Grid Operations - Program 39

Program Overview

Program Description
In many ways, today's power system must be operated to meet objectives for which it was not explicitly designed. The transmission system is operated to transfer larger amounts of energy over greater distances utilizing an increasingly higher percentage of non-traditional resources than were considered when it was built. Generation resources are more constrained and increasingly more variable and uncertain. Demand resources are now considered as an option for resource adequacy and providing ancillary services in many regions. All of the changes are occurring at a rate that is outpacing corresponding growth in transmission infrastructure. As a result, today's grid is operated much closer to the margin.

Under these circumstances, it is imperative that operators be provided with good information based on real-time data regarding the status of the system, as well as decision-making support to respond to rapid changes that might occur in the near future. The emergence of new sources of real-time data that are becoming available from synchrophasor measurements, asset health sensors, and forecasts of future load and variable renewable output levels enable the possibility of providing operators with increased situational awareness and advanced decision-support tools. System operators need such tools to continue to reliably and economically operate the system in the face of emerging challenges.

EPRI's Grid Operations research program is addressing these needs by improving real-time situational awareness, developing tools that use synchrophasor and other measurements to assess the present system operating point relative to thermal, transient, and voltage stability operating limits, and developing tools to manage the grid through extreme events and restore the system in the event of an outage.

Research Value
The mission of EPRI's Grid Operations research program is to support the development of next-generation situational awareness, analysis, and control capabilities that will be required to operate the transmission grid in the most reliable and economical manner as the grid continues to evolve at an unprecedented rate. In 2014, this will be accomplished through a collaborative process in which EPRI works hand-in-hand with its utility and ISO members to identify existing research gaps and associated project needs that would provide value to EPRI members. Once identified, the EPRI Grid Operations team of technical and project management experts works with members and the world's foremost experts in related research areas to structure and conduct specific projects and products that provide value in the near-term, mid-term, and long-term. Finally, this value is transferred to members through collaborative advisory and task force interactions, workshops and webcasts, and company-specific applications and demonstrations of the developed methods and tools.

Approach
EPRI's Grid Operations research program delivers value using the shared experiences and understanding of its utility and independent system operator (ISO) members in conjunction with the expertise of EPRI's staff and network of top-level contractors. The program conducts research projects that lead to prototype methods and tools that can be utilized by system operators to validate methods that are then distributed to commercial vendors that supply and support member applications. EPRI also engages with external industry standards, regulatory, and research efforts to ensure that the EPRI research program is taking advantage of broader industry efforts and advancing the state of the art.

This research program also strives to provide members near-term, mid-term, and long-term value each year. For example, the 2014 Grid Operations research program will finalize the development of prototype tools for identifying and mitigating potential voltage stability concerns and deliver the integrated restoration decision support module for the EPRI Operator Training Simulator. At the same time, EPRI will continue development/evaluations of advanced data processing, computing technologies, and solution algorithms to improve the performance of all operational analytics and decision making.
Accomplishments

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

- **Reactive Power Management to Address Long-Term Voltage Stability Using Voltage Control Area (VCA) Technique (1024258):** This software tool delivered in 2012 investigates voltage security problems and identifies the voltage control areas to address steady-state stability problems and effective deployment and utilization of reactive power resources.

- **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.

- **Decision Support Tool for Optimal Blackstart Capability (1024262):** This technical update delivered in 2012 describes a new algorithm and associated prototype software tool to identify the optimal location and size of blackstart units with the objective function of maximizing total generation output within a given restoration time frame. The update also describes two case studies with member ISOs to demonstrate the prototype software capabilities and remaining needed functions to be added to the tool in 2013.

- **Prototyping a Decision-Support Tool for the Evaluation of System Restoration Strategy Options:** This project studied industry practices 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 system characteristics, energy sources, and constraints of power grids, and can then be examined through 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 of the system until it achieves complete restoration.

Current Year Activities

In 2014, EPRI's Grid Operations research program will offer its members a focused research portfolio with the following objectives:

- Improve system reliability and reduce operational risks through the improved situational awareness of operators, including incorporating equipment health information into the control center and the identification of multiple operating boundaries and margins into aggregated visualizations.

- Support operators in identifying potential voltage stability concerns in real time and ensuring that steady-state and post-contingency system voltage performance is maintained utilizing the optimal mix of available reactive resources.

- Reduce the risk of wide-area events through early-warning detection tools.

- Improve restoration time and reduce outage costs through identifying optimal blackstart capability requirements and developing restoration decision-support applications.

- Develop advanced analysis algorithms that utilize emerging hardware- and software-enabled approaches to increase computational efficiency and improve the performance of control room applications, while increasing the resolution of the calculations to take advantage of new inputs such as synchrophasor data to support operator situational awareness and decision support.

- Investigate tools and techniques that utilize synchrophasor data to assess power system stability and predict unstable system behavior in a forecasted time window.

Estimated 2014 Program Funding

$3.5M
Summary of Projects

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<tr>
<th>Project Number</th>
<th>Project Title</th>
<th>Description</th>
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<tr>
<td>P39.011</td>
<td>Situational Awareness Using Comprehensive Information</td>
<td>This multi-year project will help improve system operators’ situational awareness by integrating comprehensive information, such as operating boundary/margin information and asset-related information, into control centers.</td>
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<tr>
<td>P39.012</td>
<td>System Voltage and Reactive Power Management</td>
<td>This goal of this project is to develop advanced study techniques, mitigation measures, and decision-support tools for grid operators and planners to address potential voltage stability and management problems.</td>
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<tr>
<td>P39.013</td>
<td>Decision Support Tools for System Emergency and Restoration</td>
<td>This project will develop methods and tools to provide decision support for system engineers during system restoration that ultimately can be integrated with commercial Energy Management System (EMS) platforms.</td>
</tr>
<tr>
<td>P39.014</td>
<td>Application of New Computing Technologies and Solution Methodologies in Grid Operations</td>
<td>This project is expected to investigate, identify, and develop advanced data processing and computing technologies for control centers to improve online simulation performance with respect to the speed, accuracy, robustness, and depth of information presented.</td>
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<tr>
<td>P39.015</td>
<td>Synchrophasor Applications: Stability Analysis and Prediction Using Synchrophasors</td>
<td>This project aims to develop practical systems and computational techniques to effectively apply synchrophasor data in an online monitoring and control environment to improve operators’ situational awareness and control capability against major stability issues.</td>
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P39.011 Situational Awareness Using Comprehensive Information (070591)

Description

Situational awareness is critical for grid operators to maintain system reliability and minimize major power outages. At present, the rapid growth of regional electricity markets, increasing integration of variable generation resources, and lack of corresponding growth in transmission infrastructure are introducing more uncertainties into daily grid operations. These changes could result in the transmission system operating even closer to its limits and increase the likelihood of stability issues during disturbances or equipment failures.

Generally, this project aims to develop new methods and tools to improve operators’ situational awareness and decision support. In 2014, the R&D efforts in this project will continue to focus on two efforts:

- Visualization of multiple power system operating boundaries/margins in aggregated views for system operators
- Incorporating advanced asset condition related information into operations security analysis.

Operating Boundary/Margin Visualization: In 2012, EPRI started to develop a prototype software application for online visualization of power system operating boundaries and margins; this effort continued in 2013 with version 2.0. The application was designed to utilize an operator-friendly graphical user interface (GUI) with concise, easy-to-use displays. Comprehensive boundary/margin information across multiple operation limits could be visualized regarding user-definable observation variables such as interface power flows, regional loads, and main generator outputs. Interfaces with online measurements such as SCADA/EMS and synchrophasors as well as commercialized power system security assessment tools were defined for timely
updating of the estimated system operating point and operating boundaries and margins under both pre- and
post-contingency conditions.

**Asset Condition Integration in Control Centers**: In 2013, the EPRI project team developed detailed use
cases within the context of the asset condition integration roadmap to identify high-priority projects to pursue.
This involved working closely with member utility experts in equipment diagnosis and communications to
demonstrate the benefit of incorporating a transformer abnormal condition ranking index (developed by the
EPRI Substations program) to perform condition-based probabilistic contingency analysis on an actual system.

**Approach**

**Operating Boundary/Margin Visualization**: In 2014, the project will continue its efforts to enhance the
software application delivered in 2012 and 2013, and work with one or more host utilities toward an online
demonstration of the software. Additionally, the project team expects to convene a utility/vendor interest group
for technology transfer.

**Asset Condition Integration in Control Centers**: The project will focus on implementing the highest short-
term-potential use case identified in 2013. The team will work to develop analytics or procedures required to
develop the concept and visualizations and then pursue test cases to prove that particular use case.
Implementation of other use cases from 2013 will be considered based on available resources, with the potential
to pursue some through supplemental research.

**Impact**

- Increase reliability through improved system operators’ situational awareness afforded by comprehensive
  operating boundary/margin visualizations.
- Increase reliability and equipment utilization through improved system operators’ monitoring of critical
  equipment and potentially dangerous situations, and the integration of asset health into control room
  analysis functions.
- Increase security through reducing the risk of cascading outages caused by insufficient operating margins
  or equipment failures.

**How to Apply Results**

Members can integrate the online visualization of operating boundary/margin information software application
with data from their SCADA/EMS systems and security assessment programs. Technical results on integrating
equipment health information will provide guidelines and techniques for monitoring critical equipment in control
rooms, whether through manual procedures or integration into existing or new applications. Ultimately, the
methods and tools developed through both efforts will be shared with commercial software vendors for long-
term implementation and support for members.

**2014 Products**

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<tr>
<td>Integration of Asset Condition Information into Control Centers: Use Case Development and Case Study: This report will detail the development of analytics and/or manual procedures for the high priority asset condition information into control centers' Use Case chosen from the 2013 detailed Use Case development and roadmapping efforts. The Use Case will require development of analytics or manual procedures and visualizations. Then the project team will pursue a test cases to demonstrate the concept and how it could impact operations decisions regarding the asset and system. Other Use Cases will be pursued in Supplemental instead of Annual Research.</td>
<td>12/31/14</td>
<td>Technical Report</td>
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Visualization of Operating Boundaries (VOB) 3.0: This software tool would be an enhanced version based on the offline version developed in 2013.

Computation and Visualization of Operating Boundaries and Margins: This technical update will document the algorithms for computation and visualization of operating boundaries and work toward online demonstration of the software tool.

**P39.012 System Voltage and Reactive Power Management (070592)**

**Description**

Ensuring adequate voltage performance is a critical system operations responsibility. Voltage stability has been a growing concern for system planners and operators in recent years with increasing power transfers, variable generation, and prone-to-stall residential air conditioner load. As a result, identifying potential voltage instability areas and determining the required reactive power reserve in real time are technical challenges that need to be solved. There are also increasing research needs regarding techniques for optimally managing dynamic VAR reserves to allow fast voltage recovery, as well as techniques for sensing voltage recovery following disturbances.

Current state-of-the-art technologies for voltage stability analysis are based on simulations of what-if scenarios to study potential voltage stability issues. Deploying more synchrophasors opens up the opportunity of using synchrophasor data to perform voltage stability analysis in real time. In 2014, the R&D efforts in this project will continue to focus on two efforts:

- Developing hybrid methods and tools that combine the measurement-based and simulation-based approaches to help system operators better monitor and control voltage stability
- Developing methods and tools to forecast day-ahead reactive power needs and develop optimized schedules for reactive power resources.

**Approach**

**Hybrid Voltage Stability Assessment:** Utilities typically apply simulation-based voltage stability assessment (VSA) tools to simulate predefined contingencies for identifying potential voltage stability issues and determining operational limits. EPRI has developed a measurement-based voltage stability assessment technique to derive the voltage stability margins in online mode based on synchrophasors. Both the simulation-based and measurement-based approaches have advantages and limitations. A hybrid framework that integrates the advantageous aspects of both the measurement-based and simulation-based approaches for real-time voltage stability monitoring and control is being developed within this project, with the following efforts envisioned for 2014:

- Improve the strategy developed in 2013 to systematically combine results from both simulation-based and measurement-based voltage stability assessment approaches to create a superior VSA tool to effectively support operator decision making and action, as well as eventually trigger automatic control actions.
- Implement the hybrid VSA strategy in a computational tool for online application. The integrated tool will use existing production-grade simulation-based VSA software along with the measurement-based tools developed by EPRI. Improved measurement-based algorithms to be developed under a companion DOE-funded project are expected to be used for this purpose as well.

EPRI will develop the mathematical foundations, algorithms, computational approaches and technical specifications for the new generation of real-time VSA tools for system operators. Also, EPRI expects to engage EMS vendors to improve the tool and implement it as a prototype in a real EMS environment.
Short-Term VAR Forecasting and Optimization: This project will continue the efforts begun in 2013 to develop two related tools for reactive power resource management:

- Advanced forecasting algorithms and models to provide 24-hour-ahead active and reactive power forecast at the substation level.
- Voltage optimization application that utilizes the outcome of the load forecast program and a dedicated algorithm for generator unit commitment and economic dispatch to create a string of optimized active and reactive power control configurations that can be viewed as 24-hour tabulated lists.

Impact

- Provide guidance on study tools, techniques, procedures, and modeling for investigating voltage stability.
- Identify mitigation measures.
- Provide situational awareness for potential voltage stability issues.
- Facilitate decision making to help avoid or mitigate a potential voltage instability scenario.
- Provide operators an ability to arrive at an optimized plan for reactive power resources allocation and voltage profile to be followed over the course of a day. Also, provide guidance and strategies to maintain system security under foreseen system changes and events, as well as unexpected contingencies.

How to Apply Results

The developed voltage stability investigation methods described in the EPRI technical update can be used to improve study procedures for grid operations staff in real-time contingency analysis and planning staff in off-line studies. The developed Reactive Power Forecasting and Day-Ahead Scheduling software tools can be installed and used to evaluate potential voltage performance and reactive resource utilization improvements from the hour-by-hour voltage optimization. Similarly, the Hybrid Voltage Stability Assessment Tool can be installed and evaluated for improved real-time voltage assessments and situational awareness in the control room. Ultimately, as the developed methods and tools are shown to provide broad benefits, they will be shared with commercial tool vendors for implementation into supported systems for members to fully derive value.

2014 Products

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<tr>
<td>Hybrid Voltage Stability Assessment (HVSA) Strategy and Tool: The Technical Update will document the work planned in 2014, which includes implementation of the hybrid voltage stability assessment (HVSA) strategy and initial testing of the HVSA tools in an on-line environment.</td>
<td>12/24/14</td>
<td>Technical Update</td>
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<tr>
<td>24-Hour Volt/Var Scheduling Tool: This project is developing a tool that will provide operators an ability to arrive at an optimized plan for reactive power resources allocation and voltage profile to be followed over the course of a day. Also provide guidance and strategies to maintain system security under foreseen system changes and events, as well as unexpected contingencies.</td>
<td>12/31/14</td>
<td>Software</td>
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Description

Although not often required, system restoration is a critical operations function to minimize the impacts of major disturbance events when they do occur. Unfortunately, such events have been more prevalent in recent years with an increasing number of natural disasters resulting in wider-spread outages and other non-disaster wide-area disturbances. As a result, system operators and reliability entities worldwide have a keen interest in methods and tools to develop and execute efficient and effective restoration plans.
System planners and operations engineers need tools to perform blackstart capability studies as the traditional
generation mix changes significantly. Similarly, operators need online tools to evaluate restoration strategy
options in real time and efficiently determine restorative actions without causing security violations. Special
considerations need to be taken in such emergencies. This project is focused on developing such methods and
tools to develop appropriate restoration plans and provide decision support for system engineers during system
restoration.

**Approach**

Since 2009, EPRI has been working with researchers to develop methods and decision-support tools for system
restoration engineers. A novel system restoration methodology titled “Generic Restoration Milestone (GRM)”
has been successfully developed, along with an associated software application titled “System Restoration Navigator” (SRN). Additionally, a new algorithm for determining the optimal blackstart capability for a given
system to meet desired restoration objectives has been investigated and developed into a prototype software
tool.

This project will utilize techniques and tools to further enhance and demonstrate two primary software
applications for intelligent system restoration:

- Integrating the SRN tool capabilities with the Operator Training Simulator (OTS) for supporting training
  operators in restoration decision making
- Enhancing the prototype Optimal Blackstart Capability (OBC) tool for supporting planners and operations
  engineers in determining the optimal installation of blackstart capability.

**Impact**

- Improved restoration planning, including determination of blackstart requirements (capacity and location)
  and sequencing of restoration actions to achieve specified restoration goals.
- Improved operator decision making and confidence from improved restoration training and associated
  real-time decision support.
- May assist in developing precautionary emergency control plans and strategies against natural disasters.

**How to Apply Results**

System restoration engineers may use the Optimal Blackstart Capability tool to study the optimal location and
capacity for blackstart units relative to specified restoration goals. System operation staff may use the SRN
system restoration decision-support tool in training to improve their knowledge of effective restoration strategies.
EPRI may offer training courses and supplemental project opportunities to help members apply the tools.

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<tr>
<td><strong>System Restoration Navigator Module for Operator Training Simulator:</strong> This project will integrate System Restoration Navigator (SRN) with EPRI Operator Training Simulator (OTS) and develop an add-on module for the SRN function in EPRI OTS.</td>
<td>12/31/14</td>
<td>Software</td>
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<tr>
<td><strong>Learning from System Restoration and Blackstart Requirement Evaluation Case Studies:</strong> This technical update will describe insights gained from conducting case studies to apply the developed OBC and SRN tools.</td>
<td>12/31/14</td>
<td>Technical Update</td>
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P39.014 Application of New Computing Technologies and Solution Methodologies in Grid Operations (070594)

Description
As the power system becomes more complex, so do the computational requirements for modeling and simulating its operation. To manage the added complexity, the operator's job can be facilitated by deploying advanced computing technologies, which can include new simulation techniques, software, and hardware that can potentially accelerate and improve data analysis and computer simulation tasks. Areas to explore to achieve performance improvements are as follows:

- Advanced mathematical solvers to improve simulation robustness and accuracy.
- Advanced software and hardware technologies such as graphic processor units (GPUs), multi-core processors, distributed computing, and virtualization to improve simulation speeds or investment costs and utilization.
- Advanced data storage, compression and processing techniques that efficiently process enormous amounts of new types of data and models.

Approach
In prior efforts, research was conducted to identify grid operations and planning challenges relative to data processing, computing technologies, and solution methodologies to address them. The results of this assessment were eight near-term research ideas and six long-term research concepts. In 2012–2013, EPRI targeted its efforts on two of the near-term research ideas:

- Newton-Raphson (NR) power flow robust to failure
- Acceleration of power flow using GPU massively-parallelized devices.

The results of both these efforts have been promising for ac power flow. Consequently, EPRI will continue to disseminate the ideas in the industry and communicate with vendors to adopt the techniques. In 2014 and beyond, EPRI will focus on expanding the techniques and knowledge to more difficult problems that are potentially of higher value. These applications include faster dynamic stability analysis and robust techniques for ac optimal power flow. EPRI also plans to coordinate with the EPRI Information and Communications Technologies research area to explore advancements in model processing and storage to better utilize sharing models across applications and systems.

Impact
- May improve the accuracy and timeliness of online simulation and analysis techniques to improve confidence in system reliability.
- May provide an advanced computing foundation for the new smart-grid environment in which a greater abundance of online data exists.
- Improve the utilization of existing computing resources or introduce new low-cost computing technologies into control centers.

How to Apply Results
Members can evaluate the improved capability of new techniques over traditional ones to provide more accurate, robust, and timely results to system operators and engineers by working with EPRI to demonstrate the new methods applied to existing power flow problems. EPRI will also detail the methodologies and provide guidelines for implementing the techniques such that they might be more readily adopted into existing commercial software systems.
### 2014 Products

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<tr>
<td>Application of New Computing Technologies and Solution Methodologies for Grid Operations: Robust Techniques for AC Optimal Power Flow and Graphics Processing Units for Dynamic Stability Analysis: This technical update will detail the development of techniques for faster dynamic stability analysis using existing commodity processors and robust techniques for AC optimal power flow. We also detail how to apply available technologies for model processing and storage to better utilize sharing models across applications and systems. In particular we will look at: robust computational techniques to improve AC optimal power flow computational efficiency and solution meaningfulness; use Graphics Processing Units or similar vector processing hardware to reduce the simulation time of dynamic stability analysis; and the application database and processing technologies to improve large model processing and merging among control center applications and systems.</td>
<td>12/31/14</td>
<td>Technical Update</td>
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**P39.015 Synchrophasor Applications: Stability Analysis and Prediction Using Synchrophasors (072024)**

**Description**

Both rotor angle and voltage stability remain critical and challenging power system performance issues for transmission operations and planning engineers. Stability will continue to pose operational challenge in the future as the transmission grid undergoes transformation in terms of a changing generation mix, eroding transmission margins, increasing operational footprints, increasing number of transactions and participants, and greater variability in system conditions than in the past.

Traditionally, stability assessment has been dominated by simulation-based approaches, while measurement-based approaches have emerged in recent years due to the availability of high-resolution, synchrophasor measurements. Both approaches have their strengths and limitations, but they complement each other. The simulation approach has the advantage of providing predicted stability performance for “what-if scenarios,” which refers to the stability results of simulated contingencies. However, it relies on a power system model, which may not be truly representative of the actual power system. On the other hand, the measurement-based approach provides stability results in real-time, based on the actual power system. However, this approach cannot predict what-if scenarios, i.e., stability in the immediate time frame or an adjoining time window.

**Approach**

The long-term goal of this project is to develop online tools to assess power system stability and predict unstable system behavior in a forecasted time window by using synchrophasor data. In 2013, EPRI began investigating synchrophasor-based tools for online stability analysis and control that could

- expand the observability to abnormal or unstable power system dynamics, utilizing a limited set of strategically placed synchrophasors, and
- provide look-ahead capability to foresee potential instability in the immediate time window.

The 2012–2013 efforts focused on developing and validating analytical techniques and algorithms to develop reduced-order equivalent models that retain the critical dynamic characteristics of the original power system, and utilize the reduced-order models to assess stability of the original power system and predict stability performance in the immediate time window. Two research-grade software modules were also developed. In 2014, the project will improve upon the algorithms developed in 2013 and develop a prototype tool that will

- assess stability performance of the power system based on limited amount of synchrophasor data available, and
• predict stability performance in the next immediate timeframe of interest.

Additionally, EPRI will conduct an offline demonstration of the developed analytical techniques, algorithms, and software on a realistic power system.

**Impact**

• Improve system operators’ situational awareness by utilizing real-time synchrophasor data.
• Improve system operators’ ability to monitor and address stability performance of the transmission system.

**How to Apply Results**

Members will be trained through webcasts and workshops on the concepts and methodologies of this project. New tools developed through this project will be provided to members for testing on their systems, and the results will be shared among members to enhance the experience and apply the technical results of this project.

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<tr>
<td>Stability Analysis and Prediction Using Synchrophasors</td>
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<td>Technical Update</td>
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<tr>
<td>Synchrophasor-Based System Stability Assessment Tool</td>
<td>12/31/14</td>
<td>Software</td>
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Supplemental Projects

Early Warning of Potential Wide-Area Stability Problems Using Synchrophasors (072027)

Background, Objectives, and New Learning

Large power system blackouts, although infrequent, may influence up to tens of millions of people and result in huge costs. Usually, a major power outage is not caused by a single fault; rather, it is more likely to be the result of a sequence of disturbances, including initial events, additional failures, consequent protective actions, increasingly vulnerable conditions, and accelerated cascading outages, leading to a loss of stability. Those disturbances may gradually weaken a power system’s connections and result in growing inter-area angular oscillations. If not damped, oscillations may evolve into a loss of synchronism between two or more groups of generators and even system islanding.

Increasing deployment of synchrophasors—for example, phasor measurement units (PMUs)—on transmission systems can provide opportunities for monitoring of real-time wide-area power system dynamics. However, available applications of synchrophasors are mainly for displaying and visualizing their measurements. Grid operators need advanced applications that are able to turn raw measurements into more meaningful knowledge, such as online security margins, risks of stability problems, and indication of potential cascading outages. Since 2008, the Electric Power Research Institute (EPRI) has conducted research and development on the application of synchrophasors in the early warning of potential wide-area stability problems involving increasing oscillations and loss of synchronism between inter-connected regions. EPRI filed a U.S. patent application in 2010 on a synchrophasor-based algorithm for predicting the loss of synchronism in interconnected power systems.

Project Approach and Summary

Based on EPRI’s accomplishments in synchrophasor applications, this project will develop a software engine for the early warning of potential wide-area stability problems using synchrophasor data. If fed with a time series of synchrophasor data at dispersed locations, the software engine would offer the following functions:

- For user-definable regions (that is, groups of synchrophasors) in a power system, dynamically identify dominant inter-area oscillations between those regions and the related mode shapes.
- Among those regions, dynamically identify the most dangerous interfaces of angle separation.
- Conduct a stability assessment on the dynamically identified interfaces to estimate the angular stability margin.
- Provide a real-time warning on the potential loss of synchronism if the stability margin on any interface is found below the expected level.

The outputs of the software engine include modal information on dominant inter-area oscillations and the estimated values of stability margin indices. The project will define the software’s data interfaces to phasor data and visualization tools so that the participants of the project can easily test the software engine on their grids and integrate it into their real-time monitoring systems.

Benefits

- Provide wide-area angular stability monitoring using synchrophasors.
- Provide real-time trends on the angular stability margin during a sequence of disturbances.
- Indicate the critical grid interfaces where stability problems may potentially happen and proactive control actions should be added.
- Possibly reduce the risk of cascading outages by providing early warning of insufficient stability margin so that a grid operator can employ pre-defined operating procedures on a timely basis.
Artificial Neural Network Short Term Load Forecaster (ANNSTLF) Maintenance and Support (068359)

**Background, Objectives, and New Learning**

Electric power short-term load forecasting (next hour and hourly for next 35 days) is very important to the utilities and the public. Accurate models must be designed to predict the needed power on an hourly or sub hourly period in order for the purchase of necessary power. Lack of necessary power may result in outages or under-voltage conditions. Inadequate forecasting may lead to increased generation costing from the grid, which may lead to higher rates for the public. Having an accurate load hourly, load forecasting tool may help to ensure the reliability of power delivery to the public and may improve the costing basis of that delivery. ANNSTLF is an EPRI-developed short-term load forecaster and is built upon neural net technology to achieve leading accuracy.

The objective for ANNSTLF is to continually address the changing needs of the electric power system. Investigation into new techniques is needed to meet the changing power system characteristics. The new techniques may lead to ways of improving safety and lowering costs. This is accomplished by testing new features to see if they work and if they can improve accuracy results. Once testing of new features is complete, those features that successfully meet the new environment demands are released to all participants. If the features for accuracy and hourly forecasting lose accuracy, then corrective analysis is begun within 24 hours and corrected as soon as identified and tested.

With the evolution of the electric power grid, it is recognized that a forecasting tool such as ANNSTLF, which accurately forecasts hourly loads, is needed. Participation in this project may help to further the development and expand the capabilities of the ANNSTLF Software.

**Project Approach and Summary**

EPRI will provide participating utilities with ANNSTLF maintenance and support during the participation period. Maintenance and support includes (1) support during daily use of the software, and (2) any normal upgrade version released within the participation period. The maintenance and support covers all the user regions and includes temperature and humidity forecasters if applicable.

**Benefits**

The ANNSTLF tool can offer utilities a number of benefits. These may include:

- Improved load forecasting accuracy
- Improved ability to meet the changing power system characteristics
- Improved public good by improving safety and maintaining affordable electricity prices
Demonstration of Restoration Planning and Operator Decision Support Tool (105309)

Background, Objectives, and New Learning

System restoration is important operation function to minimize the impacts of major disturbance events. The occurrence of natural disasters is one example. The impact of such events on electric power system functioning has been of interest to countries worldwide. Effective system control and restoration can promptly bring a system in blackout or separation status back to service.

In 2009-2013, EPRI has been working with researchers and members to develop methods and decision support tools for system restoration engineers. A novel system restoration methodology entitled “Generic Restoration Milestone (GRM)” has been successfully proposed. A software application entitled “System Restoration Navigator” (SRN) has been developed to assist system operators to develop and evaluate restoration plans and actions. And a software application entitled “Optimal Blackstart Capability” (OBC) has been developed to assist system planners to find the optimal installation of blackstart unit to achieve desired blackstart capability.

These tools will assist system restoration planners and operators in developing and implementing effective and adaptive restoration plans.

Project Approach and Summary

This project is going to demonstrate the capability of developed methods and algorithms, help utilities test and implement these decision support tools, and further enhance the tools to better suit the practical needs.

EPRI project team will work closely with system restoration engineers to conduct case studies using the actual system. The study results will be examined and summarized. Training on how to use the tool(s) will also be provided to system restoration engineers so that they can utilize the tool(s) in assisting their job.

With the implementation of such decision support tools, power grids will be better prepared and equipped for handling extreme events, streamline the communication with all stakeholders, and help preserve and pass on the knowledge to future engineers.

Benefits

- May assist in developing precautionary emergency control plans and strategies against natural disasters
- May increase blackstart capability
- May shorten system restoration time to reduce loss
- Improve system operators’ confidence when making decisions
- Learn how to utilize the developed tools