Smart Grid Demonstrations
Focus on Integrating Distributed Energy Resources

THE STORY IN BRIEF

EPRI's Smart Grid Demonstration Initiative is a seven-year international collaborative effort that addresses the major challenges to integrating distributed energy resources with utility distribution systems. Now in its third year, the initiative involves 11 host sites, with individual projects focused on integrating such resources as rooftop photovoltaics, smart charging of electric vehicles, and demand response.

As utilities pursue innovative approaches to improve power factor, manage voltage, and connect distributed energy resources to the grid, the adoption of advanced metering, new sensors, and communications infrastructure is moving the concept of a smart grid toward reality. These technologies enable such intermittent energy resources as solar photovoltaics and wind to be integrated into the grid. A key challenge will be to incorporate growing numbers of these resources, along with demand response and storage, into the distribution systems and their operations.

Electric vehicle charging, for example, may change power profiles along the distribution feeder for some utilities, which are trying to understand the options and impacts of charging at various times and locations. Charging when variable resources such as wind and photovoltaic generation are available may help balance demand and supply on the grid. Grid-connected photovoltaics have increased significantly for more than a decade, raising operational issues ranging from safety to maintaining the voltage within specific limits along the feeder. Using smart inverter technology, utilities may have the opportunity to use the distributed electric vehicle resource to manage power quality in the distribution system.

Information and communications technologies in smart grids are required for integrating distributed energy resources. Deploying automated meters and distribution automation systems supports those infrastructure requirements and may be more cost-effective for utilities than adding new central generation plants and related power delivery facilities, but questions remain about how best to deploy these resources. To help answering these questions, EPRI in 2008 launched the seven-year Smart Grid Demonstration Initiative, which now involves 19 international utilities and includes 11 large-scale smart grid demonstration projects. One goal is to share the best information and lessons learned on integrating distributed energy resources and specific technical issues of various distribution systems. These issues include how to achieve better voltage/VAR (volt-ampere-reactive) control when accommodating more renewable resources.

Growing industry interest and the many new smart grid projects around the world have prompted EPRI to extend the initiative through 2014, and it is again accepting new members in the international collaborative research project.

"The Smart Grid Demonstration Initiative provides a unique opportunity to develop ways of coordinating the operation of a large number of distributed energy resources with two-way communications, while giving participants hands-on experience with the integration process," said EPRI program manager Matt Wakefield. "At the same time, the interoperability standards will allow higher penetration of distributed energy resources so that they can achieve their full potential."

Operations Improvements

Even before work began at the utility host sites, EPRI had been working with participants to develop a foundation of tools and references to support the design of smart grid implementation. Host-site projects are applying EPRI's IntelliGrid[SM] methodology to define the applications and identify the communication, information, and control infrastructures required to facilitate integration of distributed energy resources. Applications include distribution system planning and operations, integration into existing distribution automation approaches, and the capabilities required for these resources to be monitored and dispatched by the utilities' operations control centers and included in market operations.

One major result is the Distributed Resource Integration Framework, which stakeholders can use in planning and comparing integration projects.

For example, Kansas City Power & Light (KCP&L) adopted a design model that centers on the SmartSubstation concept. Using this design, KCP&L is working with select partners to integrate distributed energy resources to benefit an underserved population in a designated "Green Impact Zone" and in the surrounding urban area. Smart grid elements in this demonstration include rooftop photovoltaics, grid-connected battery storage, distribution voltage control, and demand-response thermostats and other devices on customers' premises.

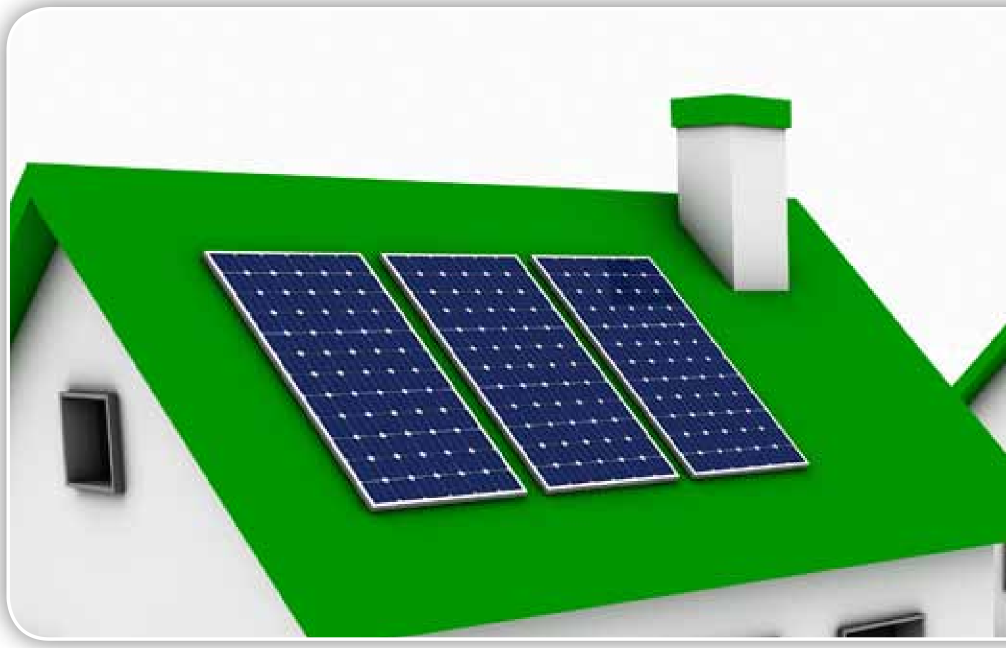
FirstEnergy is focusing on demand management for its design. The company has programs that use a two-way communications system to provide 23 megawatts of direct load control on equipment at 20,000 residential customer locations. The plan also includes installing permanent peak load shifting equipment, energy storage units, and distribution line sensors. The Integrated Distributed Energy Resource (IDER) load management platform will integrate these technologies to deliver distribution system operational benefits.

Surge of Distributed Photovoltaics

Thanks to favorable policies and the steady improvement in the efficiency and cost of photovoltaics, the deployment of distributed photovoltaic systems has grown 25%–40% over the past decade. At the same time, there has been a shift from stand-alone installations in remote areas to grid-connected systems, which now account for about 90% of capacity additions. As a result, distributed photovoltaic systems are affecting distribution networks, requiring additional controls for operating feeders with a high penetration of these devices. Smart grid technologies will provide distribution companies with the monitoring and control functions necessary to effectively manage the power generated by the new systems while maintaining the voltage profile along the feeder.

Renewable portfolio standards and other regulations are driving photovoltaics' deployment in ways that point to a future with greater reliance on distributed resources. For example, photovoltaic systems can be owned by consumers and can be connected to the grid. Utilities own and install photovoltaic systems on their property or on leased rooftops and connect them to the distribution system as an energy resource. These can be treated the same as other regulated assets within the utility's control. Of the 11 smart grid demonstrations, 8 involve photovoltaic-related projects.

PNM Resources is exploring ways to integrate high-penetration distributed photovoltaic systems at customer sites and utility substations with storage capability. This project will evaluate smart inverter interface technologies to enhance system



benefits and identify rate structures and storage control algorithms to help resolve time-related issues associated with a high penetration of renewable generation. PNM also is studying ways to use buildings' energy management systems to smooth some of the intermittency of photovoltaic generation. For example, adjusting the speed of ventilation fans in a large building can help compensate for fluctuations in the power output without affecting building temperature.

"When distributed energy resources such as photovoltaics begin to challenge voltage regulation, coordination of protection, and eventually energy balance, utilities can utilize their smart grid technologies to control the impact," said EPRI program manager Tom Key. "The current demonstration projects will provide critical insights on how to manage this process, as well as reveal new opportunities for utilities to take advantage of increased photovoltaic use to meet their own technical and business needs."

Preparing for Electric Vehicles

The smart grid demonstrations address another major utility concern: coping with an expected increase in electricity use resulting from widespread use of plug-in electric vehicles (PEVs). Charging PEVs may create new patterns of electricity use and require utilities to assess the distribution system impact of various charging options.

Duke Energy's smart grid demonstration project examines how residential photovoltaic systems can be used to help the utility prepare for widespread adoption of PEVs and stationary energy storage. The utility will equip several homes with 2.5-kilowatt photovoltaic units, which can be used to charge electric vehicles in conjunction with a home energy management system. Duke expects 300–500 PEVs will be on the roads and using its grid for charging by the end of 2011. The project also involves installing some 40,000 advanced meters and the use of dynamic pricing for load control.

The demonstration project of Ireland's ESB Networks will examine charging levels and times for PEVs and investigate optimizing rates and controls in order to maximize the ability of secondary networks to accommodate them. ESB plans to install some 2,000 residential charging points across its service territory by 2011. By testing time-of-use rates, it plans to gauge the impacts of smart meters and dynamic pricing on customer behavior. With significant wind generation already in service, the utility targets 40%

of electricity provided from renewables by 2020 and expects about half of that will be connected to the distribution system. It is evaluating optimal scenarios for large penetration of distribution-connected wind generators and the potential for electric vehicle charging as a ballast load for wind generation.

Standards Development

Another objective of the Smart Grid Demonstration Initiative is to identify the most effective approaches for integrating distributed resources and the best ways to provide these insights to the standards-making process for the interoperability of equipment used in smart grids. EPRI is taking the lead for creating a common set of semantics for two important standards promulgated by the International Electrotechnical Commission (EIC): the IEC Common Information Model, widely used to support real-time power system operations, and the IEC 61850 series of standards, which apply primarily to substation automation. Individual demonstration projects will identify additional gaps in existing standards and help coordinate standards implementation with the National Institute of Standards and Technology.

Assessing Benefits

Smart grids are expected to provide numerous benefits for consumers, utilities, and other stakeholders. These include reducing peak load, increasing utilities' operating efficiency, facilitating greater penetration of distributed renewable resources, and providing for smart charging of PEVs. It can be difficult, however, to estimate specific costs and benefits from individual smart grid functions for each stakeholder. EPRI and the U.S. Department of Energy are jointly developing a methodological framework for estimating these benefits.

The framework sets out a 10-step process for identifying smart grid functions, mapping those functions to potential benefits, and quantifying the monetized value of the benefits. It also provides the basis for further assessment, including developing a computational tool. It will be used to estimate costs and benefits of demonstration projects already under way and to estimate potential benefits of proposed projects.

"One of the most beneficial applications will be integrating distributed energy resources into utility applications," said Wakefield. "Ultimately, the goal is to create a way of coordinating the operation of large numbers of distributed energy resources so that they can be dispatched as a virtual power plant. Such interoperability is critical if these resources are to reach the level of penetration needed to have this major impact."

Tom Key added: "Smart grid technologies will be critical for introducing more renewable resources at the distribution system level. The current demonstrations allow utilities to get hands-on experience with a range of distributed energy technologies, evaluate new applications, and identify best practices and opportunities for grid modernization."

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Tom Key, technical leader for renewable and hydropower generation, started in 1989 at EPRI PEAC, which became part of EPRI in 2005 with the restructuring of the Institute's subsidiaries. Previously he worked at Sandia National Laboratory, specializing in the compatible interface of end-use equipment and distributed power systems. Key earned a B.S. in electrical engineering from the University of New Mexico and an MS in electrical power engineering and management from Rensselaer Polytechnic Institute.

Matt Wakefield, program manager of Smart Grid Demonstrations, oversees the development of the smart grid with a focus on emerging information and communication technologies that can be applied to electric grid infrastructure. Prior to joining EPRI, he worked at Wisconsin Public Service Corp. (WPS) in the Instrumentation and Control group of the Kewaunee Nuclear Plant before becoming manager of the Applied Technology group at Integrys Energy group, the holding company of WPS. Wakefield received his B.S. in technology management from the University of Maryland University College.