39 Grid Operations

Program Overview

Program Description
Grid operation is a fundamentally important function for utilities, transmission companies, and ISOs/RTOs. EPRI's Grid Operations program has been providing critically needed technologies and information for its members over many years.

In 2009, the Grid Operations program will offer its members a focused research portfolio that will provide the major benefits of more reliable grid operations and increased grid operator effectiveness. There are three major focused areas:

- Situational Awareness helps system operators improve monitoring and visualization capabilities
- Online Stability and Control helps system operators improve real-time analyzing and controlling capabilities
- Controlled Separation and System Restoration helps system operators improve restoring capabilities and reduce outage cost

By providing the state-of-the-art technologies that enable a reliable power grid, this program will allow members to take technical leadership in the industry.

Industry Needs and Issues Addressed

- Operate transmission system under complex conditions
- Improve reliability of grid operations and prevent blackouts
- Improve wide-area protection and control performance
- Improve understanding of cascading failures and capability to recognize vulnerable operating conditions
- Improve capability to handle extreme events and restore system
- Manage increased power flows associated reliability risks

Impact

- Improve system reliability and reduce operational risks
- Improve real-time situational awareness
- Increase transfer capability and reduce congestion cost
- Increase controllability and effectiveness of system operation
- Reduce the risk of blackout and restoration time to reduce outage cost

Key Accomplishments

- Developed tools such as Community Activity Room (CAR), Power System Voltage Stability Region (PSVSR), and Power System Transient Stability Region (PSTSR) for online visualization of operating boundaries due to thermal, voltage, and transient stability constraints. ()
- Developed international standard of Common Information Model (CIM) starting with energy management system applications
- Developed neural network-based short-term load forecasting and wind forecasting tools (ANNSTLF)
- Developed Operator Training Simulator (OTS)
- Developed online tools for available transfer capacity (TRACE)
- Developed online tools for dynamic security assessment (DSA)
- Developed Dynamic Tutorial training book

Current Year Objectives

- Technical update on proof of concept for combined MW Flows and MVAR-voltage-related alarm message root cause diagnostics
- Technical report on wide area system visualization
- Online Risk Monitor of Potential Cascading Outages software
- On-line Field Demonstration of Reactive Power management tool
- Technical report on measurement-based voltage stability monitoring and control for load center
- Technical report on the detection and mitigation of inter-area oscillations using PMU measurements
- Technical report on interactive system restoration strategies
- Technical report on application of PMU for controlled separation, load shedding, and generation rejection

Industry Involvement

- Estimated 2009 funding: $2.2M

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Summary of Projects

PS39A Situational Awareness (067422)

Project Set Description: The objective of this project set is to improve system operators' situational awareness and monitoring capability.

Project Number	Project Title	Value
P39.001	Advanced Alarm Management	During a potential cascading event, grid operators need to assess thousands of alarm messages. In many cases today, grid operators suffer from information overload, which impairs their ability to implement corrective actions in timely fashion to prevent continuing cascading events. This project will develop an advanced alarm management system using model-based technology with online real-time root-cause analysis to help system operators quickly identify the root causes of the event and implement the appropriate corrective measures to prevent a cascading blackout.
P39.002	Technology Assessment on Wide Area Power System Visualization	Visualization techniques to improve operators' situational awareness have received increasing attention in recent years. A number of research organizations and utilities have already made efforts in this area. In 2009, this project will perform an extensive survey of wide-area power system monitoring and visualization to understand the existing visualization technologies, implementation experiences, areas for further improvements, and new requirements for next-generation power system visualizations.

Project Descriptions

P39.001 Advanced Alarm Management (055940)

Issue

During a potential cascading event, grid operators need to assess thousands of alarm messages, quickly identify the root causes of the event, and implement the appropriate corrective measures to prevent a cascading blackout. In many cases today, grid operators suffer from information overload, which impairs their ability to implement corrective actions in timely fashion to prevent continuing cascading events. Cascading outages can cost millions or even billions of dollars in direct costs and socioeconomic impacts.

Description

This project will develop an advanced alarm management system using model-based technology with online real-time root-cause analysis. The project will also include research in situational awareness, visualization, and developing operator guides on remedial actions and human factors.

A supplemental project on model-based alarm management was initiated in 2006. It demonstrated the potential superiority of this method over rule-based or artificial intelligence alarm processing. The software developed by GoalArt was enhanced to enable automatic model generation. In 2007, this project was continued in Program 127, which investigated the challenges of root-cause diagnosis under changing power flow patterns. In 2008, continuing research will expand root-cause diagnosis capabilities to include voltage and reactive power events. Research in the standardization of human-machine interface for enhancing operator situational awareness is scheduled to be performed also in 2008. For 2009, an approach will be developed to combine MW flows and MVAR-voltage root cause relationships into a demonstration with historical alarm messages. A study will be done to analyze the effectiveness of the method to reduce the number of messages to those most meaningful and informative to operators. This work will be issued as a request for proposals for vendors of energy management systems to respond, with cost-sharing. The objective is to move the technology into commercialization.

Situational awareness research will also continue in the direction of controllability awareness and predictive awareness.

Value

- Save millions of dollars in economic losses from cascading blackouts by reducing the probability of such blackouts.
- Reduce information overload with effective online diagnosis tools so grid operators can quickly identify root causes among potentially thousands of alarm messages.
- Enable grid operators to implement corrective actions in real time to prevent continuing cascading events with correct diagnosis of root causes.
- Speed operators’ ability to recognize potential problems and take corrective actions with better human factor designs.
- Simplify grid operators’ tasks of monitoring wide-area transmission grids through enhanced visualization of system stressors with drill-down capabilities at various levels.
- Afford operators more lead time to head off any potential problems later in the day by providing predictive situational awareness.

How to Apply Results

The alarm management tool will be used by control room operators to identify root causes during alarm cascades, thereby providing them with critical information necessary to take corrective action quickly. The intent is to commercialize the alarm management tool in conjunction with commercial vendors of energy management systems, using supplemental projects funded by EPRI members. Results of this research will also be available to EPRI members as a demonstration system in the form of the EPRI Operator Training Simulator (OTS) integrated with the alarm management module. A demonstration can be arranged by contacting the EPRI project manager of this project. Research results will also be published in technical updates for EPRI members' use as training materials on situational awareness for grid operators.

2009 Products

Product Title & Description	Planned Completion Date	Product Type
Proof of Concept for Combined MW flows and MVAR-Voltage-related Alarm Message Root Cause Diagnostics: A technical update report proving the combined method of alarm message root cause diagnosis of MVAR-voltage-related and MW flows alarm messages in a realistic demonstration of historical alarm messages.	12/31/2009	Technical Update

Future Year Products

Product Title & Description	Planned Completion Date	Product Type
Commercial Alarm Management: Software implementing the advanced alarm management methods to be developed by the commercializer of this technology, with cost sharing by the commercializer.	2010	Software

P39.002 Technology Assessment on Wide Area Power System Visualization (067444)

Issue

Operators and reliability coordinators of large interconnected power systems need to improve situational awareness about the current, hour-ahead, and day-ahead system operating conditions under a range of normal and potential contingency operating scenarios. The North American Electric Reliability Corporation (NERC) has recently launched the North American Synchronous Phasor Measurement Initiative (NASPI). More and more GPS-based synchronous phasor measurement units (PMU) will be installed in the Eastern Interconnection and Western Electricity Coordinating Council (WECC) systems. Currently, the potential of synchronous PMU measurements has not been fully utilized.

EPRI recently performed research and development in the area of power system visualization using Smart Client technology with PMU measurements and power system data from EMS system. More R&D effort is required to develop advanced visualization applications using real-time PMU and other real-time or historical power system measurements to provide wide-area visualization tools that improve situational awareness, identify and display the location of disturbances when they occur, show the related operating margins in various operating conditions, investigate corrective or preventative controls, and predict and avoid, whenever possible, potential cascading outages. Existing power system visualizations do not provide sufficient corrective or preventive controls that operators can use to improve system reliability or prevent large cascading outages. The R&D and implementation of the wide-area power system visualization should consider the framework, integration, and requirements of the advanced wide-area monitoring, visualization and control systems.

Description
This project will include the following technical tasks:
Phase 1 (2009)

- Perform an extensive survey of wide-area power system monitoring and visualization to understand existing visualization technologies, implementation experiences, areas for further improvements, and new requirements for next-generation wide-area power system visualizations.
- Organize a workshop focusing on wide-area power system visualization. The workshop will include presentations and discussion of existing and future power system visualization technologies, user experiences, best practices, and new requirements and recommendations.
- Prepare a final report to describe the results of the survey and the functional requirements, implementation guidelines, and recommendation for next-generation-wide-area power system monitoring and visualization technology.

Phase 2 (2010)

- Work with vendors to develop next-generation wide-area power system monitoring and visualization, which will incorporate the new technologies and implement the advanced features and recommendations described in the final report (2010) of this project.
- Prepare a technical update report for the R&D project.

Value

- Improves operator situational awareness of current and future wide-area operating conditions under various operating scenarios
- Enables power system operators or reliability coordinators to make informed corrective or preventive controls to improve system security and reliability, and to prevent potential large-scale cascading outages
- Allows operators, regional coordinators, and power system engineers to perform the replay and engineering analysis of existing large system disturbances
- Enables early detection of potential system disturbances so that operators may implement protective measures rapidly and avoid cascading events.
- Strengthens grid reliability and robustness
- Reduces the economic impacts of cascading outages to member companies and their customers

How to Apply Results
This project is aimed at power system operators; operational planning engineers, including ISO/RTOs and transmission operators; transmission planners and control center operation management; and regional reliability coordinators. The final report of this R&D project will provide valuable information related to the current status, future direction, requirements, and guidelines for the R&D and implementation of wide-area monitoring and visualization. Members can participate in demonstration projects and share their experiences in implementing wide-area power system monitoring and visualization technology. Depending on their needs, members can also use applications developed through this project to:

- Transfer research results, best practices, implementation guidelines, and recommendations on wide-area power system visualization via technical report, webcasts, and workshops
- Participate in the EPRI Situation Awareness task force
- Install the wide-area power system visualization and detection of large disturbance applications in a central location for each interconnection (for example, one location for WECC and one or two locations for Eastern Interconnection) and interface the applications with the related PMU database.
- Install the wide-area power system visualization software in the control centers of an ISO/RTO or an electric utility and interface with the utility's real-time or historical database. A user group will be established to share knowledge and other software applications. EPRI will provide technical support for software installation and integration, and will provide training.

2009 Products

Product Title & Description	Planned Completion Date	Product Type
Final Report – Wide area power system visualization: The wide-area power system visualization report will describe the survey results of the wide-area power system visualization project, its functional requirements and implementation guidelines, and recommendations for next-generation wide-area power system monitoring and visualization.	12/31/2009	Technical Report

Future Year Products

Product Title & Description	Planned Completion Date	Product Type
Next generation power system visualization application: The next-generation wide-area power system visualization application will include an executable application, a user guide, and an installation guide.	2011	Software
Technical Update: The technical update report for the wide-area power system visualization will describe: • R&D results of next-generation power system visualization. • Results of the EPRI demonstration project of the wide-area power system visualization: • Technical approach • Implementation guidelines • Experiences and lessons learned • Further improvements and recommendations	2010	Technical Report

PS39B Online Stability & Control (067423)

Project Set Description: The objective of this project set is to help system operators improve controllability in order to minimize the impact of the contingency on the transmission grid.

Project Number	Project Title	Value
P39.003	Reactive Power Management and Control	This project will focus on developing highly automated methods for effective reactive power management, considering all critical contingencies and power transfer scenarios. More effective use of reactive power sources/sinks and voltage control from generation and transmission facilities will improve power system operation reliability, security, and the functioning of electricity markets.

P39.004	Measurement-based Voltage Stability Monitoring and Control	Current voltage stability assessment (VSA) adopts a simulation-based approach and relies on the state estimator to provide a steady-state solution. In extreme operating conditions when state estimator fails to converge, online VSA programs also fail to help operators monitor and control system voltage stability. Given the limitations of VSA program, this project investigates using measurement data to calculate voltage stability margin in real time to help system operators monitor system voltage stability.

Project Descriptions

P39.003 Reactive Power Management and Control (063323)

Issue
Today, the critical role of reactive power is not adequately recognized in negotiating power market contracts or considering ways to prevent loop flows that contribute to system congestion. For example, generators can either supply or absorb reactive power but are compensated for real power, so that increasingly complex economic and technical trade-offs must be made when determining how particular generators should be dispatched. Grid operators may not know how much reactive power reserve exists in a region nor what is needed to prevent a voltage collapse if the next contingency should occur. Contributing causes in recent blackouts have been the lack of reactive power reserve in a region to handle the next contingency.

Description
The Interregional Reactive Power Management (IRPM) project aims to develop better methods for effective reactive power management, considering all nonlinearities, for efficient use of reactive power sources and sinks and voltage control from generation and transmission facilities. These methods will improve power system operation reliability, security, and the functioning of electricity markets. Managing reactive power more effectively in large, interregional power systems can help improve utilization of transmission assets, reduce congestion, and increase power transfer capabilities over the existing infrastructure to meet increased demand.

The objectives of the project are to:

- Develop a highly automated method that can identify “coherent reactive power zones” or “critical voltage control areas” (VCAs) using Decision Tree (DT) techniques from on-line system snapshots (for wide ranging topology, conditions, transfers and contingencies).
- Determine required reactive power reserves using regression trees (RT) for each of the identified VCAs using key system attributes. DTs and RTs have the added benefit of identifying the most important parameters associated with a specified outcome, such as voltage instability. This is expected to provide valuable information to operators.
- Identify the optimal size, location, and type of needed static and dynamic reactive power support.
- Enable the continuous monitoring of reactive power reserves versus anticipated contingencies.
- Identify the most effective remedial action to avoid voltage instability and blackouts

The current status of the project is:

- An off-line identification framework has been developed. The framework is clearly identifying voltage control areas, areas prone to voltage instability, system conditions and contingencies, margins to voltage instability, critical contingencies, reactive power reserve requirements, and allocation of reactive power reserves amongst generators.
- On-going work aims to extend the developed framework for use in the on-line real-time environment.

Value

- Defers capital investment by increasing capacity of existing transmission grids by effectively managing reactive power resources and reserves
- Improves transmission grid performance by avoiding voltage instability and voltage collapse events
- Quantifies the effect of managed reactive power on increasing real power transfer levels of security-market-constrained transmission grids
- Improves performance and quality of power delivery by avoiding system-wide blackouts

How to Apply Results

Electric utility system operators and planners will use the technical results from this project to improve grid reliability by establishing reactive power reserve criteria and monitoring reactive power reserve margins in various voltage control areas. Transmission planners will be able to defer capital investment, and improve transmission grid performance and power quality, by effectively managing reactive power resources and reserves.

2009 Products

Product Title & Description	Planned Completion Date	Product Type
On-line Field Demonstration of Reactive Power Management tool: This technical update report will document the on-line pilot field demonstration results of the developed reactive power management tool in order to establish an implementation procedure and identify needed enhancements.	12/31/2009	Technical Update
Reactive Power Management Software: The reactive power management tool offers system operators an effective tool to monitor power system voltage stability.	12/31/2009	Software

Future Year Products

Product Title & Description	Planned Completion Date	Product Type
Experience of Applications of the IRPM at Utility Grids	2010	Technical Report

P39.004 Measurement-based Voltage Stability Monitoring and Control (067445)

Issue

Voltage stability is a major concern in power system operation and a leading factor that limits power transfers in the prevailing open access environment. Voltage stability assessment (VSA) is a computer simulation tool to help operators monitor and control system voltage stability. The accuracy of VSA results fully depends on the accuracy with which the generation, load, and transmission facilities are modeled. Uncertainties in these factors pose challenges to obtaining accurate voltage stability analysis results using VSA program, which may in turn lead operators to make incorrect decisions and increase the risk of voltage collapse. Moreover, VSA program also relies on the state estimator to provide steady-state solution for further analysis. In extreme operating conditions when state estimator fails to converge, VSA programs also fail to help operators monitor and control system voltage stability.

Given the limitations of VSA program, this project investigates using measurement data at the substation level to calculate voltage stability margin in real time and send that information to the control center to help system operators monitor system voltage stability.

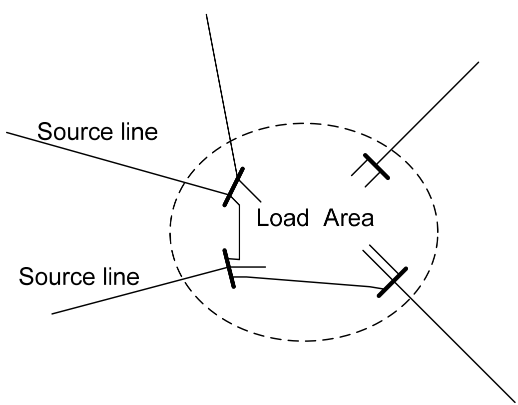
Description

EPRI invented a new algorithm titled "Voltage Instability Load Shedding (VILS)" that is able to calculate the voltage stability margin continuously at a local bus using measured voltage and current waveforms. The calculated voltage stability margin, which is expressed as active, reactive, and apparent power, can be used as the adaptive criteria to determine when the load at this local bus reaches the maximum value due to voltage stability limit. The VILS algorithm can be used to monitor and control local load buses.

However, a voltage stability problem is not just a local problem. The next level of voltage stability problem is load center, generally defined as a particular geographical area where load demand is high. A load center usually has few local power plants. Therefore, a high proportion of load needs to be provided by the external system. Generally, a load center has the following properties:

- Local power plants can not satisfy the local power demand
- The load center is supplied by multiple sources through a numbers of substations
- Heavy power flows on the interface transmission lines.

Because of these properties, a load center is typically a voltage-weak area more susceptible to voltage instability. The figure below illustrates a load center supplied by multiple power sources.



To monitor and control the voltage stability of a load center supplied by multiple power sources, the following issues need to be investigated in 2009.

- Determine the key substations of the load center, which is supplied by multiple power sources through a number of substations. Those substations are key substations that need to implement the VILS algorithm to calculate the voltage stability margin. A load center has its own mesh network that serves the local loads. The voltage stability margin calculated at each individual key substation cannot represent the voltage stability margin of the entire load center.
- Develop a new method to calculate the voltage stability margin for an entire load center using the voltage stability margin calculated at its key substations. The voltage stability margin is calculated in terms of active and reactive power. This can help system operators understand how much more power can be transferred before the load center reaches the voltage stability limits.
- Validate the new method using the time domain simulation. A practical power system will be used for validation purposes. Time domain simulation will be performed to simulate the voltage collapse scenario of a load center. The simulated data will be used as the measurement data to validate whether the developed new method can correctly identify the voltage collapse problem.

This measurement-based voltage stability monitoring and control project is visualized as a multi-year R&D effort. Once measurement-data can be used to monitor and control the voltage stability condition at the control center level, the next step is to move toward control at the load center level. As a result, system operators will be able to monitor and control voltage stability of the entire transmission system.

Value

- Improve system operators' capabilities to monitor and control voltage stability of the transmission system
- Avoid the potential problems of using simulation-based online Voltage Stability Assessment method
- Prevent wide-area voltage collapse

How to Apply Results

The results of this project offer system operators a new method to monitor and control voltage stability condition at the load center level. System operators first need to implement the VILS algorithm at a load center's key substations to calculate the voltage stability margin at those substations. The calculated voltage stability margin at each key substation will be transmitted to a central substation of the load center or the control center. System operators then apply the new developed method from this project to calculate the voltage stability margin for the entire load center using the voltage stability margin calculated at individual key substations.

EPRI also provides an application service to help utility members implement this technology through supplemental projects.

2009 Products

Product Title & Description	Planned Completion Date	Product Type
Measurement-based Voltage Stability Monitoring and Control for Load Center: This technical report will document the methodology and validation results of measurement-based voltage stability and control for load centers.	12/31/2009	Technical Report

PS39C Controlled Separation and System Restoration (067424)

Project Set Description: The objective of this project set is to help system operators separate the out-of-step transmission network in a controlled manner and restore the system quickly after a blackout occurs.

Project Number	Project Title	Value
P39.005	Interactive System Restoration Strategy	Power system restoration is well recognized as one of the most important tasks of system operators. Restoration plans are developed off-line and then used as guidelines for dispatchers in an on-line environment. Operators need to adapt to the actual outage scenario and available resources, and be able to develop a strategy based on their experience. In 2009, this project will focus on developing interactive system restoration strategies. It will develop the necessary computational methods and tools for evaluating system restoration strategy options. This will help system operators improve system restoration procedures and reduce system restoration time, thereby improving the reliability of the transmission system.
P39.006	Application of PMU for	Controlled separation of the network before its passive islanding is

Project Number	Project Title	Value
	Controlled Separation, Load Shedding and Generation Rejection	an effective resort to mitigate severe cascading failures by directly isolating the faulted area or disconnecting already out-of-step areas in a designed manner. This project will address where, when, and how to separate the network, and what steps should be taken after separation.

Project Descriptions

P39.005 Interactive System Restoration Strategy (065229)

Issue

Power system restoration is well recognized as one of the most important tasks of system operators. System reliability depends heavily on the efficiency of system restoration. Following a power outage, system operators in the control center work with field crews to re-establish the generation and transmission systems and then pick up load and restore service. Unfortunately, few decision support tools are available to system operators and restoration planners today. Restoration plans are developed off-line and then used as guidelines for dispatchers in an on-line environment. Operators need to adapt to the actual outage scenario and available resources, and be able to develop a strategy based on their experience.

Past blackouts are powerful reminders that system restoration requires advanced decision support tools. Blackout events and aging transmission infrastructures in the United States demand that great attention be paid to R&D for system restoration and its associated decision support tools.

Description

This project will continue R&D efforts undertaken in 2008. In 2008, this project investigated adaptive islanding schemes that divide the system in response to real-time, out-of-step conditions, and then balance the generation and load within islands. This project also completes the review of industry practice in system restoration area.

In 2009, this project will focus on developing interactive system restoration strategies. It will develop the necessary computational methods and tools for evaluating system restoration strategy options. This will help system operators improve system restoration procedure and reduce system restoration time, thereby improving the reliability of the transmission system.

This project has the following tasks:

- Task 1: Develop a computational method for development and evaluation of system restoration strategy options. This task will provide computational models and techniques for the generic restoration milestones during system restoration, such as cranking non-black-start units with black start units, forming electrical islands, and establishing transmission grids.
- Task 2: Develop analytical techniques to estimate the time to restore service to subsystems and the entire system.
- Task 3: Simulate the proposed restoration strategy with realistic system models. Computer simulations of the proposed algorithm will be performed on realistic power grid models. Industry advisors will be consulted concerning the specific systems and scenarios that will be incorporated in this project. The scenarios will include outages of subsystems and a complete shutdown.

To accomplish the above tasks requires multi-year R&D efforts. Once the interactive system restoration strategy software is developed, the next step is to integrate this tool with EPRI Operator Training Simulator (OTS) so that system operators can practise system restoration strategies.

Value

- Improve grid reliability by reducing outage durations via quick grid restoration.
- Reduce economic impacts caused by major power outages DOE estimates the cost of a major blackout in the United States to be $4–$6 billion.

How to Apply Results

System operators can use the interactive and systematic restoration strategies document to learn advanced system restoration strategies and update their system restoration procedures using those strategies. EPRI plans to organize a workshop and training service to help utility members enrich their system restoration knowledge.

2009 Products

Product Title & Description	Planned Completion Date	Product Type
Interactive System Restoration Strategies: This technical report will document the algorithm for computation and evaluation of restoration strategy options.	12/31/2009	Technical Report

P39.006 Application of PMU for Controlled Separation, Load Shedding and Generation Rejection (067446)

Issue

Many utilities are operating power systems closer to security limits in order to meet the requirements of rapidly growing electricity market. Thus, there is a higher probability that unexpected events may cause cascading failures that, if spread in an uncontrolled manner, could separate a transmission system into unsustainable islands—for example, with excessively imbalanced generation and load that would inevitably cause large-area power outages. Controlled separation of the network before its passive islanding is an effective resort to mitigate severe cascading failures by directly isolating the faulted area or disconnecting already out-of-step areas in a designed manner. To realize successful controlled separation, the following key issues need to be addressed:

- Where to separate the network? Most existing controlled separation strategies determine the boundaries of islands by engineering experiences or offline studies based on typical operating conditions and generator grouping modes. However, without making use of online information, the offline-determined boundaries may not succeed in separating the system into sustainable islands. Thus, a big challenge is to solve the issue online, making effective use of online and even post-fault information.
- When and how to separate the network? That is, determining the separation timing and coordinating the actions of separation devices such as out-of-step relays. Most utilities open the lines across predetermined boundaries according to local measurements; however, that may lead the separation in an uncontrolled manner and even trigger more severe cascading failures. To achieve a really controlled separation, criteria for determining the separation timing at the system level must be developed to specify which separation devices should be coordinated to disconnect the right group of lines at the same time.
- What must be done after separation? Load shedding/generation rejection schemes are being used by utilities to maintain acceptable frequencies and voltages under disturbances. The action of separation—either controlled or uncontrolled—can be regarded as a special, system-wide disturbance that generates separate islands. Thus, operators should investigate whether a particular load shedding/generation rejection scheme is suitable for post-separation control in each island. A new scheme may need to be developed and deployed.

PMUs installed in transmission systems provide important real-time data for solving the above issues. A methodology for controlled separation based on PMUs needs to be developed.

Description
This multi-year project develops a methodology of applying PMUs to address the above key issues in controlled separation by conducting the following tasks:

- Task 1: Solve the “where” issue. The project team will develop a PMU-based scheme for determining the boundaries of islands in real time, which includes two stages: offline screen out potential boundaries that all satisfy given conditions, such as avoiding islands with large generation/load imbalances and overloaded transmission lines; and real-time identification of the generator grouping mode and optimization of the island boundaries among the potential options determined offline.
- Task 2: Solve the “when” and “how” issues. The project team will investigate and develop criteria for determining separation timing at the system level and design PMU-based out-of-step relays, which could be placed at potential boundaries of islands. Once the criteria indicate good separation timing, the operator may coordinate the relays on the optimal boundaries determined in real time to disconnect the lines between islands.
- Task 3: Solve the “what” issue. The project team will investigate load shedding/generation rejection schemes under separation conditions, and then develop a post-separation control scheme to stabilize each island and regulate frequencies and bus voltages.

For this multi-year project, the EPRI project team will focus on Task 1 in 2009. Future research directions will be influenced by the inputs from the task force.

Value

- Enhance each member’s self-healing ability against severe cascading failures and blackouts via timely and optimal controlled separation based on real-time PMU phasor data.
- Reduce economic impacts caused by major blackouts, estimated by DOE at $4–$6 billion for a major blackout in the United States.
- Increase members’ knowledge about their systems’ vulnerabilities, post-fault generator grouping modes, critical boundaries of islands, and important locations for installing new PMUs in terms of mitigating cascading failures.

How to Apply Results
System planners can conduct separation studies to determine potential boundaries of islands using the scheme developed. System planners can also adapt the post-separation control scheme developed in this project to their systems. System operators can control PMU-based out-of-step relays to separate their system according to the real-time optimal boundaries and separation timing determined by the scheme and separation criteria developed. System operators can implement load shedding/generation rejection actions according to the post-separation control scheme developed.

EPRI will offer the following supplemental project opportunities to help utility members apply this work:

- Implementation of the PMU-based scheme for determining the boundaries of islands in real time
- Demonstration of coordinating the PMU-based out-of-step relays to implement controlled separation
- Implementation of the post-separation control scheme

2009 Products

Product Title & Description	Planned Completion Date	Product Type
Application of PMU for Controlled Separation, Load Shedding and Generation Rejection: A technical report including a PMU-based scheme to online determine the boundaries of islands for controlled separation.	12/31/2009	Technical Report