Integration of Variable Generation and Controllable Loads - Program 173

Program Overview

Program Description

A number of ongoing environmentally driven regulatory issues—including greenhouse gas reductions and climate change initiatives, the U.S. Clean Water Act: Cooling Water Intake Structures, and the U.S. Clean Air Act: Interstate and Mercury Rules—have increased implementation of renewable energy resources and adoption of distributed generation (DG) and demand-side resources.

Research Value

EPRI research and development in integrating generation and controllable load area will produce knowledge and tools that will help system operators and planners:

- Understand the impacts of variable generation and controllable load on system reliability
- Control variable generation and controllable load to minimize operational risks
- Design robust transmission systems to integrate variable generation and controllable load.

Approach

The Integration of Variable Generation and Controllable Load program offers members both short- and long-term value that can be realized in a number of ways:

- Anticipating future developments, creating new strategies, and outlining roadmaps
- Developing methods and tools
- Demonstrating and deploying technologies
- Providing training and staff development
- Sharing knowledge, information, and experience
- Building networks and conducting outreach.

Accomplishments

The Integration of Variable Generation and Controllable Load program was created in 2009. Program products in that year included:

- Technical update on transmission infrastructure to integrate renewable energy
- Technical update on determining planning and operational reserve requirements for intermittent resource integration, with case studies
- Technical update on operational tools and methods for high-penetration wind systems.

Current Year Activities

In 2010, this research program expects to accomplish these objectives:

- Understanding the state of the art, best practices, and gaps of existing tools
- Preparing a set of requirement specifications for expanding the capabilities of tools to deal with the variability of resources
- Exploring new methodologies to deal with uncertainty of variable generation and controllable load
- Business case studies to quantify financial benefits of controllable load and storage

Estimated 2010 Program Funding

$1.3M

Program Manager

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Summary of Projects

Project Number	Project Title	Description
P173.003	Grid Performance and Modeling of Variable Generation and Evolving Power System Resources	This project aims to describe the technical performance requirements of variable generation and other emerging generation technologies, help develop generic non-proprietary models for modeling and planning the integration of such resources into the utility grid, and guide efforts in model validation.
P173.004	Determination of Optimal Reserve with Consideration of Variable Generation and Controllable Loads	Determine energy and reserve schedules with consideration of power system uncertainties arising from conventional and emerging energy technologies such as controllable loads, price-sensitive demand, energy storage, and PHEVs.
P173.005	Advanced Frequency Control for High Variable Generation Systems and Evolving System Resources	System operators presently depend on generating resources to supply frequency regulation through the load frequency control (LFC) portion of AGC. Present LFC algorithms may be tuned in a way that does not provide optimal or even adequate frequency control for high penetrations of variable generation. For example, recent EPRI studies performed on a small island system with high wind penetration showed that control tolerances had to be loosened to prevent hunting, or over-control, which degraded control performance. This project will evaluate potential changes to existing LFC functionality and maintenance for high variable generation scenarios. Additionally, the project will assess gaps in existing control algorithms, communications infrastructure, or any other barrier that would preclude new sources that provide system flexibility from participating in frequency control. This information will then be used to create a roadmap and possible demonstration efforts needed to take the concept to an implementation phase.
P173.006	Advanced Planning Tools to Study the Impact of Variable Generation and Controllable Loads	This project will investigate future load composition, system load shapes, business cases for energy storage, regulatory policy impacts and the value of ancillary services as affected by integrating high penetrations of renewable generation, controllable loads, PHEV, energy storage, and demand response. Information developed through this project will prove useful to members when planning their future transmission grids.

P173.003 Grid Performance and Modeling of Variable Generation and Evolving Power System Resources (067489)

Key Research Question

Many states have passed renewable energy requirements, and the prospects for a federal requirement seem good. Many of these requirements include specific targets for wind and solar generation. As a result, there is an increasing effort to integrate solar photovoltaic (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 PV generation with respect to voltage and frequency variations in the power grid. PV, solar thermal, demand

response, plug-in hybrid electric vehicles (PHEVs), and other evolving system resources have performance characteristics that can differ from those of conventional generation. System planners and operators, as well as owners of the new system resources, need to understand the requirements for each of the technologies to supply services required by the system.

Approach

This project will investigate and develop technical specifications for the dynamic performance of evolving power system resources. For example, should PV have fault ride-through, as is now accepted and implemented for wind power plants? This effort will build on work from a supplemental project begun in 2009 that provides for developing these technical specifications for wind generation technologies. The 2010 project will extend these specifications to other technologies such solar PV, solar thermal, energy storage, demand response, and PHEVs. The order of development will be prioritized with project members. In addition to furthering technical specifications for advanced resources to provide system performance needs, this project will also develop guidelines for representing such devices in bulk system planning studies. This effort will:

- Review available technical literature on inverter-based PV testing and modeling, and review any readily available field measurements for existing PV installations. This literature and data review will also be conducted for other advanced sources, such as PHEVs, to serve as the basis for developing bulk system modeling guidelines for these devices in future efforts.
- Identify gaps that may exist in the understanding of inverter-based PV generation that potentially limit the ability to develop representative bulk transmission system models. Determine whether further laboratory testing of certain units may provide a better understanding of such issues. If so, develop a plan for obtaining equipment, develop test plans, and conduct additional tests in the future. Similar gaps should be identified for other evolving resources.
- Develop a detailed scope for future project work to develop models for inverter-based solar generation and other evolving resources, and methods to include representation of these devices in commercially available bulk power system planning tools. Such models need to be non-proprietary and open for use by all, disseminated to the industry to allow their implementation in standards and widely used commercial power system analysis software. This effort would coordinate with ongoing efforts by IEEE, WECC, and other organizations developing models for variable generation resources. The project would also aim to develop ways to validate the models.
- Based on a literature search and experience with wind generation, provide a qualitative assessment of the potential impacts that a large proliferation of inverter-based distributed generation, such as PV, may have on the bulk transmission grid. Accordingly, make recommendations on what aspects of standards and future inverter-based PV and DG control strategies may need to be investigated and revised to address those issues. Such standards development is clearly outside the scope of EPRI's work, and the goal would be to make technical recommendations to standard organizations such as NERC.

Impact

- This work is necessitated by the growing demand for renewable and distributed generation technologies. On the system modeling and planning side, existing tools and models do not yet adequately represent the breadth of capabilities and performance of these emerging technologies. Being able to develop the models needed and technical performance guidelines for applying these new technologies will be a significant step in providing system planners with the tools they require to plan the power system in coming years. This research can help members by:Defining the control features and capabilities that emerging variable generation sources need to match existing generation technologies
- Providing models and guidance on the use of models of these new technologies for system planning studies
- Validating existing or in-development models.

How to Apply Results

Provide workshops, tutorials and training webcasts. Also, disseminate key results and models through industry forums such as IEEE and CIGRE.

2010 Products

Product Title & Description	Planned Completion Date	Product Type
Workshop on Variable Generation Performance and Modeling	12/31/10	Workshop, Training, or Conference
Technical Report on Variable Generation Performance and Modeling	12/31/10	Technical Report

P173.004 Determination of Optimal Reserve with Consideration of Variable Generation and Controllable Loads (067490)

Key Research Question

New NERC requirements for Operational and Planning Reserve (BAL-002-RFC-02, RES-001-1) recognize the need for improved methodologies and algorithms beyond the traditional contingency analysis to accommodate increasing levels of uncertainty in the behavior of intermittent resources and demand response. This research is new and compelling, due to the introduction of renewable portfolio standards and the use of demand response for mitigating the impacts of high-priced energy sources.Unlike conventional generation from fossil fuels, nuclear, and hydropower energy sources, emerging generation technologies such as wind, solar, and demand-side energy sources offer new uncertainties and are not easily controlled. Specifically, their variability makes it more difficult for system operators to determine reserve requirements. Current practice, which uses a deterministic approach, is no longer sufficient. A new approach is needed for determining reserve requirements.

Approach

This project will apply a stochastic model to determine robust energy and reserve schedules. The model minimizes the overall cost of energy and establishes reserve schedules and post-contingency correction controls, while maintaining the reliability of power system operation under both normal and contingent scenarios. The methodology determines energy and reserve schedules with consideration of power system uncertainties arising from conventional and emerging technologies. Such technologies include intermittent generation, controllable and price-sensitive loads, energy storage, and plug-in hybrid electric vehicles (PHEVs). The project team proposes to use a stochastic optimal power flow (SOPF) model with reserve determination under different types of uncertainties. This model formulation forms the core of a new approach to network modeling for describing and simulating new behaviors of network resources. It can be applied to planning and operations studies, and can also help determine long-term system capacity requirements. In a market context, the model formulation forms the basis for understanding system performance under uncertainty. It can be used to help market operators, market monitors, and regulators determine sufficient capacity requirements for short- and long-term needs. Through models and case studies, this project will provide examples of a detailed analytical method for determining planning and operational reserve requirements. The project will proceed as follows:

- Review existing capacity evaluation methods utilized in various jurisdictions (statistical analysis of capacity in worst hours versus probabilistic-based simulations)
- Review empirical data (including CA 2006, ERCOT, Denmark, and Germany)
- Evaluate new approaches, such as stochastic optimal power flow and others.

Impact

Power system operators and planners will have new capabilities for determining reserve requirements that balance the installation of emerging energy technologies with system reliability. This capability can be used to determine short-term reserve and long-term capacity requirements.

- Determine reserve requirements subject to new demand-side and renewable resource uncertainties.
- Quickly compute stochastic optimal power flows.
- Use a new approach to network modeling, incorporating components with uncertain behavior.

How to Apply Results

EPRI offers project status updates, training webcasts, and reporting exercises to communicate the strengths and applications of the reserve determination under uncertainty. Training and workshops will help users become familiar with the detailed aspects of the technology and the variety of options and experience. Members will develop the capability to utilize stochastic model formulations with commercial simulation tools, as well as handle emerging energy technologies in operational and planning studies.

2010 Products

Product Title & Description	Planned Completion Date	Product Type
Technique for Reserve Determination with Consideration for Conventional and Emerging Technologies	12/31/10	Technical Report
Model for Reserve Determination with Consideration for Conventional and Emerging Technologies	12/31/10	Software

P173.005 Advanced Frequency Control for High Variable Generation Systems and Evolving System Resources (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. How does the availability of demand response and distributed energy storage impact existing operational planning and control strategies and implementation to ensure sufficient balancing and frequency regulation?

Approach

EPRI will draw on studies from small islanded systems with high wind penetrations and engage operators from other systems with increasing variable generation penetration to identify potential performance impacts and needs. This project may also engage automated generation control (AGC) vendors for one or more systems on which new algorithms might be tested.

Impact

This project will provide system operators with insights concerning 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

- Read the technical report and implement recommendations for existing AGC system.
- Work with associated vendors to develop and test identified algorithms in a modified AGC system.

2010 Products

Product Title & Description	Planned Completion Date	Product Type
Advanced Frequency Control for High Variable Generation Systems and Evolving System Resources	12/31/10	Technical Report

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 highly 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 world. To date, smart grid implementation ideas have been largely limited to the development of smart meters, whose availability will likely precede that of other technologies on the bulk power grid level. Deployment of smart meters connected to customers with controllable loads will require grid planning to model them effectively, thereby improving grid reliability and reducing system operating costs. In addition, energy storage will be urgently needed to complement renewable generation and customer demand. Research is needed to develop advanced planning tools that integrate the planning and operation of customer demand, energy storage, and renewable generation. In the absence of such tools, blackouts are more likely to happen. This project is needed by system planners modeling planning studies and evaluating the impact of variable generation and controllable loads on transmission capacity requirements and grid reliability.

Approach

This project is new. It will continue for three years and be completed at the end of 2012. In 2010, the project includes the following activities:

- 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 complete treatment of the random outage and production distribution of renewable generation will be developed. This work will incorporate research results by EPRI and others on modeling the intermittent nature of renewable generation.
- Develop system renewable generation outage probabilities and production distributions with various assumptions on penetration scenarios (15%, 20% and even 33%).
- Develop system load shapes and load factors with various assumptions on penetration scenarios of controllable loads, before and after applying control.
- Develop advanced planning tools to perform reliability assessments for comparing alternative transmission expansion plans to accommodate a high penetration of renewables and controllable loads. The impact of renewable resources and controllable loads on capacity requirements will also be evaluated.

Impact

The value and benefits this project will deliver to its members include:

- Understanding of the technical and financial benefits of controllable loads—including energy storage, PHEVs and demand response—if holistic planning is applied to the entire power supply and delivery chain. Improvements in reliability and reduction in system operating costs may be direct benefits.
- Ability to use project results to assess the impact of controllable loads on future transmission capacity requirements. Members will find that tremendous savings in transmission investments can be achieved if a holistic planning approach is taken to optimally control and complement all the resources and demands over the entire power supply and delivery chain, instead of using disjointed criteria to plan the transmission grid.

How to Apply Results

The project report 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. Business cases for applying energy storage will be excellent sources of information for members planning a possible role for energy storage in their future systems. Survey results and summaries of regulatory impacts as well as the value of ancillary services will also be valuable. Webcasts will be held regularly to engage members in research effort and for information transfer.

2010 Products

Product Title & Description	Planned Completion Date	Product Type
Technical update on the issues and methods for assessing and planning for customer demand and energy storage for regional transmission grid: Technical update on the issues and methods for assessing and planning for customer demand and energy storage for regional transmission grid.	12/31/10	Technical Update