate the operating risk of failure, and develops proactive measures to extend transformer life and reduce the risk of failure. Benefits include: <ul style="list-style-type: none"> <li>• Reduces unplanned outages</li> <li>• Enhances understanding of environmental effects on transformer life</li> <li>• Improves prediction of loss of transformer life</li> <li>• Enables dynamic assessment capabilities of transformer conditions</li> </ul>

## Project Descriptions

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

#### Issue

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

#### Description

This project has three broad themes that guide the research:

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

Each year results are delivered through tasks performed under each of the themes. The stability in the themes allows for a clear multiyear plan approach. Utility members have two distinct areas of influence on

the multiyear plan. First, in the selection of themes and, second, in the prioritizing of the annual tasks that support these themes.

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

#### EPRI Power Transformer Guidebook Development

In 2007, the Guidebook content was debated with the members and published. In each subsequent year, chapters will be developed and published. The Guidebook parts thus become immediately useful, even before the final, full Guidebook is complete. The goal is a comprehensive reference book to be used by utility personnel responsible for all aspects of transformer operation, maintenance, procurement, and life-cycle management. It can be used as a training aid and as a repository for all pertinent information on transformer ownership. The electronic version includes applets that perform some of the more common calculations necessary for transformer management.

#### Develop and Demonstrate New Condition Monitoring Sensors and Techniques

Under this theme EPRI conducts the vital research into improved techniques for assessing the condition of a transformer. The research develops new transformer diagnostic tools and evaluates existing hardware and software for transformer and LTC condition assessment. The project develops specialized sensor hardware to provide insights into transformer health that are not obtainable using traditional techniques. Examples of research under this theme include

- Design of a bushing tap coupler for both on-line frequency response analysis (FRA) and partial discharge detection
- Data fusion of vibration and radio frequency (RF) signals into 3D acoustic emission for more accurate diagnostics
- Research into holey-fiber technology for cost-effective and robust gas-in-oil detection
- On-line LTC condition monitoring using advanced optical techniques
- Forensics of transformers at end-of-life: comparing diagnostic technologies with actual condition

#### Develop and Demonstrate Tools to Convert Transformer Data into Useful Information for Action

Under this theme EPRI uses the knowledge and experience of the world's leading transformer engineers to develop diagnostic algorithms and expert system modules to convert transformer monitoring data into useful information for action. The results address the pressing need that utility staff face in distilling large volumes of monitoring data into clear maintenance or planning actions. EPRI's results will be produced in a way that enables utilities to easily and rapidly apply the results. In many cases (e.g., the Acoustic Emission and on-line LTC research), EPRI results are being directly implemented into hardware and software solutions through licensing with appropriate hardware and software developers.

#### **Value**

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

#### **How to Apply Results**

Substation engineers, designers, and operations and maintenance personnel can use the results of this project to obtain complete information about the condition of a transformer to make decisions on the disposition of transformers without additional consultation, testing, and analysis. Results will take the form of hardware, software, and guidebooks. The transformer guidebook will be a comprehensive reference book that would be used by utility personnel responsible for all aspects of transformer operation,

maintenance, procurement, and life-cycle management. It will be used as a training aid and as a repository for all pertinent information on transformer ownership. The electronic version will include applets that will be used to perform some of the more common calculations necessary for transformer management.

**2009 Products**

Product Title & Description	Planned Completion Date	Product Type
<p><b>EPRI Power Transformer Guidebook development (select chapters):</b> EPRI Power Transformer Guidebook Development</p> <ul style="list-style-type: none"> <li>By 2009, the first four chapters will be complete. In 2009, that existing Power Transformer Guideline will have the following two chapters added: "Shipping and Installation" and "Transformer Operation." This extended Guideline will be issued in 2009 to include these two chapters and all preceding chapters. Further chapters will be added in subsequent years.</li> </ul>	12/31/2009	Technical Update
<p><b>Develop &amp; Demonstrate Tools to convert transformer data into useful information for action:</b> Develop &amp; Demonstrate Tools to convert transformer data into useful information for action.</p>	12/31/2009	Technical Update
<p><b>Develop &amp; Demonstrate new Condition Monitoring Sensors and Techniques:</b> Develop and Demonstrate New Condition Monitoring Sensors and Techniques:</p> <ul style="list-style-type: none"> <li>Dissolved Gas Analysis (DGA) detection using fiber optics for low-cost, robust sensing: Laboratory demonstrations.</li> <li>On-line LTC diagnostics for contact wear and overheating: Final prototype for field trials.</li> <li>On-line 3D acoustic emission detection: Data fusion with vibration, DGA, and RF signals for enhanced transformer diagnostics.</li> </ul>	12/31/2009	Technical Update
<p><b>XVISOR Enhancements to include latest research results</b></p>	12/31/2009	Technical Update

**P37.002 Transformer Life Extension (058559)**

**Issue**

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

**Description**

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

- Application of novel on-line filtration materials and techniques
- Development of a Forensic Library to better predict future failures in an aging transformer fleet.

Each year results are delivered through tasks performed under each of the themes. The stability in the themes allows for a clear multiyear plan approach.

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

**Application of novel on-line filtration materials and techniques**

New research has demonstrated the possibility for on-line filtration of oxygen and moisture without the need for cartridge replacements. EPRI research will explore these technical advances and conduct tests under laboratory conditions in 2009. Furthermore, recent EPRI research has demonstrated the feasibility of a variety of novel filtration materials to remove precursors to transformer aging and LTC coking. Research in 2009 is focusing on moving these successes from the laboratory into field demonstrations.

**Forensics Library**

The EPRI research will examine failed units that have aged to full maturity (i.e., excluding design, materials, or workmanship flaws). The resulting forensics library will provide members with new insights into likely end-of-life scenarios for the increasing population of aging transformers. Each forensic study will include both the physical evidence of the failure and the life history of the unit (including historical test information, monitored data, and loading). EPRI’s collaborative approach to this research will bring multiple members’ forensics to the study – allowing for a far more rapid development of typical failure mechanisms. Presently these valuable lessons are often lost after a failure due to the operational urgencies. EPRI’s research in this area will capture and share this vital knowledge. This multiyear effort will be paced by access to transformer failures and historical data. Each year will produce an updated library based on all prior investigations.

**Value**

- Extended transformer life through application of novel filtration materials and techniques
- A Forensics Library that will provide members with new insights into likely end-of-life scenarios for the increasing population of aging transformers

**How to Apply Results**

Project funders can use the software tools to perform dynamic risk assessments of their transformers under all operating conditions. The algorithms developed will also be incorporated into third-party commercial software and monitoring systems available for incorporation into utility in-house applications. The research on the solid-state LTC designs will eventually culminate in a commercial device that utilities will be able to purchase for retrofit on existing transformers and for specification on new transformers.

**2009 Products**

Product Title & Description	Planned Completion Date	Product Type
<b>Transformer life extension through enhanced oil filtration</b>	12/31/2009	Technical Update
<b>PTLOAD Enhancements to include research results</b>	12/31/2009	Technical Update
<b>Transformer life extension through novel on-line filtration materials that do not require cartridge replacement:</b> Technologies to perform on-line, continuous moisture and oxygen removal without the need for cartridge replacement.	12/31/2009	Technical Update
<b>Forensics Library: Assessments of aged transformers:</b> The assessments of aged transformers will provide members with new insights into likely end-of-life scenarios for the increasing population of aging transformers.	12/31/2009	Technical Update

### PS37B Improve Overall Substation Maintenance Management (056065)

**Project Set Description:** This project set addresses substation maintenance from the top down. It starts with accepted maintenance practices and techniques. It establishes best-of-breed practices and then applies these practices to specific equipment. This, in turn, drives the required sensor, inspection, data collection, equipment models, equipment assessment, and maintenance actions. The research develops methodologies and tools to address the need for an optimized maintenance strategy. Efforts are organized in the following project areas: Predictive Reliability and Risk Assessment; Life Extension and Best Practices Guidelines for Substation Equipment; Performance-Focused Maintenance for Transmission Substation Equipment; Integrated Monitoring and Diagnostics; Industry Equipment Performance Database and CIM Data Standardization; and Equipment Risk and Performance Assessment Methods and Tools. The overall strategy develops an integrated set of tools that can operate on company-wide real-time and historical data to support continuous risk and performance assessment.

Project Number	Project Title	Value
P37.003	Best Practices and Life Extension Guidelines for Substation Equipment	Establishes a substation equipment knowledge asset. Benefits include: <ul style="list-style-type: none"> <li>• Contributes to reduced life cycle costs</li> <li>• Provides training tools for new personnel to accelerate knowledge of substation equipment maintenance</li> <li>• Enables utility asset and maintenance personnel to work cost-effectively and efficiently</li> </ul>
P37.004	Performance Focused Maintenance for Substation Equipment	Integrates predictive, condition, and time-based maintenance techniques. Benefits include: <ul style="list-style-type: none"> <li>• Reduces overall maintenance costs</li> <li>• Improves reliability and availability</li> <li>• Enables more effective use of existing infrastructure and efficient use of maintenance personnel</li> </ul>
P37.005	Integrated Monitoring and Diagnostics	Develops state-of-the-art tools for an integrated monitoring system and substation diagnostic system. Benefits include: <ul style="list-style-type: none"> <li>• Prevents premature failure and failure costs</li> <li>• Reduces maintenance costs</li> <li>• Extends equipment life</li> </ul>
P37.006	Industry-wide Equipment Performance Database	Provides data and information resources to assist in developing repair/refurbish/replace strategies for aging substation equipment fleets. Benefits include: <ul style="list-style-type: none"> <li>• Improves management of existing infrastructure issues</li> <li>• Reduces costs by using consistent data sharing and analyses based on industry standards</li> <li>• Simplifies implementation of key performance indicators and metrics</li> <li>• Identifies “bad actors” early, reducing unplanned outages</li> </ul>
P37.007	Equipment Performance and Risk Assessment Tools	Develops analytic methods, software platforms, and applications for maintenance and asset management decisions. Benefits include: <ul style="list-style-type: none"> <li>• Enables more cost-effective use of maintenance and capital resources</li> <li>• Enables more timely maintenance and identification of conditions for enhanced system reliability</li> </ul>

## Project Descriptions

### P37.003 Best Practices and Life Extension Guidelines for Substation Equipment (062155)

#### Issue

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

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

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

#### Description

- Produce and annually update an information resource of recommended best practices for substation equipment maintenance, condition assessment, and life extension
- Address changing technology and business environment, and engage utility members by providing on-line access for content review and use.
- Coordinate with on-going research in parallel EPRI program areas, such as Transformer and Circuit Breaker Life Management and Performance Focused Maintenance.
- Address international terminology and practices
- Develop and include business case drivers that make specific inspection, monitoring, and maintenance methods "best practices."
- Develop a User Group that facilitates ongoing content review, updating, and expansion.
- Enhance usability and accessibility of technical content through technology transfer activities—field guides, workshop seminars, and flash cards.

#### Value

This project establishes a substation equipment knowledge asset compiled with collaborative support from the utility and vendor community. It uses their expertise in proven practices for condition assessment, maintenance, and replacement/refurbishment of substation equipment with the results of EPRI research to yield the following benefits:

- **Improve Reliability and Reduce Applied O&M:** Provide a readily accessible source of information that can contribute to reduced life-cycle costs while enabling improvement in the reliability of critical equipment and help optimize a maintenance program.
- **Knowledge Retention/Training:** Provide a centralized knowledge repository to serve as an on-the-job training tool for new recruits to help them accelerate their learning in the area of substation equipment maintenance.
- **Knowledge Retention/Application:** Offer a user-friendly and regularly updated reference support tool to assist utility asset and maintenance personnel to carry out their work in the most cost-effective and efficient manner.

### How to Apply Results

Asset managers, operations and maintenance supervisors/staff, and equipment technical subject matter experts can use the results of this project to better understand and implement best practices in substation equipment life extension, maintenance, and condition assessment. The revised and updated versions of the Life Extension Guidelines can be accessed using the latest developments in software-based techniques for content management—web-enabled content on e-learning modules, searchable CD-ROM's/DVD's, bi-annually issued hard copy "color book" version, and a series of field guides developed as a result of needs assessment. In addition EPRI will continue to offer workshops and services to assist utilities with implementing the practices identified in the technical reports.

### 2009 Products

Product Title & Description	Planned Completion Date	Product Type
<b>Technical Content Review for Knowledge Asset Needs Assessment in Protection, Control and Data Acquisition Assets in Substations:</b> Review technical content with utility advisors, perform needs assessment, and develop an outline to update existing technical content for maintenance, operation, and fleet management of Protection, Control and Data Acquisition Assets in Substations.	12/31/2009	Technical Update
<b>LEG – KA Technical Content and Best Practices Technical Content Update – HV Circuit Breakers:</b> Based on outline developed and plans prepared in 2008, assign appropriate experts to prepare circuit breaker content.	12/31/2009	Technical Update
<b>Updated and Revised “Best Practices and Life Extension Guidelines for Substation Equipment” – Teal Book in EPRI Color Book Series – Issued in Hard Copy and Electronic Format:</b> Re-issue entire “Best Practices and Life Extension Guidelines for Substations Equipment” with updated Transformers and HV Circuit Breaker chapters in hard copy (EPRI Color Book Series – Teal Book) and electronic format (searchable CD-ROM).	12/31/2009	Technical Report
<b>XVI Substations Equipment Inspection, Maintenance and Diagnostics Conference:</b> Organize and hold conference to share experiences from practices, ongoing research, and industry advances.	12/31/2009	Technical Resource
<b>New Pictorial Guides:</b> Conduct needs assessment, and identify high-value work requested by utilities. Field guides in print and software form. Guides designed for field use: pocketbook size (8 x 4 inches). Electronic versions also available.	12/31/2009	Technical Resource

**Future Year Products**

Product Title & Description	Planned Completion Date	Product Type
<p><b>LEG-KA Technical Content Update – 2009 – Relays and Protection Assets:</b>  <i>LEG-KA Technical Content Update – 2009 – Relays and Protection Assets</i> - Based on outline developed and plans prepared in 2008, assign appropriate experts to prepare chapter content.</p>	2010	Technical Update
<p><b>E-learning Modules, Webcasts and Workshops for Best Practices and Life Extension Guidelines for Substation Equipment:</b> <i>E-learning Modules, Webcasts and Workshops for Best Practices and Life Extension Guidelines for Substation Equipment</i> - Draw from Life Extension Guidelines and Field Guides for materials to train O&amp;M personnel. Computer-based training will be developed with one initial on-line module.</p>	2010	Technical Resource
<p><b>XVII Substations Equipment Inspection, Maintenance and Diagnostics Conference:</b> <i>XVII Substations Equipment Inspection, Maintenance and Diagnostics Conference</i> - Organize and hold conference to share experiences from practices, ongoing research, and industry advances.</p>	2010	Technical Resource

**P37.004 Performance Focused Maintenance for Substation Equipment (058560)**

**Issue**

Maintenance engineers and managers face critical decisions in managing aging power equipment. Such decisions are made under stringent expense controls, limited capital, and increased concern about reliability. These factors combine to make well-informed decisionmaking more crucial and yet more elusive than ever. Decisionmaking confidence and results would be enhanced, providing the ability to

- Ensure optimal allocation of limited resources and select most appropriate O&M tasks.
- Forecast reliability and manage risk of deferring maintenance, and identify asset that deserves most attention in relation to others in fleet.
- Quantify the value of resulting performance improvements for investments made in equipment maintenance or replacement.
- Evaluate risk moving forward, as compared to “current state” evaluation, and determine the impact of incremental dollars added or subtracted from the “current state” maintenance and investment portfolio.
- Evaluate the impact on maintenance of the 2005 Energy Policy Act and future requirements and expectations from utility maintenance strategies as the role of the Electric Reliability Organization becomes clearer.

**Description**

Over the past decade different approaches—Reliability Centered Maintenance, Just-in-time Corrective Actions, and Predictive Tools & Techniques—have been explored. The basic objective for past, ongoing, and proposed research is to provide continually improved decision support methodologies primarily in the form of data models and algorithms. These deliverables build upon and further enhance existing concepts in a more holistic manner. The resulting framework adapts methodologies to forecast reliability and assess risk, using leading indicators, and ranks equipment for action.

**Value**

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

**How to Apply Results**

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

**2009 Products**

Product Title & Description	Planned Completion Date	Product Type
<p><b>The Use of Substation Equipment Criticality Factors in Maintenance Decisions:</b> Quantification of equipment, circuit, and substation criticality would assist in prioritizing maintenance and in directing efforts to the areas that would most benefit key performance indicators.</p>	12/31/2009	Technical Update
<p><b>Enhanced Methodologies for Equipment Modeling for Implementation in Asset Management and Smart Grid:</b> This project will address gaps in existing maintenance and end-of-life modeling approaches and techniques and applicability to performance-focused maintenance with attention to utilization of existing or easily obtained data. It will also develop practical models that can be implemented and integrated with other EPRI tools.</p>	12/31/2009	Technical Update
<p><b>Framework for Risk Assessment for Substation Equipment Implementation in Asset Management and Smart Grid:</b> A report on the development of a methodology for the systematic and consistent assessment of substation equipment risk. The methodology will include templates for evaluating the likelihood and consequences of equipment performance short-falls to help with prioritization of maintenance and capital investment.</p>	12/31/2009	Technical Update
<p><b>Substation Equipment Performance Focused Maintenance Workshop:</b> A workshop that will include both tutorials on the material contained in the Performance Focused Maintenance technical reports and presentations on utility experiences and examples of the application of the project's results.</p>	12/31/2009	Technical Resource

## Future Year Products

Product Title & Description	Planned Completion Date	Product Type
<b>Substation Equipment Performance Focused Maintenance Workshop:</b> A workshop that will include both tutorials on the material contained in the Performance Focused Maintenance technical reports and presentations on utility experiences and examples of the application of the project's results.	2010	Technical Resource

### P37.005 Integrated Monitoring and Diagnostics (058561)

#### Issue

Utilities are continuously seeking to improve their cost-benefit ratios by reducing the human intervention in equipment condition monitoring. One approach to achieving this is by implementing an automated and integrated monitoring and diagnostic system for substation operations that continuously assesses equipment in real time.

#### Description

Research in this project builds on the past years of successful results to further develop state-of-the-art tools for an integrated monitoring system and substation diagnostic system that enables continuous and near-real-time assessment of risk of equipment failure to support both system operation and equipment maintenance. Critical research focuses on validating the algorithms using case studies and pilot applications in host utilities.

This project has two broad themes that guide the research:

- Development of field guides for substation-wide inspections
- Development of technology (e.g., sensors) and knowledge (e.g., algorithms) for substation-wide inspection.

Each year results are delivered through tasks performed under each of the themes. The stability of the themes allows for a clear multiyear plan approach. Utility members have two distinct areas of influence on the multiyear plan: first, in the selection of themes and, second, in the prioritizing of the annual tasks that support these themes.

#### Value

- Prevent premature failure and failure costs, reduce maintenance costs, and extend equipment life via real-time diagnostics and condition-based maintenance, along with dynamic and "near-real-time" risk-of-failure operations and maintenance (O&M) assessment
- Allow maximum use of existing data, and add only those sensors critical for decisionmaking.
- Predict and prevent animal interactions in substations through real-time image processing of both infrared and visual images.
- Enable new capability to expose, audit, and even customize underlying reasoning for risk assessments.

#### How to Apply Results

Members can apply the real-time diagnostic algorithms within software tools and participate in pilot projects to evaluate and implement algorithms. They can also access the algorithms and approaches in report format to apply the results in any appropriate existing in-house systems.

## 2009 Products

Product Title & Description	Planned Completion Date	Product Type
<b>Field Guide: Infrared Thermography for Substations:</b> A laminated, pocket field guide that transfers key guidance to inspectors when identifying issues in a substation.	12/31/2009	Technical Update
<b>Real-time image processing for substation equipment inspection, security and animal interactions:</b> This deliverable will provide members with a laboratory pilot of a system that includes both the hardware and the software dedicated to addressing equipment inspections, security, and animal interactions on substations.	12/31/2009	Technical Update

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

#### Issue

Energy companies can maximize their return on assets by ensuring that existing equipment is not replaced before it reaches the end of its “useful” life, while still maintaining reliable system operations. However, without historical performance data of assets with similar characteristics, this can be difficult. Companies need an easily accessible repository of industry-wide equipment performance and failure data to more accurately project future performance.

#### Description

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

#### Value

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

#### How to Apply Results

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

**2009 Products**

Product Title & Description	Planned Completion Date	Product Type
<p><b>Industry wide Substation Equipment Performance and Failure Database Strategic Plan:</b> Architect, design, and specify requirements for a functional IDB. Develop strategy for a “production” IDB and associated tools, interface, and notification methods such as alerts and “push” reports. Investigate cooperative efforts (e.g., FERC/NERC).</p>	12/31/2009	Technical Update
<p><b>Industry-wide Substation Equipment Performance and Failure Database - Enhancements:</b> Continue expansion of existing Transformer IDB. Develop data models for the acquisition of information to support fleet management, enhanced diagnostics, and risk and performance assessment (as in Performance Focused Maintenance). Investigate value proposition for expanding transformer IDB to include additional data such as furan analysis, forensic reports, and other advanced assessment information. Explore value proposition for identifying industry needs for collecting failure/performance for current transformers (CT's) and voltage transformers (VT's). Continue development of Circuit Breaker IDB.</p>	12/31/2009	Technical Report
<p><b>Industry-wide Substation Equipment Performance and Failure Database - Implementation Software (Alpha Version):</b> Continue to broaden data sets by adding more data. Develop statistical analysis results and continued refinement of methodology to develop metrics suitable for application such as fleet management, enhanced diagnostics, and risk and performance assessment (as in Performance-Focused Maintenance). Continue to further strengthen value proposition by enhancing results library.</p>	12/31/2009	Software

**Future Year Products**

Product Title & Description	Planned Completion Date	Product Type
<p><b>Industry-wide Substation Equipment Performance and Failure Database - Implementation Software (Beta and Production Versions):</b> Continue to broaden data sets by adding more data. Develop statistical analysis results and continued refinement of methodology to develop metrics suitable for application such as fleet management, enhanced diagnostics, and risk and performance assessment (as in Performance-Focused Maintenance). Continue to further strengthen value proposition by enhancing results library.</p>	2010	Software

**P37.007 Equipment Performance and Risk Assessment Tools (065593)**

**Issue**

Maintenance and asset life-cycle management decisions depend on determining current equipment conditions. Understanding the physical and chemical processes that result in equipment degradation and failure is not adequate; this knowledge must be incorporated into tools and methodologies that can analyze and interpret diagnostic and operational data and measurements, and readily provide information to support maintenance and asset management decisions. Often diagnosis and data interpretation

depend on individual experience, and synergies between data from different tests or sources are not fully exploited. There is a need for enhanced diagnostic and performance-assessment tools to address these issues.

### Description

This project uses fundamental equipment and component knowledge developed in other programs and projects and develops analytic methods, software platforms, and applications using that data to provide actionable information to support maintenance and asset-management decisions. EPRI has established a solid foundation with tools such as PTLOAD, XVISOR, and MMW; however, these tools were designed as standalone applications and do not incorporate the most up-to-date software technologies. Initial project efforts focus on assessing utility needs and gaps in the existing tools and developing a roadmap to address the identified issues. The work focuses on utilizing the best available artificial intelligence techniques to combine and use multiple data sources for diagnosis and decision support.

### Value

- Enable more cost-effective use of maintenance and capital resources via enhanced diagnostic and performance assessment tools.
- Enable more timely maintenance and identification of conditions for enhanced system reliability.
- Enable better assessment of current and future operational risk.
- Enable rule-based analysis to provide action-oriented triggers to manage risk and key performance indicators.

### How to Apply Results

Participants can use these tools to implement more effective maintenance and asset management decisions.

### 2009 Products

Product Title & Description	Planned Completion Date	Product Type
<b>Integrated Substation Equipment Risk and Performance Assessment Tool for Asset Management and Smart Grid Implementation:</b> An enhanced diagnostic and performance assessment tools platform will be specified to allow for efficient and effective use of algorithms and performance data developed in other program areas. Envisioned is an approach that will fully utilize information from multiple sources, including Performance-Focused Maintenance and the Industry-wide Equipment Performance Database, to provide a complete view of current and projected performance and operating risk in customizable views for multiple stakeholders.	12/31/2009	Technical Update

Product Title & Description	Planned Completion Date	Product Type
<p><b>Integrated Substation Equipment Risk and Performance Assessment Tool for Asset Management and Smart Grid Implementation:</b> Enhanced diagnostic and performance assessment spreadsheet-based tools will be developed for efficient and effective application of available data in algorithms for assessing substation equipment condition and operational risk. The methodology will utilize information from multiple sources (including Performance-Focused Maintenance and the Industry-wide Equipment Performance Database, on-line monitoring, and test results) to provide a complete view of current and projected performance and operating risk in customizable views for multiple stakeholders. The tools will incorporate expert knowledge and, through rule-based analysis, will provide action-oriented triggers to manage risk and key performance indicators.</p>	12/31/2009	Software
<p><b>Algorithms, Methodology and User Guidelines for Integrated Substation Equipment Risk and Performance Assessment Tool for Asset Management and Smart Grid Implementation:</b> A technical report describing algorithms, analytical methodology, and data requirements for implementing tools to facilitate an integrated approach to Substation Equipment Risk and Performance Assessment for Asset Management and Smart Grid Implementation. The report will also provide instructions to the tool end-user for using spreadsheet-based tools, as well as incorporating the same in a more sophisticated application environment.</p>	12/31/2009	Technical Report

**Future Year Products**

Product Title & Description	Planned Completion Date	Product Type
<p><b>Integrated Substation Equipment Risk and Performance Assessment Tool for Asset Management and Smart Grid Implementation:</b> An enhanced diagnostic and performance assessment tools platform will be specified to allow for efficient and effective use of algorithms and performance data developed in other program areas. Envisioned is an approach that will fully utilize information from multiple sources, including Performance-Focused Maintenance and the Industry-wide Equipment Performance Database, to provide a complete view of current and projected performance and operating risk in customizable views for multiple stakeholders.</p>	2010	Software

**PS37C SF<sub>6</sub> Environmental Management (056066)**

**Project Set Description:** This project set focuses on significantly improving the performance of sulfur hexafluoride (SF<sub>6</sub>)-insulated equipment, including providing tools to extend and estimate equipment life, reduce maintenance and operating costs of SF<sub>6</sub> equipment, manage SF<sub>6</sub> environmentally, and protect the significant investment in SF<sub>6</sub>-insulated equipment. Additionally, work will focus on accurately tracking the development of SF<sub>6</sub> replacements and SF<sub>6</sub> policy issues to provide appropriate and timely guidance on the future of SF<sub>6</sub>.

Project Number	Project Title	Value
P37.008	SF <sub>6</sub> Environmental Management and Equipment Performance	<p>Provides tools and continuing research into a range of SF<sub>6</sub> issues. Benefits include:</p> <ul style="list-style-type: none"> <li>• Reduce costly SF<sub>6</sub> emissions and labor costs</li> <li>• Mitigate risks of potential health hazards via safe handling techniques, tools, and guidelines</li> <li>• Minimize environmental emissions of SF<sub>6</sub></li> <li>• Explore more environmentally benign alternatives to SF<sub>6</sub></li> <li>• Enable utilities to stay abreast of evolving political and legislative developments</li> </ul>

## Project Descriptions

### P37.008 SF<sub>6</sub> Environmental Management and Equipment Performance (052021)

#### Issue

Sulfur hexafluoride (SF<sub>6</sub>) is a powerful greenhouse gas with a 100-year GWP (global warming potential) of 23,900 (i.e., 23,900 times more powerful than carbon dioxide). Utilities face increasing pressures in the areas of SF<sub>6</sub> emissions, safety, training, leak detection, destruction, and SF<sub>6</sub> analysis. As pressure to reduce greenhouse gas emissions grows and cost pressures continue to escalate, energy companies need focused solutions to meet these challenges.

#### Description

This project has three broad themes that guide the research in this project:

- Reducing the impact of SF<sub>6</sub> on the environment
- Capturing and sharing of SF<sub>6</sub> knowledge
- Improving the performance of SF<sub>6</sub> insulated equipment

Each year results are delivered through tasks performed under each of the themes. The stability in the themes allows for a clear multiyear plan approach. Utility members have two distinct areas of influence on the multiyear plan: first, in the selection of themes and, second, in the prioritizing of the annual tasks that support these themes.

This project provides tools and continuing research into a range of SF<sub>6</sub> issues, including CD-based SF<sub>6</sub> training tools, development of national and international standards to support members on SF<sub>6</sub> issues, and training on SF<sub>6</sub> handling, safety, and emissions reduction programs. The CD-based training tools retain knowledge and educate new staff and refresh staff on the issues associated with SF<sub>6</sub>. This project's research provides important input to the national and international standards bodies, including chairing working groups and developing guides that allow for the results to enter daily utility practices. Workshops rapidly transfer practical knowledge to participants, including practical demonstrations.

#### Value

- Reduces costly SF<sub>6</sub> emissions and amount of labor needed to perform regular top-ups of leaking equipment.
- Mitigates risks of potential health hazards via safe handling techniques, tools, and guidelines.
- Minimizes environmental emissions of SF<sub>6</sub>.
- Explores alternatives to SF<sub>6</sub>.
- Enables utilities to stay abreast of evolving political and legislative developments.

### How to Apply Results

Funders will have ready access to the CD-based SF<sub>6</sub> training tools, with the only requirement being a PC and a printer. Workshop attendance enables utility personnel to receive hands-on training for streamlined application in the field.

### 2009 Products

Product Title & Description	Planned Completion Date	Product Type
<b>Pocket Field guide for SF<sub>6</sub> Management in a Substation – 2009 Revision:</b> The pocket guide provides members with an updated on-site reference of vital information on SF <sub>6</sub> safety, handling, and analysis.	12/31/2009	Technical Update
<b>SF<sub>6</sub> and the Environment: Guidelines for Electric Utility Substations:</b> This guideline is updated every two years. This 2009 revision will include the latest guidance on the full range of SF <sub>6</sub> issues related to substations.	12/31/2009	Technical Update
<b>EPRI training and hands-on workshop on SF<sub>6</sub>:</b> Workshops combine theoretical and practical issues and provide a valuable forum for users to share their own experiences.	12/31/2009	Workshop, Training, or Conference
<b>CD-Based SF<sub>6</sub> training tools – complete library. 2009 revision:</b> The updated four-CD set covers the topics of SF <sub>6</sub> and the environment, and SF <sub>6</sub> handling, safety, and analysis.	12/31/2009	Assembled Package

### PS37D Advanced Solid-State Substation Techniques (062108)

**Project Set Description:** The project set supports the drive toward greater penetration of solid-state devices within substations. Advances to date include solid-state relays and meters, commercial optical current transformer (CT) and voltage transformer (VT) technology, and common use of local area network (LAN) technologies within the substation control house. The most significant benefits that clients realize from this project set include the dramatic reduction of oil dielectrics, reduction in fault currents, elimination of discrete CTs and VTs, harmonic filtering, voltage sag correction, revised design standardization, reduction in substation footprint, and less design margin. Efforts under way include the study of new switching devices and the solid-state current limiter, as well as tracking the development of the Intelligent Universal Transformer (IUT).

Project Number	Project Title	Value
P37.009	Solid-State Load Tap Changer Development	Develops a Solid State Current Limiter (SSCL) to limit fault current issues. Benefits include: <ul style="list-style-type: none"> <li>• Mitigate fault currents from multiple generation sources</li> <li>• Avoid replacement of current limiters, switches, and grounding systems</li> <li>• Improve power quality for sensitive loads</li> <li>• Prolong transformer life</li> </ul>
P37.010	Solid-State Fault Current Limiter Development	Develops a technical road map for the widespread adoption of solid-state power electronic switching technology. Benefits include: <ul style="list-style-type: none"> <li>• Reduce environmental impacts by better utilization of existing power delivery infrastructure</li> </ul>

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Project Number	Project Title	Value
		<ul style="list-style-type: none"><li>• Relieve system congestion via enhanced utilization of existing resources</li><li>• Reduce energy losses at transmission, substation, and distribution levels</li><li>• Improve reliability and power quality</li><li>• Improve physical and cyber-security</li></ul>

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## Project Descriptions

### P37.009 Solid-State Load Tap Changer Development (060475)

#### Issue

The legacy load tap changers on utility transformers are based on electro-mechanical technology and include numerous precision mechanical parts, which wear and require frequent maintenance and down time. The legacy tap changers also create arc when switching taps, causing degradation of the cooling liquid and deteriorating the dielectric property. With solid-state tap changers based on advanced semiconductor device technology (super-gate turn-off thyristor [GTO]) and the latest control and communication components, these problems can be addressed, because this technology provides a compact, reliable, and cost-effective solution. Additional maintenance and supervisory functions can be added to further improve the performance, life cycle, and operating cost of the power delivery system.

#### Description

The overall project objective is to offer commercial solid-state load tap changers (SSLTCs) at competitive costs compared with conventional load tap changers. In 2006, the feasibility of reliable, compact, and cost-effective SSLTCs was reassessed. In 2007, the concept demonstrator was built and tested for power circuit topology and key functional demonstration. The project focus for 2009 is on construction of a 15-KV SSLTC that is prototypical for performance testing and later on to be used for field testing. The design will be modular and scalable for application in other voltage classes. The module will be using advanced power semiconductor devices (e.g., super-GTO) to switch the current flow from one tap to next. Higher-volume production of identical SSLTC modules should reduce overall costs.

#### Value

- Improve uptime of the utility system by minimizing trouble-shooting and repairs.
- Improve economics by generating more revenue and reducing maintenance cost.
- Improve power quality by quick response to change in load demands.
- Improve equipment life by eliminating equipment degradation due to arc and formation of gas.
- Prolong the life of transformers, which will no longer be exposed to the arcing from electro-mechanical load tap changers.

#### How to Apply Results

Participants use project findings and deliverables in implementing SSLTCs in appropriate applications.

## 2009 Products

Product Title & Description	Planned Completion Date	Product Type
<b>Design update of a 15 kV SSLTC:</b> A report on the design update of a 15-kV SSLTC including overall size, weight, packaging, performance, and modularity/scalability using super GTOs.	12/31/2009	Technical Update

## Future Year Products

Product Title & Description	Planned Completion Date	Product Type
<b>Construction and test results of a 69 kV Solid State Fault Current Limiter for Field Testing:</b> A comprehensive report on the design, development, and test results of a 69-kV SSCL.	2010	Technical Report
<b>Construction of prototypical 15kV 3ph SSLTC for design verification testing:</b> A comprehensive report outlining the design, development, and test protocols for a SSLTC.	2010	Technical Report

## P37.010 Solid-State Fault Current Limiter Development

### Issue

Continuing developments in solid-state power electronic switching devices are enabling enormous efficiency improvements in the electrical energy utilization sector. Increasingly, multimewatt solid-state power control systems are becoming implemented in critical industrial electrical installations. In the electric utility sector, pilot field demonstration projects operating Flexible AC Transmission Systems (FACTS) and Custom Power have established their effectiveness in improving the power delivery infrastructure, although their deployments have been modest. While FACTS devices are devoted to the improvement of the transmission system, Custom Power devices focus on distribution systems.

### Description

In this project, opportunities for improving functionality within power substations through the implementation of power electronics are investigated, with a focus on future challenges and solutions. This project develops a technical roadmap for the widespread adoption of solid-state power electronic switching technology as an opportunity to meet the challenges of future power delivery systems.

In 2006, a technical update was delivered on the status of power electronics controllers and their application in solving the most significant issues facing substations of the future. In 2007, a technical report was prepared on the application of an advanced power electronic controller for solving a selected substation issue. 2008 work includes an implementation plan for deploying advanced power electronics controllers in substations, based on previous research and on detailed consultations with utility and vendor industry experts. A preliminary cost-benefit study estimates the economic and financial benefits of the implementation plan. Depending on the cost-benefit study, the status of technology advancement, and participant commitment, multiple projects may be initiated.

**Value**

- Reduce environmental impacts by better utilization of existing power delivery infrastructure and enabling easier integration of environmentally benign distributed generation.
- Promote economic growth through generation of new jobs and improved productivity across various sectors by advancing broad application of power electronics technology in the electric power industry.
- Relieve system congestion via enhanced utilization of existing resources.
- Reduce energy losses at transmission, substation, and distribution levels via improved controllability.
- Improve reliability and power quality through the use of various power electronics technologies at substations, mitigating events such as momentary outages, voltage sags/surges, and harmonics.
- Improve physical and cyber-security.

**How to Apply Results**

Project funders use project findings and deliverables in their system planning efforts to evaluate potential applications of advanced power electronics controllers in substations for a variety of issues (e.g., managing load growth, life extension of existing facilities, reduced maintenance of reactive power support devices, mitigation of voltage fluctuation produced by nonlinear loads and varying generation sources, improving distributed generation [DG] interfaces, and fault current handling).

**2009 Products**

Product Title & Description	Planned Completion Date	Product Type
Technical Update Design and Test Document	12/31/2009	Technical Update

**Future Year Products**

Product Title & Description	Planned Completion Date	Product Type
Technical Update Design and Test Document	2010	Technical Update

**PS37E Switching Safety and Reliability (056068)**

**Project Set Description:** This popular project set pursues goals to significantly improve overall safety in substations. Participating clients have found EPRI annual conferences on power switching safety and reliability to be a very effective tool for exchanging experiences, sharing lessons learned, and keeping abreast of the latest accepted practices.

Project Number	Project Title	Value
P37.011	Switching Safety and Reliability	<p>Conducts research and develops tools to reduce switching errors, improve worker safety, reduce unscheduled outages, and improve power quality. Benefits include:</p> <ul style="list-style-type: none"> <li>• Increase reliability and safety</li> <li>• Reduce worker productivity losses</li> <li>• Promote sharing of lessons learned among peers</li> <li>• Develop best practices and new methods</li> <li>• Enable open exchange of information</li> </ul>

## Project Descriptions

### P37.011 Switching Safety and Reliability (052029)

#### Issue

Safety and reliability are at the top of every utility's list of concerns and commitments. Utility personnel must be safeguarded as they carry out their responsibilities. Utility customers expect an uninterrupted supply of power. Switching errors must be prevented because they can create hazardous situations and unexpected power interruptions. Although some utilities have achieved very low error rates, others can benefit from further improvements.

#### Description

This project conducts research with the goal of reducing switching errors, improving worker safety, reducing unscheduled outages, improving power quality, and enhancing utility operating efficiency and compliance with regulatory changes. It also sponsors an annual switching safety and reliability conference to transfer the research results to the utility industry. Using experts knowledgeable about the details of switching, the project analyzes data and procedures to highlight areas that might be improved, and to identify industry "best practices." Specific goals for 2009 include:

- Provide Annual Update on Lessons Learned from Accidents, Including Near-Misses.
- Develop an outline of a SS&R Reference Book.
- Develop recommendations for certification of switching personnel.
- Discover weak links in switching processes, and define remedial and preventive strategies
- Share "lessons learned."
- Improve system integrity and worker safety through safe switching, safe work procedures in substations, and improved ground grids.
- Develop multimedia-based training materials.
- Monitor new industry trends and developments—such as use of high-temperature conductors, dynamic thermal circuit rating (DTCR), and increased use of work on energized lines—and develop guidelines and training materials to meet the associated challenges.

#### Value

- Increase reliability and safety while reducing errors through best practices and guidelines for T&D switching.
- Reduce worker productivity losses via implementation of appropriate switching procedures that include effective safety elements.
- Promote sharing of lessons learned among peers.
- Develop best practices and new methods via comparisons of current practices.
- Enable open exchange of information on incidents and findings among participants via annual power switching safety and reliability conference.

#### How to Apply Results

Reports produced by this project serve as industry benchmarks that individual utilities can use to gauge their own performance. Studies of industry "best practices" identify weaknesses and vulnerabilities within procedures in use at a utility, and provide guidance for improvements and development of error-insensitive procedures.

**2009 Products**

Product Title & Description	Planned Completion Date	Product Type
<p><b>Periodic newsletter on project activities and findings:</b> This newsletter provides an update on recent research activities of the Switching Safety and Reliability project. It is well-recognized in the industry, and its publication will remain an ongoing activity of the project.</p>	12/31/2009	Technical Resource
<p><b>Annual conference on switching safety and reliability:</b> The conference is an opportunity for managers, supervisors, and operations personnel to exchange information about switching policies and procedures that contribute to improved safety and reliability. The conference addresses issues ranging from detailed switching procedures and associated software, through programs for training, audits, and incident investigation, to management strategies and policies.</p> <p>The annual conference has proven to be a great success and attracts more than 150 participants annually. It will remain a continuing part of the project.</p>	12/31/2009	Workshop, Training, or Conference
<p><b>Annual Update on Lessons Learned from Accidents, Including Near-Misses:</b> Available incident reports will be analyzed and lessons to be learned will be summarized. This compilation will be updated annually.</p>	12/31/2009	Technical Update
<p><b>Recommendations for Certification of Switching Personnel:</b> Investigation of feasibility and effective ways of implementing industry-wide certification of switching personnel.</p>	12/31/2009	Technical Update
<p><b>Barriers to Switching Errors report – revise &amp; training materials:</b> This project was initiated in 2005 and produced Technical Update 10106124. This report will be reviewed and updated, and training materials will be developed.</p>	12/31/2009	Technical Update
<p><b>Switching safety and reliability handbook:</b> Reports produced by this project over the years will be reviewed and will serve as basis for a Safety and Reliability Reference Handbook. Gaps in knowledge will be identified and placed on the work plan for future consideration.</p>	9/30/2009	Technical Update

**Future Year Products**

Product Title & Description	Planned Completion Date	Product Type
<p><b>SS&amp;R Reference Book:</b> Reports produced by this project over the years will be reviewed and will serve as basis for a Safety and Reliability Reference Handbook. Gaps in knowledge will be identified and placed in the work plan for future consideration. The Final Report will be prepared, and feedback from users regarding contact and future amendments will be sought.</p>		

Product Title & Description	Planned Completion Date	Product Type
<p><b>Barriers to Switching Errors report – revise &amp; training materials:</b> This project was initiated in 2005 and produced Technical Update 10106124. This report will be reviewed and updated, and training materials will be completed. Training seminars will be offered.</p>		
<p><b>Local Human Machine Interface/Digital Control System(s):</b> Survey of utility experiences with human machine interface/digital control system devices to develop benchmark. Report documenting results.</p>		
<p><b>Update of the 2000 report 1000123 “Switching Practices Survey – Toward Improved Safety and Reliability”:</b> This project was initiated in 2000 and produced Technical Update 1000123. This report will be reviewed and updated, and training materials will be completed. Training seminars will be offered.</p>		

### PS37F Circuit Breaker Life Management (058485)

**Project Set Description:** This project set represents an area of growth for the substations program. In previous years, the work scope was limited and focused. However, second only to transformers, circuit breakers represent the most critical investment for utilities, and their use involves associated maintenance and operation responsibilities. Research under this project set provides utilities with better capabilities in managing these critical assets in the areas of investment decisionmaking, increased reliability, reduced failures, safer operating practices, reduced maintenance costs, and extended component life. This project set contains two projects. The first focuses on circuit breaker condition assessment and life extension. The second considers the opportunities presented by advances in metering and protection equipment to provide much needed circuit breaker monitoring and diagnostic functions.

Project Number	Project Title	Value
P37.012	Circuit Breakers Condition Assessment and Life Extension	Develops application guide for circuit breaker and disconnect switch lubrication. Benefits include: <ul style="list-style-type: none"> <li>• Avoid capital investment for replacement breakers</li> <li>• Increase reliability through improved circuit breaker operations</li> </ul>
P37.013	Using Relays and Metering Data for Circuit Breaker Diagnostics	Develops integrated approach to control and diagnostic data in order to utilize data from existing sources for improved circuit breaker condition assessment and enhanced maintenance operations. Benefits include: <ul style="list-style-type: none"> <li>• Avoid capital investment and reduce capital costs</li> <li>• Improve reliability of circuit breakers</li> <li>• Increase reliability of monitoring systems</li> </ul>

## Project Descriptions

### P37.012 Circuit Breakers Condition Assessment and Life Extension (058562)

#### Issue

The life-cycle performance of power circuit breakers is, to a large degree, determined by the performance of constituent materials and components. Some deterioration (e.g., linkages and interrupter) is not time dependent, while the rate of deterioration of lubricants and seals is. Together these elements drive the requirements for maintenance and refurbishment. Despite the importance of these issues, utilities have little quantifiable data or a complete understanding of breaker material performance to enable cost-effective methods for instituting condition-based maintenance or selecting work practices and tasks.

#### Description

Combine knowledge gained about circuit breaker and disconnect switch lubrication and a quantitative understanding of the aging and deterioration rates and expected life of circuit breaker component materials and subsystems with maintenance best practices. Enhance cost-effective methods for implementing a condition-based maintenance approach.

Task force advisors (drawn from project contributors) and industry experts will work to define the scope, time scales, and milestones. The task force will guide project execution and scoping of all deliverables, such as technical reports, including a circuit breaker and disconnect switch lubrication guide. As opportunities arise via supplemental funding, field trials of the ideas and concepts developed will be pursued.

#### Value

- Avoid capital investment for replacement breakers via more effective maintenance of existing assets.
- Increase reliability through improved circuit breaker operations as a result of enhanced maintenance effectiveness and better condition assessment.

#### How to Apply Results

Project funders can use project results to implement more effective circuit breaker maintenance programs.

#### 2009 Products

Product Title & Description	Planned Completion Date	Product Type
<b>A Novel Method for HVCB Maintenance Ranking:</b> A technical report documenting analytical methodology, algorithms, data requirements, glossary of terminologies, and instructions for using EPRI - HVCB (high-voltage circuit breaker) Maintenance Ranking Tool.	12/31/2009	Technical Report
<b>Utility Use Cases using EPRI HVCB Maintenance Ranking Methodology:</b> Develop a report that documents utility case studies, business case development, and risk assessment scenarios using the CBMR tool/methodology.	12/31/2009	Technical Report
<b>EPRI Lubrication Selection and Application Guide - Field Use Effectiveness Assessment:</b> Develop field use case studies using EPRI CB Lubrication Guidelines to assess the value and effectiveness of the CB lubrication application guide.	12/31/2009	Technical Report

Product Title & Description	Planned Completion Date	Product Type
<b>Power Circuit Breaker Materials and Subsystems Life Cycle Performance:</b> Continue research and development initiated in 2008 to provide a quantitative understanding of the aging and deterioration rates and expected life of selected circuit breaker component materials and subsystems.	12/31/2009	Technical Update
<b>HVCB Life Management Workshop:</b> An annual workshop that will include both tutorials on the material contained in the project deliverables and presentations on utility experiences and examples of the application of the project's results.	12/31/2009	Technical Resource

### Future Year Products

Product Title & Description	Planned Completion Date	Product Type
<b>Power circuit breaker materials and subsystems life cycle performance:</b> Continue research and development initiated in 2008 to provide a quantitative understanding of the aging and deterioration rates and expected life of selected circuit breaker component materials and subsystems.	2010	Technical Report

## P37.013 Using Relays and Metering Data for Circuit Breaker Diagnostics (060478)

### Issue

The growing use of microprocessor-based protective relays has resulted in utility interest in better understanding a number of issues related to their possible application for circuit breaker maintenance such as:

- Practical benefits and limitations of programming relays for diagnosis and alarming or reporting—how helpful this really is for maintenance attention and for population asset management.
- Ability to communicate useful diagnostic data, raw or processed by relay programming, from typical T&D substations.
- How to process communicated data into maintenance tickets and asset management extracts.
- Challenges in programming relays for breaker diagnosis, and in accessing and using collected data and results.

### Description

The focus in this project is to benefit from combining knowledge of equipment diagnostics and equipment characteristics with an understanding of relay capabilities to develop a seamless approach to maintenance.

*Planned 2008 work on breaker diagnostics with relay data includes:*

- Relay vendor engagement to document relay capabilities.
- Planning with selected EPRI member utilities on practical easy-to-implement diagnostic techniques, and beginning field demonstrations of those techniques.
- Beginning the gathering of experience data from field studies.

The practical diagnostics comprise a combination of programming in relays, and data gathering by communications with relays.

*Continuing to build on this work, the proposed research tasks in 2009 include*

- Continue field studies—work with 2008 demonstration project utilities on implementation—programming, data gathering and utilization, and results.
- Engage more utilities in field demonstrations to increase deployment experience and database building.
- Develop improved algorithms, and tools for data gathering and processing, for use in field demonstrations and in a field guide.
- Work with relay manufacturers, and with substation or enterprise software vendors, to implement designs that better support breaker diagnostics and reporting. Summarize in a technical report.
- Organize a workshop of users and vendors to influence product design direction.
- Analyze and present database results to the industry in a technical report with optional associated Workshop—show benefits and experience of using relay data, including results on usefulness to utility participants.
- Develop a field guide—an application guide for use of relay data for breaker diagnostics.

**Value**

Programming and accessing breaker diagnostics in relays as proposed in this ongoing project work offers:

- Improved breaker reliability via repairs carried out before breaker failures.
- Appropriate population maintenance program development, focusing field crew efforts on real problems and reducing unneeded maintenance.
- Improved utilization of installed assets – modern protective relays have innate monitoring capability, which is not widely used today.
- Support of business case for replacement of aging electromechanical relay populations with modern, programmable microprocessor relays.
- Advances in design features of relays for breaker diagnostics, leading to easier and better field implementations at utilities.

**How to Apply Results**

Project funders can directly use tools documented in project results to create practical programs for use of monitoring data from existing relays, to diagnose circuit breaker condition. With these tools, they can more efficiently and effectively maintain breaker fleets.

**2009 Products**

Product Title & Description	Planned Completion Date	Product Type
<p><b>Using Relay and Metering Data for Circuit Breaker Diagnostics – Results and Findings Summary of Utility Use Cases:</b> <i>Results, Findings, Methodology, Technique Description, and technical papers as appropriate,</i></p> <ul style="list-style-type: none"> <li>• Experiences with first-generation demonstration by the first utility group, including technical and practical results, and business case results.</li> <li>• The approach and initial demonstration experience with expanded group of participating utilities.</li> </ul>	12/31/2009	Technical Update

Product Title & Description	Planned Completion Date	Product Type
<b>Diagnostic Information and New Techniques Catalogue:</b> Technical Update on diagnostic improvements and new techniques developed through research efforts of investigators.	12/31/2009	Technical Update
<b>Circuit Breaker Diagnosis Using Relay and Metering Data – A Practical Field Guide:</b> Field guide for practical use of programmable communicating relays or other Intelligent Electronic Devices (IEDs) for circuit breaker diagnostics and maintenance management.	12/31/2009	Technical Resource
<b>Industry wide Knowledge Base on practices, tools and techniques to used Relay and Meter data for Circuit Breaker Diagnostics:</b> An industry database of breaker diagnostic experiences – first results and ongoing strategy beyond 2009.	12/31/2009	Technical Resource

### Future Year Products

Product Title & Description	Planned Completion Date	Product Type
<b>Standardization of Pertinent Topics:</b> In 2009 or beyond, initiate industry standards development activity for design features that should have a common implementation – proposed so far are functions for contact wear versus interruption data, and file formats for diagnostic or asset management data. Other standardization topics could arise.	2009	Technical Resource

### PS37G Fault Current Management and Substation Grounding (063288)

**Project Set Description:** In recent years, considerable attention has been directed at substation grounding. The drivers are diverse. The first driver remains ensuring safety of both staff and equipment. The second is that, with each passing year, the ground grid is prone to corrosion and decay. Also, ever-increasing fault current levels require a reassessment and enhancement of existing ground grids to meet the higher service duty. The ground grid needs constant attention and refurbishment. This is a difficult, time-consuming and costly exercise. Many years ago, EPRI developed the "smart" ground meter that simplified these assessments. With advances in technology and new insights into how the technologies perform, efforts are under way to improve the "smart ground meter." This project set focuses on improving this meter and then turning attention to ground-grid maintenance and refurbishment.

Project Number	Project Title	Value
P37.014	Fault Current Management Issues	Develops tools and techniques that address fault current management issues. Benefits include: <ul style="list-style-type: none"> <li>• Avoid equipment replacement costs</li> <li>• Avoid costs due to system outages</li> <li>• Realize more revenue by increasing power flows using existing assets</li> <li>• Contribute to improved grid reliability</li> <li>• Increase safety in substations and on transmission corridors</li> </ul>

Project Number	Project Title	Value
		<ul style="list-style-type: none"> <li>• Reduce overall costs of transmitting power</li> </ul>
P37.015	Ground Grid Evaluation, Maintenance, and Refurbishment	Develops a guide to the design and construction of new ground grids. Benefits include: <ul style="list-style-type: none"> <li>• Improve ease and accuracy of evaluating adequacy of installed grounding systems</li> <li>• Provide effective methods to install new grids, bolster grids that have deteriorated, or improve grids that need upgrading because of higher fault current levels</li> <li>• Increase substation worker safety as well as public safety in areas adjacent to the substation</li> </ul>

## Project Descriptions

### P37.014 Fault Current Management Issues (065594)

#### Issue

Utilities worldwide are experiencing increased fault current levels due to increased distributed energy sources as well as systems being operated at higher power levels than previously. The issues related to increased fault currents include equipment failures and system outages.

#### Description

This project addresses fault current management in a systematic way by investigating issues such as the impacts of fault currents on protection and metering as well as identifying new techniques to mitigate fault currents. This project is divided into several tasks:

#### Task 1 – Fault Current Management Guidebook

Due to increased load demands and reduced incentives to build new transmission, energy companies are increasing power flows on existing transmission assets, which in turn increases fault current levels throughout the power system. In addition, unplanned generation sources on the transmission and distribution network increase the power flows and fault current levels in the system. Under increased power flow conditions, limiting fault currents is important to avoid equipment malfunctioning and damage. This comprehensive guidebook documents the state of the science for limiting fault currents in transmission and distribution assets. It describes possible schemes for limiting fault currents, and reports on studies conducted at a few member sites to examine the impact of these schemes and document economic comparisons of each of the technologies. The guidebook draws from a combination of information on other EPRI technology, industry experts, documented case studies, and associated engineering and safety guidelines. A course will be developed to directly support the guidebook.

#### Task 2 – Impact of Fault Currents on Protection and Metering

Existing protection systems, such as relays and breakers, and metering systems, such as current transformers (CTs) and potential transformers (PTs), may not be able to function properly at increased fault current levels. This project studies the impact of different fault current levels on protection coordination, as well as on metering equipment, including lab and field testing with varying levels of fault currents, and monitoring of protection and metering equipment performance. In addition, the task develops simulation models based on the testing results, and uses these models to study the impacts at sufficiently large (abnormal) fault current levels. The project documents all field test and simulation results and provides recommendations regarding the impacts and the percentage of increased fault current levels at which abnormal functions occur.

### Task 3 – Study of Mechanical Forces in the Primary Equipment at Increased Fault Currents

Increased fault currents may develop higher mechanical forces in primary equipment, such as transformers, cables, and other substation modules. Additional weight on substation structures due to increased bus work to limit fault currents may also increase mechanical forces in the equipment. This task conducts lab and field tests to explore mechanical force levels at different levels of increased fault currents, and develops mathematical models based on these results. It also investigates the impact of mechanical forces on equipment failure, and provides recommendations regarding the level of mechanical forces that may cause equipment failures and their corresponding fault current levels.

### Task 4 —Application of Advanced Technologies to manage Fault Currents

EPRI has been developing solid-state current limiters (SSCLs) to address the issue of limiting fault currents. EPRI is also developing short-circuit current limiters (SCCLs), which could be used for fault current limitation. While research on these two developments continues in their respective EPRI program areas (Program 37, Transmission Substations and Program 122, Power Delivery Applications of Superconductivity), this project investigates other possible technologies to limit fault currents. The project develops concepts of new technologies for fault current limitation, develops prototypes, and then conducts field demonstrations.

#### Value

- Avoid equipment replacement costs by reducing or eliminating equipment damage due to high fault currents.
- Avoid costs due to system outages.
- Realize more revenue by increasing power flows using existing assets.
- Contribute to improved grid reliability by avoiding equipment damages and subsequent outages.
- Increase safety in substations and on transmission corridors by avoiding equipment explosions.
- Reduce overall costs of transmitting power over the grid.
- Improve customer satisfaction with reduced interruptions and utility energy rates.

#### How to Apply Results

Project funders can use project results to make informed decisions when choosing options for limiting fault currents. By implementing one or more of the options, funders can obtain increased power flows without damaging equipment due to high fault currents. Project funders will also be able to understand whether their existing protection and metering systems are adequate at increased fault currents or whether the protection equipment needs replacement.

#### 2009 Products

Product Title & Description	Planned Completion Date	Product Type
<b>Updated Fault Current Management Guidebook (Maroon Book):</b> The Fault Current Management Guidebook, also known as the Maroon Book, will be updated with the latest fault current limiter technologies as well as with the results from the other R&D projects in this area.	12/31/2009	Technical Update
<b>New technologies for fault current limiting:</b> This project will investigate new ways, either by system reconfiguration strategies or by using different methods, to limit fault currents in T&D systems.	12/31/2009	Technical Update

### Future Year Products

Product Title & Description	Planned Completion Date	Product Type
<b>Updated Fault Current Management Guidebook (Maroon Book):</b> The Fault Current Management Guidebook will be updated with the latest developments in fault current limiters as well as with the results of the other R&D projects in this area.	2010	Technical Update
<b>New Technologies for Fault Current Limiting:</b> New technologies for fault current limiting will be developed for practical application by the utilities.	2010	Technical Report
<b>Lab / Field Demonstration of New Technologies for Fault Current Limiting:</b> Promising new technologies will be demonstrated in a laboratory environment and at utility sites.	2011	Technical Update

### P37.015 Ground Grid Evaluation, Maintenance, and Refurbishment (058564)

#### Issue

A substation ground grid is an essential component for at least three reasons: 1) it serves as a safety feature for any personnel who may be in the substation during a fault; 2) it minimizes hazards to the public, such as step and touch voltages near the substation; and 3) it provides adequate ground for substation equipment, especially control room electronics. The ground grid must be carefully designed to ensure that even the worst available faults will not damage equipment or harm staff. Today substation ground grids are receiving more attention because of increasing fault current levels. Facilities that were designed and installed 40 or more years ago were often based on a calculated fault current from the generation sources and interconnections of that time. Although the common practice then was to base needs on a conservative calculation of available fault levels, over the years additional generation and introduction of increased power flow measures have resulted in increased fault levels. At the same time, there are sites at which enough corrosion has occurred over the decades to measurably decrease the effectiveness of the ground grid.

#### Description

In the early 1980s, EPRI developed software for the design of substation grounding grids, and, in the early 1990s, EPRI developed the Smart Ground Multimeter (SGM), an instrument for measuring substation ground grid impedance without requiring an outage. In 2006, EPRI completed the enhancements to the third-generation Smart Ground Multimeter. Building on these accomplishments, this project conducts a study of ground grid designs with the view to enhancing their fault current ratings and refurbishing deteriorated grids. This includes full-scale experiments to verify the studies and their recommendations. The project deliverable is a guide to the design and construction of new ground grids with increased current ratings, ground grids to which an incremental area is being added, and ground grids that must be augmented to increase their fault current rating. The guide will provide advice on when to consider the possibility of corrosion of the ground grid, what choices can minimize the degradation of corrosion, and how deteriorated grids can be refurbished in the most economical manner.

#### Value

- Improve ease and accuracy of evaluating adequacy of installed grounding systems.
- Provide effective methods to install new grids, bolster grids that have deteriorated, or improve grids that need upgrading because of higher fault current levels.

- Increase substation worker safety as well as public safety in areas adjacent to the substation via design of high-quality substation ground grids.

### How to Apply Results

Ground grid design, maintenance, and refurbishment guides developed by this project can be used by utilities for planning new grids and enhancements to existing grids, evaluation of the condition and degree of deterioration of existing grids to ensure worker and public safety, and repair of grids based on sound economic principles.

### 2009 Products

Product Title & Description	Planned Completion Date	Product Type
<b>Condition assessment of connectors, conductor, ground rods: Complete Phase 2:</b> Development of a prototype instrument for condition assessment of connectors, ground grid conductors, and ground rods.		Technical Report
<b>Staged fault tests - review previously performed tests:</b> Staged fault data will be collected, reviewed, and analyzed to assess the performance of healthy and deteriorated grids.		Technical Update
<b>Training materials for Smart Ground Multimeter (final report or DVD):</b> Multimedia training materials to aid technicians in field deployment of the SGM and in resolving practical problems encountered in the field.		Workshop, Training, or Conference

### Future Year Products

Product Title & Description	Planned Completion Date	Product Type
<b>Develop cost-effective approaches to augmenting or repairing grounding grids:</b> A report providing guidelines for augmenting grids to handle increased faults currents and to repair defective grids.	2010	Technical Update
<b>Develop handbook for the design and construction of new ground grids, augmenting ground grids, and increasing their fault current ratings:</b> A practical handbook for design, construction, augmentation, and repair of substation ground grids.	2010	Technical Update
<b>“Blind study” - three audits (“as is”, “damaged”, “repaired”):</b> Conduct a three-stage “blind” study using the Smart Ground Multimeter: <ul style="list-style-type: none"> <li>- Assessment of the “as-is” condition of an aging (possibly damaged) ground grid</li> <li>- Assessment of the condition of the grid in the same substation after unknown modifications (additional damage) performed by the utility, without informing the researchers of the details of the modifications</li> <li>- Assessment of the condition of the grid in the same substation after repairs performed by the utility, without informing the researchers of the details of the repairs</li> </ul>	2011	Technical Report

## PS37H Protection and Control (067420)

**Project Set Description:** Numeric relays have a number of advantages over Electromechanical (EM) relays. Numeric relays provide discrete signal processing and allow higher accuracy and shorter tripping times than their EM counterparts. They support intelligent evaluation techniques and filters allow improved selectivity, even during some complex faults. They are multifunctional, providing many protection functions and disturbance recording. However, the technology brings with it a number of issues; including standardization, design, security, training and maintenance.

Utilities are struggling as they replace electro-mechanical and first generation semiconductor relays. This project set helps utility engineers make a seamless transition to numeric relays and help extract to most value from their investment.

This project set contains two projects. The first supports intelligent transition to numeric relays. This will include best-in-class practices for reliability, cyber security, spare parts policies, misoperation indices, issues with design (enclosures, plug & play), relay failure root cause analysis, event analysis, and electronic advisories for urgent fixes.

The second project supports deployment of numeric relays to enable the intelligent grid. It will develop feature requirements of the next-generation protective device and its associated wide area communications, control, and management network.

Project Number	Project Title	Value
P37.016	Addressing Emerging Protective Relaying and Control Issues	This project provides a vehicle for participating utilities to resolve some of the most important emerging issues associated with the new numeric (digital) relays.
P37.017	Next Generation Relays	This project will <ul style="list-style-type: none"> <li>• assess the current state of utility technology and practices to identify key issues facing utilities in this area</li> <li>• facilitate cross-industry learning through idea exchange with information technology and telecommunications industries to understand best practices</li> <li>• develop feature requirements of the next-generation protective device and its associated wide area communications, control, and management network similar to SNMP agents</li> </ul>

## Project Descriptions

### P37.016 Addressing Emerging Protective Relaying and Control Issues (067440)

#### Issue

The project is designed to give utility engineers and technicians the means to resolve some of the most pressing issues associated with use of the new numeric (digital) protection relays. Numeric relays have become common in the protection arena and are replacing electromechanical relays (and first- and second-generation electronic relays) at different, but increasing rates, across the world.

### Description

This project provides a vehicle for participating utilities to resolve some of the most important emerging issues associated with the new numeric (digital) relays. In particular this project will cover the following areas:

- Standardization issues
- Design issues
- Security issues
- Maintenance issues
- Event analysis
- Relay misoperations
- Root cause analysis

This project will also set up a dedicated workgroup and database, to be fully operational in 2010, where participating utilities can share best practices and collect valuable information associated with numeric relays.

### Value

- Demonstrate utility commitment to more reliable supply of power through better approaches to dealing with protective relaying issues.
- Share best practices between utilities in the areas of protection and control.
- Make the grid more secure by making the protective relaying more secure and hack resistant.

### How to Apply Results

Utility engineers can use the knowledge contained in the project findings and deliverables to deal with critical issues related to the new numeric relays, enhance system reliability, increase sharing of best practices with other utilities, streamline and improve maintenance practices, increase system security, evaluate available technologies, and influence designs and enhancements for the protective relays and control.

### 2009 Products

Product Title & Description	Planned Completion Date	Product Type
<b>Technical Workshop</b>	9/15/2009	Technical Resource
<b>Numeric relays emerging issues</b>	12/31/2009	Technical Update

### P37.017 Next Generation Relays (067441)

#### Issue

As the electric power industry moves forward with development of the Smart Grid, a number of issues emerge with the existing protective relay devices. Devices deployed today were essentially developed as replacements for electromechanical devices. As utilities begin to deal with large deployments of smart devices or microprocessor-based products, significant issues arise with management, configuration, security, and change management. The current method employed by many utilities, where a technician visits a substation and then connects to each device via a laptop, is too time consuming, inefficient, and costly. Also, if a significant flaw in a particular brand or model of relay were to be discovered and need rapid replacement, the current method would be hard challenged to deliver a rapid response. New

computer-based tools and product enhancements are necessary to effectively manage these large deployments.

### Description

This multiyear project will address a number of research areas. One of the most critical aspects of this project is to learn how to manage massive deployments of thousands, if not millions, of smart devices. Other industries today have the responsibility and have developed tools to remotely manage millions of devices. The most prominent is information technology, where millions of desktop and laptop computers are managed with Simple Network Management Protocol (SNMP) agents, or the telecommunications industry with millions of mobile phones. Tools and designs need to be adopted so that similar techniques can be implemented in the electric utility sector. This project will

- assess the current state of utility technology and practices to identify key issues facing utilities in this area
- facilitate cross-industry learning through idea exchange with information technology and telecommunications industries to understand best practices
- develop feature requirements of the next-generation protective device and its associated wide area communications, control, and management network similar to SNMP agents

### Value

- Improve management of field-deployed smart devices through knowing what devices are deployed, how they are configured, and what the current firmware and software versions are.
- Improve access control and audit trail of changes made to devices (who did what when).
- Improve substation designs to better accommodate these concepts.

### How to Apply Results

Protection engineers, network operations staff, and information systems engineers will be able to use the results of this project to better understand the current state of the technology associated with management of microprocessor-based protective relays. They will also benefit from the cross-industry workshop through gained knowledge of tools and techniques employed in related industries such as information technology, cellular networks, and set top boxes. Lastly, the roadmap for the next-generation protective devices will enable engineers to significantly participate in the requirements specification development, thereby enabling more efficient implementation and management of these devices. This will facilitate smoother transition to these devices at participating utilities.

### 2009 Products

Product Title & Description	Planned Completion Date	Product Type
<p><b>Current State Assessment:</b> This project will assess the current state of key issues facing utilities with large deployments of smart devices or microprocessor-based products. There are significant issues arising with the management, configuration, security, and change management of these devices. This effort would identify, prioritize, and set the direction for subsequent tasks.</p>	12/31/2009	Technical Report

Product Title & Description	Planned Completion Date	Product Type
<p><b>Cross Industry Workshop:</b> The first part of this task would facilitate cross-industry learning through idea exchange with both the information technology and telecommunications industries to understand best practices and methods employed by them to manage and maintain their vastly distributed networks of devices. The second part would be to build upon the knowledge gained from the other industries and investigate and document approaches whereby the electric utility industry may adopt useful techniques learned. The second step would require participation by both utilities and product manufacturers.</p>	12/31/2009	Workshop, Training, or Conference
<p><b>Develop roadmap for the next generation protective devices</b> This task will identify the critical functions of the next-generation protective devices and also sequence them into a logical development process. This task will build upon the insights learned in the previous two tasks and provide the industry with the necessary guidance for building next-generation devices and software support tools. Key features of this task will most likely be the enablement of a wide-area communications, control, and management network with tools built upon improved hardware features that provide capability comparable to SNMP agents.</p>	12/31/2009	Technical Report

**Future Year Products**

Product Title & Description	Planned Completion Date	Product Type
<p><b>Develop feature requirements for the next generation protective devices – phase I:</b> This project will define and develop the features and functions of next-generation protective devices in order to provide the industry with the necessary guidance for building the devices and software support tools needed. The deliverables will be fairly detailed requirements suitable for suppliers and industry standards groups to act on. Phase I will identify the foundation elements necessary to provide for a wide-area communications, control, and management network with tools built upon improved hardware features that provide capability comparable to SNMP agents.</p>	2010	Technical Report
<p><b>Develop feature requirements for the next generation protective devices – phase II:</b> This project will define and develop the features and functions of next-generation protective devices in order to provide the industry with the necessary guidance for building the devices and software support tools needed. The deliverables will be fairly detailed requirements suitable for suppliers and industry standards groups to act on. Phase II will identify the enhanced set of features that provide capabilities beyond those identified in phase I.</p>	2011	Technical Update