

## Grid Operations - Program 39

### Program Overview

#### Program Description

Grid operation is a fundamentally important function for utilities, transmission companies, and ISOs/RTOs. EPRI foresees the following industry trends:

- More reliability standards
- Increasingly aging infrastructures and workforce
- Increasing renewables, demand response, and need for storage.

Based on these trends, system operators will operate transmission systems in a complex environment. EPRI members have the following technical needs:

- Improve real-time situation awareness
- Improve wide area protection and control performance
- Improve capabilities to handle extreme events and restore the system.

#### Research Value

In 2010, the Grid Operations program will offer its members a focused research portfolio:

- Situational Awareness Project Set, which helps system operators improve monitoring and visualization capabilities
- Online Analysis Project Set, which helps system operators improve real-time analyzing capabilities
- System Control Project Set, which helps system operators improve control capabilities.

By deploying these advanced technologies, program members will:

- Improve system reliability and reduce operational risks
- Increase transfer capability and reduce congestion cost
- Reduce the risk of blackouts and improve restoration time to reduce outage costs
- Improve coordination between operations and planning.

The vision of the Grid Operation program is to help members develop next-generation monitoring, analyzing, and controlling capabilities to help enable a smart transmission grid.

#### Approach

The Grid Operations program offers members both short- and long-term value in a variety of ways, including:

- Helping anticipate the future, and developing strategies and roadmaps
- Developing methods and tools
- Demonstrating and deploying technologies
- Providing training and staff development
- Sharing knowledge, information and experience
- Building networking and outreach opportunities.

#### Accomplishments

EPRI's Grid Operations program has provided critically needed technologies and information for its members over many years. Examples include:

- Generic Operator Training Simulator (OTS), Version 2.0. The EPRI Generic Operator Training Simulator is a PC-based training simulator that allows hands-on training for dispatchers, using a generic 29-station model. The Generic OTS, which can be run on multiple platforms, allows for realistic simulations of many power system phenomena. Users may employ a generic power and light model, or incorporate their own models into the OTS. The generic OTS has also been integrated with several Energy Management System (EMS) vendors.
- Situation Awareness (SA) in Power System Operations. This technical update represents a detailed study of the use of color, automated systems, and predictive SA tools in the power industry. Data was gathered through site visits with three control centers and an online color survey. A total of 27 survey responses from 25 separate EPRI members were collected and analyzed.
- Prototyping a Decision Support Tool for Evaluation of System Restoration Strategy Options. This project studied industry practice and documentation of system restoration plans. A new concept, generic restoration milestone (GRM) during system restoration, was proposed. Based on that, a prototype decision support tool for evaluating system restoration strategy options was developed. A specific restoration strategy can be established by a combination of GRMs based on the system characteristics, energy sources and constraints of power grids, and then be examined by simulations. Different combinations or sequences lead to different strategy options and performances. Simulation studies have shown that the developed decision support tool enables a power system in a blackout status to restart and self-organize various parts until it achieves complete restoration.

### Current Year Activities

In 2010, this research program expects to accomplish:

- Technical report on advanced alarm management
- Technical report on human-centered situational awareness
- Technical update on integrating substation and equipment health information to improve operation awareness
- Technical update on indicating cascading outages using measurement data
- Technical update on real-time reactive reserve requirements and optimal allocation among resources
- Technical update on measurement-based voltage stability monitoring and control for control center
- Measurement-based voltage stability analysis software
- Technical update on online stability assessment with comprehensive dynamic models
- Technical report on preventive and emergency controls to minimize the impact of system separation
- Decision support tool of interactive system restoration software
- Operator Training Simulator (OTS) software

### Estimated 2010 Program Funding

\$2.5M

### Program Manager

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## Summary of Projects

### PS39D New Control Center Applications (069243)

#### Project Set Description

The objective of this project is to develop operational applications to help system operators improve on-line monitoring, analysis, and control functions.

Project Number	Project Title	Description
P39.007	Development of Next Generation Control Center Applications	This project expects to develop operational applications to help system operators improve on-line monitoring, analysis, and control functions.
P39.008	Guidelines for Implementing Dynamic Thermal Circuit Rating (DTCR) in EMS	The research project will develop practical guidelines for integrating DTCR into EMS.

### P39.007 Development of Next Generation Control Center Applications (069244)

#### Key Research Question

System operators are operating transmission systems that are becoming increasingly complex. EPRI organized a workshop in 2009 to discuss the key operation issues faced by the industry. Key technical issues include:

- Reliability
- Forward looking analysis
- Data sharing capabilities
- Visualization
- Smart grid impact to operations
- Topology solutions
- Voltage collapse
- Equipment health.

A new set of operating tools is needed to improve system operators' monitoring, analysis, and control capabilities.

#### Approach

The objective of this project is to develop operational applications to help system operators improve on-line monitoring, analysis, and control functions. In 2010, EPRI project team will focus on the following tasks:

- Task 1: The EPRI project team will organize a series of webcasts and workshops to work with industry advisors and vendors on developing the functional requirements for next-generation control center applications.
- Task 2: Based on the functional requirements developed in Task 1, EPRI will issue a request for proposal to EMS vendors. After receiving the responses, EPRI will work with industry advisors to review the proposals and determine the vendor who can perform the work. EPRI will work with the selected vendor to develop next-generation control center applications, monitor the status of development work, and organize a series of webcasts and workshops to provide industry advisors with technical updates on a regular basis. EPRI will also test the developed applications to ensure their quality.

## Impact

With deployment of the advanced technologies developed through this program, members will:

- Improve system reliability and reduce operational risks
- Increase transfer capability and reduce congestion cost
- Reduce the risk of blackouts and improve restoration time to reduce outage costs
- Improve coordination between operations and planning.

## How to Apply Results

The methods and tools developed in this project can be implemented at control centers and used by operators and operational planners. Members can utilize the methods as functional specifications to develop advanced EMS application tools, and can implement the tool into EMS to manage reactive power in operating environments. EPRI will provide application services to help members apply the technologies developed through this project as well as through supplemental project opportunities.

## 2010 Products

Product Title & Description	Planned Completion Date	Product Type
<b>Functional Requirements of New Control Center Applications:</b> The technical updates documents the functional requirements of next-generation control center applications.	12/31/10	Technical Update

## P39.008 Guidelines for Implementing Dynamic Thermal Circuit Rating (DTCR) in EMS (069245)

### Key Research Question

The ratings of power equipment via DTCR (Dynamic Thermal Circuit Rating) are typically 5% to 15% higher than conventional static ratings. Application of dynamic ratings may enhance economical operation by enabling less constrained operation and timely mitigation action to avoid dangerous system insecurity conditions by tracking the thermal state of equipment. There are a number of practical implementation issues to consider, including SCADA/EMS flexibility and capability, communication links, instrument reliability, and engineering acceptance regarding dynamic rating and its variability. Due to these issues, dynamic ratings are still not widely integrated into power system operations.

Dynamic thermal ratings must be integrated into power system operations if they are to be useful. This project will develop and document practical guidelines whereby dynamic ratings and monitoring data can be useful in system operations, both as displayed values to operators in EMS and as input for many other EMS applications.

### Approach

This project plans to focus on the following activities:

- Identify practical issues hindering the wide integration of DTCR into power system operations and seek to understand operators' perspectives on DTCR through surveys and workshops. These implementation issues may include flexibility and capability of current EMS and its applications in incorporating dynamic ratings, reliability and functionality of measurement devices, availability and reliability of communication links to SCADA/EMS, practical methods for utilizing varying weather and loading conditions to calculate or predict dynamic ratings, and representing and storing continuously changing ratings in EMS. The survey and workshop should help achieve wider engineering acceptance for integrating DTCR into EMS, and learn what system operators need from DTCR and its EMS applications.

- Develop functional specifications for implementing DTCR into EMS, and practical guidelines to resolve the aforementioned issues in incorporating DTCR into the EMS based on thorough engineering and market efficiency studies as well as an investigation of utility practices in using DTCR.
- Future year efforts may include demonstrating the beneficial impact of integrating DTCR into EMS in terms of improved system reliability and efficiency. The specific scope may depend on the number of participants, but could include deploying instruments at appropriate locations, communicating monitoring data with SCADA/EMS, and interpreting and utilizing the dynamic ratings from DTCR in EMS applications based on the technical guidelines developed.

## Impact

Successful completion of this project could:

- Help operators take advantage of increased power equipment utilization
- Improve operators' situational awareness of potentially dangerous or damaging situations, and help them act appropriately to reduce loading due to DTCR implemented into EMS
- Improve system reliability
- Help system operators avoid false congestion and security alarms by providing sound operating limits through real-time ratings of system equipment
- Provide sound engineering judgments in applying dynamic ratings to operational decisionmaking.

## How to Apply Results

- Operators can better understand the value and issues of using dynamic ratings in system operations through practical guidelines developed through this project.
- ISOs or RTOs may integrate DTCR into their EMS applications based on the guidelines, and pursue improved system and market efficiency.
- Transmission owners may achieve benefits in terms of increased equipment utilization and reliability, and avoid damaging critical components.

## 2010 Products

Product Title & Description	Planned Completion Date	Product Type
<b>Guidelines for Implementing Dynamic Thermal Circuit Rating (DTCR) in EMS:</b> This technical report will summarize research efforts in 2010. Results are expected to include an examination of practical issues and guidelines for implementing DTCR into EMS.	12/31/10	Technical Report

## PS39A Situational Awareness (067422)

### Project Set Description

The Situational Awareness Project Set is designed to help system operators improve situational awareness through better monitoring and visualization capabilities.

Project Number	Project Title	Description
P39.001	Human-Centered Situational Awareness	Develop human factor guidelines for improving the situational awareness of operators.
P39.009	Improve Operational Awareness using Component Health Information	This project will develop functional requirements for integrating sensors and substation information into system operations and develop algorithms to utilize advanced sensors to anticipate equipment failures.

Project Number	Project Title	Description
P39.010	Indication of Potential Cascading Outages using Measured Data	This project will develop a measurement-based complementary strategy of simulation-based DSA tools for indicating potential cascading outages by precursor signal recognition.

## P39.001 Human-Centered Situational Awareness (055940)

### Key Research Question

Situational awareness by grid operators is the single most important factor in preventing blackouts. Human-centered research is needed to increase operator situational awareness. In many cases, grid operators suffer from information overload, which impairs their ability to implement corrective actions in a timely fashion to prevent continuing cascading events that can cost millions or even billions of dollars in direct costs and socioeconomic impacts.

### Approach

This project will continue research in improving situational awareness in view of today's challenges of integrating large-scale and highly variable wind power plants into grid operation. EPRI will develop human factor guidelines for improving operators' situational awareness through standardized human-machine interfaces and streamlined visualization software. The program will continue work done in 2008 that developed guidelines for color usage, automation, and predictive awareness for grid operations. It will identify new types of data or information that will be needed to increase operator awareness due to the integration of renewable and variable generation. It will also propose standard ways of displaying salient information graphically (e.g., with icons) and appropriate visual and audible effects to convey the most important information to grid operators. In addition, the project will propose effective ways to inform operators which remedial actions to take when an alarm state is activated. A report and a public workshop open to software vendors will be held to deliver the results of this research.

### Impact

- Provide effective guidelines to system operators and in-house IT support staff for improving situational awareness.
- Provide input for functional specifications of new energy control center designs for human-machine interfaces.
- Avoid millions of dollars in potential economic losses from cascading blackouts by reducing the probability of such blackouts.
- 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

Research results in situational awareness will be published in technical updates for EPRI members to use as training materials. The public workshop will be a forum for disseminating the guidelines and research results of this entire project. By opening the workshop to the public and vendors, as was done in 2008, EPRI's research results will deliver greater benefits to the public and increase the speed of implementation.

## 2010 Products

Product Title & Description	Planned Completion Date	Product Type
<b>Workshop on situation awareness guidelines:</b> This workshop will present human factor guidelines for improving the situational awareness of operators through standardized human-machine interfaces and streamlined visualization software. It will be open to the public and software vendors will be invited.	12/31/10	Workshop, Training, or Conference
<b>Guidelines for Human-centered Situational Awareness:</b> A technical update to document standard ways of displaying salient information graphically (e.g., with icons) and appropriate visual and audible effects to convey the most important information to grid operators.	12/31/10	Technical Update

### P39.009 Improve Operational Awareness using Component Health Information (069241)

#### Key Research Question

System operators seek forward-looking functionality to identify potential problems, their likelihood of occurrence, and how they affect operating margins. Current EMS systems do not provide a flexible tool for that type of analysis. The wide application of online monitoring devices (such as sensors) creates an opportunity to improve situational awareness. The technical challenge will be integrating equipment health information into system-wide operations to improve situational awareness.

#### Approach

This project will work to develop and demonstrate a new methodology to quantify equipment health information based on a measured data streams from advanced sensors. Incorporating such a method into existing EMS functions would create a new application to improve operation awareness. The research activities may include:

- Host a Project Initiation Meeting to review, interpret and disseminate key results of using monitoring devices to calculate or predict equipment health condition at transmission and substation levels. Sharing information and experiences will help members understand available technologies and avoid duplication of effort.
- Develop mathematical models to predict failure rates for different components using real-time sensors. To avoid problems of system complexity and compatibility, the project team will specify and recommend one type of advanced metering technology for a particular part of the grid (e.g., generator, transmission line, or transformer). Unlike traditional failure rate predictions, which use historical off-line measurements to estimate the longevity of applications using the devices, models will use real-time sensing data with history to predict failures and facilitate preventive actions.
- Integrate and centralize substation and equipment health information into system operation. Although predicted component failure information based on sensor technologies will be valuable for early identification of component outage, it will further require a set of models to be useful for system-wide assessment of transmission reliability. The project team will assess the integrated modeling platform in the existing EMS and define additional requirements for integrating substation and sensor information.

#### Impact

- Innovation: First-of-its-kind, focused analysis introducing the concept of sensory information in transmission grid operations
- Process excellence: Highly automated methodology helping utility assessment and management of transmission operations to improve situational awareness

- Commitment to members: Work with utility members to predict and quantify equipment health condition in system operations, and provide members with decision-support information to improve situational awareness
- Commitment to society: Avoid damaging and costly blackouts of transmission grids

### How to Apply Results

Results of this research will be available to EPRI members in a report that documents the potential capability of sensory information for improving situational awareness. Functional specifications will also be available to EPRI members in a report that documents extra EMS functionality needed for integrating substation and sensory information.

### 2010 Products

Product Title & Description	Planned Completion Date	Product Type
<b>Functional Requirements: Integration of Substation and Equipment Health Information to Improve Operation Awareness:</b> The predicted component failure information provided by metering technologies is valuable for early identification of component outage. However, to be useful for system-wide assessment of transmission reliability, they require a set of upgrades for existing EMS models and function. This product will assess an integrated modeling platform in existing EMS functions.	12/31/10	Technical Update

### Future Year Products

Product Title & Description	Planned Completion Date	Product Type
<b>Integration of Substation and Equipment Health Information to Improve Operation Awareness:</b> This report will document the proposed mathematical models used to predict failure rates for different components using real-time sensors.	12/30/11	Technical Report

## P39.010 Indication of Potential Cascading Outages using Measured Data (069242)

### Key Research Question

Simulation-based Dynamic Stability Assessment (DSA) tools have difficulty recognizing the early stages of cascading outages because:

- They must wait for state estimation results to assess online stability; however, state estimators cannot capture dangerous real-time changes in operating conditions, which are critically important in alerting operators to potential cascading outages.
- They simulate only pre-defined N-1 or N-2 critical contingencies; however, in fact, failures that are likely to trigger cascading outages are quite unpredictable.

Thus, new situation awareness technology for real-time indication of potential cascading outages needs to be developed. Since PMUs can provide real-time and synchronized measurements of system variables for operators to monitor system dynamics, they may be the basis for a new situation awareness technology. EPRI research shows that "precursor signals," which indicate potential cascading and instability, usually appear in the real-time measurements of some system variables before an irreversible system collapse happens. These signals are abnormalities in either the values or dynamic patterns of those variables, and are easily captured if PMUs are applied. Consequently, the timely capture of precursor signals from PMU

measurement data will help operators recognize potential cascading outages and take preventive actions according to control guidelines.

Key research questions concerning the early recognition of cascading outages include:

- Are there any common characteristics of precursor signals that can be learned offline?
- How will operators recognize precursor signals in real time from PMU data?
- Where can PMUs be placed for effective recognition of cascading outages?

## Approach

This multi-year project will develop new situation awareness technology for the early indication of potential cascading outages using measurements from PMUs or other devices. The project may include the following activities:

- Simulate cascading scenarios on several test power systems to investigate the common characteristics of the precursor signals indicating instability. The project team may investigate two types of precursor signals: abnormal values, and abnormal dynamic patterns of system variables. An approach to clearly visualize precursor signals will be developed.
- Identify methods select buses for monitoring precursor signals and create criteria for PMU placement.
- Perform technology investigations and development for quick recognition and evaluation of precursor signals. The risk of cascading outages will be estimated in real time for system operators to decide whether to take preventive actions.
- Future year efforts may test and validate the developed situation awareness scheme using simulation data about cascading outages or real measurement data regarding large disturbances.

## Impact

This project is expected impact members' operations and benefit the public in the following ways:

- Reduce the risk of blackouts by providing a real-time situation awareness scheme for early indication of potential instability or cascading outages
- Improve real-time situation awareness through better monitoring and visualization capabilities
- Help system operators understand the precursor signals indicating potential cascading outages
- Suggest preferred buses to install PMUs for real-time monitoring and visualization purposes.

## How to Apply Results

System planners may use the tools developed to study the precursor signals of cascading outages in their systems, and identify buses to equip with PMUs.

System operators may use the situation awareness scheme developed to monitor their systems and visualize precursor signals of potential cascading outages. They can also estimate the real-time risk of cascading outages as a reference for making decisions of preventive control.

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

- Investigating the precursor signals of potential cascading outages from measurement data
- Indicating potential cascading outages using pattern recognition technologies.

## 2010 Products

Product Title & Description	Planned Completion Date	Product Type
Indication of Potential Cascading Outages using Measurement Data:	12/31/10	Technical Update

### PS39B Online Analysis (067423)

#### Project Set Description

The Online Analysis Project Set is designed to help system operators develop preventative control strategies through better online analyzing capabilities.

Project Number	Project Title	Description
P39.003	Real-time Reactive Reserve Requirements and Optimal Allocation Among Resources	The reactive power management project has developed methods and tools to help system operators and operational planners find voltage stability problem areas and determine the corresponding required reactive power reserves for each area. This project will continue R&D efforts for optimally allocating the required reactive power reserve and investigating the dynamic voltage recovery standard.
P39.004	Measurement-based Voltage Stability Monitoring and Control	EPRI has designed a three-level hierarchical measurement-based voltage stability monitoring, analysis, and control architecture. This project will develop the tools based on the algorithms produced from the past efforts. This project will also enrich the measurement-based approach by developing functional specifications at the control center level for operators to visualize the voltage stability margin information calculated at local substations and load centers.

### P39.003 Real-time Reactive Reserve Requirements and Optimal Allocation Among Resources (063323)

#### Key Research Question

Voltage stability is a major concern in power system operation and a leading factor that limits power transfers in the prevailing open access environment. Reactive supply is an important ingredient in maintaining healthy power system voltages and facilitating power transfers. Inadequate reactive supply is a major factor in causing voltage instability or collapse events. It is the responsibility of system planners and operators to plan for reactive power requirements and make any short-term arrangements needed to ensure that adequate reactive power resources will be available.

#### Approach

EPRI aims to develop better methods for effective reactive power management, considering all nonlinearities, to achieve efficient use of reactive power sources, sinks, and voltage control from generation and transmission facilities. Before 2010, EPRI developed an automated method and a software package that can identify "coherent reactive power zones" or "critical voltage control areas" (VCAs) using Decision Tree (DT) techniques from on-line system snapshots and determine required reactive power reserves using regression trees (RT) for each of the identified VCAs based on key system attributes. In 2010, the project will focus on the following activities:

- Develop methods to determine the needed static and dynamic reactive power support, and identify the optimal location to allocate the required reactive power reserve. Using this information, system operators can develop the most effective preventive control actions to avoid voltage instability.
- Review the existing dynamic voltage recovery standards and then investigate the proper dynamic voltage recovery standards from the required reactive power reserve point.

### Impact

- Reduce operational risk associated with voltage instability and voltage collapse events.
- Increase power transfer capabilities using the existing transmission infrastructure.

### How to Apply Results

The methods and tools developed through this project can be implemented at control centers and used by operators and operational planners. EPRI will provide application service to help members apply the technologies developed from this project.

### 2010 Products

Product Title & Description	Planned Completion Date	Product Type
<b>Real-time Reactive Reserve Requirements and Optimal Allocation among Resources:</b> This technical report will document methods to allocate the required reactive power among resources in real-time in addition to the results of investigations on dynamic voltage recovery standards.	12/31/10	Technical Report

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

### Key Research Question

Voltage stability is a major concern in power system operations 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 depend 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 a VSA program, which may in turn lead operators to make incorrect decisions and increase the risk of voltage collapse. Moreover, a VSA program also relies on the state estimator to provide steady-state solution for further analysis. In extreme operating conditions when the state estimator fails to converge, VSA programs also fail to help operators monitor and control system voltage stability.

Given the limitations of VSA programs, this project will investigate using measurement data from synchrophasors (e.g. PMUs) installed 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.

### Approach

EPRI envisions measurement-based voltage stability monitoring, analysis, and control as a three-level hierarchical control architecture, and has invented an algorithm called "Voltage Instability Load Shedding" (VILS) that continuously calculates the voltage stability margin at a local bus using real-time measured voltage and current waveforms. EPRI has also invented another algorithm, "Measurement-based Voltage Stability Monitoring and Control for Load Centers," that can calculate in real-time the voltage stability margin for an entire load center using the synchronized voltage and current measurement data obtained at its boundary substations with PMUs installed. The calculated voltage stability margin—which is expressed as active, reactive, and apparent power—can be used as the adaptive criteria to determine when a local bus or load center reaches the voltage stability limit. In 2010, the project will focus on the following activities:

- Develop a software package based on the VILS algorithm to help system operators monitor the voltage stability condition at the substation level using measurement data.
- Develop a software package based on the Measurement-based Voltage Stability Monitoring and Control for Load Centers algorithm to help system operators monitor the voltage stability condition at the control center level using real-time PMU data obtained at the boundary substations of each load center.
- Engage the operators of participating utilities and experts in human factors to design an effective human-machine interface to convey critical voltage stability information calculated at the local substations and load centers.

The Measurement-based Voltage Stability Monitoring and Control project requires multi-year efforts. Looking into the future, the EPRI project team may develop a visualization tool based on the design obtained to help system operators monitor the voltage stability profile of the entire transmission network using PMUs. This will broaden the visualization methods to help system operators increase situation awareness. The EPRI project team will also work with the industry pioneers to demonstrate the three-level hierarchical control architecture.

### Impact

- Improve system operators' capabilities to monitor and control voltage stability of the transmission system using PMUs
- Provide a safety net to prevent wide-area fast voltage collapse
- Validate computation results provided by the simulation-based approach

### How to Apply Results

The results of this project offer system operators a new method and set of tools to monitor, analyze, and control wide-area voltage stability conditions of the entire transmission system. System operators can 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 can then be transmitted to a central substation of the load center or the control center. System operators then apply methods developed through this project to calculate the voltage stability margin for the entire load center. System operators can use the visualization tool developed at the control center level to monitor and control the voltage stability condition of the entire transmission system. EPRI also provides an application service to help members implement this technology through supplemental projects.

### 2010 Products

Product Title & Description	Planned Completion Date	Product Type
<b>Voltage Instability Load Shedding:</b> The Voltage Instability Load Shedding (VILS) software package is a tool to help system operators monitor voltage stability condition at the substation level.	12/31/10	Software
<b>Functional Specifications of Measurement-based Voltage Stability Analysis at Control Centers:</b> The <i>Functional Specifications of Measurement-based Voltage Stability Analysis at Control Centers</i> technical report provides a design document to help system operators visualize the critical voltage stability information calculated at local substations and load centers.	12/31/10	Technical Report

## PS39C System Control (067424)

### Project Set Description

The System Control Project Set is designed to help system operators reduce the risk of blackouts and expedite restoration time through better on-line controlling capabilities.

Project Number	Project Title	Description
P39.005	Development of Methods to Reduce Restoration Time	This project will provide a decision support tool for evaluating and designing system restoration strategies to reduce restoration time and determine the preferred level of blackstart capability.
P39.006	Preventive and Emergency Control to Minimize the Impact of System Separation	This project will develop preventive and emergency control schemes for minimizing the impact of system separation, identifying potential system separation conditions, and enabling better execution of controlled system separation.

### P39.005 Development of Methods to Reduce Restoration Time (067563)

#### Key Research Question

System restoration is a critical task of power system operations. Following a power outage, 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. System reliability depends heavily on the efficiency of system restoration. Unfortunately, few decision support tools are available for operators and restoration planners today. System restoration is still primarily manual work. Restoration plans are developed off-line with basic simulation tools, and then used as guidelines for operators in an on-line environment. Operators need to utilize their experience and also adapt to actual outages and available resources during the system restoration process. Recent major blackout events are powerful reminders that system restoration requires advanced decision support tools. Blackout events and aging transmission infrastructures in the United States demand a focus on R&D for system restoration and its associated decision support tools.

Based on a new concept called "Generic Restoration Milestone" (GRM), a decision support tool was prototyped by EPRI in 2008 for evaluating and designing restoration strategies. A specific restoration strategy can be established by a combination of GRMs based on system conditions. Different GRM combinations lead to different strategy options. This tool helps evaluate different restoration strategy options to determine an effective strategy without violating security constraints. R&D must be conducted to develop necessary computational models and techniques for this tool. Research will be enhanced by estimating the restoration time for each given scenario and the adequacy of blackstart capability.

#### Approach

This multi-year project focuses on developing computer simulations and realistic system models. In 2010, this project will continue R&D efforts in enhancing the decision support tool. The project may include the following activities:

- Continue the development of computational models and techniques for evaluating restoration strategy options and estimating system restoration time to enhance the decision support tool.
- Develop an interactive system restoration software tool, which may be applied either by operators to practice restorations or by planners to design restoration strategies. A reference procedure for designing an effective restoration strategy may be developed and documented in detail. The EPRI project team may also study how to integrate this tool with the EPRI Operator Training Simulator (OTS).

- Based on this decision support tool, develop an approach to determine the preferred level of blackstart capability.
- Validate the decision support tool and the level of blackstart capability on realistic power grid models. Industry advisors may be consulted concerning specific systems and scenarios.

### Impact

This research project may benefit the public and impact members' operations in the following ways:

- Provide methods to reduce system restoration time and lower the costs of power outages
- Improve power system reliability by determining the preferred level of blackstart capability
- Help system operators practice system restoration using an interactive software tool
- Help system planners evaluate and develop restoration strategies using an interactive software tool.

### How to Apply Results

System planners may use the interactive software support tool to evaluate restoration strategy options and design more effective system restoration strategies. System operators may use the interactive software tool to practice system restoration. EPRI may offer training courses and supplemental project opportunities to help members enrich their system restoration knowledge and improve their restoration practices.

### 2010 Products

Product Title & Description	Planned Completion Date	Product Type
<b>Development of Methods to Reduce Restoration Time and Determine the Preferred Level of Blackstart Capability</b>	12/31/10	Technical Update
<b>A Decision Support Tool for Evaluating Restoration Strategy Options</b>	12/31/10	Software

## **P39.006 Preventive and Emergency Control to Minimize the Impact of System Separation (067446)**

### Key Research Question

Many utilities are operating transmission systems closer to security limits in order to meet the requirements of a rapidly growing electricity market. There is a higher probability that unexpected events (e.g. snow storms or hurricanes) could cause multiple lines in a transmission system to trip and even lead to system separation. System separation (spontaneous or controlled) may impact the transmission system in the following ways:

- For any island whose load cannot be supported by local generation, excessive load must be dropped to maintain voltage and frequency at acceptable levels. If the lack of generation is significant—e.g. in the case that a load center is islanded—large-area power outages will be inevitable.
- The action of separating the system may cause severe generator oscillations in each island, which, if not damped in a timely manner, may lead to instability and further system separation.

In fact, the impact of system separation can be reduced if appropriate preventive and emergency control actions are taken, such as:

- Preventive generator re-dispatching and power-flow reconfiguration to reduce the imbalance in each potential island before separation
- Emergent generation rejection and load shedding within each island after separation to stabilize generators and regulate frequency and bus voltages.

Those preventive and emergency control actions need to be studied. Potential separation conditions should be known, helping system operators decide whether to add control to system separation. PMUs can provide important real-time data to help detect system separation and improve controlled separation.

### Approach

This multi-year project on system separation will develop preventive and emergency control schemes to reduce the impact of system and may include the following activities:

- Investigate possible separation scenarios for a study system and develop an on-line algorithm to identify high-risk separation scenarios for the current operating condition and network configuration. Available emergency control capabilities of each potential island will be investigated. Potential sets of separation points will be analyzed and compared for each high-risk separation scenario. The set of separation points with the minimum need for preventive and emergency control may be suggested if controlled separation is considered.
- Determine inter-area power flows for each high-risk separation scenario to reduce the load dropped after separation. Once the risk of any scenario reaches a predefined alert level, the scheme could provide operators with preventive control options.
- Future year activities may investigate a PMU-based algorithm for real-time detection of system separation. Once separation is detected, the emergency control scheme may provide operators with load shedding or generation rejection suggestions to quickly stabilize each island and regulate frequency and voltages.

### Impact

This research project may benefit the public and impact members' operations in the following ways:

- Provide methods to lower the impact of system separation and the risk of large-scale power outages
- Increase members' knowledge of potential system separation scenarios and instability issues involved in system separation
- For members with controlled separation strategies, this research will improve the execution of controlled system separation.

### How to Apply Results

System planners can conduct separation studies using the approaches developed to identify high-risk separation scenarios and potential separation points. System planners can utilize the preventive and emergency control schemes developed to study preventive and emergency control options for system operators.

Results of this project will help system operators execute the best preventive control option to reduce the impact of potential system separation once its risk reaches an alert level. In addition, system operators may execute the best emergency control option once system separation is detected.

EPRI may offer supplemental project opportunities to help utility members apply this work.

### 2010 Products

Product Title & Description	Planned Completion Date	Product Type
<b>Preventive and Emergency Control to Minimize the Impact of System Separation</b>	12/31/10	Technical Update