

## Substations - Program 37

### Program Overview

#### Program Description

This program helps substation owners enhance safety, reliability, equipment life, and performance despite shrinking maintenance budgets. It offers a complete portfolio of tools and technologies such as transformer monitoring. The program also includes resources such as failure databases and aging models to improve transformer and circuit breaker life management. It may also help operations and maintenance (O&M) engineers extend equipment life, optimize maintenance costs, and reduce outages.

#### Research Value

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

- Extend equipment life with maintenance guidelines
- Reduce maintenance costs via condition-based maintenance
- Reduce losses via improved sulfur hexafluoride (SF<sub>6</sub>) management
- Implement predictive maintenance practices for reduced outages
- Prevent failure of critical transformers

#### Approach

EPRI substation research will yield a variety of beneficial data and knowledge to program members. This information will be delivered in a number of forms and is expected to include the following:

- Component aging models
- Equipment diagnostic and risk assessment tools and software
- Maintenance best practice guidelines
- Reference books, guidelines, and field guides
- Development of solid-state devices
- Industry-wide failure databases
- Collaborative environments for sharing near misses and best practices

#### Accomplishments

In the past, the substations program has delivered valuable information that has helped its members and the industry. Some examples are listed below.

##### **PTLOAD: Development of Algorithms to Include New Research Data on Loss of Life**

- Transformer insulation life depends largely on temperature, moisture, and oxygen. A research project investigated the combined effects of temperature, moisture, and oxygen on transformer insulation aging. From experiments, curves of acceleration factor under five moisture levels at low oxygen were obtained and made available in early 2008. To effectively incorporate the results into the aging calculation of PTLOAD software, a new aging model that accounts for the combined effects of temperature and moisture is proposed.

##### **SF<sub>6</sub> Complete Library, Version 2.0**

- The SF<sub>6</sub> (Sulfur Hexafluoride): Computer-Based Training Modules, Version 2.0, are a set of four CDs for computer-based training on SF<sub>6</sub> safety, handling, and analysis that include the impact of SF<sub>6</sub> on the environment.

### **Guidelines for Applications and Analysis of Transformer Industry Database (IDB) - Data and Models**

- Most utilities are interested in better understanding and projecting transformer service life to help manage risk; however, generic reliability data are inadequate for today's decision support needs. A single company's data may not be sufficiently extensive nor represent statistically diverse asset population subsets. Therefore, this project's database efforts emphasize, but are not limited to, life analysis and better understanding of failure rates as a function of age and other parameters.

### **Guidelines for the Life Extension of Substation Equipment**

- This report presents the results of an effort to establish the evolving industry needs for an updated chapter on high-voltage circuit breakers for the EPRI report, *Guidelines for the Life Extension of Substations: 2002 Update* (1001779), also known as the Substation Equipment Life Extension Guidelines (LEG). The effort included an assessment undertaken to document current power circuit breaker asset management and maintenance practices, in order to identify utility needs that could be better supported through updated LEG chapters.

### **Current Year Activities**

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

- Transformer and circuit breaker aging models
- Transformer reference book (Copper Book)
- Transformer diagnostic and risk assessment tools and software
- Substation life-extension guidelines
- Circuit breaker life management and lubrication
- Development of fault current limiters to the 69 kV level
- Circuit breaker diagnostics using relay data
- Fault current management and substation grounding best practices
- Switching safety and reliability conference and practice sharing
- Management of legacy relays and integration of the next generation

### **Estimated 2010 Program Funding**

\$5.0M

### **Program Manager**

Andrew Phillips, 704-595-2234, aphillip@epri.com

## 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 online condition assessment. Recently, the project set has been expanded to include the design aspects relating to geomagnetically induced currents (GICs) within transformers. Even if GIC is not currently a key concern for a company, the focus on design provides invaluable insights that will help it with future transformer specifications.

Project Number	Project Title	Description
P37.001	Transformer End-of-Life and Condition Assessment	Effective transformer life management via novel condition-monitoring techniques and new algorithms for turning that condition monitoring data into actions.
P37.002	Transformer Life Extension	This project provides a mix of field tools and forensics analysis to extend transformer life and improve decisionmaking on these critical substation devices.

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

#### Key Research Question

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

#### Approach

Three broad themes guide the research:

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

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

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

#### Copper Book (EPRI Power Transformer Guidebook) Development

In 2010 we plan to add four chapters to the Copper Book. In each year of development, the work-to-date is published to allow members to use the materials as they are produced. The ultimate goal is a comprehensive reference book that can be used by members responsible for all aspects of transformer operation,

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

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

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

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

#### Impact

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

#### How to Apply Results

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

#### 2010 Products

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

## Future Year Products

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

## P37.002 Transformer Life Extension (058559)

### Key Research Question

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

### Approach

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

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

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

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

#### Application of novel online filtration materials and techniques

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

#### Forensics Library

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

## Impact

The impacts of this research include the following:

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

## How to Apply Results

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

## 2010 Products

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

## Future Year Products

Product Title & Description	Planned Completion Date	Product Type
<b>New tracer compounds to estimate transformer life on-line</b>	12/31/11	Technical Update
<b>Extension of the Forensics Library of aged transformers</b>	12/31/11	Technical Update
<b>New materials for transformer insulation and cooling: laboratory studies and early field experiences</b>	12/31/11	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: Life Extension, Maintenance and Condition Assessment Guidelines for Substation Equipment, Risk Mitigation and Maintenance Strategies for Substation Equipment; Integrated Monitoring and Diagnostics; Industry Equipment Performance Database and CIM Data Standardization; and Balance of Substation - Inspection, Assessment and Maintenance Strategies. 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	Description
P37.003	Maintenance, Condition Assessment and Life Extension Guidelines for Substation Equipment	Provide practical reference material for integrated and consistent best practice actions for maintenance, condition assessment and life extension actions for substation equipment.
P37.004	Risk Mitigation and Maintenance Strategies for Substation Equipment	Analytics for Substations Asset Performance: Development of data models and analytics which combine condition information with fundamental understanding of the equipment to provide decision support for improved performance and risk management.
P37.005	Integrated Monitoring and Diagnostics	This project provides immediate and comprehensive knowledge of substation sensors and fast-tracks examination of new sensors from other industries in the EPRI Sensor Laboratory—allowing for confident decisionmaking on potential substation applications.
P37.006	Industry-wide Equipment Performance Database	This project builds and maintains a unique, independent repository and analysis tools to collect and analyze equipment performance data to provide information that supports maintenance and asset management decisions.
P37.007	Balance of Substation – Inspection, Assessment and Maintenance Strategies	Balance of substation inspection, assessment and maintenance strategies

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

#### Key Research Question

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

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

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

### Approach

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

### Impact

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

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

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

### How to Apply Results

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

## 2010 Products

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

## Future Year Products

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

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

### Key Research Question

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

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

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

### Approach

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

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

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

### Impact

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

### How to Apply Results

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

### 2010 Products

Product Title & Description	Planned Completion Date	Product Type
<b>Equipment Risk and Performance Assessment:</b> This product provides methodologies to help project future performance based on current condition and required future performance. It will also provide methodologies for evaluating risk mitigation measures to help select appropriate actions to achieve a desired cost and reliability, as well as other performance goals. Collectively this work will support intelligent fleet management.	12/31/10	Technical Update
<b>Catalogue and Assessment of Industry Maintenance Best Practices for Substation Equipment:</b> This product will catalogue and assess current industry practices and procedures (including lessons learned by utility experts) and identify gaps and issues with existing practices. Ongoing efforts focus on key substation equipment: transformers and circuit breakers. Over time, through task force feedback and needs assessment, other substation equipment areas will be identified and added.	12/31/10	Technical Update

Product Title & Description	Planned Completion Date	Product Type
<b>Maintenance Effectiveness Assessment:</b> This product will be a set of appropriate key performance indicators (KPI's) for measuring maintenance effectiveness. It will provide guidance on how to apply, use, and track these KPI's to improve benefits for current O&M and project incremental benefits for future O&M spending.	12/31/10	Technical Update

## Future Year Products

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

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

### Key Research Question

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

### Approach

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

#### Sensor awareness across multiple industries

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

#### Cross-industry sensor research and testing

Substation diagnostics can benefit significantly from the sensor developments in other industries (e.g., defense, automotive, space, medical). EPRI's sensor laboratory, partnered with its substation experts, provide a unique test-bed to rapidly evaluate the potential benefits offered by these new sensors. The results will enable the utility industry to effectively gain knowledge from other industries, while the collaborative research

on the issues will allow for cost-effective and rapid decisions through laboratory simulations that closely mirror the field.

### Impact

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

### How to Apply Results

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

### 2010 Products

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

### Future Year Products

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

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

### Key Research Question

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

### Approach

This project provides members with aggregated data and information resources not currently available to individual companies, to assist in developing repair/refurbish/replace strategies for aging substation equipment fleets. The project collects equipment performance and failure data in a common format from

many sources to establish a database that enables statistically valid analysis to determine equipment failure rates, identify “bad actors” early, and help identify best maintenance and specification practices. Data models and software applications will be developed and presented to task force advisors for comment and further refinement. Associated supplemental projects may be launched to populate the Industry-wide Equipment Performance Database (IDB) with historical data and develop company-specific applications. Transformers, tap-changers, circuit breakers and other substation equipment are included in this development.

### Impact

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

### How to Apply Results

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

### 2010 Products

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

## Future Year Products

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

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

### Key Research Question

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

### Approach

To address these issues, this project provides the following:

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

## Impact

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

## How to Apply Results

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

## 2010 Products

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

## Future Year Products

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

## PS37C SF6 Environmental Management (056066)

### Project Set Description

This project set focuses on significantly improving the performance of sulfur hexafluoride (SF<sub>6</sub>)-insulated equipment. It will include providing tools to extend and estimate equipment life, reducing maintenance and operating costs of SF<sub>6</sub> equipment, managing SF<sub>6</sub> environmentally, and protecting the 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	Description
P37.008	SF6 Environmental Management and Equipment Performance	This project helps members address SF <sub>6</sub> issues by helping them to improve equipment performance and safety, reduce environmental impacts, and capture and share SF <sub>6</sub> knowledge.

## P37.008 SF6 Environmental Management and Equipment Performance (052021)

### Key Research Question

Sulfur hexafluoride (SF<sub>6</sub>) is a powerful greenhouse gas with a 100-year global warming potential (GWP) of 23,900 (i.e., it is 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.

### Approach

Three broad themes guide this project's research:

- 1) Reducing the impact of SF<sub>6</sub> on the environment
- 2) Capturing and sharing SF<sub>6</sub> knowledge
- 3) 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 prioritization 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 help users retain knowledge, as well as refresh staff and educate new staff on the issues associated with SF<sub>6</sub>. This project's research contributes 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.

### Impact

- 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 members to stay abreast of evolving political and legislative developments.

### How to Apply Results

The results are designed for easy and rapid application: 1) 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. 2) The field guide is designed as a laminated pocket guide, enabling field staff to rapidly verify critical information onsite. 3) Workshop attendance enables personnel to receive hands-on training, to facilitate streamlined application of the information in the field.

### 2010 Products

Product Title & Description	Planned Completion Date	Product Type
<b>Pocket Field Guide for SF<sub>6</sub> Management in a Substation - 2010 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.	12/31/10	Technical Update
<b>Computer-Based SF<sub>6</sub> Training Tools - 2010 revision:</b> The four-CD set of training tools will be fully revised and brought up to date in the areas of SF <sub>6</sub> safety, SF <sub>6</sub> and the environment, SF <sub>6</sub> handling, and SF <sub>6</sub> analysis.	12/31/10	Assembled Package
<b>EPRI Training and Hands-on Workshop:</b> Workshops provide a forum for members to become rapidly informed of the latest EPRI SF <sub>6</sub> results while also sharing relevant experiences.	12/31/10	Workshop, Training, or Conference

### Future Year Products

Product Title & Description	Planned Completion Date	Product Type
<b>Potential replacements for SF<sub>6</sub> (or alternatively, new SF<sub>6</sub>-free technologies)</b>	12/31/11	Technical Update
<b>EPRI Training and Hands-on Workshop</b>	12/31/11	Workshop, Training, or Conference
<b>Advanced tools for automated SF<sub>6</sub> emissions reporting</b>	12/31/11	Technical Update

## PS37E Switching Safety and Reliability (056068)

### Project Set Description

This project set seeks 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	Description
P37.011	Switching Safety and Reliability	This project aims to develop controls and procedures that prevent errors in power switching, enhance worker and public safety, and improve power delivery reliability.

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

### Key Research Question

Safety and reliability are at the top of every utility's list of concerns and commitments. Personnel must be safeguarded as they carry out their responsibilities, and 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.

### Approach

This project conducts research with the goal of reducing switching errors, improving worker safety, reducing unscheduled outages, improving power quality, and enhancing 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 the following:

- Provide an 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.

### Impact

- Increase reliability and safety while reducing errors through best practices and guidelines for transmission and delivery (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 an open exchange of information on incidents and findings among participants via the 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 being used and provide guidance for improvements and development of error-insensitive procedures. The project also sponsors the annual Switching Safety and Reliability Conference that provides 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 is open to all interested parties.

## 2010 Products

Product Title & Description	Planned Completion Date	Product Type
<p><b>Recommendations for certification of switching personnel:</b> This project is a culmination of past research on industry practices and procedures for certification of switching personnel. It identifies the most common requirements and skills needed for certification and identifies a feasible certification process. It also evaluates the merits of industry-wide certification versus utility-level or regional certification and suggests the possible profile of a certification agency.</p>	12/31/10	Technical Update
<p><b>Switching Fundamentals Guide and Training Manual:</b> The EPRI Power Switching Safety and Reliability project has produced more than 25 valuable reports on this subject matter. Reports evaluate procedures for establishing error-preventing barriers, provide examples of errors and near-misses and derive "lessons learned", address situation awareness and human performance issues, and contain training materials. This project will complete consolidation of the various elements from previous reports into a comprehensive switching procedures guide and training manual. The guide and manual will be reviewed every few years as new materials become available.</p>	12/31/10	Technical Update
<p><b>Communication between field personnel and control center - Utility practices:</b> Communication between field personnel and control center personnel is often a major cause or contributor to switching errors and near-misses. This project completes a multi-year study of the subject, presents examples of communication that can lead (or has led) to errors, proposes measures to prevent communication errors, and proposes error-immune communications procedures. The results of this project can be used by utilities to gauge their performance against common industry practices.</p>	12/31/10	Technical Update
<p><b>Identifying error-likely situations in power switching:</b> This project will analyze know incidents and near-misses and will derive "lessons learned" with the goal of identifying situations and indicators of impending errors in power switching. This information will be used to devise means of preventing the occurrence of such dangerous situations, and in training personnel dealing with power switching.</p>	12/31/10	Technical Update
<p><b>Database of incidents and near-misses in switching:</b> This is an ongoing project that collects information on and reports of incidents and near-misses in power switching. A reporting template developed in 2008 is used to gather the essential information. The searchable database will be populated annually with new available information.</p>	12/31/10	Technical Update
<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>	12/31/10	Workshop, Training, or Conference

## Future Year Products

Product Title & Description	Planned Completion Date	Product Type
<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>	12/31/11	Workshop, Training, or Conference
<p><b>Database of incidents and near-misses in switching:</b> This is an ongoing project that collects information and reports on incidents and near-misses in power switching. A reporting template developed in 2008 is used to gather the essential information. The searchable database will be populated annually with new information.</p>	12/31/11	Technical Update
<p><b>Switching Fundamentals Guide and Training Manual:</b> The EPRI Power Switching Safety and Reliability project has produced more than 25 valuable reports on this subject matter. Reports evaluate procedures for establishing error-preventing barriers, provide examples of errors and near-misses and derive "lessons learned," address situation awareness and human performance issues, and contain training materials. This project will complete consolidation of the various elements from previous reports into a comprehensive switching procedures guide and training manual. The guide and manual will be reviewed every few years as new materials become available.</p>	12/31/11	Technical Update
<p><b>Identifying error-likely situations in power switching:</b> This project will analyze known incidents and near-misses and will derive "lessons learned" with the goal of identifying situations and indicators of impending errors in power switching. This information will be used to devise means of preventing the occurrence of such dangerous situations and in training personnel dealing with power switching.</p>	12/31/11	Technical Update

## 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 decision-making, 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	Description
P37.012	Circuit Breakers Condition Assessment and Life Extension	This project assesses the life-cycle performance of power circuit breakers which is, to a large degree, determined by the performance of constituent materials and components such as seals and o-rings as well as lubricants, compressors and hydraulic systems.
P37.013	Using Relays and Metering Data for Circuit Breaker Diagnostics	Microprocessor protective relays already installed for fault protection are connected to signals from circuit breakers, and can monitor the operation of breakers in normal service. The relays include AC measurements and programmable logic that can be configured to detect operating or timing problems and to flag breakers for maintenance attention before a breaker failure. Project P37.013 investigators are cataloging the specific breaker problems and detection methods, developing the breaker and system programming, and working with utility participants on practical challenges of deployment across fleets of relays and breakers. When developed, these diagnostic tools also support performance information gathering for breaker population asset management.

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

### Key Research Question

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 and sub-system performance to enable cost-effective methods for instituting condition-based maintenance or selecting work practices and tasks.

### Approach

To address these needs, this project will undertake the following:

#### Characterization and aging of lubricants, O-rings, seals, and gaskets:

- Collect and analyze samples of greases, oils, and hydraulic fluids to determine degradation and effective life
- Collect and analyze field-aged samples of circuit breaker components
- Catalogue examples and/or samples of utility lubrication related problems or parts failures
- Define and quantify HVCB lubrication technical issues
- Characterize possible consequences on breaker performance of degraded lubricants (e.g., slow trip, abnormal mechanism wear, compressor/pump failures)
- Characterize old grease, mixed grease, and dirty grease

**Assessment of industry best practices:** Gather information about current practices for lubrication of power circuit breaker mechanisms and equipment such as compressors, pneumatic and hydraulic systems, control relays, and switches

#### Combine knowledge gained about circuit breaker and disconnect switch lubrication into the following:

- A quantitative understanding of aging and deterioration rates.
- Expected life of circuit breaker component materials and subsystems.
- Enhanced cost-effective methods for implementing a condition-based maintenance approach.

## Impact

- 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.

## 2010 Products

Product Title & Description	Planned Completion Date	Product Type
<b>Report on power circuit breaker components and sub-system degradation modes:</b> This product will summarize results of ongoing research and outline a living development plan to investigate and understand degradation further. It will form the foundation of high voltage circuit breaker fleet management that will be developed.	12/31/10	Technical Update
<b>Field Guide: HVCB Component Degradation Condition Assessment – O-Rings, Seals and Gaskets:</b> This product will provide guidance on techniques for condition and degradation assessment of field aged o-rings, seals, and gaskets.	12/31/10	Technical Update
<b>Field Guide: HVCB Component Degradation Condition Assessment – Pumps, Compressors and Control Valves:</b> This product will provide guidance for recognizing and quantifying performance issues with pumps, compressors and control valves, and maintenance improvement for addressing these issues.	12/31/10	Technical Update
<b>New Versions of HVCB Lubrication Field Guide:</b> Existing versions of this guide focus on general guidance for the application and removal of lubricants, with member feedback on their effectiveness. New versions will help members select of the proper lubricant for specific applications, components, and sub-systems. Over time, guidance for disconnect switches will also be incorporated.	12/31/10	Technical Update

## Future Year Products

Product Title & Description	Planned Completion Date	Product Type
<b>Report on power circuit breaker components and sub-system degradation modes:</b> This deliverable will summarize results of ongoing research and outline a living development plan to investigate and understand degradation further. It will form the foundation of high voltage circuit breaker fleet management that will be developed.	12/31/11	Technical Update
<b>New Versions of Pictorial Field Guides - Power circuit breaker component degradation assessment and testing</b>	12/31/11	Technical Update
<b>New Versions of HVCB Lubrication Field Guides</b>	12/31/11	Technical Update

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

### Key Research Question

The widespread use of microprocessor-based protective relays has led to interest in better understanding a number of issues related to their possible application for circuit breaker condition monitoring and maintenance such as the following:

- Practical benefits and limitations of programming relays for diagnosis and reporting or alarming of circuit breaker condition. How helpful is relay data for discovering breaker malfunctions requiring maintenance and for gathering breaker population performance information for asset management?
- Ability to communicate useful diagnostic data, either raw or processed by relay programming, from typical transmission and delivery (T&D) substations.
- How to process communicated relay data into maintenance work orders and asset management extracts.
- Practical challenges in deploying relay program templates for breaker diagnosis and in accessing and using collected data and results.

### Approach

The focus of this project is to combine knowledge of circuit breaker diagnostics, characteristics, and malfunctions with understanding of analytic capabilities of microprocessor relays already connected for protection tasks, to develop a seamless approach to breaker diagnostics and maintenance. The practical breaker diagnostic tools comprise a combination of programming in relays and data gathering by communications with relays.

#### **Prior research on breaker diagnostics with relay data included the following:**

- Relay vendor engagement to document relay capabilities.
- Analysis and listing of breaker malfunctions and detection methods using in-service relay data, as compared to existing off-line maintenance diagnostic tests.
- Planning with selected EPRI members on practical easy-to-implement diagnostic techniques and beginning proposals and discussions of field demonstrations of those techniques.
- Gathering of utility field experience data and views through seminars and meeting discussions.

#### **The ongoing 2009 research program includes the following:**

- Using the listing of malfunctions and detection methods to develop logic and measurements for programming in microprocessor relays.
- Assessing the suitability of individual diagnostics for inclusion in first field demonstrations with participating members.
- Developing relay logic setting templates and a design for reporting or gathering diagnostic results and alarms, working with participating members.
- Conducting lab tests of circuit breaker diagnostic logic programmed in relays, and communications of diagnostic results.
- Beginning steps toward field deployment and commissioning across selected relay fleets at target utilities.
- Gathering experience-based inputs from circuit breaker manufacturers on breaker problems that relays can diagnose.
- Gathering any new utility field reports on breaker diagnostic experience.
- Creating a project report documenting work program, relay logic and programming, test results, and field deployment and field test plans.
- Continuing to report on North American Electric Reliability Corporation (NERC) PRC-005-02 development – Protection system condition-based maintenance opportunities and strategies leading to the reduction or elimination of time-based maintenance activities for relays and associated equipment. This separate but closely related task carries on in parallel with circuit breaker diagnostic work.

**The 2010 proposed research program includes the following:**

- Deploying logic templates and breaker condition reporting tools to the field in relay fleets of participating utilities.
- Commissioning installations and integrating alarms and report gathering.
- Analyzing initial results from the circuit breaker fleet and adjusting settings to distinguish reportable timing or performance issues of breakers.
- Collecting results of relay-based maintenance programs, including feedback from utility field engineering and maintenance staff.
- Creating a project report that documents the available field experience and results, and recommends further steps with utilities and vendors.
- Developing a knowledge base or field guide for circuit breaker diagnostics using relay data. This effort's timing depends on level of project support, implementation progress, and available results.
- Continuing to report on impact and opportunities or NERC PRC-005-2 as described above for 2009 work. This will continue as a major industry focus topic with impact and absorption issues for years to come.

**Impact**

Using the programmability and breaker diagnostics in relays and integrating this capability with maintenance programs as proposed in this ongoing project may offer the following:

- 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 (for example, modern protective relays have an innate monitoring capability, which is not widely used today).
- Support of a 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 or adapt tools and logic templates documented in project results to create practical implementations of breaker problem diagnosis and reporting with their own microprocessor relays. With these tools, they can more efficiently and effectively maintain breaker fleets, utilizing the value of capital investment in relays already installed nearby.

## 2010 Products

Product Title & Description	Planned Completion Date	Product Type
<p><b>Field Experiences of using Relay Data for Circuit Breaker Diagnostics:</b></p> <p>The technical report will contain the following:</p> <ul style="list-style-type: none"> <li>• An overview of the relay logic development and deployment program.</li> <li>• Relay logic templates and settings and breaker condition reporting tools, as developed for use at participating utilities, with technical explanations and documentation.</li> <li>• Experiences with commissioning installations and report gathering.</li> <li>• Analysis of available results from the live field circuit breaker fleet, including adjustment of logic and settings to distinguish reportable performance issues of breakers.</li> <li>• Discussion of feedback and experience from utility field engineering and maintenance staff.</li> <li>• Further steps.</li> <li>• A summary report on the effects and opportunities of NERC PRC-005-2, Protection System Maintenance. The focus is on progress in covering increasing percentages of the NERC-defined Protection System with condition-monitoring techniques and remotely analyzed time-based performance results to eliminate human testing activities.</li> </ul> <p>Depending on support level, implementation timing, and results that are available, either the 2010 or 2011 research project deliverables will include the following:</p> <ul style="list-style-type: none"> <li>• A knowledge base or field guide for circuit breaker diagnostics, using relay data.</li> </ul>	12/31/10	Technical Update

**PS37I Fault Current Management and Substation Equipment Rating (069264)**

## Project Set Description

Fault current levels are increasing in substations, and there is a growing need to increase the power flow through existing assets. This situation exerts greater stresses on substation equipment and poses new challenges for utilities. This project set provides resources and develops tools and technologies to address these issues. The "Fault Current Management Guidebook" (Maroon Book) is updated annually to provide utility engineers with a central resource to address pertinent issues and to raise awareness of the most recent approaches and techniques. The Ground Grid Evaluation project assists members in the design, evaluation, and refurbishment of substation ground grids (which have an increasingly important role in protecting workers within the substation and the public outside the substation fence) and proper operation of substation equipment. Solid state current limiters are being developed and, when commercially available, they will provide additional tools to manage increasing fault currents. Guides and tools will also be developed to help utility engineers address both static and dynamic ratings of substation components.

Project Number	Project Title	Description
P37.010	Solid-State Fault Current Limiter Development	This research project focuses on developing solid-state fault current limiters for transmission and distribution applications. It will start with prototype developments and then move into field demonstrations by deploying the fault current limiters at utility sites. Finally the operating experience of the fault current limiters will be documented.

Project Number	Project Title	Description
P37.014	Fault Current Management Issues	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.
P37.015	Ground Grid Evaluation, Maintenance, and Refurbishment	This project conducts research and develops guidelines and tools for design and performance evaluation of substation grounding grids.
P37.018	Increased Power Flow Guidebook and Ratings of Substation Equipment	Provide state-of-the-science reference and training materials for optimizing and increasing power flow through transformers and other substation equipment, and entire transmission circuits. Optimize the power transfer capabilities of transmission circuits safely, reliably, and in a scientifically justified manner that meets the requirements of FERC and other regulatory bodies.

## P37.010 Solid-State Fault Current Limiter Development (102105)

### Key Research Question

Continuing developments in solid-state power electronic switching devices are enabling enormous efficiency improvements in the electrical energy utilization sector. Increasingly, multi-megawatt solid-state power control systems are being 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. As more renewable generation such as wind and solar are added to the existing transmission and distribution systems, the fault current levels are increasing, and these need to be limited to protect the existing infrastructure. Deployment of power electronics-based solid-state current limiters at strategic transmission and distribution (T&D) locations is one way of limiting these fault currents to acceptable levels. In the near future there will be a need for transmission and distribution class solid-state fault current limiters (SSFCLs). This need can be met only by conducting research and building prototypes, followed by production-grade fault current limiters.

### Approach

This project is investigating opportunities for improving functionality within power substations through the implementation of power electronics, with a focus on future challenges and solutions. It will develop 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. The 2008 and 2009 work included 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 developmental projects, especially in the area of fault current limiters, will be initiated in 2010 and beyond.

EPRI is already collaborating with the U.S. Department of Energy (DOE) to develop a 69 kilovolt (kV) transmission class solid-state current limiter prototype. Additional efforts are underway to develop a 15 kV distribution class solid-state current limiter, collaborating with California Energy Commission. In addition EPRI is collaborating with the U.S. Navy and DOE to develop fault current limiters using Super Gate Turn Off

devices (S-GTOs) with advanced materials such as silicon carbide (SiC) and gallium nitride (GaN). The lessons learned from these collaborative projects will be useful to continue the fault current limiter development in 2010 and beyond. EPRI will continue to seek further collaborations with utilities, government agencies, and vendors to enhance and develop cost-effective solid-state fault current limiters.

### Impact

- Reduce environmental impacts by better utilization of existing power delivery infrastructure and by 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 use 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.
- Reduce fault currents using fault current limiters and thus save millions of dollars by avoiding equipment failures due to high fault currents.

### 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).

### 2010 Products

Product Title & Description	Planned Completion Date	Product Type
<b>SSFCL Design and Test Document</b>	12/31/10	Technical Update
<b>SSFCL Prototype Development:</b> Develop prototypes of solid state current limiters for transmission and distribution applications.	12/31/10	Hardware

### Future Year Products

Product Title & Description	Planned Completion Date	Product Type
<b>SSFCL Design and Test Document</b>	12/31/11	Technical Report
<b>SSFCL Prototype Development:</b> Develop solid-state fault current limiter prototypes.	12/31/11	Hardware
<b>SSFCL Field Demonstration:</b> Demonstrate solid-state fault current limiter at utility sites.	12/31/12	Technical Update
<b>SSFCL Field Demonstration:</b> Demonstration of solid-state fault current limiters at utility sites.	12/31/12	Hardware
<b>SSFCL Field Demonstration:</b> Demonstration of solid-state fault current limiters at utility sites.	12/31/13	Technical Report

Product Title & Description	Planned Completion Date	Product Type
<b>SSFCL Field Demonstration</b>	12/31/13	Hardware
<b>SSFCL Operating Experience:</b> Document the operating experience of the solid-state fault current limiters at utility sites.	12/31/14	Technical Update

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

### Key Research Question

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.

### Approach

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:

#### 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 technology. 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.

#### 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. It will include 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.

#### 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.

### Application of Advanced Technologies to manage Fault Currents

EPRI has been developing solid-state and superconducting current limiters to address the issue of limiting fault currents. 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.

### Impact

- 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 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.

### 2010 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 research and development (R&D) projects in this area.	12/31/10	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.	12/31/10	Technical Update

### Future Year Products

Product Title & Description	Planned Completion Date	Product Type
<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.	12/31/11	Technical Update
<b>Updated Fault Current Management Guidebook (Maroon Book):</b> Fault Current Management Guidebook will be updated with the latest information.	12/31/11	Technical Report

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

### Key Research Question

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.

### Approach

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 activity 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.

### Impact

- 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 grid repair based on sound economic principles.

## 2010 Products

Product Title & Description	Planned Completion Date	Product Type
<p><b>Training materials for Smart Ground Multimeter (final report or DVD):</b> EPRI funded the development of the Ground Grid Evaluator (commercially known as "Smart Ground Multimeter") instrument for assessment of substation ground grids, step and touch voltages, soil resistivity, and related substation grid parameters. Operation of the instrument is rather simple; however, interpretation of results in the field during the measurement session can be quite involved. This project will develop training materials to help technicians performing grid assessment interpret measurements and resolve difficulties that can occur in the field.</p>	12/31/10	Workshop, Training, or Conference
<p><b>Step and Touch Voltage Measurements on Field Installed Ground Grid and Concrete Slabs:</b> Concrete is used as building material in substations (within the substation fence) and around substations (outside the fence) for driveways, foundations, walkways, oil containment, sidewalks, walls, and more. This project will evaluate the effects of various types (reinforces, non-reinforced) and conditions (dry, wet) of concrete structures on step, touch and transfer-touch voltages in and around substations.</p>	12/31/10	Technical Update

## Future Year Products

Product Title & Description	Planned Completion Date	Product Type
<p><b>Training materials for Smart Ground Multimeter (final report or DVD):</b> EPRI funded the development of the Ground Grid Evaluator (commercially known as "Smart Ground Multimeter") instrument for assessment of substation ground grids, step-touch voltages, soil resistivity, and related substation grid parameters. Operation of the instrument is rather simple; however, interpretation of results in the field during measurement session can be quite involved. This project will develop training materials to help technicians performing grid assessment interpret measurements and resolve difficulties that can occur in the field.</p>	12/31/11	Workshop, Training, or Conference
<p><b>Develop cost-effective approaches to augmenting or repairing grounding grids:</b> This report will provide guidelines for augmenting grids to handle increased faults currents and to repair defective grids (grids that have been corroded over the years, inadvertently damaged by in-station construction activities or compromised by copper theft, and grids that have been improperly installed in the construction phase).</p>	12/31/11	Technical Update
<p><b>"Blind study" - three audits ("as is", "damaged", "repaired"):</b> Conduct a three-stage "blind" study using the Smart Ground Multimeter:</p> <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 damages) are 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 are performed by the utility, without informing the researchers of the details of the repairs</li> </ul>	12/31/12	Technical Report

## P37.018 Increased Power Flow Guidebook and Ratings of Substation Equipment (069265)

### Key Research Question

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

### Approach

This project develops and delivers an industry guidebook, training, software tools, and methodologies for the purpose of increasing the power capacity of transmission circuits (including transformers and other substation equipment) without the capital costs of major new equipment purchases. The *Increased Power Flow Guidebook* (the IPF Guidebook) documents state-of-the-science technical options for increasing power flow on transmission and substation equipment. The guidebook, along with its *IPF Wizard* and training materials, provides a means to guide engineers, operators, designers, and planners in applying increased power flow strategies for transformers and other substation equipment. It also provides learning materials for the next generation of power industry personnel. In 2008, the IPF Guidebook was published with a “platinum” color and became part of EPRI’s color book series. In 2010 EPRI will publish a new edition of the IPF Guidebook.

The new edition will add case studies related to design, engineering, system planning, and operations. Also, the existing material will be updated with the latest developments, and the presentation of visual materials will be improved. Information on improved thermal models of substation equipment will be included, as will developments of new instruments and other hardware. The IPF Wizard and training materials will also be updated with the latest information.

This project will also continue with the development of software and methodologies for increasing and optimizing the power transfer capabilities of transmission lines. The software products being developed can be used:

- for real-time ratings,
- to help operators get through emergency situations safely,
- for rating studies to help meet the FERC requirements regarding setting reliable and safe substation equipment ratings, and
- for forecasting circuit ratings hours or days into the future to facilitate bulk power transfer planning, and
- for optimizing daily power flows.

The products being developed include:

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

The DTCR and DAP programs will be significantly improved to make them more accurate, robust, user friendly, and acceptable to a conservative utility culture. Ultimately, they will be combined into a single workstation environment in order to make their features more widely applicable. The project also develops methodologies for establishing transmission circuit ratings to optimize power capacity within the practical constraints of the utility's operating philosophy, while fulfilling FERC, and other requirements. This project focuses on transformers and other substation equipment, and it is executed in coordination with corresponding projects for underground cables (project P36.004) and for overhead lines (P35.013).

## Impact

- Provide guidance and training to new and experienced technical personnel
- Increase and optimize power flow through entire transmission circuits, including transformers and other substation equipment
- Defer capital expenditures
- Improve transmission circuit reliability and safety
- Meet new mandatory FERC requirements for circuit ratings
- Optimize power transfer planning
- Optimize energy transactions through rating forecasts
- Ride out emergency situations safely and reliably
- Avoid unnecessary system outages

## How to Apply Results

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

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

## 2010 Products

Product Title & Description	Planned Completion Date	Product Type
<b>Increased Power Flow Conference:</b> As part of its technical transfer activities, EPRI sponsors a biennial conference on the topic of Increased Transmission Capacity. Project P37.018 will cosponsor the activity in 2010 and will present sessions on the recent developments and applications of the technology.	11/30/10	Workshop, Training, or Conference
<b>IPF Guidebook (Platinum Book), Third Edition :</b> A technical report will be published as the next version of the <i>Increased Power Flow Guidebook</i> (also known as the "Platinum Book"), as part of the EPRI color book series.	12/31/10	Technical Report
<b>IPF Trans Circuit Rating Wizard, 2.0:</b> The IPF Wizard will be updated to reflect the latest IPF developments discussed in the IPF Guidebook.	12/31/10	Software
<b>DTCR 5.1:</b> The Dynamic Thermal Circuit Rating program will continue to be developed and enhanced in 2010 to make it more accurate, robust, and user friendly to a conservative utility culture. Several significant features will be added.	12/31/10	Software
<b>DAP 2.0:</b> The Data Analysis Program (DAP) is a software product designed to work in conjunction with other programs, particularly DTCR, for the purpose of pre-processing and post-processing data, performing data analysis, and providing data plots and graphical user interfaces for ease of application. It is particularly useful for performing statistical data analyses of rating data for optimizing an approach to static ratings that meets the scientifically rigorous requirements of regulatory bodies. In addition, the product provides tools to help ride out emergency situations.	12/31/10	Software

## Future Year Products

Product Title & Description	Planned Completion Date	Product Type
<b>Transmission Circuit Ratings Workstation 1.0:</b> Following the development of updated versions of the DTCR and DAP software, they will be integrated into a comprehensive workstation.	12/31/11	Software
<b>Transmission Circuit Ratings Workshop:</b> A workshop will be conducted to cover the Transmission Circuit Rating Workstation. It will include presentation of the underlying concepts and hands-on software exercises.	12/31/11	Workshop, Training, or Conference
<b>Increased Power Flow Guidebook, Technical Update:</b> New material on the latest IPF technologies will be produced as a Technical Update.	12/31/12	Technical Update
<b>Transmission Circuit Ratings Workstation 2.0:</b> The Transmission Circuit Ratings Workstation will go through its first revision following a year of experience. It will be improved using feedback from EPRI member engineers, operators, designers, and planners.	12/31/12	Software
<b>Increased Power Flow Conference:</b> This project will cosponsor and participate in an open technical transfer activity, such as an IPF Conference.	12/31/13	Workshop, Training, or Conference
<b>Increased Power Flow Guidebook, Fourth Edition :</b> Following four years of application and new developments, an updated version of the IPF Guidebook will be planned for release in 2014.	12/13/14	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 electromechanical and first generation semiconductor relays. This project set helps utility engineers make a seamless transition to numeric relays and help extract the most value from their investment.

This project set consists of two projects. The first supports intelligent transition to numeric relays. This project will include best-in-class practices for reliability, cyber security, spare parts policies, misoperation indices, issues with design (enclosures, plug and play), relay failure root cause analysis, event analysis, and electronic advisories for urgent fixes. The second project supports deployment of numeric relays to enable an 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	Description
P37.016	Emerging Issues for Managing Protective Relays	This project addresses new issues when using digital protection devices including relay fleet management, cyber security challenges and event interpretation.

Project Number	Project Title	Description
P37.017	Next Generation Relays	This project will develop functional requirements for future protection devices including wide area communications, parameter management and audit trails.

## P37.016 Emerging Issues for Managing Protective Relays (067440)

### Key Research Question

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.

### Approach

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

- Standardization issues
- Relay miss-operations
- Event analysis
- Design issues
- Root cause analysis
- Security issues
- Maintenance issues

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

### Impact

- Demonstrate commitment to a more reliable supply of power through better approaches to dealing with protective relay issues.
- Share best practices among utilities in the areas of protection and control.
- Reach higher levels of cyber security by making the protective relaying more secure and hack resistant.

### How to Apply Results

Utility engineers can use the knowledge 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 controls.

### 2010 Products

Product Title & Description	Planned Completion Date	Product Type
<b>Synchrophasor Issues:</b> This project will address the variety of issues related to enabling synchrophasors with the utility environment. It will address implementation issues for both stand-alone and relay-based units, connection to NASPInet, communication issues, and other related topics.	12/31/10	Technical Update

Product Title & Description	Planned Completion Date	Product Type
<b>Technical Workshop:</b> Workshop addressing emerging protective relay issues.	12/31/10	Workshop, Training, or Conference
<b>Emerging Protective Relay Issues:</b> This product is a technical resource that covers a variety of protective relay issues of interest to relay system designers, field technicians, and other interested parties involved in the test and management of these systems.	12/31/10	Technical Update

### Future Year Products

Product Title & Description	Planned Completion Date	Product Type
<b>Technical Workshop:</b> Workshop addressing emerging protective relay issues.	12/31/11	Workshop, Training, or Conference
<b>Emerging Protective Relay Issues:</b> Technical resource covering a variety of protective relay issues of interest to relay system designers, field technicians and other interested parties involved in the test and management of these systems.	12/31/11	Technical Update
<b>Synchrophasor Issues:</b> This project will address the variety of issues related to enabling synchrophasors with the utility environment. Implementation issues for both stand alone and relay based units, connection to NASPInet, communication issues and other related topics	12/31/11	Technical Update

## P37.017 Next Generation Relays (067441)

### Key Research Question

As the electric power industry moves forward with development of a 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, it would be difficult to deliver a rapid response using the current method. New computer-based tools and product enhancements are necessary to effectively manage these large deployments.

### Approach

This multiyear project will address a number of research areas. One of this project's most critical aspects 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 conduct the following activities:

- Assess the current state of utility technology and practices to identify key relay issues facing utilities

- Facilitate cross-industry learning through idea exchange with the 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

### Impact

- 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 this project's results 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 acquired 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 participate in the requirements specification development, thereby enabling more efficient implementation and management of these devices. This document will facilitate smoother transition to these devices at participating utilities.

### 2010 Products

Product Title & Description	Planned Completion Date	Product Type
<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 the software support tools needed. The product will contain 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.	12/31/10	Technical Report

### Future Year Products

Product Title & Description	Planned Completion Date	Product Type
<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 the software support tools needed. The product will contain 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.	12/31/11	Technical Update