Bulk Power System Integration of Variable Generation - Program 173

Program Overview

Program Description
Several ongoing environmentally driven regulatory issues—such as greenhouse gas reductions and associated CO₂ reduction initiatives as well as state-mandated renewable energy standards—along with improved economic viability for wind generation have resulted in the increased implementation of renewable energy. Much of the estimated development of renewables comprises variable resources such as wind generation and solar photovoltaic (PV), which, when integrated with the grid, create many new challenges for maintaining reliable system operation. Future projections are that a more significant build-out of these variable renewable resources is likely.

With these developments, power system planners and operators require new tools and resources to ensure a reliable, secure, and cost-effective supply of electricity to consumers. The new tools include improved and/or new sources of system flexibility to respond to and accommodate the increase in energy variability and uncertainty, the development of additional transmission infrastructure to deliver energy from remote locations, and planning and operational methods and software to effectively build and use these new resources.

Research Value
The mission of EPRI's Bulk System Variable Generation (VG) Integration research program is to provide variable generation scenario integration analytics; development of planning methods, tools, and models; and development of operator methods and tools to reliably and economically integrate wind and solar PV generation. In 2012, EPRI's Bulk System VG Integration research program will offer its members a focused research portfolio with the following objectives:

- Develop methods and tools to support risk-based transmission planning that integrates the uncertainty of variable generation and controllable loads when evaluating system facility requirements
- Develop methods and tools to determine operating reserve requirements for high levels of variable generation with consideration of all other system uncertainties
- Specify the requirements for operational tools and methods to support dispatch and supply surplus/deficiency decisions for high levels of variable generation
- Develop tools and methods to design and build a portfolio of supply and demand resources that provide sufficient capacity and flexibility to ensure a reliable and economic supply of energy
- Characterize the variability and uncertainty of solar PV and the resulting impacts on system operations
- Determine the impacts of increased system variability on the conventional generation fleet that must increase cycling duties to accommodate
- Develop and validate wind generation, solar PV, and other emerging flexible resource dynamic models for system planning studies

Approach
EPRI's Bulk System VG Integration research program delivers value by using the shared experiences and understanding of our utility and independent service operator (ISO) members in conjunction with the expertise of EPRI's staff and network of top-level contractors to conduct research projects that lead to actual methods and tools used by system planners and operators responding to the challenges of high penetrations of VG.

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. For example, EPRI staff serves on the leadership group of the North American Electric Reliability Corporation (NERC) Integrating Variable Generation Task Force, ensuring that member perspectives are incorporated into the activities of such groups and that EPRI research is designed to help members respond to the requirements
that emerge from such efforts. Our research program also strives to give members both short- and long-term value. For example, the 2012 Bulk System VG Integration research program will continue efforts to validate existing generic wind generation dynamic models that are being used for interconnection and planning studies today while conducting research to develop operator tools that will suggest generation re-dispatch and/or transmission network reconfiguration solutions to post-contingency or variability events.

Accomplishments
The Bulk Power System Integration of Variable Generation program was created in 2009. Program products and accomplishments in 2009 and 2010 include the following:

- Development of methods and tools to support risk-based transmission planning that integrates the uncertainty of variable generation and controllable loads when evaluating system facility requirements
- Development of methods and tools to determine operating reserve requirements for high levels of variable generation with consideration of all other system uncertainties
- Specification of the requirements for operational tools and methods to support dispatch and supply surplus/deficiency decisions for high levels of variable generation
- Development and validation of wind generation, solar PV, and other emerging flexible resource models for system planning studies
- Continued interaction and representation of member interests through the NERC Integration of Variable Generation Task Force (IVGTF) leadership team

Current Year Activities
In 2012, EPRI’s Bulk System VG Integration research program will offer its members a focused research portfolio with the following objectives:

- Develop methods and tools to support risk-based transmission planning that integrates the uncertainty of variable generation and controllable loads when evaluating system facility requirements
- Develop methods and tools to determine operating reserve requirements for high levels of variable generation with consideration of all other system uncertainties
- Specify the requirements for operational tools and methods to support dispatch and supply surplus/deficiency decisions for high levels of variable generation
- Characterize the variability and uncertainty of solar PV and the resulting impacts on system operations
- Determine the impacts of increased system variability on the conventional generation fleet that must increase cycling duties to accommodate
- Develop and validate wind generation, solar PV, and other emerging flexible resource dynamic models for system planning studies

Estimated 2012 Program Funding
$1.5M

Program Manager
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Summary of Projects

PS173A System Planning Methods, Tools, and Analytics (072093)

Project Set Description

P173 Project Set A focuses on the development of methods and tools for supporting resource adequacy and transmission planning for systems that must accommodate the variability and uncertainty of high levels of variable generation such as wind and solar PV. Planners for these systems need validated models of these new technologies and system planning/analysis platforms that use these models while representing the uncertainty of output from these variable resources over time. This project set includes research to provide these new models, tools, and methods.

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<tr>
<td>P173.003</td>
<td>Grid Performance and Modeling of Variable Generation and Evolving Power System Resources</td>
<td>This project intends to develop a model validation tool for generic nonproprietary models for wind turbine generators.</td>
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<td>P173.006</td>
<td>Advanced Planning Tools to Study the Impact of Variable Generation and Controllable Loads</td>
<td>This project develops methods and tools that allow transmission planners to incorporate and consider the added uncertainty when evaluating system reliability and facility upgrades that will be required to support future generation and load requirements.</td>
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P173.003 Grid Performance and Modeling of Variable Generation and Evolving Power System Resources (067489)

Key Research Question

Many states have already passed renewable energy requirements, and there is still the prospect for a federal requirement. Many of these requirements include specific targets for wind and solar generation. As a result, there is an increasing effort to develop bulk system interconnected wind and central solar PV plants and integrate solar PV panels in residential and commercial constructions. When connected to the distribution system in sufficient quantities, PV generation is capable of impacting power grid behavior during system disturbances. It is important to understand the characteristics of wind and solar PV generation as well as other emerging resources, whether bulk system interconnected or distributed, with respect to the way in which these devices respond to voltage and frequency variations in the power grid.

In 2011, EPRI is working in collaboration with Western Electricity Coordinating Council (WECC), International Electrotechnical Commission (IEC), Institute of Electrical and Electronics Engineers (IEEE), and other industry groups to continue to develop generic, nonproprietary wind turbine generator models and solar PV models. In addition, we are working on acquiring measurement data for wind turbine generator and wind power plants to prove the concept of model validation for the generic models using measured disturbance data. Assuming that these efforts will be successful in 2011, the intent in 2012 is to move toward the development of a software tool for model parameter estimation and validation for wind plants, similar to EPRI Power Plant Parameter Derivation (PPPD) software for synchronous generators.

Approach

This effort will build on work begun in 2010 that involved working with industry groups to develop and validate generic wind generation dynamic models and solar PV dynamic models. It is anticipated that in 2011 the project will provide for completing PV model development and the validation and development of generic wind turbine generator models.
Assuming that we have been able to achieve the intended goal of proving the concept of wind turbine generator model validation using on-line measured disturbance data, in 2012 the key goals are as follows:

1. **Software Tool Development.** This is focused on developing the algorithms and models developed and tested in 2011 into a stand-alone software tool for model validation of generic wind turbine generator models using measurement data. The tool will be developed in MATLAB® and complied into a stand-alone tool using the MATLAB® Complier. The models implemented will be the generic models developed through the WECC Renewable Energy Modeling Task Force and IEC TC88 WG27 efforts.

2. **Software Release.** We will release the model to the public through www.epri.com.

**Impact**

The benefit of this work is the public dissemination of a tool to facilitate the validation of generic wind turbine models.

**How to Apply Results**

Various forums such as webcasts will be used to demonstrate the usage of the developed software tool. In addition, a workshop or tutorial could be organized for training users in the application of the tool, but this would need to be done after the tool is developed and released and so may be scheduled in 2013.

**2012 Products**

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<tr>
<td><strong>Wind Plant Parameter Derivation Software Tool:</strong> This software tool is a stand-alone software tool for model validation of generic wind turbine generator models using measurement data. The tool will be developed in MATLAB® and compiled into a stand-alone tool using the MATLAB® Complier. The models implemented will be the generic models developed through the WECC Renewable Energy Modeling Task Force and IEC TC88 WG27 efforts.</td>
<td>12/31/12</td>
<td>Software</td>
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**P173.006 Advanced Planning Tools to Study the Impact of Variable Generation and Controllable Loads (069256)**

**Key Research Question**

Global climate concerns are influencing the ever-increasing role that renewable and variable generation will play as future energy sources. At the same time, interest in the smart grid has accelerated in the United States and the rest of the world, with smart meters connected to customers with controllable loads likely leading the way for smart grid deployments. The proliferation of high levels of variable generation and controllable loads will require grid planners to incorporate much higher levels of uncertainty in their models to adequately represent the many potential system scenarios that might result. These models will be necessary to maintain grid reliability and reduce system development and operating costs.

Research is needed to develop advanced risk-based planning tools that integrate the planning and operation of customer demand, energy storage, and renewable generation. In the absence of such tools, system operators are more likely to be required to operate in system configurations and scenarios that might not have been adequately studied in the system planning. Or, transmission planners might take a conservative approach in planning to ensure that sufficient margin exists to cover unstudied configuration and scenarios, resulting in inefficient infrastructure upgrades and overbuilt capacity. System planners need to properly evaluate transmission capacity requirements and grid reliability when higher levels of variable generation and controllable loads are anticipated.
### Approach

The objective of this project in 2012 is to develop prototype software based on EPRI's TransCARE and to prepare a functional specification for other planning software to incorporate the probabilistic models developed in 2011. This tool and methodology could be used for transmission planning with large amounts of VG. The benefit of this tool is that a more economic transmission plan can be produced while maintaining reliability at a desired level, without the need for exhaustive, costly time simulations of every feasible state.

- Model the uncertainties associated with renewables, including wind and solar. Usually, wind farms and solar collection points are combined or treated as a single entity in steady-state power flow models; such simplifications result in low-accuracy simulation. A rigorous probabilistic mathematical model will be developed to capture variations of renewable generation and take into account the correlation of these variable generations with system loads. This work will incorporate research results by EPRI and others on modeling the intermittent nature of renewable generation.

- Develop system load shapes and load factors with various assumptions of penetration scenarios of controllable loads, before and after applying control. EPRI will also identify ways that controllable loads can be used as control variables that can decrease or increase at various points in a bulk power transmission system.

Develop advanced planning tools to perform reliability assessments for comparing alternative transmission expansion plans to accommodate a high penetration of renewables and controllable loads. EPRI will implement the developed model on existing probabilistic and risk-based transmission planning tools (such as TRELSS/TransCARE—enumerative procedure based).

### Impact

Transmission planners are tasked with efficiently building a grid that operators can reliably operate. Increased uncertainty in generation dispatch patterns and load patterns increases the complexity of the planners' problem. This project develops methods and tools that allow transmission planners to incorporate and consider that added uncertainty when evaluating system reliability and facility upgrades that will be required to support future generation and load requirements. By explicitly representing the uncertainties related to variable generation and controllable loads, planners will be able to more efficiently plan system upgrades and avoid intentional overbuild solely for the purpose of providing planning margins to cover these known uncertainties.

### How to Apply Results

The project's products will help members understand how to conduct advanced planning for the entire power supply and delivery chain. Members will be able to use the best available data and information about load composition and load models that recognize all resources and demands. Typical system load shapes will be available for members to use for system studies. The tools and methods developed can be integrated into members' planning procedures to ensure that the uncertainty associated with variable generation and demand response is rigorously represented. Webcasts will be held regularly to engage members in research efforts and facilitate information sharing.

### 2012 Products

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PS173B System Operations Methods, Tools, and Analytics (072095)

Project Set Description
P173 Project Set B focuses on the development of methods and tools for supporting operational planning and real-time operations for systems that must accommodate the variability and uncertainty of high levels of variable generation such as wind and solar PV. Schedulers and operators for these systems need new visualization and dispatch support tools to economically and reliably commit and dispatch generation and to reconfigure the transmission network in response to the increased regulation, load following, and cycling required to respond to the variability of VG over time. This project set includes research to provide these new models, tools, and methods.

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<tr>
<td>P173.005</td>
<td>Operator Tools for Scheduling, Reserve Determination, and Frequency Control with Variable Generation</td>
<td>This project will develop methods and tools that allow operators to more reliably and efficiently schedule resources to meet demand while maintaining adequate reserves in the operational planning timeframe and to provide dispatch decision support and methods for improved frequency control in real-time operations.</td>
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<tr>
<td>P173.007</td>
<td>Bulk Electricity System Impacts of Distributed and Transmission System Connected Solar PV</td>
<td>This project will evaluate the integration of solar PV, both as a comparison with the integration of wind and by assessing potential adverse impacts of high levels of PV on bulk system reliability as well as provide guidelines for mitigating such negative impacts.</td>
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<td>P173.008</td>
<td>System Operational/Planning Impacts of Cycling</td>
<td>This project will develop methods to better understand the range of operating and planning impacts of increased generator cycling resulting from variable generation and propose mitigating strategies to reduce those impacts.</td>
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P173.005 Operator Tools for Scheduling, Reserve Determination, and Frequency Control with Variable Generation (069255)

Key Research Question
The variability and uncertainty associated with variable renewable generation such as wind and solar PV can have a significant impact on system performance and market operation as penetration levels increase. Specifically, the variability and uncertainty make it much more challenging for system operators to schedule the most economical set of resources to meet system requirements, determine operating reserve requirements to ensure reliability, and maintain real-time frequency and voltage performance to established standards. Consequently, new operational scheduling and control methods and tools are needed to ensure reliable system operation in the most efficient and economical manner. A stochastic optimal power flow (OPF) application has been developed; this improves generator scheduling and reserve determination by including the stochastic nature of wind and load when scheduling a system. This type of application results in a schedule that is more robust to changes in wind and load and reduces total expected costs. In 2012, EPRI will continue to develop the stochastic OPF Reserve Determination and Rapid Redispatch applications documented in 2011 on a realistic scaled system.

Approach
EPRI will continue work begun in 2010 and continued in 2011 to develop two operations applications—Reserve Validation and Rapid Redispatch—that can assess existing reserve schedules to ensure that they are adequate and rapidly determine optimal dispatches to respond to random forecast errors and contingencies.

Emphasis will be on integrating these applications into prototype tools at scale so that they can be used on operators’ and schedulers’ desks. EPRI will collaborate with commercial EMS vendors to ensure that tool
prototyping is coordinated in a way that allows the results to be used by vendors in developing commercial tools that integrate with utility and ISO EMS products.

**Impact**

- Power system operators and planners will have new capabilities to optimally schedule generation to meet demand and determine reserve requirements that balance the introduction of emerging energy resources with system reliability.
- This project will offer system operators insights into the potential impacts of variable generation on frequency control as well as new methods for minimizing any negative impacts on system frequency performance.

**How to Apply Results**

- EPRI will provide project status updates and training webcasts to communicate the strengths and applications of the developed operator tools and methods.
- Participants will read the technical report and implement recommendations for Reserve Validation and Rapid Redispatch applications.
- Participants will work with associated vendors to develop and test developed prototype tools or modified system algorithms.

**2012 Products**

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<tr>
<td><strong>Application of STOPF to Reserve Validation and Rapid Redispatch of System Operations</strong>: The report is designed to help members realize the benefits of this technology in their own business processes. Members can utilize this report to create specifications for implementing Reserve Determination and Rapid Redispatch applications by preferred vendors. The report will include and reference useful case studies that can help verify implementations.</td>
<td>12/31/12 Technical Report</td>
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**P173.007 Bulk Electricity System Impacts of Distributed and Transmission System Connected Solar PV (070599)**

**Key Research Question**

Solar PV is expected to make a significant contribution to generating capacity in the next decade. Similar to wind power, it has characteristics of variability and uncertainty in its output and is non-synchronous to the electrical grid. Because much work has already been done regarding the integration of large amounts of wind, there is a large body of knowledge that can be used to ease the integration of solar PV. Although it is expected that the impact of solar PV in terms of reliability, economics, and effect on the balance of the system will be similar to that of wind, there will be some differences. This project will quantify the differences between wind and solar PV from a bulk system point of view as well as the impacts of these differences on planning and operational procedures.

In addition, PV is likely to be connected on the distribution network. This will create challenges in assessing the impact of solar PV. For example, lack of low-voltage ride-through might result in large amounts of solar PV dropping off when there is a fault on the transmission network, resulting in further deterioration of the voltage. There is also the possibility that, rather than impacting negatively on reliability, the PV inverter could be used to improve system reliability. Therefore, the impacts of distributed PV on bulk system operation need to be assessed and mitigating strategies, possibly using the inverter, proposed.
Approach

Building on work done in P173.007 in 2011, the impact of solar PV on reliability will be further extended. Work in 2011 will examine the impact of low-voltage ride-through capabilities (or lack thereof) on the BES. Work in 2012 will extend this to more detailed case studies, examining various scenarios showing the potential benefits that various inverter capabilities (such as volt-var control) can bring. Other reliability impacts, such as under-frequency load shedding issues or reactive power provision, can be addressed. The project team will work closely with related EPRI projects being conducted to assess the impacts of smart grid developments on system reliability.

In addition, the variability and uncertainty impacts of PV will be examined using similar production cost tools to those used in wind integration studies to quantify the difference in impact between solar PV and wind. High-resolution (temporally and spatially) data will be used to quantify the variability of the PV resource on an aggregated system. A key aspect of this will be to understand the impact that the nature of PV, as a distribution network connected resource, will have from the point of view of its lack of visibility and controllability, and how that will impact reserve provision and generator scheduling. This work will be closely aligned with work done in the NERC IVGTF on bulk system impacts of distributed resources; it will also align with integration studies being done, by EPRI and others, for large amounts of PV on various networks.

Impact

This project will provide the analytical foundation and guidance for integrating large amounts of PV onto distribution and transmission networks. By using high-resolution data, several important aspects of PV integration can be assessed:

- From a bulk system point of view, the variability and uncertainty characteristics of PV will be quantified; these can then be compared to wind impacts to assess the key differences, in terms of provision of operating reserve, flexibility needs, and operation of conventional plants on a system with high PV penetration.
- The reliability impacts of distributed PV will be better understood so that they may be addressed. Examining multiple types of systems can illustrate the significance of system type to the scale of the impacts.
- The ability of the PV inverter to aid bulk system reliability will be assessed for various operating strategies.

How to Apply Results

The project’s analytical results and resulting operating and planning guidelines should be disseminated through each company’s operations, planning, and standards functions to ensure that appropriate processes are developed as solar PV becomes more broadly integrated. By using the comparisons between wind integration and solar PV integration, the best practices identified for wind integration can be adopted for solar PV integration. In addition, areas with low amounts of wind but high potential for solar PV can use results to better understand likely impacts on system operation and planning.

2012 Products

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<tr>
<td><strong>Bulk Electricity System Impacts of Distributed and Transmission System Connected Solar PV:</strong> This update will show the reliability impact of solar PV on distribution and transmission networks, and propose mitigating strategies, which have been evaluated on test systems. In addition, it will quantify the differences between the variability and uncertainty of wind and solar PV.</td>
<td>12/31/12</td>
<td>Technical Update</td>
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P173.008 System Operational/Planning Impacts of Cycling (072094)

Key Research Question

With increasing levels of variable generation (VG) being added to the grid, cycling of conventional units will increase. Cycling, which in this context refers to starting and stopping a unit or ramping a unit frequently through its operating range, can have detrimental effects on the performance, lifetime, and efficiency of conventional thermal and hydro units. Of particular concern are generators originally designed to be baseloaded, but which will be required to act as a mid-merit or peaking plant when there is a large increase in low-cost, variable energy sources such as wind and solar PV. In addition, new requirements on conventional plants resulting from environmental regulations might reduce the flexibility and increase the costs of cycling for the existing generation fleet.

This project intends to use the work to quantify cycling costs being conducted by EPRI's Generation Sector to better understand the likely impact this cycling cost knowledge will have on existing planning and operational paradigms. This knowledge can then be used to propose new methods or tools to incorporate cycling costs into planning and operational procedures. This will ensure that the potential cycling cost and reliability implications are fully considered when optimizing commitment and dispatch decisions when high levels of VG exist.

Approach

This project will examine the operational and planning changes needed to account for unit cycling costs and/or unit loss of life. Cycling cost quantification will be used from other areas (for example, EPRI's Generation Sector) to understand the impact of these costs on planning and operating systems. For example, the increase in cycling expected of a particular type of unit will be used to develop an understanding of the likely impact this will have on costs, maintenance schedules, lifetime, outage rate, emissions, and other factors. This information can then be used as input to a generator scheduling algorithm to ensure that the overall system costs can be reduced over the course of one or multiple years. Different ways to include the various cycling impacts (for example, as dynamic start costs or changed forced outage rates) in scheduling systems will be developed and assessed to best mitigate the long-term effects of cycling.

Planning techniques will also need to account for unit cycling, and the knowledge of cycling impacts on the build-out of generating capacity will be examined. Optimal system planning will consider generator cycling and its long-term impact in terms of reduced lifetimes, need for retrofitting, and increased outage rates. In addition, the way VG is treated when operating the system will be examined—for example, priority dispatch rules and their effect will be analyzed. This work will likely use a production cost model to gain a fuller understanding of the way in which production costs and expected dispatches will change when cycling is considered. The results will be a quantitative description of the effects of cycling on the planning and operational timeframes for a system, together with proposed strategies to properly integrate the cycling impacts into operational and planning tools.

Impact

This work allows quantification of the impacts and assessment of mitigating approaches to unit cycling, with a particular focus on VG. Key benefits will include:

- Identification of the extent of additional damage caused by cycling wear and tear caused by additional VG and its impact on power system operation.
- Identification and assessment of various approaches to mitigate the various cycling effects that will be caused by VG.
- Development of a better understanding of the true costs and impacts of the integration of VG.
- Provision of input into decision-making processes for future plant mix and quantify the benefits of retrofitting existing plants to allow for increased cycling.
- Development of approaches to minimize long-term impacts of cycling in operational planning.
How to Apply Results

Results from this project will be of use when planning and operating systems, particularly those for which significant levels of VG are envisioned. Although the identification of cycling costs will allow them to be quantified, for these costs to be of most benefit they need to be considered as part of the entire system. This project will enable planners and operators to better understand the impacts of cycling and to consider possible methods for better reducing its impacts as part of the ultimate goal of minimizing systems costs while maintaining reliability at desired levels. These methods will need to consider both the short- and long-term time scales to enable better operation of the system while considering longer term planning needs.

2012 Products

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<tr>
<td><strong>Impact of Generator Cycling Costs on Planning and Operation of Systems with High Variable Generation and Possible Mitigating Strategies:</strong> This update will provide an overview of the types of impacts increased cycling costs due to variable generation will have on system operation and planning; strategies to best incorporate and mitigate cycling into operational and planning procedures will be proposed and evaluated.</td>
<td>12/31/12</td>
<td>Technical Update</td>
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Supplemental Projects

Field Demonstrations of Wind and Solar PV Plants Providing System Frequency Response and Regulation (072096)

Background, Objectives, and New Learnings

Wind and solar PV generation has generally not been designed to supply inertia, primary frequency response (governor), or secondary frequency response (automatic generation control [AGC]) to the system. In systems in which large amounts of these variable resources have been installed, there are periods of time during which an increasing percentage of the load is served from these resources pushing more conventional generators, which typically supply these needed functions, off the system. As a result, studies of systems anticipating high wind and/or PV penetrations have shown potential stability concerns as penetrations increase if the renewable resources are not controlled in a way that provides some similar inertial and primary frequency response.

In response to these concerns, system planners and operators along with wind turbine manufacturers and plant owners/operators have begun to consider the extent to which wind plants might be able to provide these functions with some systems establishing requirements. In addition, some wind turbine generator (WTG) manufacturers have begun testing and deploying new control packages that allow the WTGs to emulate inertial response. To date, however, there has not been a succinct, focused effort for most North American systems to evaluate the levels at which systems might be beginning to have these potential stability issues and to evaluate the effectiveness of wind and solar PV plants to supply these needed reliability functions as they push conventional generation offline.

This project will provide for actual field verifications of the ability of wind generation and solar PV generation plants to adequately supply inertia, primary frequency, and AGC response when interconnected to the bulk power system. This work will give system operators a better understanding of the types of advanced controls that contribute to these required system functions.

Project Approach and Summary

EPRI will work with the National Renewable Energy Laboratory (NREL) to use its utility-scale test wind turbines to test various active power control schemes for contributing to system frequency responsive functions. EPRI will also pursue a partnership with a commercial wind plant that has implemented or is willing to implement a commercially available active power control package offered by the wind turbine manufacturer for the turbines used in the plant. For both the NREL test turbines and a commercial plant that will be potentially identified, EPRI will conduct measurement and verification (M&V) of the turbine/wind plant active power output during specific frequency disturbances that naturally occur on the interconnected power system.

EPRI will also work with the University of Texas at Austin (UT-Austin) to evaluate any relationships between online wind generation and the Electric Reliability Council of Texas, Inc. (ERCOT) system frequency responsiveness for disturbances in the ERCOT system. This evaluation will use synchrophasor data collected across the ERCOT system as part of a joint EPRI and UT-Austin synchrophasor network project.

Benefits

This project will give system operators and planners an understanding of the abilities of wind generation and solar PV generation to effectively contribute to the frequency responsive needs of the power system during disturbances and steady-state operation (AGC). The M&V effort will confirm whether emerging renewable resources can provide the functionality of the conventional generation that they might replace or whether there are limitations to the frequency responsiveness of wind and PV with advanced controls. If the effectiveness of these controls can be confirmed, one of the major concerns that have been voiced relative to the potential system reliability impacts of variable generation will be removed.
Impact of Renewable Energy Resources on System Protection (072097)

Background, Objectives, and New Learnings
The integration of renewable energy resources into the transmission grid presents significant technical challenges for system protection and planning engineers. The power electronics associated with some wind turbine generators (WTGs) and photovoltaic (PV) inverters can produce current waveform signatures that are significantly different from those of traditional synchronous or asynchronous generators. As such, traditional short-circuit modeling techniques do not accurately represent the behavior of renewable energy resources during short-circuit events. Accurate short-circuit models of renewable energy resources are not available; consequently, protection and system planning engineers are required to make judgments based on limited information about the behavior of these devices during short-circuit events. The primary objective of this research project is to evaluate the impact of renewable energy resources on system protection. New learning will result from an improved understanding of the way in which these devices affect system protection and of improved short-circuit models for system studies.

Project Approach and Summary
This multiphase project will address many of the technical issues faced by protection and planning engineers when analyzing systems with high-penetration renewable energy resources. Improved short-circuit models of various renewable energy resources will be developed to aid in performing system studies such as protection and coordination and circuit breaker duty. The performance of various instrument transformers (for example, current transformers, wound potential transformers, and capacitive coupled voltage transformers) when subjected to the unique waveform signatures of renewable energy resources will be evaluated, and the impact of renewable energy resources on the performance of protective relay hardware and settings will be explored.

Benefits
Utilities are under considerable pressure to increase the percentage of renewable energy resources in their generation fleet. The DOE has outlined a plan to increase the percentage of power generated in the U.S. from wind power to 20% by 2030, and large-scale PV integration will increase the percentage of renewable energy resources even higher. As the percentage of renewable energy resources increases, so will the likelihood of experiencing problems caused by the assumptions being made regarding the short-circuit behavior of renewable energy resources. This research will proactively address these issues before they become a hindrance to the long-term sustainability of high-penetration renewable energy resources.