Smart Inverters Ease Integration of Solar Power

A solar inverter converts DC voltage from photovoltaic (PV) installations to AC voltage that can be harnessed by homes and businesses or by the electrical grid. Much like the first cell phones, which rapidly evolved into today's handheld computers, solar inverters are becoming more intelligent. The advanced—or "smart"—inverter is endowed with functions that communicate with and even improve the performance of the smart grid.

As utilities connect more solar and other distributed energy resources (DERs) to their grids, they must deal with some troubling side effects. For example, solar power and wind power are intermittent, causing voltage fluctuations as clouds pass over and winds cease. Additionally, when a fault occurs on the grid, many solar inverters may disconnect their outputs and then recover at the same time, causing an overvoltage that may trip protective devices. And feeders that were designed to carry current in one direction are now summoned to carry current in two directions, further complicating optimal operation of the grid.

A Cautionary Case

A decade ago, Germany eagerly joined the solar movement, resulting in a high penetration of PV installations. "At times, solar generation has accounted for more than half of Germany's power requirements, and grid operators struggled to maintain quality and reliability of electricity," said Lindsey Rogers, senior project manager, Integration of DER at the Electric Power Research Institute (EPRI). To remedy the problems, Germany recently retrofitted over 30 million inverters with new firmware and hardware to perform smart functions that enable Germany's grid to operate with higher levels of wind and solar generation.

Seeking Solutions in the United States

With solar penetration in the United States estimated to double over the next decade, U.S. electric utilities are highly incentivized to avoid the problems that emerged in Germany. "Electric utilities in the United States want to get in front of those kinds of problems," said Rogers. In fact, standard IEEE 1547 is being revised to require a certain level of inverter functionality to prevent the problems experienced in Germany and support the smart grid.

To help manage the expected growth of PV installations, EPRI has been working with utilities and inverter vendors to advance inverter capabilities to the smart grid. In 2011, EPRI launched a five-year demonstration project, part of the U.S. Department of Energy's SunShot Initiative (Solar Energy Grid Integration System—Advanced Concepts). The project's objective was to find out how smart inverters could better integrate distributed PV with the power grid. "While standard functions and communication protocols had been defined for the smart inverter, they had not yet been implemented and tested in the field," said Rogers.

"Using an advanced inverter for grid support was new, and we needed to better understand its capabilities. We knew how it would work on paper, but would it behave as intended in the real world? Was it equipped with the right functions? Would it have any adverse impacts on the grid's performance?" The project, "Demonstration of Smart Grid Ready Inverters with Utility Communication," set out to answer those questions.

Smart inverters do more than connect photovoltaic arrays to the grid. When called upon, they can also support the grid in several significant ways.

Challenge

With growth in renewable energy, utilities are facing new challenges related to the integration of solar photovoltaic (PV) installations and other intermittent sources of energy with the electric grid. They seek advanced solutions beyond traditional communication and control technologies, so that they can continue to add renewable resources while ensuring the safety and stability of the grid.

Solution

To resolve some of the problems inherent in large-scale integration of solar power, smart inverters are equipped with features that support more reliable grid operations, enabling utilities to expand their portfolios of renewable energy.

Results and Benefits

Bolstered by the successful results of testing at actual PV installations, utilities can begin to confidently rely on smart inverters to significantly increase the amount of solar generation that the grid can handle safely, reliably, and efficiently.

The project team included EPRI; the U.S. National Renewable Energy Laboratory (NREL); various vendors, including inverter manufacturer Yaskawa-Solectria Solar and grid-management consultant BPL Global; and several utilities eager to discover the potential of smart inverters.

Development, Deployment, and Demonstration

The project consisted of five phases:

1. Designing and building advanced PV inverters to support the grid
2. Laboratory testing at EPRI and NREL laboratories
3. Computer modeling and simulation
4. Implementing the advanced inverters in the field
5. Field testing the inverters at selected utility PV installations

Testing at Utility PV Installations

Two utilities, National Grid and DTE Energy, participated in the project from the beginning, including eight months of field testing at their own solar installations. DTE Energy installed an inverter at a 224-kilowatt (kW) site, which serves both commercial and residential loads in Ann Arbor, Michigan. "This project was an opportunity to participate in research and find an effective solution to mitigate saturation issues on a feeder," said Teresa Tran, construction project manager for DTE Energy.

The utility was able to demonstrate that smart inverters could regulate voltage on a circuit, reducing wear on the tap changers of substation transformers and compensating for a capacitor failure. DTE Energy also experimented with the settings of smart inverters to gain an advantage over the fixed settings of a capacitor bank.

Part of the DTE Energy demo was to test the efficacy of a direct transfer trip to remotely disconnect a PV installation using a private radio network. For example, if a substation relay detects a fault, a trip signal can be sent to inverters to trip them offline. Testing a scheme to quickly clear a fault and avoid adverse islanding of solar power led to a highly cost-effective communication solution for DTE Energy, said Tran.

National Grid installed inverters at two PV sites in Massachusetts—one serving primarily residential customers and another serving mostly commercial and industrial loads. The sites are part of the utility's program to help Massachusetts meet its aggressive clean-energy goal—to generate 20 percent of the state's electricity with renewable energy by 2020.

"Considering the increase in PV penetration on our distribution system, we needed to understand how the next generation of inverters could better support the grid," said Justin Woodard, principal engineer for Customer Solutions on National Grid's New Energy Solutions team.

"Having our own solar generation helps us understand the challenges our customers face in adopting new technologies," said Woodard. "Our solar program is based on a 'best value' proposition—not just producing kilowatt-hours, but rather providing quality kilowatts when our customers need them the most."

The Results

The project revealed the challenges of grid integration, how smart inverters perform in the laboratory versus in the field, and their impact on the distribution grid. Advanced inverters can help to balance and regulate voltage on the grid. The demonstration also contributed to pending revisions of IEEE 1547 and validated IEC-61850 standards for smart inverter functions and the DNP3 communication protocol.

More to Do

The project identified areas for inverter improvement, such as the accuracy of an inverter's voltage readings. Also, the results of field testing were not always consistent with lab results. Rogers emphasized a "need for standard communication and functional certifications across the industry in light of utilities' differing communication and control systems and the array of makes, models, brands, and types of DERs."

Benefits to the Electricity Industry

As solar and other distributed energy resources become a larger portion of the industry's generation portfolios, this demonstration and others across the United States are helping utilities better understand the benefits and challenges of smart inverter technologies. This work also helps inform and validate industry standards, giving utilities a higher level of confidence that advanced inverters will provide the grid support they need. EPRI will continue to collaborate with member utilities on further demonstrations while many utilities conduct field testing on their own, using the results of the demonstrations as guidance.

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